
ANESTHESIA OUTSIDE
of the OPERATING ROOM



RICHARD D. URMAN | WENDY L. GROSS | BEVERLY K. PHILIP

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Anesthesia Outside of the Operating Room

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Anesthesia Outside of the Operating Room

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*To my parents
and Zina Matlyuk-Urman, MD,
for their love and encouragement*

—R. D. U.

*To my family and my colleagues
who make every day a learning experience*

—W. L. G.

*To the outstanding physician, scientist,
and husband, James H. Philip, MD*

—B. K. P.

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Anesthesia Information Management Systems Outside of the Operating Room is available online at
www.isobs.org/aims

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Foreword

This volume represents a lifeboat for anesthesiologists across the nation who have been coping with a growing demand for outside-of-the-operating-room (OOOR) anesthetics through a “catch as catch can” strategy in recent years. A scattered literature and mostly anecdotal experiences reported in professional conferences have been the main resources available to guide this emerging practice.

The unifying thread throughout the content of these chapters is the imperative to achieve levels of efficiency and safety in the diverse settings described that are comparable to those seen in the traditional operating room setting. Anesthesiology’s culture of safety echoes throughout the discussions and, thus, it is a volume of which the specialty can be proud. It is also a genuine contribution to the work of a diverse group of professional colleagues in other areas of medicine who have come to call upon anesthesiologists.

The vexing problem we face—and will increasingly face as systems develop to deliver OOR services more and more effectively—is that the demand for our services can easily grow beyond the capacity of the anesthesia workforce to deliver them. As an OOOR proceduralist, why wouldn’t you seek anesthesiology support for all your procedures requiring sedation? The involvement of a team of anesthesia specialists boosts efficiency, increases capacity and throughput, reduces professional liability, and diminishes the burden of managing a dimension of patient care for which your training is probably minimal. Current fee-for-service payment models provide no incentive to do otherwise, although this may change soon. When demand exceeds capacity, we will need to know when to say “no” and effectively triage the limited resources available and understand the full range of options for patient management. Great caution is warranted in considering the business relationship between users and providers of anesthesia services. There are dangerous potential conflicts of interest when economic interests are superimposed on judgments of necessity.

A role for anesthesiologists in the training and monitoring of personnel delivering sedation will inevitably emerge. Reflex reluctance and fear of empowering one’s competition must be overcome and the rightful place of the anesthesiologist as the expert authority in such care should be embraced. Doing so strengthens, not weakens, the stature of the specialty across many disciplines and professions and will be a necessary ingredient to insure both quality and efficiency in the delivery of care in a health system strained to meet the needs of an aging population.

The reader will find useful guidance in defining the institutional investments that must be made in support of OOOR care. Physical distance from the mass of support (people and equipment) available in traditional settings is a challenge that must be overcome. First-rate equipment and communication tools will be critical and are justifiably identified as a prerequisite for establishing OOOR services. Consider these chapters fair warning that failure to insist on this investment will produce regret (or worse) later. Similarly, the inherent inefficiencies of multiple sites demands well-organized scheduling support as its antidote. This is a book that will be waved at hospital administrators as validation that your “demands” are justified—use it well!

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Preface

The number of procedures performed outside of the operating room (OOOR) continues to expand tremendously. The need for cost containment, along with rapid technological advancement and an increasing population of ageing and medically involved patients, has increased the demand for minimally invasive surgical alternatives and complex diagnostic and therapeutic procedures. These are now commonly performed in non-operating room (OR) areas of the hospital, freestanding surgicenters, and physicians' offices. As a result, anesthesiologists are now frequently requested to provide services outside of the traditional operating room environment. Areas such as invasive radiology, invasive cardiology, and the gastroenterology suites are common sites for such procedures.

In the light of such a significant expansion in the venue of anesthesiology practice, there is an urgent need for a definitive, evidence-based textbook that encompasses all vital aspects of OOOR care, including preoperative patient evaluation, perioperative monitoring, anesthetic techniques, and quality assurance. In putting this book together, our overall goal was to clarify the basic principles of anesthesia care in unique OOOR settings and to reframe our standards of safety and medical practice so that they are appropriate for anesthetizing locations that are outside of the main OR. Hundreds of thousands of procedures such as cardiac catheterization, aesthetic surgery, and imaging are performed in remote locations, putting the anesthesia provider into an unfamiliar environment with limited resources. Often such venues are far away from the conventional ORs and qualified help. Recent evidence suggests that non-OR anesthesia malpractice claims have a higher rate of severe injury and substandard care than OR claims. At the same time, we now see a surge in OOOR procedures performed with minimal to deep sedation by nonanesthesia providers.

Anesthesia providers as well as nonanesthesia members of the patient care team will derive a significant benefit from reading this textbook—especially given the rapid changes in procedural guidelines, anesthetic practices, reimbursements, and technological progress. We begin by discussing anesthetic and patient monitoring techniques, preprocedure evaluation and postprocedure care, financial considerations, patient safety, and procedural sedation performed by nonanesthesia providers. The second part of the textbook contains a practical discussion of surgical procedures and anesthetic considerations by procedure location. This includes radiology, endoscopy, radiation therapy and cardiology suites, infertility clinic, physician offices, field and military environments, intensive care units, the emergency room, pediatric settings, and many others. Given the rapid shift towards electronic medical records, we also have added a special chapter on anesthesia information management systems (AIMS), available online.

This textbook, written by practitioners from various academic institutions, provides a unique and convenient compendium of expertise and experience. We believe that both anesthesia providers and nonanesthesiologists will find it a useful resource in their practices. We thank our contributors for their insights and dedication to advancing the cutting edge of anesthesiology practice, and we are indebted to our colleagues and families for their encouragement and support.

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Challenges of Anesthesia Outside of the Operating Room

WENDY L. GROSS, MD, MHCM and
RICHARD D. URMAN, MD, MBA

As health care bears the simultaneous burden of rapid technological development and increasing financial constraints, diagnostic and therapeutic interventions are performed more frequently outside of the operating room (OOOR) by a broadening spectrum of medical practitioners. The broadening scope and complexity of noninvasive procedures as well as the increasing acuity of patients undergoing them often make deeper sedation, general anesthesia (GA), and robust hemodynamic monitoring necessary and challenging. Anesthesiologists are more frequently called upon to provide care for sicker patients (American Society of Anesthesiologists (ASA) III/IV patients) undergoing novel, unfamiliar procedures in nontraditional locations. As technology advances, the number of procedure areas and the need for anesthesia services proliferates. As the OOOR cases continue to grow at an exponential rate, the landscape of anesthesiology is changing; new challenges and opportunities emerge.

The OOOR environment confronts the anesthesiologist with considerable and diverse clinical challenges. The proliferation of practitioners and the variety of service environments (Table 1.1) expands the professional relationship beyond that of the traditional anesthesiologist–surgeon interface. Evolving concerns encompass clinical, financial, safety, and political questions.

ASSESSMENT AND DESIGN OF OOOR PROCEDURE LOCATIONS

The provision of anesthesia care outside of the operating room requires flexibility (both physical and intellectual) and good communication skills on the part of the anesthesiologist. For the most part, OOOR locations are not built with anesthesiologists in mind. It is often necessary to rearrange equipment, particularly monitors, anesthesia machines, airway equipment and pumps so that they are close to the patient. Many suites are located in the most remote parts of the hospital. They are often small, crowded and not conducive to the introduction of anesthesia machines or monitoring devices. For example, radiology suites are designed and built to house complex, heat-sensitive computers, and magnetic resonance imaging

TABLE 1.1. OOOR Anesthetizing Locations (Sites and Physicians Involved)

Radiology suites (radiologists, urologists, neurosurgeons)
Interventional radiology (neuroradiology and angiography)
Magnetic resonance imaging
Computed tomography
Ultrasound
Cardiac catheterization and electrophysiology (EP) laboratory (cardiologists)
Endoscopy suite (gastroenterologists, surgeons)
Family planning and obstetrics unit (obstetricians, gynecologists)
Emergency room (ER physicians, surgeons, internal medicine physicians)
Lithotripsy suite (urologists)
Outpatient procedure rooms (dermatologists, surgeons, dentists, podiatrists)
Electroconvulsive therapy unit (psychiatrists)
Critical care units (surgeons, cardiologists, neonatologists)

OOOR, outside of the operating room.

Source: Adapted from Russell GB, *Alternate-Site Anesthesia*. Oxford, England: Butterworth-Heinemann, 1997.

(MRI) facilities expose personnel and equipment to high-level magnetic fields. Radiotherapy suites require delivery of anesthesia in heavily shielded radiation-proof rooms where only remote surveillance of the patient via a video camera and a vital signs monitor is possible. It may be difficult for the anesthesiologist to see the progress of the procedure, talk to the proceduralist, or even observe the patient's vital signs.

Many items routinely utilized in traditional operating rooms (ORs) may not be present, and the individuals performing the procedure may be unaware of the importance of such equipment. Gas scavenging may be unavailable, oxygen or suction sources may be limited, and thermostats may be fixed to accommodate imaging equipment while increasing a risk of hypothermia in the patient under anesthesia. In addition, ancillary caregivers may have limited understanding of what constitutes an airway or anesthetic emergency and what the response to such a situation should be.

TABLE 1.2. *Summary of the ASA Statement on Non-Operating Room Anesthetizing Locations*

1. A reliable source of oxygen
2. An adequate and reliable source of suction
3. An adequate and reliable system for scavenging waste anesthetic gases
4. A self-inflating hand resuscitator bag capable of administering at least 90% oxygen as a means to deliver positive pressure ventilation; adequate anesthesia drugs, supplies, and equipment for the intended anesthesia care; adequate monitoring equipment to allow adherence to the *Standards for Basic Anesthetic Monitoring*. If inhalation anesthesia is to be administered, there should be an anesthesia machine maintained to current operating room standards.
5. Sufficient electrical outlets
6. Adequate illumination of the patient, anesthesia machine, and monitoring equipment
7. Sufficient space to accommodate necessary equipment and personnel and to allow expeditious access to patient, anesthesia machine, and monitoring equipment
8. An emergency cart with a defibrillator, emergency drugs, and other equipment needed to provide cardiopulmonary resuscitation
9. Adequate staff trained to support the anesthesiologist
10. All applicable building and safety codes and facility standards should be observed.
11. Appropriate postanesthesia management should be provided.

ASA, American Society of Anesthesiologists.

Source: Based on *Statement on Non-Operating Room Anesthetizing Locations of the American Society of Anesthesiologists*. A copy of the full text can be obtained from ASA, 520 N. Northwest Highway, Park Ridge, Illinois 60068-2573.

Regardless of these challenging physical parameters of the OOR environment, anesthesiologists must be sure that their practice conforms to the same standards adhered to in the main OR. The American Society of Anesthesiologists (ASA) has established guidelines designed to improve the safety of OOR anesthetic practice. The *ASA Statement on Non-Operating Room Anesthetizing Locations*¹ is summarized in Table 1.2. It is important to note that these are minimum standards recommended for all OOR locations.

NEW SITE EVALUATION

When evaluating new sites, it is important to consider both the needs of anesthesiologists and the context of the available and necessary technical and procedural priorities of the specialty requiring anesthesiology support. Ideally, the anesthesia service should be involved with the design and site selection in the planning phase so that all anesthesia-specific requirements are taken into consideration before the new site is constructed. This ultimately allows for better case management and resource utilization. Table 1.3 outlines questions to be asked during site evaluation for potential OOR anesthesia.

MONITORING AND EQUIPMENT CONSIDERATIONS

Equipment and monitoring considerations are critical when assessing and designing new OOR locations. Many anesthesiologists bring portable equipment to the site, whereas some locations routinely stock anesthesiology equipment at the site. Some of equipment required for the safe delivery of anesthesia care outside of the OR *may be even more extensive* than it is in the OR. Depending on the patient's condition, more advanced monitoring may be needed if the OOR site is distant from the OR or isolated from the main part of the hospital. Frequently, the specific procedures performed dictate the need for specific monitoring. Some procedures may require cerebral oximetry, whereas others may require echocardiography equipment. Defibrillators should be uniformly present at all procedure sites, just as they are in the OR. Whatever monitoring is utilized, it should be accessible by, and visible to, the anesthesiologist delivering the anesthetic. For example, electrocardiogram (EKG) equipment visible only to the cardiologist in the cardiac catheterization lab is essentially not available to the anesthesiologist. Special equipment may be needed for specific sites such as MRI-compatible equipment for the magnetic resonance tomography (MRT) suite. Smaller, more portable anesthesia machines are readily available and are more practical for some sites.²⁻³

No matter the physical or financial constraints imposed by the procedure area itself, standard essential monitors for the safe delivery of anesthetic care must be present. Since all regional or local anesthesia can require conversion to a general anesthetic, the standards of care practiced in the OR must be followed in OOR areas: an anesthesia machine should be available and present in all OOR anesthetizing locations.

Proper patient monitoring is key to improving patient safety in any OR location. The ASA has published *Standards for Basic Anesthetic Monitoring*,⁴ which specifically state the following:

1. Qualified anesthesia personnel must be present in the room throughout the conduct of all anesthetics.
2. The patient's oxygenation, ventilation, circulation, and temperature must be continually evaluated.

A more detailed discussion on patient monitoring is found in Chapter 3 (Patient Monitoring). Many investigators have written about the capability of monitors to reduce morbidity and mortality. Several closed claims analyses⁵⁻⁶ suggest that appropriate monitoring leads to more timely rectification of potentially deleterious states and therefore prevention of untoward events. Because sicker patients are being cared for outside of the OR and more complex procedures are evolving, there may be less room for error than ever before. OOR sites are usually removed from core locations of anesthesia care delivery and the availability of backup equipment and extra staff is therefore reduced. Anesthesiologists, who have achieved tremendous success advancing safety in the OR with the use of appropriate monitoring, must maintain monitoring and other practice standards in OOR sites. *Since every*

TABLE 1.3. *Considerations during OOR Site Evaluation*

1. Where will anesthesia be induced (procedure bed, stretcher, in another room), and where will the patient recover?
2. Are oxygen and suction close enough to the patient and dedicated to anesthesia utilization, or are they shared?
3. Are lighting and temperature control adequate?
4. Is it possible to monitor the patient and vital signs outside of the procedure room if the anesthesia provider needs to step outside (i.e., due to significant radiation exposure)?
5. How can additional help be obtained if needed urgently?
6. Are monitors in place and adequate, or is it necessary to transport additional equipment?
7. Where is the code cart? Does every care team member know where it is and how to call a code?
8. Are the personnel on site aware of what constitutes an anesthetic emergency and how to address it?
9. Is there enough physical space dedicated to anesthesia personnel and all the required or potentially required anesthesia equipment?

OOOR, outside of the operating room.

Source: Adapted from Russell GB, *Alternate-Site Anesthesia*. Oxford, England: Butterworth-Heinemann, 1997.

minimal-moderate sedation case outside of the OR can potentially devolve into a deep sedation or general anesthesia case, appropriate patient monitoring outside of the operating room is truly critical.

ORGANIZATION AND INTEGRATION OF ANESTHESIA AND PATIENT CARE TEAMS

The patient care team outside of the OR environment includes medical practitioners and consultants who may not be familiar with the scope and practice of anesthesiology. This team includes ancillary personnel such as radiology technicians, nurses, and other technical and physician (nonanesthesia) staff. In addition, anesthesiologists dispatched to OOOR sites may be unfamiliar with the procedures that they are supporting. It is clear that the experience of anesthesia providers as well as the settings in which they practice do impact outcome. Thus, the lack of understanding of the unique requirements of a particular OOOR site on the part of both the procedure suite staff and the anesthesia team can undermine the provision of optimal patient care. In addition, the priorities of anesthesiologists may be challenged by the flow of cases in procedural areas. Uninformed ancillary personnel may obstruct the normal flow of anesthetic delivery; at the same time, uninformed anesthesiologists may obstruct the flow of a procedure. Communication among the procedure-site staff and the anesthesia care team is therefore essential. The *ASA Statement on the Anesthesia Care Team*⁷ addresses the structure of the anesthesia team performing the anesthetic.

However, structure does not always dictate function and the goal is to integrate services, include nonanesthesia staff in decision making, and plan responsibility. An emphasis on teamwork and communication in the context of patient safety is imperative in OOOR locations, and interdisciplinary collaboration is necessary. Team leadership, situational awareness, and establishment of an environment where continued learning is supported are all critical features of an arena in which an integrated patient care teams can develop and operate optimally.⁸ Goals must be clarified and broadened to include those of proceduralists, anesthesiologists, and all members of the patient care team. In some circumstances the anesthesiologist essentially becomes a consultant; communication and resolution of conflict is therefore critical. Effective conflict resolution in the OR is a well-described need,⁹⁻¹¹ yet the same need exists outside of the OR. In the case of the latter, the process is potentially more complicated. Conflict resolution is more difficult in an environment where the equipment of one specialty imposes physical constraints on the capacity of another to work, and where the vocabulary of one discipline does not necessarily include the vocabulary of another.

Preoperative assessment must be clearly addressed and discussed by both the proceduralist and the anesthesiologist, since it affects the delivery and type of anesthetic as well as the course of the procedure. Proceduralists may not be aware of the results of preoperative assessments or the potential limitations these might impose on the performance of procedures or the postprocedure care of patients. Although preop visits and checklists are standard in many hospitals with respect to OR cases, this may not be so with respect to procedures performed outside of the OR. Because many such interventions are “noninvasive,” the perception is that they are less dangerous and/or less risky. However, this is often not the case. OOOR procedures are frequently undertaken simply because the patient population is deemed “too sick” for the OR. Despite all efforts, conflict can be hard to avoid in medical settings where multiple specialties interact. Overlapping areas of expertise, tradition, culture, and vocabulary may contribute to this environment. However, inclusion and negotiation are critical to optimal outcome.

SAFETY GUIDELINES

Anesthesiologists enhance safety in the OR by standardizing and utilizing protocols for many procedures. Algorithms abound in the OR. Characteristic room setup, equipment maintenance, preprocedure setup and checklists, and postprocedure care priorities all contribute to a smooth process. Outside of the OR, anesthesiologists often find themselves outside of their comfort zone in environments that lack rigor and standardization. Unfamiliar equipment may be in place outside of the OR, variation in physical setup is common, patient records may be unavailable, the procedure may be new, and proceduralists may not understand the nuances of anesthetic management. The OOOR location may be quite a distance from the OR itself so that support is less available

when an emergency arises. For all of these reasons, consistent safety standards and guidelines must be in place. Site evaluation, assessment of space and equipment needs, and monitoring requirements must be standardized across locations if consistent patient safety is to be realized.^{8,12} Although anesthesiology has dramatically moved OR safety forward in the past 10 years, anesthesia providers must continue to drive this theme further as the perimeter of practice extends outward to include OOR venues. Although economic and political pressures may interfere with this process, it is the anesthesiologist's responsibility to maintain the priorities of the specialty in order to practice quality medicine and achieve optimal results while pursuing medical practice at the cutting edge. Strong leadership by the anesthesia provider is a key feature of success in OOR environments. The procedures performed are often complex, as are the patients. Procedural equipment may be new, sophisticated, and outside of the realm of anesthesiology practice.

PREPROCEDURAL EVALUATION OF PATIENTS AND POSTPROCEDURE CARE

Anesthetics performed outside of the OR pose many challenges. The most significant of these is that the concept of an "anesthetic" is unclear to medical proceduralists, who may be under the impression that anything that does not include an endotracheal tube and an anesthesia machine is simply "sedation." Since the procedures as well as the patients are often complex, consistent and effective preprocedure evaluation is critical to both optimization of outcome and operational efficiency outside of the OR. The ASA *Basic Standards for Preanesthesia Care*¹³ apply to all patients who receive care from an anesthesiologist. It is the responsibility of the anesthesia provider to review the available medical record, interview the patient, perform a focused examination, order and review pertinent available tests and consultations, prescribe appropriate preoperative medications, and obtain anesthesia consent. It is also imperative that the anesthesiologist discuss these findings with the proceduralist involved, because preprocedure assessment must be accomplished in the context of a clear understanding of the technical demands and goals of the procedure itself. Specific limitations of the procedure suite may also be important to consider. Because any procedure performed outside of the OR may develop into a situation requiring urgent patient transfer to the OR, good communication and a thorough appreciation of the patient's comorbidities is imperative. Complications outside of the OR as well as in the OR are associated with extremes of age, increasing ASA status, and obesity.¹⁴ Although the patient population for elective procedures may include relatively healthy individuals, it also includes patients with multisystem disease who either need urgent procedures or who are deemed high risk for surgery. For some patients, anesthesia preprocedure workups take place right before the procedure, whereas for others a separate preprocedure appointment is needed. The decision to involve an anesthesiologist may be a function of the patient's physical status, the technical complexity of the

procedure, or both. Appropriate triage pathways must be developed so that anesthesiologists are made aware of patients who will require their attention as early as possible. A more detailed discussion of preanesthesia patient assessment can be found in Chapter 2.

As OOR sites evolve, additional post anesthesia care units (PACUs) for patient recovery are needed. Many complications occur in the postoperative period, with respiratory depression and aspiration being the most common. Therefore, it is imperative that properly trained staff be available to care for the post procedure patient in an appropriate environment. Concise and consistent handoff from one caregiver to another is imperative. This is also a focus of the goals published by The Joint Commission. Having PACUs that specialize in caring for patients undergoing a subset of OOR procedures encourages both specialization and standardization of protocols. This can improve efficiency and care while minimizing burdens on post-surgical PACU capacity. The principles of patient recovery are the same whether care is delivered by PACU nurses, recovery area nurses in a radiology suite, or the anesthesiologist in an office-based setting. Guidelines established by the American Society of PeriAnesthesia Nurses (ASPAN) describe recommended nurse–patient ratios relative to patient characteristics. Patients requiring life-supportive care such as mechanical ventilation or vasopressor support need 1:1 nursing, whereas patients who have undergone a major procedure but are stable require a 1:2 nursing ratio.

The ASA and other professional organizations offer guidelines that standardize practices that affect quality of care and patient safety. For example, the ASA has published *Standards for Postanesthesia Care*¹⁵ that apply to all locations. These standards emphasize the need for the following:

1. Appropriate postanesthesia management for all patients who receive general anesthesia, regional anesthesia, or monitored anesthesia care
2. A member of the anesthesia care team to accompany the patient to the PACU
3. A verbal report to the responsible PACU nurse by the member of the anesthesia care team
4. Continued evaluation of the patient's condition while in the PACU
5. A physician to be present and responsible for the discharge of the patient from the PACU

However, publication of guidelines alone is not a substitute for collaborative, interdisciplinary discussion among involved caregivers. Recovery room practice often dictates case turnover time, for example, and therefore it is critical that all involved understand the goals to be accomplished by each unit. The existence of infrastructure alone does not guarantee that "the parts" will all move at the right time or in the right direction.

ADMINISTRATION OF ANESTHESIA BY NONANESTHESIA PROVIDERS

The inclusion of an anesthesiologist in an OOR case is often at the request of the evaluating or treating physician. After the

consulting anesthesiologist evaluates the patient's medical status and the nature of the planned procedure, he or she should make a recommendation as to whether involvement of an anesthesiologist is necessary or whether the procedure can be completed with sedation administered by a trained non-anesthesiologist. Many OOR cases do not require the presence of an anesthesiologist. Most institutions have developed their own anesthesia consult criteria and have policies in place that govern the administration of conscious sedation by nonanesthesiologists. Again, timely communication among the patient's care team members is essential. The ASA recently issued two statements that address the administration of moderate and deep sedation by nonanesthesiologists. The *ASA Statement on Granting Privileges for Administration of Moderate Sedation to Practitioners Who Are Not Anesthesia Professionals* states that only physicians, dentists, or podiatrists who are qualified by education, training, and licensure to administer moderate sedation should supervise the administration of moderate sedation.¹⁶ The *ASA Statement on Granting Privileges to Nonanesthesiologist Practitioners for Personally Administering Deep Sedation or Supervising Deep Sedation by Individuals Who Are Not Anesthesia Professionals* states that due to a significant risk that patients who receive deep sedation may enter a state of general anesthesia, privileges to administer deep sedation should be granted only to practitioners who are qualified to administer general anesthesia or to appropriately supervised anesthesia professionals.¹⁷ This last statement emphasizes the fact that sedation is essentially a "continuum" and that each patient may respond differently to the sedation being administered: that is, what is intended as "moderate" sedation can quickly evolve into "general" anesthesia. Consequently, the ASA, in its statement on *Continuum of Depth of Sedation: Definition of General Anesthesia and Levels of Sedation/Analgesia* emphasized the need for practitioners intending to produce a given level of sedation to be able to rescue patients whose level of sedation becomes deeper than initially intended.¹⁸ The topic of sedation administration under the supervision of nonanesthesia providers is discussed in Chapter 6 (Procedural Sedation by Nonanesthesia Providers).

QUALITY ASSURANCE AND IMPROVEMENT

The transition to OOR practice must build upon the collective experience and standards of anesthesiology practice, which has provided a foundation for notable improvements in OR patient safety and quality of care over the past 20 years. The same attention to rigor and detail exercised in the traditional OR practice must be ensured in remote anesthesia locations. Unfortunately, there are limited data available regarding patient safety and outcomes in the OOR. One recent analysis¹⁴ examined data from 63,000 patients undergoing diagnostic or therapeutic procedures in OOR locations under sedation or anesthesia; 41% of patients were sedated by nonanesthesiologists. The data suggested that the use of capnography allowed for faster detection of apnea and respiratory compromise. The results point to a need for robust

quality assurance systems that can accurately track adverse events associated with procedural sedation and anesthesia in order to improve clinical practice and patient safety.

A recent ASA closed claims analysis of 87 cases¹⁹ performed under anesthesia in remote locations found that compared to OR claims, remote location claims involved older and sicker patients, and they demonstrated an increased incidence of death and significant respiratory events that were judged as potentially preventable with better monitoring. These data suggest that remote anesthetizing locations pose a significant risk to patients and that a large fraction of adverse outcomes is associated with oversedation, inadequate ventilation, and inadequate oxygenation during monitored anesthesia care (MAC). Such findings emphasize the need for institution of the same monitoring and anesthesia standards in OOR locations as in the traditional OR settings. However, in reality the imposition of new rules and culture in medical procedure suites can be difficult.

COMMON PROBLEMS IN OOR ANESTHETIZING LOCATIONS

Anything that can go wrong inside the OR can go wrong outside of the OR. Remote locations are far from OR supplies, equipment, and anesthesia colleagues. Rapid-response assistance may be anything but "rapid." What is easy to deal with in the OR may be difficult in the hinterlands of the hospital. Careful planning and readiness for possible problems are critical. The following problems are unique to OOR locations.

Patient Transport: Safety Parameters

OOR anesthesia frequently involves patient transport and may require moving hemodynamically unstable or intubated patients to radiology or cardiac catheterization suites usually found in remote locations within the hospital. The same is true when the patient needs to be transported to the intensive care unit (ICU) or the PACU after the procedure, and critically ill or intubated patients will require ventilatory support. These patients need to be continuously monitored, in which case a portable monitor capable of displaying EKG, pulse oximetry, blood pressure (invasive or noninvasive), and capnography is needed. Patients who are intubated will need ventilatory support via a resuscitation bag connected to appropriate oxygen flows or a portable mobile ventilator machine. It is important to ensure adequate oxygen supply. If the patient is awake, then ascertaining that the patient is stable and cooperative before transport is preferable. However, some patients are best transported intubated and sedated to and from an ICU or the PACU. It is important to have an adequate supply of drugs such as propofol, thiopental, or fentanyl in case the patient needs to be anesthetized or further sedated during transport. The anesthesia provider should also have access to a neuromuscular blocker (succinylcholine), vasopressors (ephedrine, phenylephrine), and antihypertensives (labetalol, hydralazine). One also should consider bringing an appropriately sized endotracheal tube, a functioning laryngoscope,

a resuscitation bag (even if the patient is not intubated), oral and nasal airways, and a laryngeal mask airway (LMA). A member of the patient's care team must accompany the anesthesiologist during transport and handoff.

Cardiac Arrest/Airway Emergency

Cardiac arrest or an airway emergency can occur at any stage; this includes the preoperative holding area, the procedural area, the recovery room, or en route to or from the procedure area. All patient care personnel must be familiar with the location of essential emergency equipment such as the defibrillator and the emergency airway cart. They must also be able to call for help and properly describe the location of the patient in distress. It is important that all patient care staff familiarize themselves with the basic life support (BLS) and/or advanced cardiac life support (ACLS) protocols (see Appendix 2), according to their specialty and hospital policy requirements. Periodic team training of the OOR personal and "mock codes" may be of significant benefit.

Other Potential Adverse Events

Additional problems sometimes encountered in the OOR settings include adverse reactions to drugs and materials. These include anaphylactic reactions to antibiotics, latex, or iodinated contrast dye, which require immediate treatment for their potentially life-threatening effects such as bronchospasm, airway edema, or hypotension.²⁰ Malignant hyperthermia (MH) is a rare but serious condition that can be caused by potent inhalation anesthetics or depolarizing neuromuscular blockers such as succinylcholine. Prompt recognition and initiation of resuscitative measures can significantly improve patient outcome. Familiarity with the MH treatment protocol and the necessary equipment by the OOR staff is necessary. The MH protocol is outlined in Appendix 3. Familiarity with the treatment of local anesthetic toxicity is important as well. Significant cardiovascular side effects are more likely to occur with the repeated infiltration of large volumes of local anesthetic.

FINANCIAL CONSIDERATIONS

Important financial considerations continue to drive the practice of anesthesiology as it expands its perimeter. The need to at least maintain budget neutrality in the face of increasing demand, the cost of technological innovation, the cost of poorly integrated care, and the financial implications of potential modifications to resource management in the OR (i.e., changes in staffing models, use of CRNAs, creation of "shifts") are all relevant to the future of anesthesiology as a specialty. Financial silos tend to drive the benefits of efficient staffing toward proceduralists and away from anesthesiologists; bundling of fees and poor reimbursement reinforce this trend. Budget inspection often fails to reveal costly practices because the analyses are fragmented across departments.

In the current environment, anesthesia service provided outside of the OR for routine cases is not well reimbursed. Newer, high-tech procedures tend to be well reimbursed, at least initially. Opportunity costs for anesthesia departments are enormous because coverage outside of the OR often requires a ratio of 1:1 staffing. Scheduling is often poorly organized. As a result, anesthesiologists cover non-OR cases in an ad-hoc manner, which is expensive. The demand for comprehensive and reliable anesthesiology services outside of the OR is growing, but the benefits commonly accrue to other departments and to hospitals as a whole. Just as surgical procedures in the OR often require an integrative and interdisciplinary approach to patient care and strategic management of reimbursements, so, too, do many of the emerging minimally invasive procedures performed outside of the OR. Creative financing and alternative staffing models may need to be considered.

The future promises to be even more complex: Medicare (Acute Care Episode demonstration project²¹) is considering bundled payments that lump together institutional and provider payments for certain procedures. In this model, the providers themselves, rather than Medicare fee schedules, will make decisions about the value of each provider's contribution to the care of the patient. Bundled payments and shift of financial risk from insurers to providers will provoke discussions among providers about the value of anesthesia services.

In the present financial model, enlisting the services of an anesthesiologist increases efficiency, reduces risk, lowers the patient care burden, and costs the facility nothing (unless the insurance company refuses to pay for anesthesia services; this occurred when Aetna tried to impose limitations on payment for anesthesia services during endoscopy).²² Financial integration of providers in a bundled payment model turns this arrangement on its head because the cost of anesthesia services comes from a fixed budget—as do all services. The debate about who pays for health care might best be focused on what (and how) health care is paid for, and this may determine our practice parameters more profoundly than anything else.²³

CONSIDERATIONS FOR THE FUTURE

As anesthesiologists adjust to the expanding perimeter of anesthesiology practice, new problems and opportunities emerge. Some of these derive from new environments, some from complex technologies, and some arise simply because the procedures are new and the patients are sick. We are likely to need all of our abilities as perioperative physicians as we deal with these new issues and the exponential growth of OOR procedures. As anesthesiologists, we will clearly need to improve our communication skills, assume leadership positions, and encourage teamwork among our colleagues. In the process, we will have to leave behind some cultural boundaries and prejudices. While economic and political pressure may temporarily reshape our environment, we must be vigilant in assuring that our practice standards are not degraded or driven by financial constraints or the politics of resource allocation.

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2 Preoperative Patient Evaluation for Anesthesia Care Outside of the Operating Room

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Preoperative evaluation and optimization of medical status of patients are important components of anesthesia practice. Increasing numbers of patients with serious comorbidities undergo procedures that require anesthesia services outside of the operating room (OOOR). Often the location alters the challenges of caring for these patients. Surgical, anesthesia, or nursing personnel who can assist with airway and resuscitation management may not be available; equipment and medications may be limited. Many OOOR locations will not have the usual support of an intensive care unit (ICU), skilled postanesthesia recovery personnel, respiratory therapy, or ready access to an inpatient bed, blood banking, interventional cardiology, or diagnostic services. Many of the patients are elderly, ill, and even unlikely candidates for conventional surgery (e.g., transmucosal resection of gastric tumors, transjugular intrahepatic portosystemic shunts). Yet patients and/or providers may be reluctant to expend time and energy in extensive preoperative evaluation before a seemingly minor procedure. This chapter will outline the basics of preprocedure preparation of patients scheduled to receive anesthesia in OOOR settings. At a minimum, the guidelines of the American Society of Anesthesiologists (ASA) indicate that a preanesthesia visit should include the following¹:

- An interview with the patient or guardian to review medical, anesthesia, and medication history
- An appropriate physical examination
- Review of diagnostic data (laboratory, electrocardiogram, radiographs, consultations)
 - Assignment of an ASA physical status score (ASA-PS).
 - A formulation and discussion of anesthesia plans with the patient or a responsible adult

Many anesthesiologists rely on screening batteries of tests to evaluate patients. This practice may be based on institutional policies or on the mistaken belief that tests can substitute for taking a history or performing a physical examination. Preoperative tests without specific indications lack utility and may lead to patient injury because they prompt further testing to evaluate abnormal results, or they may lead to unnecessary

interventions, delay of surgery, anxiety, and even inappropriate therapies. Studies showing that elimination of “routine” testing does not increase risk required preoperative clinical evaluation of enrolled patients.^{2,3} Complete and thorough histories not only assist in planning appropriate and safe anesthesia care but also are more accurate and cost-effective than screening laboratory tests for establishing diagnoses.⁴ The task of gathering the necessary information and sharing it among the various providers can be challenging.

The important components of the anesthesia history are shown in Table 2.1. The form can be completed by the patient in person (paper or electronic version), via Internet-based programs, a telephone interview, or by anesthesia staff. The patient’s medical problems, medications, allergies, past operations, and use of tobacco, alcohol, or illicit drugs are documented. Cardiovascular, pulmonary, or neurologic symptoms are noted. Equally important as identifying the presence of disease is establishing its severity, stability, current or recent exacerbations, treatment of the condition, or planned interventions. A determination of the patient’s cardiorespiratory fitness or functional capacity is useful in guiding evaluation and predicting outcome and perioperative complications.^{5,6} Better fitness improves cardiorespiratory reserve, and it decreases morbidity through improved lipid and glucose profiles, and reductions in blood pressure and obesity. Conversely an inability to exercise may be a result of cardiopulmonary disease. An inability to perform average levels of exercise (4–5 metabolic equivalents or the ability to walk four blocks or go up two flights of stairs) identifies patients at risk of perioperative complications.⁶ A personal or family history of adverse events related to anesthesia is always important, but severe postoperative nausea or vomiting, prolonged emergence or delirium, or susceptibility to malignant hyperthermia or pseudocholinesterase deficiency have added significance given the often limited resources, as previously described.

At a minimum, the preanesthetic examination includes the airway, heart and lungs, vital signs, oxygen saturation, height, and weight. Examination of the airway, always a necessary assessment before anesthesia, has special significance.

TABLE 2.1. *Patient History*

Patient's name _____ Age ____ Sex ____
 Date of surgery _____
 Proposed operation _____
 Primary care doctor (PCP) _____ phone # _____
 Cardiologist _____ phone # _____
 Other physicians _____ phone #s _____

1. Please list **All Operations** (and approximate dates)

- a. _____ d. _____
- b. _____ e. _____
- c. _____ f. _____

2. Please list any **Allergies** to medications, latex, food or other (and your reactions to them)

- a. _____ c. _____
- b. _____ d. _____

3. Circle **TESTS** that you have already completed, list where and when you had them. Please bring all your existing reports for your visit.
 We are NOT suggesting that you have these tests, unless they have already been completed.

- | | | | |
|------------------------------------|-------------|-----------------------|-------------|
| a. EKG | Date: _____ | d. BLOOD WORK | Date: _____ |
| LOCATION: _____ | | LOCATION: _____ | |
| b. STRESS TEST | Date: _____ | e. SLEEP STUDY | Date: _____ |
| LOCATION: _____ | | LOCATION: _____ | |
| c. ECHO/ultrasound of heart | Date: _____ | f. Other: _____ | Date: _____ |
| LOCATION: _____ | | LOCATION: _____ | |

4. Please list **All Medications** you have taken in the last month (include over-the-counter drugs, inhalers, herbals, dietary supplements and aspirin)

<i>Name of Drug</i>	<i>Dose and how often</i>	<i>Name of Drug</i>	<i>Dose and how often</i>
a. _____	_____	f. _____	_____
b. _____	_____	g. _____	_____
c. _____	_____	h. _____	_____
d. _____	_____	i. _____	_____
e. _____	_____	j. _____	_____

- (Please check YES or NO and circle specific problems)
- | | | |
|---|--------------------------|--------------------------|
| | YES | NO |
| 4. Have you taken steroids (prednisone or cortisone) in the last year?..... | <input type="checkbox"/> | <input type="checkbox"/> |
| 5. Have you <u>ever</u> smoked? (Quantify in ___ packs/day for ___ years)..... | <input type="checkbox"/> | <input type="checkbox"/> |
| Do you still smoke? (Quantify in ___ packs/day)..... | <input type="checkbox"/> | <input type="checkbox"/> |
| Do you drink alcohol? (If so, how much?) _____ | <input type="checkbox"/> | <input type="checkbox"/> |
| Do you use or have you ever used any illegal drugs? (we need to know for your safety) | <input type="checkbox"/> | <input type="checkbox"/> |
| 6. Can you walk up one flight of stairs without stopping?..... | <input type="checkbox"/> | <input type="checkbox"/> |
| 7. Have you had any problems with your heart? (circle all that apply)..... | <input type="checkbox"/> | <input type="checkbox"/> |
- (Chest pain or pressure, heart attack, abnormal ECG, skipped beats, murmur, palpitations, heart failure)

CONTINUE OVER ►

(Please check YES or NO and circle specific problems)	YES	NO
8. Do you have diabetes?.....	<input type="checkbox"/>	<input type="checkbox"/>
9. Do you have high blood pressure?.....	<input type="checkbox"/>	<input type="checkbox"/>
10. Have you had any problems with your lungs or your chest? (circle all that apply)..... (shortness of breath, emphysema, bronchitis, asthma, TB, abnormal chest x-ray)	<input type="checkbox"/>	<input type="checkbox"/>
11. Are you ill now or were you recently ill with a cold, fever, chills, flu or productive cough?..... Describe recent changes _____	<input type="checkbox"/>	<input type="checkbox"/>
12. Have you or anyone in your family had serious bleeding problems? (circle all that apply)..... (Prolonged bleeding from nosebleed, gums, tooth extractions, or surgery)	<input type="checkbox"/>	<input type="checkbox"/>
13. Have you had any problems with your blood? (circle all that apply)..... (Anemia, Leukemia/Lymphomas, Sickle cell disease, Blood clots, transfusions)	<input type="checkbox"/>	<input type="checkbox"/>
14. Have you ever had problems with your: (circle all that apply)		
Liver (Cirrhosis; Hepatitis A, B, C; jaundice)?.....	<input type="checkbox"/>	<input type="checkbox"/>
Kidney (Stones, failure, dialysis)?.....	<input type="checkbox"/>	<input type="checkbox"/>
Digestive system (frequent heartburn, hiatus hernia, stomach ulcer)?.....	<input type="checkbox"/>	<input type="checkbox"/>
Back, Neck or Jaws (TMJ, rheumatoid arthritis, Herniation)?.....	<input type="checkbox"/>	<input type="checkbox"/>
Thyroid gland (under active or overactive)?.....	<input type="checkbox"/>	<input type="checkbox"/>
15. Have you ever had: (circle all that apply)		
Seizures or epilepsy?.....	<input type="checkbox"/>	<input type="checkbox"/>
Stroke, facial, leg or arm weakness, difficulty speaking?.....	<input type="checkbox"/>	<input type="checkbox"/>
Cramping pain in your legs with walking?.....	<input type="checkbox"/>	<input type="checkbox"/>
Problems with hearing, vision or memory?.....	<input type="checkbox"/>	<input type="checkbox"/>
16. Have you ever been treated with chemotherapy or radiation therapy? (circle all that apply)..... List indication and dates of treatment: _____		
17. Women: Could you be pregnant? Last menstrual period began: _____	<input type="checkbox"/>	<input type="checkbox"/>
18. Have you ever had problems with anesthesia or surgery? (circle all that apply)..... (Severe nausea or vomiting, malignant hyperthermia (in blood relatives or self), prolonged drowsiness, anxiety, breathing difficulties, or problems during placement of a breathing tube)	<input type="checkbox"/>	<input type="checkbox"/>
19. Do you have any chipped or loose teeth, dentures, caps, bridgework, braces, problems opening your mouth, swallowing or choking? (circle all that apply).....	<input type="checkbox"/>	<input type="checkbox"/>
20. Do your physical abilities limit your daily activities?.....	<input type="checkbox"/>	<input type="checkbox"/>
21. Do you snore?.....	<input type="checkbox"/>	<input type="checkbox"/>
22. Please list any medical illnesses not noted above: _____ _____		
23. Additional comments or questions for the physician's assistant or anesthesiologist? _____ _____		

THANK YOU FOR YOUR HELP!

When challenging airways are identified, advanced planning is needed for equipment and skilled personnel. Auscultation of the heart and inspection of the pulses, peripheral veins and extremities for the presence of edema are important diagnostically and in development of care plans. The pulmonary examination includes auscultation for wheezing and decreased or abnormal breath sounds. Cyanosis or clubbing and the effort of breathing are noted. For patients with deficits or disease or those undergoing neurologic procedures or regional anesthesia, a neurologic examination is performed to document abnormalities that may aid in diagnosis or interfere with positioning, and to establish a baseline. The following section discusses the most important conditions that are likely to affect the administration of anesthesia in OOR locations.

Coronary artery disease (CAD) varies from mild, stable disease with little impact on perioperative outcome to severe disease accounting for significant complications during anesthesia and surgery. The basis of cardiac assessment includes the history and the physical examination. Review of medical records and previous diagnostic studies, especially stress

tests and catheterization results, is necessary. Often a phone call to the primary care physician or cardiologist will yield important information and obviate the need for further testing or consultation.

The most recent American College of Cardiology/American Heart Association (ACC/AHA) guidelines for cardiovascular evaluation for noncardiac surgery have decreased recommendations for testing or revascularization.⁶ The guidelines have an algorithm to be followed in stepwise fashion, stopping at the first point that applies to the patient (Fig. 2.1). Step 1 considers the urgency of surgery. If emergency surgery is needed, the focus is perioperative surveillance (e.g., serial electrocardiograms [ECGs], enzymes, monitoring) and risk reduction (e.g., beta blockers, statins, pain management). Step 2 considers active cardiac conditions such as acute (within 7 days) or recent (within 30 days if established that further myocardium at risk) myocardial infarction (MI), unstable or severe angina, decompensated heart failure (HF), severe valvular disease (severe aortic stenosis or symptomatic mitral stenosis), or significant arrhythmias (new onset ventricular tachycardia,

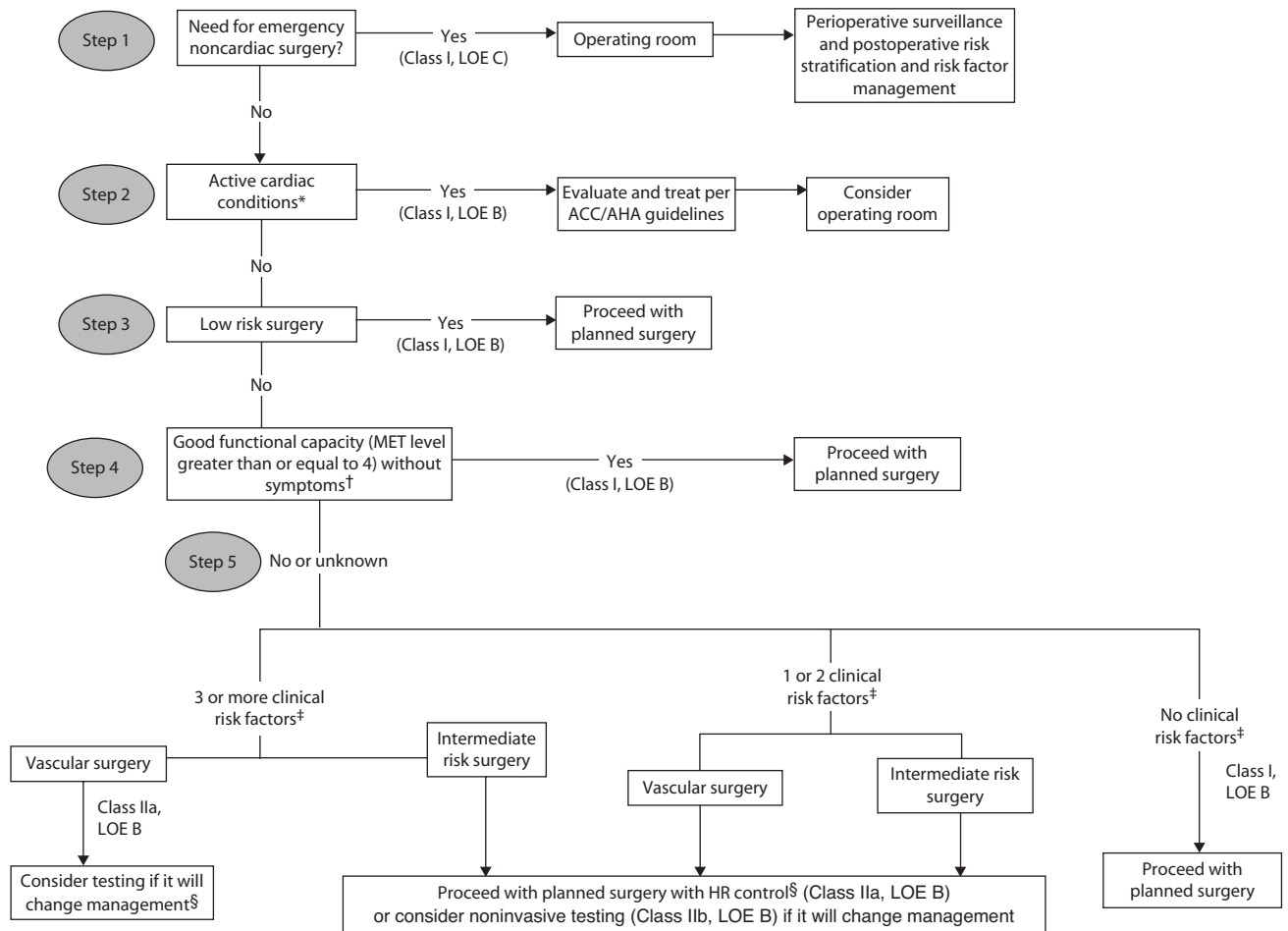


FIGURE 2.1. American College of Cardiology/American Heart Association algorithm for cardiac evaluation for noncardiac surgery. (Reprinted with permission 2007 American Heart Association. Guidelines on perioperative cardiovascular evaluation and care for noncardiac surgery. *J Am Coll Cardiol.* 2007;50:1707–1732. © 2007 American Heart Association, Inc.)

symptomatic bradycardia, supraventricular arrhythmia such as atrial fibrillation with rate greater than 100, and high-grade heart conduction abnormalities such as third degree or Mobitz atrioventricular block. Active cardiac conditions warrant postponement for all except life-saving emergency procedures. Step 3 considers the surgical risk or severity. Patients without active cardiac conditions (see Step 2) who will undergo low-risk surgery (most OOR procedures) can proceed without further cardiac testing. If the patient will undergo intermediate-risk or open vascular surgery, use Step 4 to assess functional capacity as defined by metabolic equivalents.⁵ Asymptomatic patients with average functional capacity (4–5 METs) can proceed to surgery. Step 5 considers patients with poor or indeterminate functional capacity who need intermediate-risk or vascular surgery. The number of clinical predictors (CAD, compensated HF, cerebrovascular disease, diabetes, and renal insufficiency) from the Revised Cardiac Risk Index (RCRI) determines the likely benefit of further cardiac testing. Patients with no clinical predictors proceed to surgery. Those with 3 or more RCRI predictors may benefit from further testing but only if the results

will alter management. The traditional risk factors for CAD such as smoking, hypertension, older age, male gender, hypercholesterolemia, and family history have not been shown to increase perioperative risk.

The benefits versus the risk of coronary revascularization before noncardiac surgery are controversial. The only randomized prospective study of preoperative revascularization versus medical management failed to show a difference in outcome.⁷ Noncardiac surgery soon after revascularization is associated with high rates of morbidity and mortality.^{8–10} Patients who have had a percutaneous coronary intervention (PCI), especially with a drug-eluting stent (DES), require months, if not a lifetime of antiplatelet therapy to prevent restenosis or acute thromboses.^{9,11} The type of stent, drug-eluting or bare metal, must be identified and managed in collaboration with a cardiologist. A scientific advisory offers recommendations for managing patients with coronary stents (Table 2.2).¹¹ Antiplatelet agents should not be withdrawn without consultation with a cardiologist familiar with coronary stents and an in-depth discussion with the patient regarding the risks of stopping these drugs.¹¹ Elective procedures

TABLE 2.2. Recommendations for Perioperative Management of Antiplatelet Agents in Patients with Coronary Stents

• Health care providers who perform invasive procedures must be aware of the potentially catastrophic risks of premature discontinuation of thienopyridine (e.g., clopidogrel or ticlopidine) therapy. Such professionals should contact the patient's cardiologist to discuss optimal strategies if issues regarding antiplatelet therapy are unclear.

• Elective procedures involving risk of bleeding should be deferred until an appropriate course of thienopyridine therapy (12 months after drug-eluting stents [DES] and 1 month after bare-metal stents [BMS]) has been completed.

• Patients with stents who must undergo procedures that mandate discontinuing thienopyridine therapy should continue aspirin if at all possible and have the thienopyridine restarted as soon as possible.

Source: Reprinted from Grines CL, et al. Prevention of premature discontinuation of dual antiplatelet therapy in patients with coronary artery stents. *J Am Coll Cardiol* 2007;49:734–9 with permission from Elsevier.

that necessitate interrupting dual antiplatelet therapy should be delayed during the high-risk period (Fig. 2.2). Aspirin is best continued throughout the perioperative period, and the thienopyridine (typically clopidogrel) restarted as soon as possible. Evidence supports the low risk of bleeding complications with continued aspirin during most procedures.¹²

Premature discontinuation of dual antiplatelet therapy can cause catastrophic stent thrombosis, MI, or death. Noncardiac surgery and most invasive procedures increase the risk of stent thrombosis, which is associated with high mortality.^{9–11} Stent thrombosis is best treated with PCI, which can be performed safely even in the immediate postoperative period.¹³ High-risk patients may best be managed in facilities with immediate access to interventional cardiology.⁹

Heart failure is a significant risk factor for perioperative adverse events. Patients with compensated HF have a 5%–7% risk of cardiac complications, but those with decompensated failure have a 20%–30% incidence. Heart failure may be due to systolic dysfunction (decreased ejection fraction [EF] from abnormal contractility), diastolic dysfunction (elevated filling pressures with abnormal relaxation but normal contractility and EF) or a combination. Diastolic HF accounts for almost half of all cases, but there is little science to guide perioperative care. Hypertension can cause diastolic dysfunction, and left ventricular hypertrophy on an ECG raises suspicion of hypertension and diastolic dysfunction. Ischemic heart disease is a common cause of systolic dysfunction (50%–75% of cases). Recent weight gain, complaints of shortness of breath, fatigue, orthopnea, paroxysmal nocturnal dyspnea, nocturnal cough, peripheral edema, hospitalizations, and recent changes in management are significant. Elective surgery should be deferred for patients with decompensated HF.⁶ Measurement of left ventricular EF and diastolic function with echocardiography

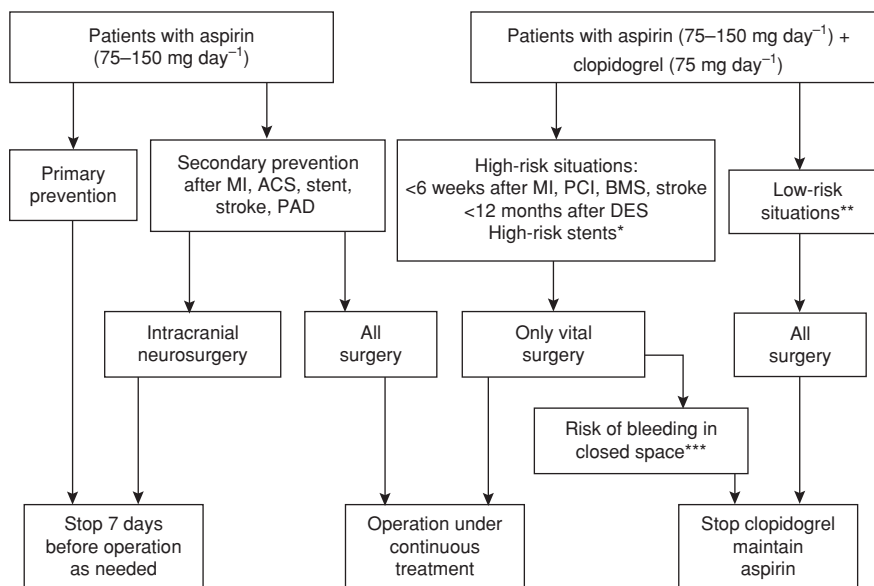


FIGURE 2.2. Algorithm for preoperative management of patients taking antiplatelet therapy. ACS, acute coronary syndrome; BMS, bare metal stent; DES, drug eluting stent; MI, myocardial infarction; PAD, peripheral arterial disease; PCI, percutaneous coronary intervention. *High-risk stents: long (>36 mm), proximal, overlapping, or multiple stents, stents in chronic total occlusions, or in small vessels or bifurcated lesions. **Examples of low-risk situations: >3 months after BMS, stroke, uncomplicated MI, PCI without stenting. ***Risk of bleeding in closed space: intracranial neurosurgery, intramedullary canal surgery, posterior eye chamber ophthalmic surgery. In these situations, the risk/benefit ratio of upholding versus withdrawing aspirin must be evaluated for each case individually; in case of aspirin upholding, early postoperative reinstitution is important. (Reprinted with permission from Chassot PG, Delabays A, Spahn DR. Perioperative antiplatelet therapy: the case for continuing therapy in patients at risk of myocardial infarction. *Br J Anaesth*. 2007;99:316–328.)

may be helpful. Patients with class IV failure (symptoms at rest) should be evaluated by a cardiologist before undergoing general anesthesia. Minor procedures with sedation may proceed as long as the patient's condition is stable.

Cardiac murmurs can be clinically unimportant or caused by significant valvular abnormalities. Functional murmurs from turbulent flow across the aortic or pulmonic outflow tracts are found with high outflow states (hyperthyroidism, pregnancy, anemia). Elderly patients, those with risk factors for CAD, a history of rheumatic fever, volume overload, pulmonary disease, cardiomegaly, or an abnormal ECG are likely to have valvular pathology. Echocardiography is beneficial, especially if general or spinal anesthesia is planned. Diastolic murmurs are always pathologic and require evaluation. Regurgitant disease is tolerated perioperatively better than stenotic disease. Aortic stenosis (AS) is the most common valvular lesion in the United States (2%–4% of adults >65 years); severe AS is associated with a high risk of perioperative complications. Aortic sclerosis, present in 25% of people 65–74 years of age and 50% of those >84 years old, causes a systolic ejection murmur similar to that of AS, but it has no hemodynamic compromise.¹⁴ Patients with severe or critical AS should not have anesthesia (unless emergency and life saving) without a cardiology evaluation.¹⁵ Antibiotic prophylaxis to prevent infective endocarditis is no longer recommended for patients with valvular abnormalities except for patients with heart transplants; prophylaxis is indicated for those with valve replacements.¹⁶

Pacemakers and implantable cardioverter-defibrillators (ICDs) can be affected by electrical/magnetic interference. Consultation with the device manufacturer or cardiologist may be needed. Patients usually have a wallet card with important device information and phone numbers. Patients with ICDs invariably have HF, ischemic or valvular disease, cardiomyopathies, or potentially lethal arrhythmias. Some monitors, ventilators, vibrations, or chest prepping may fool the sensors into increasing pacing, leading to ischemia or inappropriate treatment. Special features such as rate-adaptive mechanisms in some pacemakers are disabled or the device is reprogrammed to asynchronous pacing to prevent interference.¹⁷ Antitachyarrhythmia functions are disabled before procedures if interference or unexpected patient movement is undesirable.¹⁷ During delicate intracranial, spinal, or ocular procedures, an unexpected discharge with patient movement can be catastrophic. Central line placement can trigger cardioversion. Typically ICDs are deactivated only after arrival to a facility with monitoring and external defibrillation devices. Many devices are complex, and reliance on a magnet to disable them, except in emergencies, is not recommended. Some devices are programmed to ignore magnet placement. Magnets can permanently disable antitachyarrhythmic therapy for some ICDs. Magnets affect the antiarrhythmia function, not the pacing function of an ICD. If a pacemaker or ICD is reprogrammed, or if a magnet is used at any time, the device needs to be re-interrogated and re-enabled before the patient leaves a monitored setting.

Hypertension severity and duration correlate with the degree of end-organ damage, morbidity, and mortality.

Ischemic heart disease, HF, renal insufficiency, and cerebrovascular disease are common in hypertensive patients. However, there is little evidence of an association between preoperative blood pressure (BP) <180/110 mmHg and perioperative cardiac risk. It is generally recommended that elective surgery be delayed for patients with severe hypertension (DBP >115 mmHg; SBP >200 mmHg) until BP is <180/110 mmHg. If severe end-organ damage is present, the goal is to normalize BP as much as possible before surgery.¹⁸ Effective lowering of risk may require weeks of therapy for regression of vascular changes, and too rapid or extreme lowering of BP may increase cerebral and coronary ischemia. Studies suggest that intraoperative hypotension is far more dangerous than hypertension.¹⁸ For BP <180/110 mmHg there is no evidence to justify cancellation of surgery, although if time allows preoperative interventions are appropriate.

Pulmonary disease increases risk for both pulmonary and nonpulmonary perioperative complications. Postoperative pulmonary complications (PPCs) occur frequently, and they increase costs, morbidity, and mortality. Predictors of PPC are advanced age, HF, chronic obstructive pulmonary disease (COPD), smoking, general health status (including impaired sensorium and functional dependency), and obstructive sleep apnea (OSA).^{19,20} Well-controlled asthma does not appear to increase perioperative complications.²¹ However, patients whose asthma is poorly controlled, as evidenced by wheezing at the time of anesthesia induction, have a higher risk of complications.²¹ Unlike asthma, COPD does increase the risk of PPC, and the more severe the COPD, the greater the risk, but there is no prohibitive degree of severity that precludes surgery. Surprisingly the risk with COPD is less than that with HF, advanced age, and poor general health. Preoperative corticosteroids and inhaled beta-agonists markedly decrease the incidence of bronchospasm after tracheal intubation, and they may shorten hospital and ICU stays.^{21,22} Recovery time, pain, and reduction in lung volumes are less after laparoscopic procedures, but it is unclear whether this lowers PPC rates.¹⁹ PPC risk is lower for percutaneous interventions; in a study of endovascular versus open abdominal aortic aneurysm repair, PPC rates were 3% and 16%, respectively.¹⁹ General anesthesia carries greater risk than peripheral nerve blocks. Two large meta-analyses, and retrospective and randomized trials, suggest that PPC rates are lower for patients who have spinal or epidural anesthesia and/or epidural analgesia postoperatively.^{19,22} Routine pulmonary function tests, chest radiography, or arterial blood gases do not predict PPC risk and offer little more than can be determined by clinical evaluation.²² Maximizing airflow in obstructive disease, treating infections and HF, and lung expansion maneuvers, including cough, deep breathing, incentive spirometry, positive end-expiratory pressure (PEEP), and continuous positive airway pressure (CPAP), reduce PPC rates.

Obstructive sleep apnea is caused by intermittent airway obstruction. It affects up to 9% of women and 24% of men, and most are unaware of the diagnosis.²³ Snoring, daytime sleepiness, hypertension, obesity, and a family history of OSA are risk factors for OSA.²³ A large neck circumference (>17 inches in men, >16 inches in women) predicts a greater

chance of OSA.²⁴ Patients with OSA have increased rates of diabetes, hypertension, atrial fibrillation, bradyarrhythmias, ventricular ectopy, stroke, HF, pulmonary hypertension, dilated cardiomyopathy, and CAD.²⁵ Mask ventilation, direct laryngoscopy, endotracheal intubation, and fiberoptic visualization of the airway are more difficult in patients with OSA. Airway obstruction, hypoxemia, atelectasis, ischemia, pneumonia, and prolonged hospitalizations occur in patients with OSA.²⁰ If the patient uses a CPAP device, he or she should be advised to bring it on the day of the procedure. The ASA has published recommendations for the perioperative care of patients with OSA, including a scoring system to predict perioperative risk.²⁶

Renal disease is associated with hypertension, cardiovascular disease, volume overload, electrolyte disturbances, metabolic acidosis, and a need for modification of anesthetic drugs; it is also a risk factor for CAD. In elective procedures, it is recommended that dialysis be performed within 24 hr, but not immediately before, because of acute volume depletion and electrolyte alterations. It may not be necessary to correct chronic hyperkalemia if $K < 6$ mEq/dl and within a range of a given patient's established levels. Radiocontrast media transiently decreases glomerular filtration rate (GFR) in almost all patients, but patients with diabetes or renal insufficiency are at highest risk. For patients with a $GFR < 60$ ml/kg⁻¹/min⁻¹ alkalinizing renal tubular fluid with sodium bicarbonate or simple hydration may reduce injury.

Diabetic patients are at risk for multi-organ dysfunction, with renal insufficiency, strokes, peripheral neuropathies, and cardiovascular disease most prevalent. Tight glucose control in stroke, coronary bypass surgery, or critically ill individuals may improve outcomes, but it is controversial.²⁷ However, it has yet to be proven that tight control in the immediate perioperative period for noncardiac surgery confers benefit or simply increases the risk of hypoglycemia. Chronically poor control increases comorbid conditions such as vascular disease, HF, and infections, and likely increases the risk of surgery. It is unlikely that simply targeting perioperative glucose control will have a substantial impact on outcomes in diabetics having ambulatory surgery. No data exist that support cancellation of procedures for any level of elevation of blood glucose, or even treatment of such. Diabetic ketoacidosis and hypoglycemia (glucose < 50 g/dL) are the only conditions that absolutely warrant perioperative intervention. Preoperative goals of diabetic glucose control are to prevent hypoglycemia during fasting and extreme hyperglycemia and ketosis.

Extreme obesity is defined by a BMI ≥ 40 and these patients may have OSA, HF, diabetes, hypertension, pulmonary hypertension, a difficult airway, decreased arterial oxygenation, and increased gastric volume. Special equipment is needed such as blood pressure cuffs, airway management devices, procedure tables, and gurneys to support the additional weight.

Anemia is common preoperatively, is a marker of increased perioperative mortality, and a predictor of short- and long-term outcomes in the general population.²⁸ Preoperative anemia is the strongest predictor of the need for transfusions which increase morbidity and mortality.²⁸ If patients have a

hemoglobin > 6 g/dL, are asymptomatic, and have no history of CAD, the minimal physiologic perturbations with a well-conducted anesthetic and a low-risk procedure are unlikely to pose enough risk to warrant transfusion.

Pregnant patients with a viable fetus may require fetal monitoring. Plans to manage preterm labor or delivery should be made.

Extremes of age may affect the selection of patients for procedures in OOR locations. An ex-premature baby < 60 weeks postconceptual age needs overnight observation to monitor for postanesthetic apnea after receiving anesthesia. Patients > 85 years of age with a history of hospital admission within the previous 6 months have a high risk of postoperative admission after ambulatory surgery.²⁹

Diagnostic testing and the benefits of disease-indicated testing versus "routine" preoperative tests have been studied, and few abnormalities detected by nonspecific testing result in changes in management, and rarely have such changes had a beneficial patient effect.^{30,31} On average, 1 in 2000 preoperative tests result in patient harm from pursuit of abnormalities detected by those tests.⁴ It has been suggested that not following up on an abnormal result is a greater medico-legal risk than not identifying the abnormality to begin with.

In a pilot study by Chung involving over 1000 patients undergoing ambulatory surgery, no increase in adverse perioperative events occurred in patients who had no preoperative testing.² There was no increase in OR delays or cancellations, or differences in outcome from lack of testing. Similarly, Schein et al. showed that routine medical testing in patients having cataract surgery who were evaluated preoperatively by primary care physicians did not offer benefit.³ These studies corroborate other studies showing that ambulatory surgery is extremely safe, and the adverse events that typically occur (nausea, vomiting, laryngospasm, hypertension) will not be prevented by more testing.^{2,32,33} Several studies indicate that preoperative resting 12-lead ECGs do not add value to the care of ambulatory surgical patients.^{6,34} The specificity of an ECG abnormality in predicting postoperative cardiac adverse events is only 26%, and a normal ECG does not exclude cardiac disease.³¹ An ECG should not be done simply because the patient is of advanced age. Recommendations for age-based testing were derived from the high incidence of abnormalities found on ECG of elderly patients. A prospective observational study in patients aged 50 years or older having noncardiac surgery found abnormalities in 45% of the preoperative ECGs, and bundle branch blocks were associated with postoperative MI and death but had no added predictive value over clinical risk factors.³⁵ The Centers for Medicare and Medicaid Services (CMS) do not reimburse for "preoperative" or age-based ECGs.³⁶ The ASA Preoperative Evaluation Practice Advisory recognized that ECG did not improve prediction beyond risk factors identified by patient history.¹ The ACC/AHA guidelines state that "ECGs are not indicated in asymptomatic persons undergoing low-risk surgical procedures."⁶ Chest radiographs have not been shown to predict postoperative pulmonary complications.¹⁹

Healthy patients of any age and patients with known, stable, chronic diseases undergoing low-risk procedures are

unlikely to benefit from any “routine” tests. A test should be ordered only if the results will impact the decision to proceed with the planned procedure or alter the care plans. Discovering abnormalities in blood tests or on ECGs and chest X-rays does not impact outcomes for patients receiving anesthesia for low-risk procedures. Eliciting a history of increased dyspnea on exertion, new onset chest pain, or syncope, and providing patients with appropriate preoperative medication instructions is of greater benefit than ordering ECGs or blood tests.

According to the ASA Preoperative Evaluation Practice Advisory the literature “. . . is insufficient to inform patients or physicians whether anesthesia causes harmful effects on early pregnancy,” and pregnancy testing may be offered to women if the test result would alter patient management.¹ Some practices and facilities provide patients with information about the potential risks of anesthesia and surgery on pregnancy but allow them to decline testing. Other practices mandate that all females of child-bearing age undergo a preoperative pregnancy test. It has been suggested that if a mandatory testing policy is utilized that patients be informed that consent for surgery or anesthesia includes consent for pregnancy testing. Recommended testing guidelines are in Table 2.3.

Medication instructions that advise patients to continue or discontinue drugs will likely improve outcomes more than testing will. The patient’s comorbidities and the nature of the procedure should be considered when managing medications preoperatively. Continuing medications may be beneficial or detrimental, and in some cases suddenly stopping them has a negative effect. A summary of recommendations for

perioperative administration of medications is in Table 2.4. Several drug classes and emerging controversies deserve special mention.

Generally, cardiac medications and antihypertensive agents are continued preoperatively. Selectively continuing or discontinuing these drugs depends on the volume and hemodynamic status of the patient, the degree of cardiac dysfunction, the adequacy of blood pressure control, and the anticipated anesthetic and volume challenges. Continuing all medications for patients with severe disease having minor procedures is likely best. Angiotension converting enzyme inhibitors (ACEIs) and angiotension receptor blockers (ARBs) may cause refractory hypotension. A suggested approach is to continue these drugs and alter the anesthetic plan, especially induction dosages and drugs, and have vasopressin available to prevent or mitigate significant hypotension.³⁷ The potential for refractory hypotension must be balanced against the positive therapeutic impact of continuing these agents perioperatively on a case-by-case basis. Furosemide can be administered intravenously after induction of anesthesia.

Aspirin is commonly used to lower the risk of events in patients with known vascular disease, diabetes, renal insufficiency, or simply advanced age. Traditionally aspirin has been withdrawn in the perioperative period because of concern of increased bleeding. However, this practice has come under scrutiny. A meta-analysis involving almost 50,000 patients undergoing a variety of noncardiac surgeries (30% on perioperative aspirin) found that aspirin increased bleeding complications by a factor of 1.5, but not the severity of bleeding complications except in patients undergoing intracranial surgery and possibly transurethral resection of the prostate.¹² When surgeons are blinded to aspirin administration they can not identify patients taking or not taking aspirin based on bleeding.¹³ There is an increased risk of vascular events when aspirin is stopped perioperatively in patients who take it regularly.³⁸ A rebound hypercoagulable state may result.³⁹ Acute coronary syndromes occurred 8.5 ± 3.6 days and acute cerebral events 14.3 ± 11.3 days after aspirin cessation, the typical duration of cessation before surgery. Events were twice as common in patients who had stopped aspirin in the previous 3 weeks than in those who had not.¹² Stopping aspirin for 3–4 days should be sufficient, if aspirin is stopped at all, and dosing should be resumed as soon as possible. New platelets formed after aspirin (half-life of ~15 minutes) is stopped will not be affected. Normally functioning platelets $> 50,000/\text{mm}^3$ are adequate to control surgical bleeding. For many minor, superficial procedures such as cataract extraction, endoscopies, and peripheral procedures, the risk of withdrawing aspirin in at-risk patients is greater than the risk of bleeding. A review article recommends discontinuing aspirin if taken only for primary prevention (no history of stents, strokes, MI). See Figure 2.2.³⁸ Continuing aspirin, if taken for secondary prevention (history of stents, vascular disease), is recommended except for procedures with a risk of bleeding in closed spaces (e.g., intracranial, posterior chamber of the eye). Neuraxial or peripheral anesthesia is safe for patients taking aspirin.⁴⁰ The risk of spinal hematoma with clopidogrel is unknown. Based on labeling and guidelines of the American Society of Regional

TABLE 2.3. *Preoperative Testing Guidelines for Patients Outside of the Operating Room*

<i>Procedure/Patient Type</i>	<i>Tests^a</i>
Injection of contrast dye	Creatinine ^a
Potential for significant blood loss	Hemoglobin/hematocrit ^a
Likelihood of transfusion requirement	Type and screen
Possibility of pregnancy	Pregnancy test ^b
End-stage renal disease	Potassium level ^c
Diabetes	Glucose level on day of surgery ^c
Active cardiac condition (e.g., decompensated heart failure, arrhythmia, chest pain, murmur)	Electrocardiogram ^a

^aResults from laboratory tests within 3 months of surgery are acceptable unless major abnormalities are present or a patient’s condition has changed.

^bA routine pregnancy test before surgery is not recommended *before* the day of surgery. A careful history and local practice determine whether a pregnancy test is indicated.

^cThere is no absolute level of either potassium or glucose that precludes surgery and anesthesia. The benefits of the procedure must be balanced against the risk of proceeding in a patient with abnormal results.

TABLE 2.4. *Summary of Medication Instructions*

<i>Continue on Day of Surgery</i>	<i>Discontinue on Day of Surgery Unless Otherwise Indicated</i>
Antidepressants, antianxiety, and psychiatric medications (including monoamine oxidase inhibitors)	
Antihypertensives	Antihypertensives
Generally to be continued	Consider discontinuing angiotensin-converting enzyme inhibitors or angiotensin receptor blockers 12–24 hr before surgery; especially if: Procedures: lengthy, significant blood loss or fluid shifts, use of general anesthesia Patients: taking multiple antihypertensive medications, well-controlled blood pressure, for whom hypotension is dangerous
Aspirin	Aspirin
Patients with known vascular disease	Discontinue 5–7 days before surgery:
Patients with drug-eluting stents <12 months	If risk of bleeding is greater than risk of thrombosis
Patients with bare metal stents <1 month	For surgeries with serious consequences from bleeding
Before cataract surgery (if no bulbar block)	Taken only for primary prophylaxis (no known vascular disease)
Before vascular surgery	
Taken for secondary prophylaxis	
Asthma medications	
Autoimmune medications	Autoimmune
Methotrexate (if no risk of renal failure)	Methotrexate (if risk of renal failure)
	Entanercept (Enbrel) 2 weeks before surgery
	Infliximab (Remicade) 6 weeks before surgery
	Adalimumab (Humira) 8 weeks before surgery
Birth control pills	
Cardiac medications	
Clopidogrel (Plavix)	Clopidogrel (Plavix)
Patients with drug-eluting stents <12 months	Patients not included in group recommended for continuation
Patients with bare metal stents <1 month	
Before cataract surgery (if no bulbar block)	
Cox-2 inhibitors	Cox -2 inhibitors
	If surgeon concerned about bone healing
Diuretics	Diuretics
Triamterene, hydrochlorothiazide	Potent loop diuretics
Eye drops	
Estrogen compounds	Estrogen compounds
When used for birth control or cancer therapy	When used to control menopause symptoms or for osteoporosis
Gastrointestinal reflux medications (Prilosec, Zantac)	Gastrointestinal reflux medications (Tums)
	Herbals and nonvitamin supplements
	7–14 days before surgery
	Hypoglycemic agents, oral
Insulin	Insulin
Type 1 diabetes: take ~1/3 of intermediate to long-acting (NPH, lente)	Regular insulin (exception: insulin pump—continue lowest basal rate—generally nighttime dose)
Type 2 diabetes: up to ½ long-acting (NPH) or combination (70/30) preparations	Discontinue if blood sugar level <100
Glargine (Lantus)	
If insulin pump delivery, continue lowest night time basal rate	

Narcotics for pain or addiction**Seizure medications**

Statins (Zocor, simvastatin, others)

Steroids (oral or inhaled)

Thyroid medications**Warfarin**

Cataract surgery, no bulbar block

Nonsteroidal anti-inflammatory drugs

48 hr before day of surgery

Topical creams and ointments

Viagra or similar medications

Discontinue 24 hr before surgery

Vitamins, minerals, iron**Warfarin**

Discontinue 5 days before surgery

Anesthesia, clopidogrel is discontinued 7 days before planned neuraxial blockade.⁴⁰

Low-molecular weight heparin (LMWH) is discontinued 12–24 hr before procedures with a risk of bleeding or planned neuraxial block.⁴⁰ Warfarin may increase bleeding except for minor procedures such as cataract surgery without bulbar blocks. The usual recommendation is to withhold 4–5 doses of warfarin before operation if the INR is 2–3, until the INR decreases to <1.5, a level considered safe for surgical procedures and neuraxial blockade.⁴⁰ If the INR is >3.0, it is necessary to withhold warfarin longer. If the INR is measured the day before surgery and is >1.8, a small dose of vitamin K (1–5 mg orally or subcutaneously) can reverse anticoagulation.⁴¹ Substitution with shorter-acting anticoagulants such as unfractionated or LMWH, referred to as bridging, is controversial. Kearon recommends preoperative bridging only for patients who have had an acute arterial or venous thromboembolism within 1 month before a procedure that cannot be postponed.⁴¹

Type 1 diabetics have an absolute insulin deficiency and require insulin to prevent ketoacidosis even if they are not hyperglycemic. Type 2 diabetics are often insulin resistant and prone to extreme hyperglycemia. Both Type 1 and 2 diabetics should discontinue short-acting insulins. An exception is for patients with insulin pumps who continue their lowest basal rate, typically a nighttime rate. Type 1 diabetics should take a small amount (usually 1/3–1/2) of their usual morning dose of intermediate to long-acting insulin (e.g., lente or NPH) the day of surgery to avoid ketoacidosis. Type 2 diabetics should take none or up to 1/2 dose of intermediate to long-acting insulin (e.g., lente or NPH) or a combination (e.g., 70/30) insulin on the day of the procedure. Taking half of the usual dose of intermediate, long-acting, or combination insulins on the day of surgery improves perioperative glycemia compared to taking no insulin.⁴² Glargine (e.g., Lantus) insulin can be taken as scheduled.

Metformin does not need to be discontinued *before* the day of surgery. Metformin will not cause hypoglycemia during fasting periods of 1–2 days, and there is no risk of lactic acidosis with metformin except in cases of renal or hepatic failure. Do not restart this drug postoperatively until any risk of organ failure has passed. Procedures should not be cancelled if patients continue metformin. There is no data to support

the recommendation to stop metformin 24–48 hr before surgery, which increases the risk of hyperglycemia. Sulfonylurea agents with long half-lives (e.g., chlorpropamide) can cause hypoglycemia in fasting patients. Newer oral agents (acarbose, pioglitazone) used as single-agent therapy do not cause hypoglycemia during fasting. However, to avoid confusion oral hypoglycemic agents are generally held the day of surgery.

Patients who are taking steroids should take their usual dose on the day of surgery. Stress-associated adrenal insufficiency is possible in some patients unless additional steroids are given perioperatively. A normal daily adrenal output of cortisol (30 mg) is equivalent to 5–7.5 mg of prednisone. The hypothalamic-pituitary axis (HPA) is not suppressed with ≤5 mg/day of prednisone or its equivalent. In patients who have taken >5–20 mg/day of prednisone or its equivalent for ≥3 weeks, the HPA may be suppressed. The HPA is suppressed with >20 mg/day of prednisone or its equivalent taken for ≥3 weeks. The risk of adrenal insufficiency remains for up to 1 year after the cessation of high-dose steroids. Surgery, trauma, or infection may be stressful, and an intact HPA will respond by increasing output of glucocorticoids. Most OOR procedures will induce minimal physiologic stress, and nothing more than the patient's usual daily dose of steroid is required. Supplementation depends on the amount of stress, duration and severity of the procedure, and the daily dose of steroid. Infections, psychosis, decreased wound healing, and hyperglycemia increase with high doses of perioperative steroids, which are rarely necessary.⁴³

It is generally recommended to discontinue herbals and supplements 7–14 days before surgery. The exception is valerian, a central nervous system depressant that may cause a benzodiazepine-like withdrawal when abruptly discontinued. If possible, valerian consumption should be tapered. Mandatory discontinuation of these medications, or cancellation of anesthesia when these medications have been continued, is not supported by available data. Historically, monoamine oxidase inhibitors (MAOIs) have been discontinued before surgery, but because of their long duration of action, they must be stopped at least 3 weeks beforehand. Suicides and/or severe depression can occur when patients discontinue an MAOI. The safest approach is to continue these drugs and adjust the anesthetic plan.

Patients should continue narcotic pain medications to prevent withdrawal symptoms and discomfort. Drugs used to treat addiction such as methadone and nicotine-replacement therapies are continued as scheduled.⁴⁴ Inhalers and long-term medications for asthma or COPD are continued on the day of surgery.²²

Current guidelines for the adult patient recommend fasting for 6 hrs after a light meal (toast and clear liquids) or nonhuman milk and 8 hr after meals containing fried or fatty foods or meat before procedures requiring general anesthesia, regional anesthesia, or sedation/analgesia.⁴⁵ Clear liquids up to 2 hr before anesthesia are acceptable for patients without conditions that may increase the risk of aspiration, such as gastroesophageal reflux disease, hiatal hernia, diabetes mellitus, gastric motility disorders, intra-abdominal masses (including the gravid uterus), and bowel obstruction.⁴⁵

CONCLUSION

Preparation to lower the risk of complications and improve outcomes during and after procedures requiring anesthesia is the most important goal. Traditionally surgical risk has been considered more important than the anesthetic risk. However, a general anesthetic requiring instrumentation of the airway with associated significant physiologic perturbations may pose a greater risk than many procedures typically performed in OOR settings. Identification and modification of risk require fundamentally good medicine, systems of care, clinical assessment and experienced, knowledgeable, and dedicated health care providers. As the numbers of patients having anesthesia in OOR locations increase, anesthesiologists must continue to innovate to provide patients with the best preoperative services.

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3 Patient Monitoring

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The expertise and skill of the modern anesthesiologist is increasingly required when anesthesia is administered for procedures performed outside of the operating room (OOR). The OOR environment is fraught with challenges and often requires a great deal of flexibility without compromising patient care. In the practice of anesthesiology, physiological monitoring of patients is imperative and is recognized as a standard of care. Although definitive data are lacking, some studies have suggested that adverse events occurring in the OOR environment have a higher severity of injury and may result from substandard care, including lack of adherence to minimum monitoring guidelines.^{1,2} This chapter will focus on the physics, physiology, limitations, and recommendations for standard physiological monitors that should be utilized in the OOR environment. A special emphasis is placed on pulse oximetry and capnography.

MONITORS

Pulse Oximetry

Numerous studies have demonstrated significant knowledge deficits among clinicians regarding the limitations and interpretation of pulse oximetry results.^{1,3-6} An understanding of pulse oximetry is obligatory for all providers of OOR anesthesia because this technology is employed as the principal means of assuring adequate oxygenation in a sedated or anesthetized patient.

Dr. Takuo Aoyagi, a Japanese bioengineer, is credited with developing and marketing the first functional pulse oximeter in 1972.⁷ Based on a century of experimental antecedents, Aoyagi recognized that the absorbency ratios of pulsatile variations varied with oxygen saturation at different wavelengths. By the early 1980s, use of the pulse oximeter rapidly expanded, eventually becoming integrated into the clinical practice of anesthesiologists and clinicians working in operating room and critical care settings.

Pulse oximetry relies on the spectral analysis of oxygenated and reduced hemoglobin and is explained by the Beer-Lambert law.^{8,9} This law describes how the concentration of a substance in solution can be determined by transmitting a known intensity of light through a solution. With pulse oximetry, the PaO₂ is approximated by transmitting light of a specific wavelength across tissue and measuring its intensity on the other side. Red and near-infrared light readily penetrate tissue,

whereas other wavelengths of light tend to be absorbed (Fig. 3.1).

Light-emitting diodes (LEDs) are used to emit red light (660 nm) and near-infrared light (940 nm) since these two wavelengths have known absorption qualities when directed at hemoglobin (Hb). Specifically, 660 nm red light is absorbed by reduced Hb, while 940 nm is absorbed preferentially by oxygenated Hb. When these wavelengths are emitted through tissue and a vascular bed such as a finger, nostril, or earlobe, a photodiode detector on the opposite side measures the amount of light transmitted. The red/near-infrared ratio is calculated by the oximeter and compared to reference values for PaO₂ derived from healthy human subjects. The PaO₂ is further discriminated from venous blood or connective tissue by measuring the pulse-added component of the signal. This signal is comprised of alternating current, representing pulsatile arterial blood, and direct current, which corresponds to tissue, venous blood, and nonpulsatile arterial blood.¹⁰ By cancelling out the static components, the pulsatile component can be isolated and the PaO₂ estimated.

Pulse oximetry has several limitations. Nail polish and dark skin may cause a variable degree of interference; the physical obstruction to light transmittance appears to be related to darker skin pigmentation and dark-opaque nail polish.¹¹⁻¹³ In critically ill patients, a low signal-to-noise ratio may exist due to hypovolemia, peripheral vasoconstriction, or peripheral vascular disease.¹⁴ Extra “noise” in the form of ambient light, deflection of light around and not through the vascular bed (optical shunt), and motion artifact may cause false readings.¹⁵⁻¹⁷ Shivering is considered a common source of motion artifact, but normal pulse oximetry readings have been recorded in patients with tonic-clonic seizures.¹⁸

Dyshemoglobinemias represent a well-known cause of optical interference with pulse oximetry. Both carboxyhemoglobin (COHb) and methemoglobin (MetHb) absorb light within the red and near-infrared wavelength ranges utilized in pulse oximetry; standard pulse oximeters are unable to distinguish COHb and MetHb from normal oxyhemoglobin (O₂Hb). Hence, COHb will falsely absorb red light and the pulse oximeter will display a falsely high saturation reading.¹⁹ With MetHb, standard oximeters falsely detect a greater degree of absorption of both Hb and O₂Hb, increasing the absorbance ratio. When the absorbance ratio reaches 1, the calibrated saturation level approaches a plateau of approximately 85%.²⁰ Co-oximetry offers a multi-wavelength analysis that takes into account the absorption of O₂Hb, MetHb,

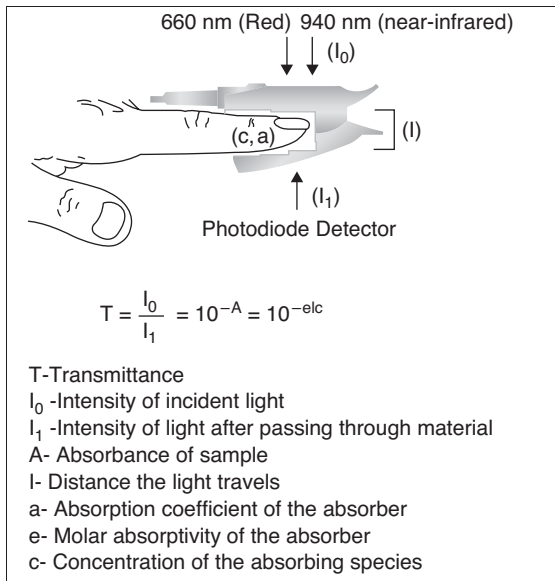


FIGURE 3.1. Pulse oximetry: Application of the Beer-Lambert law.

and COHb and should be used to determine an accurate saturation reading in cases where these dyshemoglobins are suspected to be present. Intravenous dyes such as methylene blue and indigo carmine cause reliable spurious decreases in oximetry readings.^{21,22} Fetal hemoglobin, hyperbilirubinemia, and anemia have not been found to yield inaccurate oximetry readings in most cases.²³⁻²⁵

Capnography

Over the last two decades, capnography has become a standard for monitoring in anesthesia practice.²⁶ The measurement of carbon dioxide (CO_2) in expired air directly indicates changes in the elimination of CO_2 from the lungs. Indirectly, it indicates changes in the production of CO_2 at the tissue level and in the delivery of CO_2 to the lungs by the circulatory system. Capnography is a noninvasive monitoring technique that allows fast and reliable insight into ventilation, circulation, and metabolism.²⁷ In the prehospital environment, it is used primarily for confirmation of successful endotracheal intubation, but it may also be a useful indicator of efficient ongoing cardiopulmonary resuscitation (CPR). Numerous national organizations, including the American Heart Association, now endorse capnography and capnographic methods for confirming endotracheal tube placement.²⁸ Despite these recommendations, capnography is not always widely available or consistently applied.²⁹

Capnometry refers to the measurement and display of carbon dioxide (CO_2) on a digital or analogue monitor. Maximum inspiratory and expiratory CO_2 concentrations during a respiratory cycle are displayed. Capnography refers to the graphic display of instantaneous CO_2 concentration (FCO_2) versus time or expired volume during a respiratory cycle (CO_2 waveform or capnogram). CO_2 waveforms are

displayed as two types: FCO_2 can be plotted against expired volume or against time during a respiratory cycle.

Infrared (IR) spectrographs are the most compact and least expensive means to measure end-tidal CO_2 ($ET\ CO_2$). The wavelength of IR rays exceeds 1.0 millimicrons, whereas the visible spectrum is between 0.4 and 0.8 millimicrons.³⁰ The IR rays are absorbed by polyatomic gases such as nitrous oxide, carbon dioxide, and water vapor. Carbon dioxide selectively absorbs specific wavelengths (4.3 millimicrons) of IR light (Fig. 3.2). Since the amount of light absorbed is proportional to the concentration of the absorbing molecules, the concentration of a gas can be determined by comparing the measured absorbance with the absorbance of a known standard. The CO_2 concentration measured by the monitor is usually expressed as partial pressure in mmHg, although some units display percentage CO_2 , obtained by dividing the partial pressure of CO_2 by the atmospheric pressure. Other techniques used to measure $ET\ CO_2$ include Raman spectrography, molecular correlation spectrography, mass spectrography, and photoacoustic spectrography.

A time capnogram can be divided into an inspiratory (phase 0) and expiratory segments (Fig. 3.3). Standard terminology for capnography has been adopted.³¹ The expiratory segment, similar to a single breath nitrogen curve or single breath CO_2 curve, is divided into three phases. The angle between phase II and phase III is the alpha angle. The nearly 90-degree angle between phase III and the descending limb is the beta angle.

Causes of increased or decreased CO_2 are listed in Table 3.1. Under normal circumstances, the end-tidal ($ETPCO_2$) is lower than $PaCO_2$ by 2–5 mmHg, in adults.³²⁻³⁵ The PCO_2 gradient is due to the ventilation-perfusion (V/Q) mismatch in the lungs as a result of temporal, spatial, and alveolar mixing defects. The arterial-to-end-tidal (a-ET) $PCO_2/PaCO_2$ fraction is a measure of alveolar dead space, and changes in alveolar dead space correlate well with changes in (a-ET) PCO_2 .³¹ An increase in (a-ET) PCO_2 suggests an increase in dead space ventilation; hence, (a-ET) PCO_2 can provide an indirect estimate of V/Q mismatching of the lung. Nevertheless, (a-ET) PCO_2 does not correlate with alveolar dead space in all circumstances. Changes in alveolar dead space correlate with (a-ET) PCO_2 only when phase III is flat or has a minimal slope. If phase III has a steeper slope, the terminal portion of phase III may intercept the line representing $PaCO_2$, resulting in either zero or negative (a-ET) PCO_2 , even in the presence of alveolar dead space. Therefore, the (a-ET) PCO_2 is dependent both on alveolar dead space as well as factors that influence the slope of phase III. This implies that an increase in the alveolar

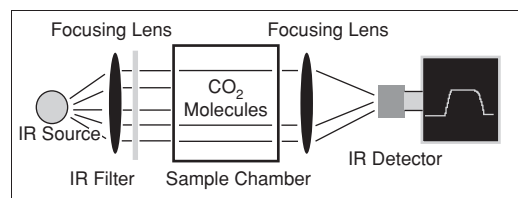


FIGURE 3.2. Infrared (IR) spectrography.

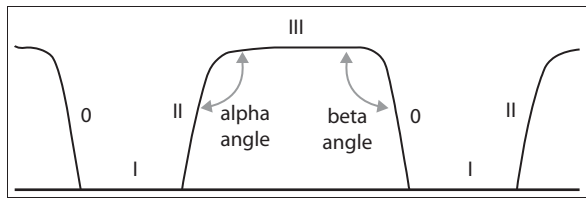


FIGURE 3.3. Current terminology for components of a time-capnogram.

dead space need not always be associated with an increase in the (a-ET) PCO_2 . The (a-ET) PCO_2 may remain the same if there is an associated increase in the slope of the phase III.

A reduction in cardiac output and pulmonary blood flow results in a decrease in ETCO_2 and an increase in (a-ET) PCO_2 . Increases in cardiac output and pulmonary blood flow result in better perfusion of the alveoli and a rise in ETCO_2 .³⁶ The decrease in (a-ET) PCO_2 is due to an increase in the alveolar CO_2 with a relatively unchanged arterial CO_2 concentration, suggesting better excretion of CO_2 into the lungs. The improved CO_2 excretion is due to better perfusion of upper parts of the lung. There is an inverse linear correlation between pulmonary artery pressure and (a-ET) PCO_2 .³⁷ Thus, under conditions of constant lung ventilation, ETCO_2 monitoring can be used as a monitor of pulmonary blood flow.

In one study of 17 elderly patients, transcutaneous monitoring of PCO_2 provided a more accurate estimation of arterial CO_2 partial pressure than PETCO_2 monitoring.³⁸ At the time of this writing, transcutaneous PCO_2 monitoring is not yet widely available and the role of this modality for monitoring in the OOR environment has yet to be defined.

ETCO_2 monitoring can be utilized in nonintubated spontaneously breathing patients. When applied in this manner, capnography waveforms can be distorted by the dilution of air or oxygen; ETCO_2 readings are typically decreased. Numerous devices are commercially available to provide capnography for nonintubated patients. While not quantitatively accurate, many of these devices provide baseline measurements, and the presence of waveforms can be used to confirm ventilation.

Blood Pressure Measurement

Blood pressure in OOR locations is commonly measured with noninvasive oscillometric devices. An electronic pressure transducer detects oscillating blood flow as the cuff is deflated. Assuming the upper extremity is used, the compressed brachial artery oscillates as restricted blood flows through it and the systolic, diastolic, and mean pressures are determined. The reader is referred to an excellent in-depth review by Polanco and Pinsky.³⁹

Electrocardiography

Both transmural and subendocardial ischemia can be detected when electrocardiography (ECG) leads are properly positioned.⁴⁰ Lead V_5 , the precordial lead originally described in Kaplan

and King's classic paper on intraoperative ischemia, has been validated and found to detect up to 75% of ischemic changes seen in all 12 leads.^{41,42} The combination of leads II, V_2 , V_3 , V_4 , and V_5 , has a sensitivity of 100% for detecting intraoperative ischemia.⁴⁰ The reader is directed to an exceptional review on perioperative electrocardiography previously published in *Anesthesiology Clinics*.⁴³

Temperature Monitoring

Perioperative hypothermia increases the incidence of adverse myocardial outcomes, increases blood loss, and increases wound infection.⁴⁴⁻⁴⁶ Mild hypothermia also changes the kinetics of various anesthetics and may delay postoperative recovery.⁴⁶ Intraoperative hypothermia usually develops in three phases. The first phase is caused by redistribution of heat from the core thermal compartment to the outer shell of the body. A slower, linear reduction in the core temperature follows and may last several hours.⁴⁶ In the last phase, the core temperature plateaus and may remain unchanged throughout the remainder of the perioperative period as thermoregulatory control is impaired during general or regional anesthesia. Numerous temperature-monitoring devices are available, but it is the site of temperature monitoring rather than the type of temperature probe that is most important. Core temperature can be estimated from accessible sites such as the nasopharynx, bladder, esophageal, or rectal sites.⁴⁶ Temperature monitoring has become a standard of care, and anesthesiologists are expected to be proactive in maintaining normothermia and preventing temperature derangements throughout the perioperative period. Practitioners should be aware that the ambient temperature in many OOR locations is deliberately kept lower to protect sensitive equipment.

Spontaneous Electroencephalographic Activity Monitors

Depth of anesthesia monitoring with the bispectral index monitor (BIS) has been shown to reduce, but not eliminate, the incidence of awareness under anesthesia.⁴⁷ In the neurocritical care setting, BIS monitoring has been shown to provide a more objective means of sedation assessment that may lead to a decrease in overall rates of propofol administration and fewer incidences of oversedation.⁴⁸ A recent Cochrane review concluded that anesthesia guided by BIS within the

TABLE 3.1. Causes of Changes in End-Tidal Carbon Dioxide as Measured by Capnography

Causes of Increased CO_2	Causes of Decreased CO_2
- Hypoventilation	- Hyperventilation
- Hyperthyroidism/thyroid storm	- Hypothermia
- Malignant hyperthermia	- Venous air embolism
- Fever/sepsis	- Pulmonary embolism
- Rebreathing	- Decreased cardiac output
- Other hypermetabolic states	- Hypoperfusion

recommended range (40 to 60) could improve anesthetic delivery and postoperative recovery from relatively deep anesthesia while reducing the incidence of intraoperative recall in surgical patients with high risk of awareness.⁴⁹ The Patient State Index (PSI) is another monitor for awareness that has not been studied as thoroughly as the BIS but has been shown to provide indications that correlate with unconsciousness.⁵⁰ For a detailed review of the current state of monitors for preventing intraoperative awareness, the reader is encouraged to review the American Society of Anesthesiologists (ASA) 2006 Practice Advisory.⁵¹

CONSIDERATIONS FOR OOR ENVIRONMENTS

The Magnetic Resonance Imaging Suite

Magnetic resonance imaging (MRI) poses a profound risk to patients with implanted ferromagnetic material because the high magnetic field may dislodge pacemakers, implants, cardiac valves, or other prostheses. Before entering the MRI suite, all ferromagnetic items need to be removed to prevent injury; a MRI-compatible anesthesia machine and equipment are compulsory (Fig. 3.4).⁵²

The intense radiofrequency may cause surface heating on the patient's body, and the lead wires from the ECG also pose

a potential burn hazard.⁵³ The ECG monitor is subject to considerable artifact from the background static magnetic field and radiofrequency impulses as well as the electronics within the device that create magnetic fields.⁵⁴ Modern devices minimize these limitations, and a variety of commercial devices for ECG monitoring in the MRI suite are available (Fig. 3.5).

Blood pressure monitoring by the oscillometric method is most commonly utilized and provides reliable readings. Pulse oximetry may be difficult in the MRI suite because the signal may become degraded due to currents in the oximetry cable and a decreased signal-to-noise ratio.⁵⁵ Capnography may be utilized; a decrease in the phase II slope of the capnogram may be observed due to a long circuit pathway. Remote monitoring via a closed-circuit monitor—preferably with zoom lens magnification capability—may be necessary.

Computed Tomography

An anesthetized patient in the computed tomography (CT) scanner presents logistical problems similar to those encountered in the MRI suite; however, the impact on interference with standard monitors is not as profound. Blood pressure should be monitored at relatively short intervals because radiocontrast media reactions may lead to a precipitous loss of systemic vascular resistance. Standard monitors such as the ECG, temperature probe, pulse oximetry, and capnography should be utilized.

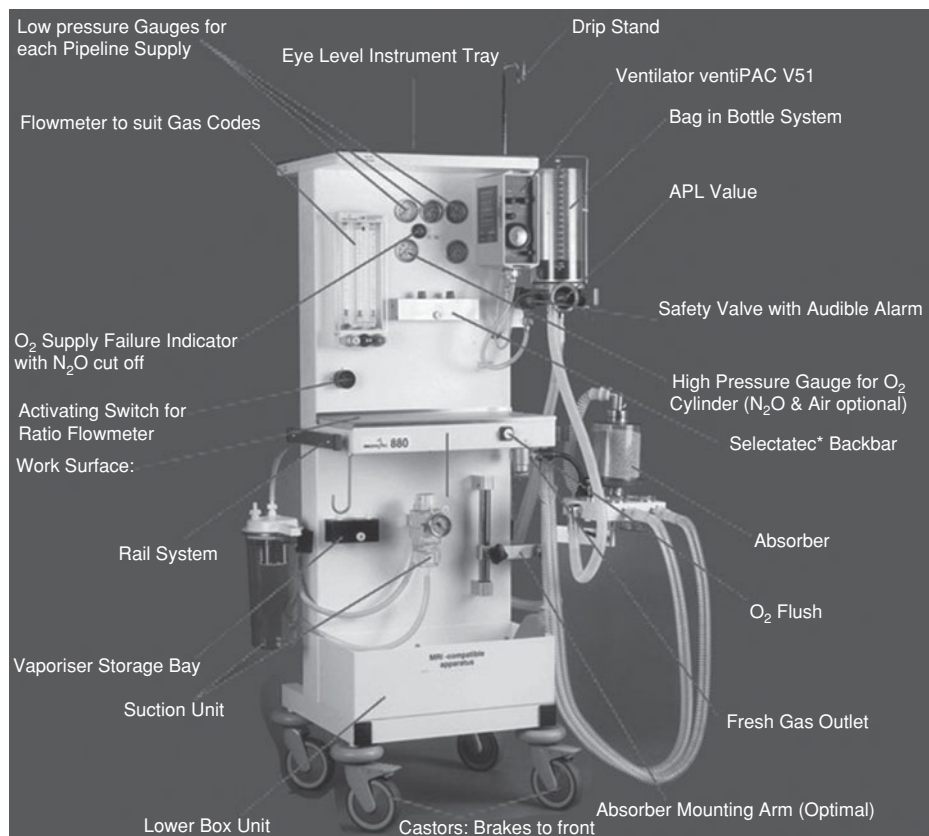


FIGURE 3.4. A magnetic resonance imaging (MRI)-compatible anesthesia machine.



FIGURE 3.5. The Veris Medrad magnetic resonance imaging (MRI)-compatible monitor. (Used under license from MEDRAD, Inc.)

As with procedures done in the MRI suite and elsewhere, remote monitoring may be required.

Electroconvulsive Therapy

Electroconvulsive therapy (ECT) is used for treatment of severe psychiatric disorders as well as depression, complex regional pain syndrome, and chronic pain.⁵⁶ Electroconvulsive therapy involves provocation of a generalized epileptic seizure by electrical stimulation of the brain. The procedure is usually preformed under general anesthesia with muscle relaxation. Excessive alterations in heart rate, blood pressure, and cardiac functions are prevented by anticholinergic and antihypertensive agents; hence, blood pressure and ECG monitoring is mandatory.⁵⁷ Train-of-four monitoring for neuromuscular blockade and BIS monitoring should also be considered. Capnography is essential for safe and effective anesthetic management of patients undergoing ECT, especially patients with intracranial disorders or coronary artery disease.⁵⁸

The Endoscopy Suite

Most endoscopic procedures are performed in an OOR environment, and in many cases, these procedures may be

accomplished with moderate or deep sedation. Capnography should be utilized in view of the fact that significant delays in detecting respiratory compromise have been demonstrated in its absence.⁵⁹ In addition to blood pressure and ECG monitoring, pulse oximetry and capnography should be considered standard monitors to ensure adequate ventilation and oxygenation during endoscopic procedures, whether they be performed under general anesthesia or varying degrees of sedation.⁶⁰

Interventional Angiography

Electrocardiogram, blood pressure, pulse oximetry, and capnography are standard monitors for procedures in interventional angiography. In addition, intracranial pressure monitoring (ICP) and invasive arterial blood pressure monitoring are frequently employed. In some instances, central venous pressure monitoring and monitoring of evoked potentials may be necessary. In recent years, the endovascular treatment of diseases of intracranial and spinal vessels has become widely accepted; invasive monitoring is frequently required based on the usual underlying pathophysiology and severity of these disorders.⁶¹

Controversies in Monitoring

Numerous investigators have focused a critical eye on the ability of monitors to prevent morbidity and mortality. In a well-known randomized controlled trial by Watkinson et al., the authors concluded that mandated electronic vital signs monitoring in high-risk medical and surgical patients had no effect on adverse events or mortality.⁶² While this study had numerous limitations that may have led to type II error, the “number needed to monitor” to alter outcomes was estimated to be large.⁶² In a systematic review of randomized controlled trials examining the role of pulse oximetry, there was no evidence of a significant difference between groups regarding duration of postoperative mechanical ventilation, duration of intensive care unit stay, or postoperative complications; the authors were unable to find reliable evidence that pulse oximetry affects the outcome of anesthesia.⁶³ Moller’s landmark studies in 1993, based on a design that was similar to both a randomized controlled trial and a cluster randomized trial that included 20,802 patients, concluded that pulse oximetry did not have a significant impact on mortality or hospital stay.⁶⁴⁻⁶⁶ In a review of clinical trials on monitoring, the authors acknowledge that pulse oximetry may enable clinicians to detect desaturation episodes more readily, and that this technology may be beneficial, but to prevent one adverse event, a large number of patients must be monitored.⁶⁷ The findings of these and other related studies were summarized in a Cochrane review that concluded that the value of perioperative monitoring with pulse oximetry is unproven.⁶⁸

Earlier studies, including a closed claims analysis, suggested that pulse oximetry was an invaluable modality for preventing adverse outcomes in anesthesia, and that improvements in monitoring—specifically pulse oximetry—may have helped

reduce serious mishaps over the last several decades by at least 35%.⁶⁹ Two additional studies suggested that monitoring with pulse oximetry facilitates prompt detection of arterial hypoxemia, allowing earlier and potentially life-saving treatment.^{66,70} Oversedation with ensuing respiratory depression is an important contributor to adverse events that have occurred under monitored anesthesia care (MAC), and appropriate use of monitoring has been cited as a crucial preventative measure that is often neglected.⁷¹ Studies based on analyses of closed claims data suggest that better monitoring may lead to earlier correction of potentially harmful perioperative events.^{72,73}

Despite numerous national guidelines and recommendations, there seems to be a paucity of data to support the use of monitors in preventing mortality outside of the operating room. In a Watkinson et al.'s 2006 study, monitoring of heart rate, noninvasive blood pressure, oxygen saturation, respiratory rate by impedance pneumography, and skin temperature did not separate groups with adverse outcomes from beneficial interventions in a heterogeneous population of 402 high-risk medical and surgical ward patients.⁶² Similarly, when a medical emergency team was tasked with closely following vital signs in an effort to rapidly recognize critical threshold patterns suggestive of potential adverse events, no benefit was found.⁷⁴ While each of these studies had significant limitations, they helped promulgate the idea that mandatory monitoring, even with a high incidence of abnormal vital signs, does not confer a mortality benefit. Nevertheless, other investigators determined that improved monitoring might have prevented a significant number of adverse outcomes identified in the ASA closed claims database.⁷⁵

Initial studies utilizing capnography as a supplement during procedures requiring sedation suggested that this practice might serve as an early warning mechanism for impending respiratory embarrassment.^{76,77} Capnography may have an advantage over pulse oximetry because capnography is a better measure of ventilation. With capnography, providers are able to institute early stimulation for nonbreathing patients, thereby preventing arterial oxygen desaturation. Lightdale et al. demonstrated that microstream capnography significantly prevented arterial oxygen desaturation in children undergoing sedation for procedures.⁷⁸ This was an important finding because most critical adverse events during sedation occur secondary to hypoventilation and respiratory failure.⁷⁹

RECOMMENDATIONS

Although data to support a mortality benefit appear to be lacking, numerous organizations, including the ASA, strongly endorse monitoring in OOR environments.^{80,81} For OOR anesthetizing locations, the ASA recommends adhering to the Standards for Basic Anesthetic Monitoring (Table 3.2).⁸²

At the Brigham and Woman's Hospital, a large tertiary care teaching hospital, in addition to the ASA Standards, we employ continuous capnography. Table 3.3 lists recommended monitoring practices for procedural sedation.

TABLE 3.2. *American Society of Anesthesiologists (ASA) Standards for Basic Anesthetic Monitoring*

<i>Parameter</i>	<i>Methods</i>
Oxygenation	Inspired gas oxygen analyzer Pulse oximetry (with audible tone) Illumination to assess the patient's color
Ventilation	PETCO ₂ monitoring: Capnography, capnometry, or mass spectroscopy with audible CO ₂ alarm to detect correct placement of endotracheal tube Utilization of a device capable of detecting disconnection of the components of the breathing system
Circulation	Continuous electrocardiogram Blood pressure and heart rate determination no less than every 5 minutes Assessment by at least one: palpation of a pulse, intra-arterial tracing of blood pressure, ultrasound peripheral pulse monitoring, pulse plethysmography or oximetry
Body temperature	Indicated when clinical significant changes in body temperature are intended, anticipated, or suspected

Source: Based on Standards for Basic Anesthetic Monitoring of the American Society of Anesthesiologists. A copy of the full text can be obtained from ASA, 520 N. Northwest Highway, Park Ridge, Illinois 60068-2573.

TABLE 3.3. *Recommended Monitoring for Procedural Sedation*

<i>Parameter</i>	<i>Methods</i>
Training	Providers must pass a procedural sedation course.
Establishment of protocols	All OOR sites should have uniform protocols with an emphasis on ease of implementation.
Oxygenation	Pulse oximetry with an audible tone should be employed. Adequate lighting should be available to assess skin color.
Ventilation	ETCO ₂ monitoring is recommended with an audible CO ₂ alarm to detect hypoventilation and apnea.
Circulation	A continuous electrocardiogram should be available. Blood pressure and heart rate should be determined no less than every 5 minutes.
Body temperature	Continuous temperature monitoring is strongly recommended, especially during long noninvasive procedures.
Protocol review/ process improvement	Periodic reviews should be conducted with appropriate amendments made to protocols to ensure that problems do not recur.

OOR, outside of the operating room.

CONCLUSION

At the end of the day, the most critical monitor is the provider of anesthesia. It is likely that the dramatic decrease in anesthetic-related mortality over the past several years is as much the result of improved drugs and technology as the result of improved training of providers of anesthesia. While the true rate of complications from anesthesia in the OOR environment is currently unknown, by implementing standards for monitoring that are similar to standards used in the operating room, the safe delivery of an anesthetic for procedures in the OOR environment can be consistently achieved.

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4 | Anesthetic Techniques

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Anesthetic techniques for procedures performed outside the traditional operating room (OOR) are as varied as the surgeries themselves and wholly dependent upon the equipment available at each specific location as well as any patient comorbidities that may exist. General anesthesia (GA) may be delivered with or without an anesthesia machine, monitored anesthesia care (MAC) with or without infusion pumps, and regional anesthesia (RA) with or without a nerve stimulator (NS) or ultrasound (US). Whatever technique is chosen, safety considerations are paramount and perioperative monitoring must always be consistent with American Society of Anesthesiologists (ASA) guidelines (see Appendix for a list of useful ASA documents). OOR procedures are widely varied and include elective office-based anesthetics and emergency room ones, endoscopic retrograde cholangiopancreatographies (ERCPs) in the gastroenterology suite, and emergency interventions in the invasive radiology department. Most of these locations have limited postanesthesia care unit (PACU) capabilities, so both rapid return to baseline functioning and the ability to discharge a comfortable patient are important goals with rare exceptions that will be discussed. This chapter will focus on the many anesthetic options available to the OOR anesthesiologist/practitioner.

There are some important caveats concerning any anesthetic provided outside the OR setting. If a non-GA technique is planned, the anesthesia professional must be ready for conversion to GA at any time. The proceduralist may need the patient to follow commands one minute, and then promptly be unresponsive for the next procedural stimulation. The anesthesia provider should be prepared to provide a rapid change in depth of anesthesia. This is complicated by the fact that many of the OOR procedures are new and evolving, and the anesthetic requirements may not be known. Furthermore, some proceduralists may not yet be used to working with an anesthesia professional and may not communicate effectively about the procedure and how it is progressing.

DEPTH OF SEDATION

It must be appreciated that sedation, as defined by the ASA, is a continuum from minimal, moderate, and deep sedation through GA (Table 4.1).¹ Minimal sedation is characterized by anxiolysis. The minimally sedated patient should maintain a normal response to verbal stimulation. The patient's airway

should remain unaffected, as should both the patient's cardiovascular function and ability to spontaneously ventilate. Moderate sedation, formerly known as conscious sedation, is characterized by a sedated patient who retains *purposeful* response to both verbal and tactile stimulation. It is important to understand that reflex withdrawal from a painful stimulus is *not* considered a purposeful response. As with minimal sedation, no external intervention should be required to assist the patient in maintaining a patent airway. Spontaneous ventilation should remain adequate and cardiovascular function is usually maintained. Similar to the moderately sedated patient, a deeply sedated one also displays *purposeful* responses to repeated or painful stimulation. However, he or she may require an intervention to maintain a patent airway. Spontaneous ventilation may be inadequate, but cardiovascular function is usually maintained. General anesthesia is characterized by a patient who is unconscious and is unresponsive, even to noxious stimulation. Maintaining a patent airway will often, but not necessarily, require an intervention. Spontaneous ventilation is frequently inadequate. Cardiovascular function may also be impaired in the patient undergoing a general anesthetic. "If the patient loses consciousness and the ability to respond purposefully, the anesthesia care is a general anesthetic, irrespective of whether airway instrumentation is required."¹

MONITORED ANESTHESIA CARE

Monitored anesthesia care does not correlate to depth of sedation. It simply refers to sedation that is delivered or supervised by a qualified anesthesia professional. It can range from minimal to deep sedation but does not include RA or GA. Many procedures performed outside the traditional OR are amenable to MAC with the use of supplemental local anesthesia, often provided by the surgeon. Other procedures can be performed under MAC without the use of supplemental local anesthesia. Such procedures include colonoscopies, upper gastrointestinal endoscopies, and magnetic resonance imaging (MRI) or computerized tomography (CT) studies. When selecting a depth of sedation for a particular procedure, it is vital that the anesthesia provider have the proper training, licensing, credentials, as well as supplies and equipment to rescue the patient from the next deeper level of sedation than what is planned. This is important because patients often drift from one anesthetic depth to another. Movement along the

TABLE 4.1. *Continuum of Depth of Sedation Definition of General Anesthesia and Levels of Sedation/Analgesia*

	<i>Minimal Sedation (Anxiolysis)</i>	<i>Moderate Sedation/ ("Conscious Sedation")</i>	<i>Deep Sedation/ Analgesia</i>	<i>General Anesthesia</i>
<i>Responsiveness</i>	Normal response to verbal stimulation	Purposeful* response to verbal or tactile stimulation	Purposeful* response following repeated or painful stimulation	Unarousable even with painful stimulation
<i>Airway</i>	Unaffected	No intervention required	Intervention may be required	Intervention often required
<i>Spontaneous ventilation</i>	Unaffected	Adequate	May be inadequate	Frequently inadequate
<i>Cardiovascular function</i>	Unaffected	Usually maintained	Usually maintained	May be impaired

*Reflex withdrawal from a painful stimulus is *not* considered a purposeful response.

Source: Based on Continuum of Depth of Sedation of the American Society of Anesthesiologists. A copy of the full text can be obtained from ASA, 520 N. Northwest Highway, Park Ridge, Illinois 60068-2573.

sedation continuum is usually a desirable condition, since the patient will need to be more deeply sedated during painful parts of the procedure (i.e., injection of local anesthesia) and less deeply sedated during others. There is no particular dose of any medication that can reliably predict a specific anesthetic depth. Each patient will have a unique response to a given dose of a drug. Therefore, vigilance by the anesthesia provider is critical in maintaining the patient at the desired depth of sedation.

Providing a patient with MAC is truly a balancing act—attempting to provide the perfect depth of sedation to meet the ever-changing level of surgical stimulation. On one end of the spectrum is the patient who is oversedated who may become disinhibited and uncooperative. This disinhibited state may actually mislead the anesthesia provider to further deepen the level of sedation (thinking that the patient may be inadequately sedated) and may ultimately result in the delivery of GA. Unrecognized oversedation can lead to hypoxia, hypercarbia, and cardiovascular instability. On the other end of the spectrum is the undersedated patient. Similar to the oversedated patient, the undersedated one may also become uncooperative. This patient's behavior may be due to pain from the surgical procedure. Pain when left untreated will often lead to tachycardia, hypertension, and myocardial ischemia. Uncontrolled sudden movements by the undersedated patient may lead to intraoperative motion, making the surgeon frustrated and the surgical procedure impossible.

“Is MAC safer than GA?” The answer to this question is not certain. A recent review of the ASA closed claims database reveals several important points regarding the relative safety of MAC.² Although MAC claims were fewer than GA claims (121 versus 1519), 40% of the MAC claims were for death or permanent brain injury. This percentage is similar to that for GA. Most patient injuries during MAC arose from patient oversedation, which resulted in respiratory depression and hypoxic injury. The median payout from a MAC injury was \$254,000 as compared to \$140,000 for GA. The authors conclude that perioperative physiologic monitoring, vigilance, and early resuscitation during MAC can prevent many of the perioperative injuries.

There are potential benefits to using MAC when appropriate. Recovery time can be shorter after a sedation case than after GA, and patients undergoing MAC may be able to bypass the phase 1 PACU and proceed immediately to either a phase 2 PACU or in the case of an inpatient, back to their hospital room immediately following the procedure.³

THE PHARMACOLOGY OF MONITORED ANESTHESIA CARE

There are many classes of drugs that can be used in the delivery of MAC. The ideal MAC drug would be associated with a fast onset, a short duration of action, have no side effects, and would be inexpensive. Unfortunately no such individual drug exists. Commonly used drugs include hypnotics (propofol), benzodiazepines (midazolam and diazepam), alpha-2 agonists (clonidine and dexmedetomidine), opioids (fentanyl and remifentanyl), and ketamine. Most anesthesia providers will use these agents in a combination that will work synergistically and limit the negative side effects of each. Specific dose recommendations appear in Table 4.2.

Propofol, a di-isopropyl phenol molecule, has long been a mainstay of ambulatory anesthesia because of its desirable pharmacokinetics and pharmacodynamics. It has a rapid onset (approximately 1 arm-brain circulation time), and because of rapid redistribution, has a short clinical duration of action (approximately 15 minutes).⁴ Even after long infusions, the context sensitive half-time of propofol remains shorter than other intravenous drugs (except remifentanyl)⁵ In addition to its hypnotic properties, propofol has an intrinsic antiemetic effect. Propofol may cause a burning sensation on injection or illicit an allergic reaction. It is also associated with bradycardia, respiratory depression, and supports microbial growth. This drug can be used alone or in combination with other agents by intermittent boluses or continuous infusion.

Midazolam has replaced the older benzodiazepines in clinical practice because of its superior pharmacokinetics and pharmacodynamics. It has a rapid onset of action (1–3 minutes) and although its elimination half-life is 3.4–11 hours,⁶ its clinical duration of action at small doses is short (approximately 30 minutes). These times provide a significant clinical improvement over the older benzodiazepines, which possess

TABLE 4.2. Reference for Induction, Bolus, and Infusion Rates of Commonly Used MAC and GA Anesthetics in Adults

Agent	Induction for GA	Bolus Doses for MAC	Infusion (MAC or GA)
Dexmedetomidine	0.5–1 µg/kg (over 10 minutes)		0.2–0.7 µg/kg/hr, not to exceed 24 hours
Fentanyl	50–100 µg/kg for single-agent GA	1–2 µg/kg for sedation	1–3 µg/kg/hr
Ketamine	1–2 mg/kg	0.25–1 mg/kg for sedation	1–2 mg/kg/hr
Midazolam	0.3–0.35 mg/kg for single-agent GA	10–20 µg/kg	0.02–0.1 mg/kg/hr
Propofol	1.5–2.5 mg/kg for single-agent GA	0.25–0.5 mg/kg	25–200 µg/kg/min
Remifentanyl		0.5–1 µg/kg	0.02–0.3 µg/kg min

GA, general anesthesia; MAC, monitored anesthesia care.

both longer onsets and half-lives. Benzodiazepines are used for their ability to provide anxiolysis and anterograde amnesia. All can cause respiratory depression, especially when used in combination with opioids and can be associated with prolonged recovery when used in large doses.

Ketamine is a phencyclidine derivative that in addition to its anesthetic properties is also a potent analgesic. It is however associated with increased saliva production and thus requires the concomitant administration of an antisialogogue agent. A significant benefit of ketamine is that it does not cause postoperative nausea and vomiting (PONV) or respiratory depression. Common side effects of ketamine include hallucinations and dysphoria, which can be ameliorated with the administration of a benzodiazepine and/or propofol.^{7,8} This drug combination has been reported in both the pediatric and adult anesthesia literature.^{9,10,11} Other side effects of ketamine include increase in intracranial pressure, tachycardia, and hypertension.

Ketamine can be used by intermittent boluses or as an infusion. Friedberg describes a regimen for facial resurfacing using a laser, which begins with a midazolam bolus of 2–4 mg intravenously, followed by a propofol infusion. After the patient is anesthetized (loss of both lid reflex and response to verbal command), a bolus of ketamine (50 mg) is given. After waiting 2 minutes, the surgeon can inject the local anesthetic while the patient remains immobile and amnesic.¹² Once the local anesthetic has been injected, the propofol infusion can be decreased. The patient will likely maintain spontaneous

respiration so supplemental oxygen can be avoided. Supplemental oxygen is problematic because it will support combustion and poses a risk of fire with the use of electrocautery.¹³

Dexmedetomidine, the dextro-enantiomer of medetomidine, is a selective alpha-2 agonist drug that was originally approved for use by the Food and Drug Administration (FDA) in 1999 for short-term sedation of patients in the intensive care unit. Its application for MAC has also been widely reported.^{14,15,16,17} It works at the presynaptic alpha-2 receptors, inhibiting the release of norepinephrine in a negative feedback mechanism.¹⁸ Because of the presence of alpha-2 receptors in the central nervous system, dexmedetomidine possesses anxiolytic, sedative, and amnesic qualities with minimal respiratory depression, and no PONV. These alpha-2 receptors are also present in the dorsal horn of the spinal cord, conferring analgesic properties to dexmedetomidine. The effects on the sympathetic nervous system can cause a decrease in cardiac output, with bradycardia and hypotension, most commonly after rapid administration.¹⁹ Vasoconstriction at high or rapid doses has also been reported. It has a relatively short half-life of approximately 2–3 hours. In a recent study by Candiotti¹¹ dexmedetomidine was used in conjunction with midazolam and fentanyl for MAC. Patients were randomized into one of three treatment groups. One group received dexmedetomidine, 0.1 microgram per kilogram, the second group was given dexmedetomidine at 0.5 microgram per kilogram, and the final group was given a placebo. All groups received midazolam titrated to level of sedation as measured by the Observer's Assessment of Alertness/Sedation Scale (OAA/S). The reported dosages of both supplemental drugs (midazolam and fentanyl) were markedly decreased by the use of dexmedetomidine. In this study, patients who had received 1 microgram/kg of dexmedetomidine had less respiratory depression, anxiety, and need for postoperative analgesics, while having higher patient satisfaction scores than did the placebo group.

The use of local and regional anesthesia should always be considered for postoperative analgesia, either alone or in conjunction with GA. The use of local or regional anesthesia in addition to GA minimizes the amount of anesthetic required, thus hastening patient recovery, and minimizing the need for opioid and its' associated PONV. Nonsteroidal anti-inflammatory drugs (NSAIDs), specifically including COX-2 drugs such as celecoxib, are another important component of postoperative analgesia. It must however be appreciated that NSAIDs may not always be adequate, and many procedures will need to include an opioid as well. Two commonly used opioids for OOR anesthetics are remifentanyl and fentanyl.

Remifentanyl is an ultra-short-acting opioid that can be used as an infusion or as a bolus. This synthetic drug is quickly hydrolyzed by tissue esterases. Because of this, and its very short context-sensitive half-time, remifentanyl does not accumulate and redistribute within the body, leading to a short duration of action (approximately 5 to 6 minutes), even after long infusion times (up to 8 hours).⁵ The benefit of these pharmacokinetics and pharmacodynamics is that remifentanyl can be used to provide intense analgesia for the painful parts of

the procedure and its effect will be eliminated quickly thereafter. Remifentanyl is associated with respiratory depression, skeletal muscle rigidity, nausea, and vomiting.

Fentanyl, an older synthetic opioid, also has a rapid onset of 1–3 minutes; it has a peak effect of 5–10 minutes and an alpha elimination half-life of 18 minutes. Fentanyl is highly lipophilic and redistributes quickly. Like all opioids, fentanyl can cause respiratory depression as well as PONV and itching. Like remifentanyl, fentanyl can also be used as an infusion. Unlike remifentanyl, fentanyl has a long context-sensitive half-time. Thus, long infusion times are associated with significant accumulation within the body and prolonged recovery times.⁵

When selecting which drugs to use, the non-operating room-practitioner must determine the needs of the particular surgery, the location of the surgery both inside and outside the hospital, and the profile and cost of the individual drugs. No anesthetic technique for providing MAC is ideal or devoid of risk. Regardless of drug(s) utilized, the patient may at any point during the anesthetic inadvertently move along the sedation continuum into a deeper than intended depth of sedation. The practitioner must always be prepared to rescue the patient from a deeper level of sedation and to alter the anesthetic plan intraoperatively should the clinical situation change.

GENERAL ANESTHESIA

General anesthesia is frequently the technique of choice for a OOR procedure. The decision to perform GA is based upon a number of factors including the patient preference, the procedure, and the surgeon. There are some patients that are not amenable to anything other than GA. They might be severely “needle phobic” and may require an inhalation induction in order to secure an intravenous line. Others may be uncooperative, unable to lie still secondary to chronic pain syndromes, and others may desire complete amnesia for the surgical event. Although amnesia under GA can never be guaranteed (incidence of awareness of 0.1%–0.2%),^{20,21} it is intuitive that the chance of successful amnesia is higher with GA than with MAC. In addition to patient-specific factors, there are also some procedures that may not be amenable to anything other than GA. Finally, there are surgeon-specific issues. The surgeon may request a GA, or a particular surgeon may not be proficient in the use of local anesthesia.

When selecting a type of GA for a OOR procedure, similar factors used to make a decision regarding drug selection for a MAC case must be considered. The induction of anesthesia (either intravenous or inhalational) should be rapid, the patients should awaken quickly at the termination of surgery; there should be minimal postoperative pain, nausea, or vomiting; and the patient should be discharge ready quickly, to home or inpatient bed, using objective discharge criteria. Furthermore, cost is always an issue.

Total intravenous anesthesia (TIVA) is a popular choice for OOR procedures. This usually consists of propofol as the hypnotic component often used in conjunction with fentanyl

or remifentanyl as the analgesic component. All three of these drugs can be given by intermittent bolus or infusion. Mathews found that remifentanyl 0.085 micrograms/kilogram per minute can substitute for nitrous oxide 66%.²² Advantages of TIVA over inhalation anesthesia include avoidance of the need for gas scavenging and a reduced incidence of PONV. Since the availability of the newer less soluble inhalation agents (e.g., desflurane and sevoflurane), many authors have compared recovery times from these agents with the recovery time after a total intravenous anesthetic using a propofol infusion.^{23,24} Recently, Gupta conducted a meta-analysis of all publications looking at this and reported an overall faster recovery from desflurane when compared to either isoflurane- or propofol-based anesthetics. Recovery was also found to be faster from sevoflurane when compared to isoflurane. However, there was more PONV as well as postdischarge nausea and vomiting in the isoflurane groups compared to the propofol ones; isoflurane may not be the best choice of inhalation agent in OOR locations, for these considerations. Overall, the inhalation agent groups required more antiemetic treatment than did the propofol groups.²⁵

The issue of PONV is quite important in any anesthetic practice, and those performed in the OOR setting are no exception. PONV may lead to delayed discharge or even result in an unplanned admission to a hospital for the ambulatory patient. More than just an annoyance, PONV is often feared more by the patient than postoperative pain.²⁶ From a patient safety standpoint, uncontrolled retching postoperatively, often associated with nausea, can cause a precipitous increase in central venous pressure. This could lead to bleeding, especially after facial cosmetic surgery, and may even necessitate an emergency reoperation. There are many well-known surgical, anesthetic, and patient risk factors for the development of PONV, such as young age, female gender, nonsmoking, history of motion sickness or previous PONV, breast or laparoscopic or plastic procedures, and duration of surgery.²⁷ Risk factors must be considered preoperatively and the use of prophylactic antiemetics, such as dexamethasone, ondansetron, and/or transdermal scopolamine, should be considered. Combination therapy has been consistently found to be more effective than single medication regimens.^{28,29}

LARYNGEAL MASK AIRWAY VERSUS TRACHEAL TUBE

When performing a GA, one may choose between securing the airway with a tracheal tube (TT) or placing a laryngeal mask airway (LMA). The TT is the classic standard for airway security and protection; however, the LMA confers several advantages. Its placement is relatively simple and does not require direct laryngoscopy, thus eliminating the sympathetic response associated with this maneuver. There is minimal risk of damage to the teeth and oropharynx as there is with the insertion of a rigid laryngoscope. Since the LMA is much better tolerated by the patient emerging from anesthesia than a TT, emergence can be smoother and opioid requirements are often less.

The LMA has become more commonly used even during surgeries that cause blood accumulation in the oropharynx such as adenotonsillectomies and rhinoplasties.³⁰ Although some believe that an LMA is helpful in preventing copious amounts of blood in the oropharynx from entering the stomach, it still must be appreciated that it may not prevent aspiration of blood into the lungs. An LMA should not be used in patients who are at risk for aspiration. Although patients at such a risk should not be considered an appropriate candidate for office-based procedure,³¹ (a subset of the OOR locations), these patients will likely present to other OOR anesthetizing venues. An LMA should also not be used if it obscures the surgical field, as in the case of intraoral surgery. It should be appreciated that a conventional LMA may become dislodged intraoperatively if the patient becomes “light” or if the surgeon moves the patient’s head and/or changes the patient’s body position during the case, or if surgery around the head and neck is planned. The concern about dislodgement is much less with the flexible (armored-tube) LMAs.

Monitoring depth of anesthesia can be considered, particularly if a total intravenous technique is planned. One such depth of anesthesia monitor is the BIS monitor (bispectral index state, BIS Aspect Medical Systems). On a scale of 1–100, an awake patient typically has a score of 100. As the patient becomes sedated, the BIS value decreases, and a score of 40–60 represents a patient under GA. In a recent meta-analysis of the existing clinical trials involving BIS monitoring, Punjasawadwong reported that utilizing the monitor during GA resulted in the intraoperative use of somewhat less propofol and volatile agents, 1.3 mg per kg per hour, and 0.17 minimal alveolar concentration equivalents, respectively. Recovery times were decreased as well, with time to eye opening by 2.43 minutes, time to response to verbal command by 2.28 minutes, and time to extubation by 3.05 minutes. However, there was no improvement in the time to home discharge readiness. In addition, the BIS also decreased the incidence of intraoperative awareness in the high-risk patient subset.³² When analyzing whether this additional monitor will improve both patient care and efficiency of the OOR anesthetic, cost of the monitor (approximately \$10,000) as well as of the price of the disposable head electrode (approximately \$12–\$15) must be considered. Also, for some procedures, the placement of the head electrode may be in the surgical field, thus limiting its utility.

THE REALITY OF GENERAL ANESTHESIA IN THE NON-OPERATING ROOM LOCATION

In a hospital OR, many anesthetic agents and a variety of technologies are readily available. However, in the non-OR setting, space (size), use of non-purpose-built locations, as well as cost may limit the technology readily available. An off-site location may not have state-of-the-art equipment. Although the anesthesia machine must not be obsolete,³³ it may not have vaporizers for newer inhalational agents. If there is no built-in gas scavenging system, activated charcoal canisters can be considered for volatile agent scavenging.

Alternatively, suction may be used for scavenging. In the absence of a reliable scavenging system, TIVA becomes the best alternative for the delivery of GA. While if an infusion pump is not available, inhalation-based anesthetic may be preferable. The anesthesia provider must be adept at performing a general anesthetic under a variety of conditions.

REGIONAL ANESTHESIA

There is very little written about the use of RA in OOR locations. Hausman et al. described 123 peripheral nerve blocks and 2 neuraxial blocks, among 242 anesthetics administered in an orthopedic surgical office-based practice. The office was equipped with a separate procedure room, the standard ASA monitors, an anesthesia machine, and a resuscitation cart with a defibrillator. Blocks utilized included interscalene, femoral/3-in-1, popliteal, and infraclavicular. All blocks were performed with nerve-stimulating (NS) techniques, except axillary blocks, which were accomplished using the transarterial approach, and ankle blocks that were placed by identifying superficial anatomic landmarks. In this study, there was one persistent paresthesia and one femoral neuropathy, both of which resolved. There were no episodes of dyspnea, local anesthetic toxicity, or unplanned admissions for pain or PONV.³⁴ This study was conducted in conjunction with an academic medical center, and each attending physician performing the blocks was accompanied by a clinical anesthesiology level 3 (CA-3) resident. This senior resident was able to expedite the process by performing a history and physical and placing an intravenous line and monitors so that as soon as the patient was brought to the postanesthesia care unit, the attending could immediately either place or supervise the placement of the next block. This staffing model minimized turnover and maximized the time available for the block to begin to work. Extrapolating to other practice models, this study underscores the need that when RA is performed in a OOR location, it is important to have a staff that supports this effort and is willing to both help expedite turnovers and lend a hand to inject agents, if necessary.

Since the mastery of peripheral nerve blocks (PNBs) frequently does not occur during residency, the successful incorporation of blocks into practice in any anesthetizing location requires that the anesthesiologist critically evaluate the practice, looking for blocks that fill specific needs, and choosing techniques that offer a high likelihood of success. Moreover, the recent trend has been toward the use of ultrasound (US) in placing blocks. The development of proficiency in US-guided blocks requires an entirely new skill set for practitioners. First, one must learn to operate the US machine and then use it to identify anatomy. Second, one must be able to simultaneously use both hands (one holding the ultrasound transducer and the other holding the block needle), while watching the display screen, and manipulate the needle into the nerve sheath. Third, it is necessary to learn to identify patterns of local anesthetic spread that are associated with the optimal plexus blockade. This process requires both a financial

commitment for the cost of equipment as well as a time commitment to learn the techniques, which may require attendance in both lectures and workshops. Several Web sites are available with instructions, diagrams, and videos that serve as excellent guides to both US and NS techniques (<http://www.usra.ca>, <http://www.nysora.com>).

Local anesthetics should be chosen to minimize onset times and prevent procedure delays and complications. The desired duration of action and degree of motor blockade required should also be considered. For example, a patient undergoing a neuroplasty at the wrist (carpal tunnel) requires dense anesthesia. This can be accomplished rapidly with an intravenous regional anesthetic (IVRA). If a brachial plexus block is chosen, one must remember that an insensate extremity may place the patient at unnecessary risk for injury secondary to the loss of protective reflex of pain or proprioception, especially after a procedure that does not cause much postoperative discomfort. Combining local anesthetics to decrease onset and increase duration of analgesia results in unpredictable blockade characteristics.³⁵ The effect of alkalization of agents on the speed of onset of the block is variable. It has been shown to offer no advantage in perivascular blocks with 0.5% bupivacaine,³⁶ but improves both onset and quality of analgesia in axillary blocks with 1.25% mepivacaine,³⁷ and in femoral and sciatic blocks with 2% mepivacaine.³⁸ Adding sodium bicarbonate to lidocaine has been shown to have no effect on the onset of axillary block,³⁹ and in rats it has been shown to decrease the both the intensity and duration of the block.⁴⁰

Practitioners who are using amide local anesthetics should consider having a 20% lipid infusion available, as it has been shown to reverse local anesthetic systemic toxicity (now referred to as LAST) associated with the intravascular injection of amide agents.^{41,42,43} Directions for the administration of lipid infusion, in the advent of a local anesthetic-induced cardiac arrest appear in Table 4.3.⁴⁴

Several blocks that are useful in the OOOR setting follow. These blocks may be performed in locations as diverse as the office-based setting to the emergency department, or even the radiology suite. The use of NS and/or US techniques will be discussed; for specific descriptions to perform each block, please consult RA sources.

Midtarsal Ankle Block

First described in 1986 by Sharrock et al.,⁴⁵ this technique blocks the five nerves to the forefoot where they are most superficial, thus requiring a small total volume of local anesthetic (10–15 ml) and offering a high degree of success. It is particularly useful for podiatric procedures and has the advantage over a traditional ankle block in that the posterior tibial nerve is anesthetized. It is possible to use US to locate the posterior tibial artery in patients where palpation is difficult.⁴⁶

Popliteal Block

The block of the sciatic nerve in the popliteal fossa provides excellent anesthesia for foot and ankle surgeries, including

TABLE 4.3. *Practice Advisory on Treatment of Local Anesthetic Systemic Toxicity*

For Patients Experiencing Signs or Symptoms of Local Anesthetic Systemic Toxicity (LAST)

- **Get help**
- **Initial focus**
 - *Airway management*: ventilate with 100% oxygen
 - *Seizure suppression*: benzodiazepines are preferred
 - *Basic and advanced cardiac life support (BLS/ACLS)* may require prolonged effort
- **Infuse 20% lipid emulsion (values in parenthesis are for a 70 kg patient)**
 - *Bolus 1.5 ml/kg (lead body mass) intravenously over 1 min (~100 ml)*
 - *Continuous infusion at 0.25 ml/kg per minute (~18 ml/min; adjust by roller clamp)*
 - *Repeat bolus once or twice for persistent cardiovascular collapse*
 - *Double the infusion rate to 0.5 ml/kg per minute if blood pressure remains low*
 - *Continue infusion for at least 10 min after attaining circulatory stability.*
 - *Recommend upper limit: approximately 10 ml/kg lipid emulsion over the first 30 min*
- **Avoid vasopressin, calcium channel blockers, β -blockers, or local anesthetic**
- **Alert the nearest facility having cardiopulmonary bypass capability**
- **Avoid propofol in patients having signs of cardiovascular instability**
 - **Post LAST events at <http://www.lipidrescue.org> and report use of lipid to <http://www.lipidregistry.org>**

Source: Reprinted with permission from Neal JM, et al. American Society of Regional Anesthesia and Pain Medicine. Practice advisory on local anesthetic systemic toxicity. *Reg Anesth Pain Med.* 2010;35(2):152–161.

repair of a ruptured Achilles tendon. The saphenous nerve must be blocked in order to provide complete anesthesia below the knee. The intertendinous approach described by Hadzic et al. uses a nerve stimulator.⁴⁷ Ultrasound-guided techniques can be performed from the posterior or lateral approaches. The use of US guidance has been associated with a significantly higher success rate of block over NS techniques at 30 minutes.⁴⁸

To supply complete anesthesia below the knee, it is necessary to add a saphenous nerve block. These authors do not recommend performing a femoral block with a popliteal block in patients undergoing office-based or ambulatory procedures. This combination of blocks renders the leg flail and will put the patient at risk of falling.

Femoral Block

The lumbar plexus gives rise to the femoral, lateral femoral cutaneous (LFC), and obturator nerves, which provide sensory and motor innervation to the leg above the knee. Using a

nerve-stimulating technique, the femoral nerve (including saphenous) can be blocked with as little as 10 ml of local anesthetic. By increasing the volume, one can encourage the spread of local anesthesia along the psoas muscle and block the lateral femoral cutaneous and obturator nerves, creating a “3-in-1” block. With 20–25 ml of a long-acting local anesthetic, a superior postoperative analgesia for anterior cruciate ligament repair has been seen, when compared to the use of intra-articular local anesthetics.^{49,50} A US approach to the femoral nerve can also be used.

Fascia Iliaca Block

The fascia iliaca block provides a more consistent block of the LFC nerve than the 3-in-1 block. There is a reported increase in the successful blocking of the LFC from 62% to LFC to 90%,⁵¹ although the obturator nerve is not reliably anesthetized. This block requires neither nerve stimulation nor elicitation of a paresthesia and can therefore be performed postoperatively to provide analgesia to a patient whose surgical site is encased in a bulky dressing or knee immobilizer.

Axillary Block

Axillary blocks are indicated for surgeries of the hand and forearm. A transarterial approach to the axillary blockade is technically simple and usually quick to perform. When large volumes (50–60 ml) of anesthetic are used, this block is associated with a high success rate.⁵² Supplemental blocks at the elbow or wrist can convert a partial block into a successful one. The use of US guidance has shown to improve axillary block success and was associated with fewer complications (intravascular injection, transient neuropathy).⁵³

Infraclavicular Block

Infraclavicular block of the brachial plexus provides anesthesia for surgery of the forearm, wrist hand, and elbow. An advantage of this block is that it can usually be performed with the patient’s arm in any position, and it does not require abduction. A motor response of the wrist or hand at a current of <0.5 mA has been associated with reliable anesthesia with minimal complications and/or side effects.⁵⁴

Supraclavicular Block

Supraclavicular blocks are performed at the level of the divisions where the nerves of the brachial plexus are closely approximated and prior to branching of nerves supplying the forearm, hand, and elbow. Anatomic techniques have resulted in up to 6% rates of pneumothorax, as they require walking posteriorly off the first rib until a paresthesia or response to nerve stimulation is achieved. The use of US has brought this block back into favor, with two large case series reporting >94% success rate.^{55,56}

Interscalene Block

Surgery of the shoulder is easily performed with interscalene block anesthesia. Multiple studies have reported that interscalene anesthesia provides excellent surgical conditions (analgesia and muscle relaxation), and patients experience less PONV and shorter nonsurgical intraoperative and PACU times than those who have GAs.^{57,58} In a study of 25 patients who had previous shoulder surgery with GA and who chose interscalene block for a second operation, 24 reported that they would prefer the regional technique if they required any subsequent procedures.⁵⁹ Although many practitioners choose general anesthesia with an LMA as the primary anesthetic for shoulder surgery, then perform an interscalene block with a lower concentration of amide anesthesia for postoperative analgesia, surgery of the shoulder can be successfully performed with an interscalene block and MAC sedation.⁶⁰

Intravenous Regional Anesthesia

For procedures of short duration below the elbow, intravenous regional anesthesia (IVRA) remains an excellent anesthetic because it has a quick onset and is easy to perform. Lidocaine 0.5% remains the agent of choice because of its low toxicity, although ropivacaine 0.2% may provide brief post-anesthetic analgesia.⁶¹ A cost analysis study of anesthetic techniques for outpatient hand surgery found that IVRA conferred an approximately 30% cost savings over general anesthesia and brachial plexus blocks, which was secondary to shorter induction times, and lower anesthetic drug and equipment costs.⁶²

Neuraxial Anesthetics for Non-Operating Room Use

Anorectal and urologic procedures are now being performed in offices and OOR locations, and occasionally spinal anesthesia may be indicated. Spinal anesthetics with pencil-point atraumatic needles have led to a reduction in postdural puncture headaches, but the optimum local anesthetic with a favorable recovery profile and low incidence of transient neurologic symptoms (TNS) has not been identified. Hyperbaric bupivacaine 7.5 mg has resulted in a 161 ± 12 minute time until out of bed and 186 ± 14 minutes to micturition.⁶³ The use of 45 mg of isobaric mepivacaine yields similar results but 7.4% incidence of TNS.⁶⁴ Procaine 5% 75–100 mg (approved for spinal anesthesia) or 30–40 mg doses of intrathecal 2-chloroprocaine have been used for intrathecal anesthesia for procedures of approximately an hour duration.⁶⁵ Epidural anesthesia with 2-chloroprocaine provided similar discharge times to GA.⁶⁶

PATIENT INSTRUCTIONS AND FOLLOW-UP

Whenever a regional anesthetic is performed, detailed instructions must be given to the patient, offering an expectation of the duration and extent of their block, the requirement to protect the insensate limb, the need to begin analgesic medications as sensation returns, prior to his or her experiencing

severe pain. Timely follow-up must be conducted to determine complete block resolution. Should any persistent neurologic deficit be discovered during a postoperative call, the patient should be reassured that it will likely resolve, and that the anesthesiologist's participation in the follow-up is assured. Discussion of a postblock deficit with the surgeon should include a plan for neurologic evaluation. Regardless of the anesthetic technique used, a responsible escort must be present if the patient is to be discharged home.

CONCLUSION

Any type of anesthetic used in a freestanding ambulatory surgery center or hospital OR can be used successfully in a OOR location, but to do so safely, the anesthesiology provider must be aware of the risks and benefits of each technique and agent employed. Although cost will play a significant role in the decision-making, patient safety should always be the driving force for every clinical decision. Anesthetics should be associated with a rapid onset and recovery, minimal risk for the development of PONV, and should allow the patient to be comfortably discharged home or back to their room soon after the termination of the procedure. Current agents and techniques available to provide GA, RA, and MAC allow for the safe delivery of anesthesia care in all OOR environments.

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5 Recovery and Discharge for Procedures Conducted Outside of the Operating Room

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Continued advances in procedural techniques, anesthetic pharmacology, and regional anesthesia allow more prolonged diagnostic and therapeutic interventions to be conducted at an increasing variety of locations outside of the operating room (OOOR). However, recovery and discharge process may vary according to the patient's condition and the specifics of the procedure. Generally, most patients are sent to the postanesthesia care unit (PACU) and ambulatory surgery unit (ASU) or a medical post-procedure recovery unit not staffed by an anesthesiologist, while some patients receive special postoperative care in a step-down or intensive care unit. Therefore, ensuring rapid postoperative recovery and safe discharge are important components following these OOOR procedures.

In this chapter, we will review contemporary perspectives on the issues of recovery assessment and monitoring, and we will provide an overview of the criteria related to transport and discharge following anesthesia. The standards and guidelines mentioned in this chapter apply not only to the anesthesiologists, but also to other physicians who supervise the recovery of patients in the different units.

DEFINITION OF RECOVERY

Recovery is an ongoing process that begins from the end of intraoperative care until the patient returns to his or her preoperative physiological state.¹ This process is divided into three phases (see Table 5.1).

At most institutions, Phase I recovery occurs in the inpatient or ambulatory surgery PACU. Once Phase I recovery is completed, homeostasis has been regained. Phase II recovery usually occurs in the ASU, medical unit, or step-down unit, which is judged to be complete when the patient is ready for discharge home. Phase III recovery continues at home until the patient returns to preoperative psychological and physical function.

TABLE 5.1.

-
- Early recovery (Phase I), from the discontinuation of anesthetic agents until recovery of protective reflexes and motor function
 - Intermediate recovery (Phase II), when the patient achieves criteria for discharge
 - Late recovery (Phase III), when the patient returns to his or her preoperative physiological state
-

MONITORING DURING THE RECOVERY PERIOD

Very little published data are available on OOOR anesthesia-related mortality and morbidity. Using the closed claims analysis methodology, Robbertze et al. noted that claims were mostly associated with monitored anesthesia care (MAC) and extreme ages.² According to the recent closed claims database by the American Society of Anesthesiologists (ASA) in 2009,³ severe respiratory depression, due to oversedation was responsible for the majority of sedation/analgesia-related adverse outcomes of OOOR procedures. Claims associated with inadequate oxygenation occurred seven times more frequently outside of the OR than the OR (21% vs. 3%, $p < 0.001$).³

Therefore, appropriate monitoring is essential in the ongoing recovery process after OOOR anesthesia. Nonanesthesia personnel involved in the postanesthetic care in an area remote from the OR may be less familiar with the overall management of patients after anesthesia. Therefore, proper monitoring could play a critical role in the recovery room, especially in emergency situations.

Periodic assessment and monitoring of the OOOR patients should include respiratory and cardiovascular function, neuromuscular function, mental status, temperature, pain, nausea and vomiting, drainage and bleeding, and urine output (Table 5.2).⁴ Postanesthesia care should be documented in the medical records.

TABLE 5.2. *Recommendations for Assessment and Monitoring*

<i>Routine</i>	<i>Selected Patients</i>
Respiratory	
Respiratory rate	
Airway patency	
Oxygen saturation	
Cardiovascular	
Pulse rate	Electrocardiogram
Blood pressure	
Neuromuscular	
Physical examination	Neuromuscular blockade
Nerve stimulator	
Mental status	
	Temperature
Pain	
Nausea and vomiting	
	Urine
	Voiding
	Output
	Drainage and bleeding

Source: Reprinted with permission from A Report by the American Society of Anesthesiologists Task Force on Postanesthetic Care. *Anesthesiology*. 2002;96:742-752.

TRANSPORTATION

Since most of the OOR procedures are conducted at some distance from the PACU and inpatient beds, issues related to the transport of patients should be addressed. This is particularly important in the cases of patients who are critically ill, ASA physical status III or IV, the elderly and the morbidly obese. It is suggested that a minimum of two people, one of them a registered nurse, should accompany the patient during the transport.⁵ A physician is required for a patient with an unstable condition who may require acute interventions. It is also recommended that personnel attending the transportation of patients be trained in basic and advanced life support.

During transportation all the equipment and monitors necessary for a safe journey should be available immediately, including the following: sufficient oxygen supplies; airway management equipment and a resuscitation bag (to allow for manual ventilation via mask or tube); continuous electrocardiographic and pulse oximetry monitoring, regular measurement of blood pressure, standard resuscitation drugs and intravenous fluids, as well as specific essential medications required by that the patient's medical condition.⁵

DISCHARGE SCORING SYSTEMS

Various scoring systems have been devised to guide the process of discharge and home readiness. To avoid inappropriate or premature discharge, physicians must ensure that the patient is "home ready" prior to discharge, that there is appropriate documentation of recovery, and that specified discharge criteria are met. If a physician does not perform the discharge assessment, it must be undertaken according to a strict policy.

For any scoring system to be useful, it must be practical, simple, easy to remember, and applicable to most or all postanesthesia settings. Using commonly observed physical signs avoids additional burden to the recovery personnel. Furthermore, by assigning numerical values to criteria indicating patient recovery, the assessment of progress becomes more objective.

Discharge from the Postanesthesia Care Unit

The Aldrete scoring system, a modification of the Apgar scoring system used to assess newborns, has been used in many PACUs since its introduction 35 years ago.⁶ The system utilizes numeric scores of 0, 1, or 2 assigned to motor function, respiration, circulation, consciousness and color, with a maximum total score of 10. More recently, oxygen saturation assessed by pulse oximetry replaced the color parameter (Table 5.3).⁷ According to this scoring system, when patients achieve a score ≥ 9 , they are considered fit for discharge from the PACU to a step-down unit, ASU, or medical unit.

Discharge Criteria from the Ambulatory Surgery Unit or Medical Unit

Discharge of patients from the ASU or medical unit requires strict adherence to predetermined criteria to ensure patient safety. This responsibility is generally delegated to nurses in the ASU or medical unit who adhere to a written protocol for patient discharge that includes specific discharge criteria or a discharge scoring system. Chung et al. devised the postanesthesia discharge score (PADS) (Table 5.4).^{8,9} This discharge score is a simple method for providing a uniform assessment, which may facilitate assessment of home readiness. It also establishes a routine of repeated evaluation, which may result in improved patient supervision. The PADS was modified to eliminate requirements for oral fluid intake and documentation of urinary output prior to discharge.

Alternatively, outcome-based discharge criteria may be used. All parameters of an outcome-based system need to be met before discharge; typically they include the following:

- Patient alert and oriented to time and place
- Stable vital signs
- Pain controlled by oral analgesics
- Nausea or emesis controlled
- Able to walk without dizziness
- No unexpected bleeding from the operative site
- Discharge instructions and prescriptions received from procedural physician and anesthesiologist

TABLE 5.3. *The Modified Aldrete Scoring System*

<i>Activity: (able to move voluntarily or on command)</i>	
Four extremities	2
Two extremities	1
Zero extremities	0
<i>Respiration</i>	
Able to deep breathe and cough freely	2
Dyspnea, shallow or limited breathing	1
Apneic	0
<i>Circulation</i>	
Blood pressure \pm 20% of preanesthetic level	2
Blood pressure \pm 20%–49% of preanesthetic level	1
Blood pressure \pm 50% of preanesthetic level	0
<i>Consciousness</i>	
Fully awake	2
Arousable on calling	1
Not responding	0
<i>O₂ saturation</i>	
Able to maintain O ₂ saturation >92% on room air	2
Needs O ₂ inhalation to maintain O ₂ saturation >90%	1
O ₂ saturation <90% even with O ₂ supplementation	0
<i>A score \geq 9 was required for discharge.</i>	

Source: Reprinted from Aldrete JA. The post-anesthesia recovery score revisited. *J Clin Anesth.* 1995;7:89-91 with permission from Elsevier.

- Patient accepts readiness for discharge
- Responsible adult present to accompany patient home

Every ASU or medical unit should adopt either the PADS or the outcome-based discharge criteria as part of the protocol for patient discharge after OOOR procedure. Discharge score or criteria should be met and documented before patients can be safely discharged home.

FACTORS AFFECTING RECOVERY AND DISCHARGE

Postoperative Nausea and Vomiting

After anesthesia, approximately one-third of patients experience postoperative nausea and vomiting (PONV), and many of them do not experience PONV until after discharge.¹⁰ The use of volatile agents, nitrous oxide and opioids, and high-dose neostigmine is related to anesthesia factors. Female sex, history of PONV or motion sickness, being a nonsmoker, and need for postoperative opioids are four main patient risk factors.¹¹ Furthermore, lengthy procedures and certain types of interventions may be procedural predictors of PONV.¹²

Anesthesia-related PONV risk factor management includes regional anesthesia, providing adequate hydration, and avoiding general inhalation anesthesia, if possible. When general

anesthesia is necessary, a low emetogenic anesthetic, such as total intravenous anesthesia (TIVA) should be used.¹³

Some controversy still remains regarding PONV prophylaxis with antiemetics. Routine antiemetic prophylaxis for all OOOR patients is not recommended, but patients at high risk can benefit from prophylaxis. Patients at moderate risk usually require single- or combined-agent antiemetic prophylaxis. Double and triple antiemetic combinations should be reserved for patients at high risk of PONV. Recent studies also support the general conclusions that comparable antiemetic effects can be obtained with a variety of agents, and that combination therapy is more effective than single agents.¹⁴⁻¹⁷

Pain

Because of the nature of the diagnostic and therapeutic interventions outside of the OR, severe postoperative pain is rare. However, inadequate analgesia after these procedures could still prolong postoperative stay and delay in returning to normal daily living function.

Postoperative pain management should be started intraoperatively by supplementing general anesthesia with short-acting opioids, nonsteroidal anti-inflammatory drugs (NSAIDs), or regional anesthesia; this should facilitate a smoother recovery.¹⁸ When opioids are used in the recovery period, rapid and short-acting drugs should be administered and titrated to desired effect.

Combinations of analgesics that act by different mechanisms result in additive or synergistic analgesia. This helps lower total doses of each drug and consequently reduce individual side effects. Such “balanced” or multimodal technique is superior to any single modality.

Hypothermia

Many of the remote anesthetizing locations, such as MRI or CT suites, are air-conditioned to avoid overheating of equipment. However, this may result in serious hypothermia if precautions are not taken.¹⁹ It is especially important in the cases of pediatric and elderly patients, due to their less effective thermal response mechanisms. Hypothermia is associated with delayed postanesthetic recovery. Accordingly, temperature monitoring and an active warming device should be used in the procedural and recovery rooms to prevent or treat hypothermia in order to minimize adverse outcomes.

Oral Fluid Intake Prior to Discharge

Oral intake of fluids is no longer a prerequisite prior to discharge home. Therefore, drinking oral fluids is not a requirement before discharge from the ASU or medical unit, and changes to this effect have been incorporated in the Practice Guidelines for Postanesthetic Care.⁴ Mandating oral fluid intake prior to discharge should be done only for selected patients on a case-by-case basis, such as insulin-dependent diabetics.

TABLE 5.4 *Postanesthetic Discharge Scoring System (PADS)*

Vital signs	
Within 20% of preoperative baseline	2
20%–40% of preoperative baseline	1
40% of preoperative baseline	0
Activity level	
Steady gait, no dizziness, consistent with preoperative level	2
Requires assistance	1
Unable to ambulate/assess	0
Nausea and vomiting	
Minimal: mild, no treatment needed	2
Moderate: treatment effective	1
Severe: treatment not effective	0
Pain	
VAS = 0–3 the patient has minimal or no pain	2
VAS = 4–6 the patient has moderate pain	1
VAS = 7–10 the patient has severe pain	0
Surgical bleeding	
Minimal: does not require dressing change	2
Moderate: required up to two dressing changes with no further bleeding	1
Severe: required three or more dressing changes and continues to bleed	0
Patients scoring ≥ 9 are fit for discharge	

Source: Reprinted with permission from Chung F. Recovery pattern and home-readiness after ambulatory surgery. *Anesth Analg.* 1995;80:896–902.

Voiding Prior to Discharge

Both general and spinal anesthesia affect detrusor muscle function. Prolonged distension of the bladder can lead to a significant morbidity. Type and duration of the procedure, old age, male sex, spinal/epidural anesthesia, and administered fluid volume are risk factors for postoperative urinary retention.²⁰ In the current practice, low-risk patients can be discharged home without voiding. They should be instructed to return to the hospital if they are unable to void within 6 to 8 hours. Patients at high risk of urinary retention should be required to void prior to discharge and display a residual volume <300 ml as measured by ultrasound. If the bladder volume is >500 – 600 ml, catheterization should be performed prior to discharge.²¹

Patient Escort

The American Society of Anesthesiologists requires a responsible adult escort to accompany patients home after procedures involving any sedation or anesthesia. Various studies have shown that there exists significant psychomotor and cognitive impairment after general anesthesia and monitored

anesthesia care. In a prospective study conducted over a period of 38 months, the incidence of patients with no escort was found to be 0.2% (60/28,391 patients).²² It is a common practice for personnel in the recovery room to ensure that patients have an escort to accompany them home. Hospitals should implement policies to prevent discharge of patients without an escort. This should be a fundamental issue of patient safety in relation to OOR anesthesia.

CONCLUSION

Procedures conducted outside of the OR will continue to grow and expand. Understanding potential complications during the recovery process, using discharge scores to facilitate discharge, updating patient information and clinical pathways based upon current best evidence, and ensuring the availability of patient escort will contribute to the safe recovery and discharge of patients following their procedures.

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6 Management of Staffing and Case Scheduling for Anesthesia Outside of the Operating Room

ALEX MACARIO, MD, MBA

“We’d like anesthesia coverage for our cases in OOR location XYZ. Can you help us out?” A good first step in answering this question is to look at your group’s service contract with the hospital to see what language exists for covering elective cases outside of the operating room (OOR). If this is the first time the anesthesia group has been asked to cover off-site cases, then discussion with the hospital is in order to negotiate an arrangement for anesthesia coverage.

Theoretically, anesthesia groups could arrange that off-site cases will be covered by an anesthesiologist at the convenience of the OOR proceduralists. This approach requires obtaining financial support, sometimes referred to as a service agreement, from the hospital to subsidize the anesthesia group so it can deliver anesthesia care as requested to cover these often poorly scheduled OOR locations. A good first step in this dialogue is for the hospital administration to identify the anesthetizing locations and hospital services that need anesthesia services.

According to a survey of hospital contracts by the Medical Group Management Association, in 2005, 57% of hospitals provided some kind of subsidy to anesthesiologists in 2004, up from approximately 50% in 2000. The stipend associated with a service agreement may be quite expensive for the hospital, and it is at risk of disappearing if hospital finances deteriorate sufficiently. As a result, many anesthesia groups are working with the hospital and the multiple OOR services to schedule cases in a way that is economically viable to both the anesthesia group and the hospital.

An anesthesia group has several important groups of people to which it provides service, including patients, surgeons, nurses, and hospital managers. Properly managing the relationship with the hospital manager customer, such as on issues related to OOR cases, is an important goal. Otherwise the anesthesia group runs the risk of losing the right to be the exclusive provider of anesthesia services at that facility. Many conflicts between the hospital and the anesthesia group have been reported where the relationship has deteriorated to the point that the anesthesia group leaves en masse. Perhaps one

factor in such a separation is opposing views on the anesthesia service. For example, a view commonly held by anesthesiologists may be that there is endless demand for anesthesia support, with minimal professional compensation. In contrast, the administrator view may be that the hospital is an extremely valuable franchise for an anesthesia group to have as exclusive provider; “They ought to be paying us for the constant flow of business they get.”¹

Hence, a proactive approach to staffing and case scheduling for OOR cases is optimal to maintain a positive working relationship in the hospital. A functional anesthesia service outside the OR will generate operational and financial advantages for the hospital that are multiples of the anesthesia revenues. The goal for the anesthesia group is to work with hospital and the multiple OOR services to schedule cases in a way that is economically viable to all parties. This reflects the hospital’s desire to retain and grow physicians’ practices, to enhance market share and reputation, and to fulfill community-service missions.

Optimizing OOR scheduling is financially important to anesthesia groups (e.g., so anesthesiologists can do consecutive cases at the same location). Some anesthesia groups manage this uneven demand by assigning an anesthesiologist daily to do “utility infielder” work for OOR cases Monday through Friday, with hours of 0730 until 1600, for example. The list of their responsibilities goes throughout the hospital, but it may consist of electroconvulsive therapy (ECT), bone marrow biopsy, and cardiology catheterization lab, with either cardioversions or implantable cardioverter defibrillator (ICD) testing. In such practices, outside this structure and timeline, the referring OOR physician needs to declare an emergency to obtain anesthesia support on a particular day. Sometimes OOR cases are simply added to the surgery waiting list, but this is unsatisfactory to everyone involved. OOR anesthetics can be challenging not only because the environment is not what the anesthesiologist is used to in the OR but also because scheduling staff for these cases brings about problems.

With proper management weeks to months ahead of time, the groundwork for an efficient (well-functioning) OOR elective schedule should be in place. This chapter's aims are as follows:

1. Reinforcing that OOR case scheduling should aim to reduce overutilized time
2. Identifying challenges of scheduling anesthesia services outside of the operating room
3. Explaining that current procedural terminology (CPT) codes for OOR cases are not predictive of anesthesia times
4. Recommending that an OOR service requesting anesthesia coverage receive a block of allocated time provided they average at least 10 hr of cases including turnovers every 2 week. The 10 hr threshold is set high to ensure that the allocated "block" remains filled. Two weeks is a reasonable length of time from the perspective of patient waiting times. An "overflow block" (i.e., first come, first scheduled time) is made available for any spillover cases or services that have less than 10 hr of cases per week.
5. Encouraging the use of computer-based enterprise-wide scheduling so that control of scheduling of OOR cases is distributed to each OOR service

OOOR CASELOAD WILL GROW

There is much pent-up demand for OOR anesthesia services. The shift to non-OR settings will continue to expand, driven by cost savings (e.g., the office has lower overhead than the OR), convenience for patients and providers, desire by hospitals to avoid sedation mishaps by nonanesthesiologists, and availability of new treatments that are not dependent on a full-fledged OR. Although these increasing requests are burdensome in the short term to manage, they do indicate that anesthesia services are valued in a growing number of health care venues. This is a big positive for the specialty in the long term.

CHALLENGES OF SCHEDULING ANESTHESIA SERVICES OUTSIDE OF THE OPERATING ROOM

"Horizontalization" of anesthesia locations that need to be covered first thing in the morning can stretch the anesthesia group's ability to promptly provide staff.² Scheduling and arranging for anesthesia coverage of an OOR case can be complex (Fig. 6.1). OOR cases have different characteristics than OR surgical cases, and this affects their management (Table 6.1).

For anesthesia groups that primarily engage in medical direction of nurse anesthetists, OOR activities are out of the surgical suite by Medicare definition. This means that medical direction of certified registered nurse anesthetists (CRNAs) is not possible due to geographic restrictions, because all medical direction should occur within the OR suite. For example,

in one OR suite, if two cases are running late, one MD could cover two residents/CRNAs. But if there is one case running late in the main OR suite, and one in the gastroenterology lab that is far away, then two anesthesiologists are needed. Sometimes (endoscopic retrograde cholangiopancreatographies (ERCPs) are scheduled in the OR with a CRNA so that medical direction can occur.

OOOR SCHEDULING SHOULD AIM TO REDUCE OVERUTILIZED TIME

OOOR caseload may be inconsistent and of varying duration (Fig. 6.2). Nothing is more important in OOR case scheduling than to first allocate the right amount of time to each OOR service on each day of the week.³

To illustrate, we will schedule two cerebral angiogram cases each lasting 2.5 hours into the Radiology Suite Room #1 (Fig. 6.3). The radiology suite nurses and one anesthesiologist are scheduled to work a 9 hr day. The matching of workload to staffing has not been optimized. Little can be done on the day of the procedures to increase the efficiency of use of the nurses and anesthesiologists.

Neither awakening patients more quickly nor reducing the turnover time, for example, will compensate for management's poor initial choice of staffing for Radiology Suite Room #1 and/or how the cases were scheduled into Room #1.

Underutilized hours reflect how early the room finishes. In Scenario #1, if an anesthesiologist and a radiology nurse were scheduled to work from 8 a.m. to 5 p.m. and instead the room finished at 2 p.m. (including 1 hr turnover), then there would be 3 hr of underutilized time. The excess staffing cost would be 33% (3 hr/9 hr). In contrast, for Scenario #2, 11 hr of OOR cases are performed in the OOR location with staff scheduled to work 9 hr.

The optimal amount of OOR time that needs to be allocated to a particular service, sometimes referred to as a "block," should minimize the amount of underutilized time and the more expensive overutilized time.⁴

On the other hand, if 11 hr of OOR cases are performed in an OOR location with staff scheduled to work 9 hr, then the excess staffing cost is 44% (Scenario #2).⁵ Overutilized hours are the hours that rooms run longer than the regularly scheduled end time, or 2 hr in this example (2 hr/9 hr = 22%, which we then multiply by a "fudge" factor of 2 to include the additional cost of staff staying late). One component of this is the monetary time-and-a-half overtime cost paid to staff, and the second is the recruitment and retention costs related to disgruntled staff unexpectedly forced to work extra hours.

If the key is to allocate appropriate time to each OOR service based on historical use, how do you deal with OOR locations consistently running late? The answer: make the allocated anesthesia OOR blocks longer. For example, if the interventional radiologist performs 12 hr worth of cases needing anesthesia on one day every 2 weeks, do not assign 9 hr of interventional radiology block time (8 a.m.–5 p.m.) and have

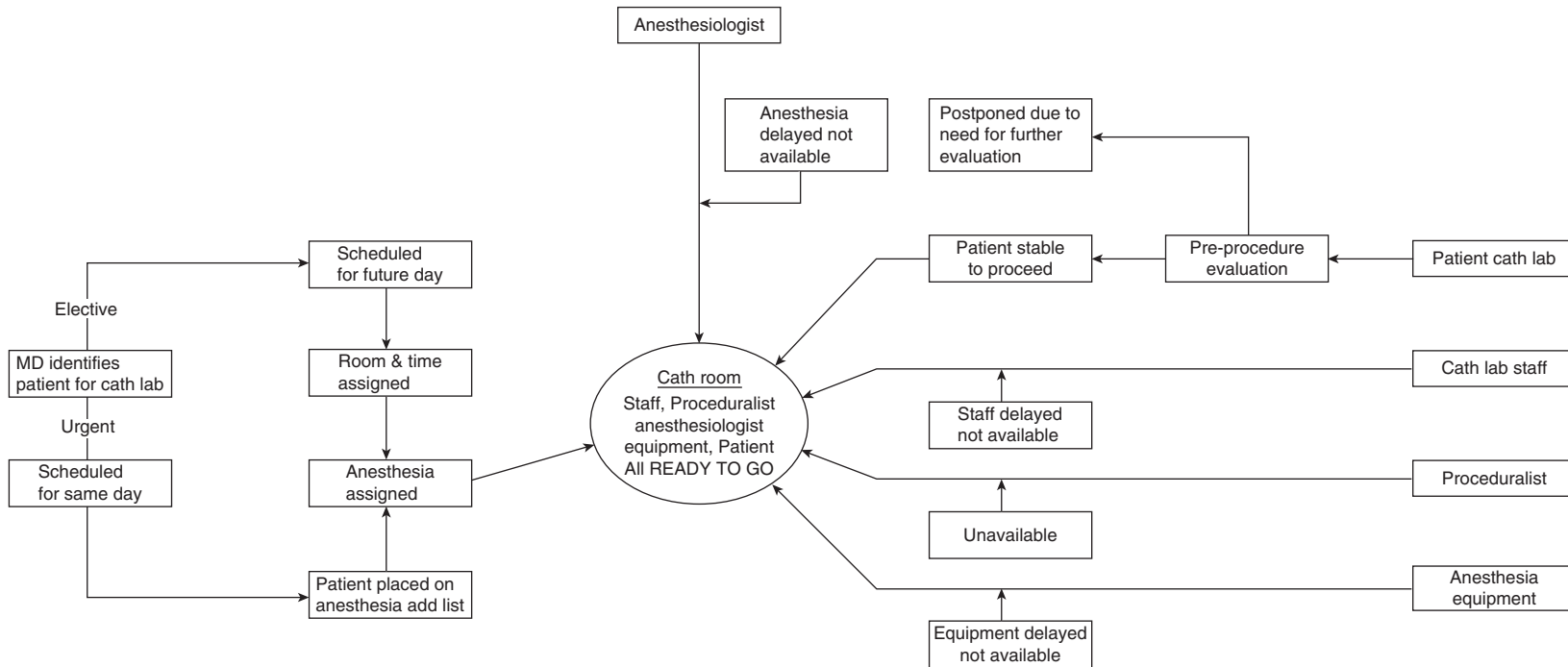


FIGURE 6.1. Process map for scheduling a case in the catheterization lab. (Figure courtesy of Dr. Cliff Schmiesing.)

TABLE 6.1. *Differences between the Surgical Suite and OOR Anesthetizing Locations*

- OOR locations are not as interchangeable as normal ORs. For example, a pediatric electrophysiologist cannot “split out” and perform his or her next case in the CT suite.
- In contrast to the surgical suite, non-OR services are often small, composed of only one or two physicians. Depending on how time is allocated and cases scheduled, variation in workload at each location on any day will be larger (e.g., due to physicians’ absences due to vacations/meetings, which will be more noticeable with a small physician group than with a bigger group).
- Whereas OR turnovers aim to be as low as 20–30 min, OOR turnovers can be 1 hr or more. This is especially true when the change involves switching from one geographical area to another. Factors affecting turnover include transporting a patient to the PACU through a maze of halls and elevators, returning to the initial site to collect equipment, and moving the equipment to a new location.
- An anesthesiologist can cover only one site at a time outside the OR. For example, an anesthesiologist supervising CRNAs/residents may do a preop evaluation on his or her OR’s next patient during the current case. This is difficult, if not impossible, when the next OOR case will be done at a separate site.
- Diagnostic radiology cases (CT/MRI) that require anesthesia are often single cases, in the middle of a list of other cases not needing anesthesia. As a result, most facilities do not assign anesthesia blocks exclusively for CT/MRI cases requiring anesthesia. The challenge then is to predict a single case’s duration.
- Unlike CT or MRI cases, interventional radiology cases requiring anesthesia are often scheduled sequentially in one room, so the management challenge is to estimate when the workday will end, not just the duration of one case.

CRNA, certified registered nurse anesthetist; CT, computed tomography; MRI, magnetic resonance imaging; OOR, outside of the operating room; OR, operating room; PACU, postanesthesia care unit.

the anesthesiologist and interventional radiology nurses frustrated by having to stay late. Rather, assign 12 hr of block time (8 a.m.–8 p.m.); by doing so, anesthesia and nursing staff know they will be there 12 hr when they arrive to work, and overtime costs (both financial and morale) will be reduced.

The common response to this approach is, “No one wants to be in the interventional radiology room till 8 p.m.” The answer to that is, “You are there now till 8 p.m., so why not make scheduled interventional radiology time 12 hr and have a more predictable workday duration?”

Optimizing staffing costs is finding the best balance between overtime and finishing early. Involvement by a high-level member of the facilities administrative staff (VP or above) is

essential to successfully bringing together the budget, staffing, and leadership to allocate such anesthesia time blocks for OOR work.

CURRENT PROCEDURAL TERMINOLOGY CODES FOR OOR CASES ARE NOT PREDICTIVE OF ANESTHESIA TIMES

Computed tomography (CT)/magnetic resonance imaging (MRI) anesthesia time estimates based on historical CPT codes are strikingly inaccurate. They are not as predictive of OOR anesthesia times as they are for surgery cases. For OOR cases, one study found that for CT and MRI cases (with overall average duration of 2 hr), the mean absolute percentage error in case duration estimate equalled 45%, which was less accurate than the 27% error for OR cases of comparable durations.⁶

Cases involving CT and MRI have many different CPT codes, and most are rare. The most common CPT (70553, MRI brain without contrast) accounted for 31% of MRI anesthetics, and the most common three CPTs accounted for 44% of MRI anesthetics.

Using ICD-9-CM procedure codes instead of CPTs yields even more inaccuracy. One cause of this inaccuracy is that procedure codes reflect organs imaged, not scanning times. For example, ICD-9-CM 88.38 could either be CT of the sinuses or CT of pelvis, which can differ by 10 min in scanning time. As a second example, ICD-9-CM 88.97 could be either an abdomen MRI or an orbit MRI, which also differ in scan duration. Differences in scanning times also arise depending on the type of machine used for imaging.

Consider taking the estimates for individual cases provided by the chief radiology technologist as a best guess.

Similarly, a diversity of scheduled procedures also exists for pediatric cardiac catheterization. It is even more difficult to schedule anesthetic times for interventional radiology cases. Again, the CPTs are nonpredictive and the anesthetics administered are usually long (average duration slightly less than 4 hr). The three most common interventional radiology CPTs accounted for 77% of Interventional Radiology anesthetics. The Interventional Radiology CPT (61624) accounted for 63% of anesthetics. This CPT encompasses a multitude of procedures and does not specify the size of the lesion—“transcatheter permanent occlusion or embolization (e.g., for tumor destruction, to achieve hemostasis, to occlude a vascular malformation), percutaneous, or any method” that involves the “central nervous system (intracranial, spinal cord).”

Because interventional radiology often schedules their elective cases into allocated time, the necessary endpoint that would be nice to predict with some accuracy is the finish time for the day’s entire list of cases including turnovers. Methods have been published to determine the time (e.g., 4 p.m.) up to when interventional radiology could schedule, so that there is an 80% chance that the anesthesia team finishes no later than a specified time (e.g., 6 p.m.).

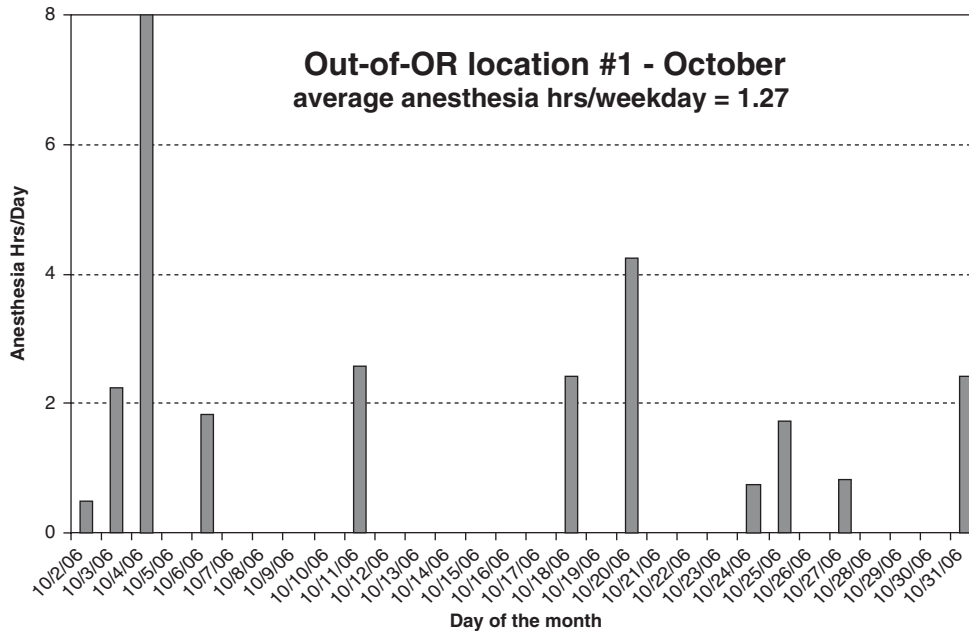


FIGURE 6.2. Anesthesia hours per day vary from day to day, from 0 hr to more than 8 hr for this outside of the operating room (OOOR) location. This prompted the anesthesia group to create a team that included the hospital administrator, scheduling personnel, the OOOR proceduralist, and the anesthesia group representative to better coordinate case scheduling.

PROVIDE ENOUGH OPEN ACCESS ANESTHESIA TIME SO THAT EACH SPECIALTY CAN ACCOMMODATE MOST OF ITS OOOR CASES WITHIN TWO WEEKS

For OOOR cases, a reasonable approach is to provide anesthesia coverage of elective OOOR patients within a reasonable number of days. This length of time can be discussed with hospital management to meet hospital needs, but 50% of patients stated that 2 weeks is the longest acceptable wait time for a procedure, 75% stated 4 weeks was the longest acceptable wait time, and 90% stated that 8 weeks or less was the longest acceptable wait time.⁷ The optimal reasonable number of days from the perspective of patient expectations of waiting times will vary by country and by medical system.

If the anesthesia department normally plans 10 hr workdays (from 7 a.m. to 5 p.m.) for their anesthetists, then an OOOR service requesting anesthesia coverage should receive a block of allocated time provided they average at least 10 hr of cases including turnovers every 2 weeks.⁸ The threshold of 10 hr is set high to ensure that the allocated time remains filled. The anesthesia time commitment needs to be a fixed time to reduce OOOR physicians from wandering off (e.g., to do consultations, etc.).

If the OOOR service has a new elective case that needs to be scheduled and all the allocated time (block) is filled for the next 2 weeks, then additional “overflow” time (i.e., first come, first scheduled “unblocked” time) is made available on another day of the week for the extra case.⁹ In this way, the new case can be performed within 2 weeks, but not by

extending the duration of the original 10 hr staffed workday. A service guarantee of a maximum patient waiting time removes the argument that the anesthesia department is causing patients to wait for an unnecessarily long time. The service guarantee is no longer a commitment to a particular block (e.g., 10 hr) of anesthesia coverage, but that the case will be performed within 2 weeks, or whatever time period is mutually agreed upon.

One goal for the anesthesia group could be to generate 8 hr of anesthesia billing time per day and to be finished by 5 p.m. (Table 6.2).

By letting professional practices grow, open-access scheduling increases revenues for the hospital and anesthesia group. Planning for future staffing can potentially be more accurate because the total hours of anesthesia time performed in the past can then be used to forecast future anesthesia needs.¹⁰

Example XYZ: Data analysis for OOOR location XYZ is summarized in Table 6.3. On Mondays, how much anesthesia time (e.g., 8 hr, 10 hr, 12 hr, 13 hr) should be allocated to XYZ?

When you run the numbers for this example using this efficiency formula, it computes out that 8 hr is the optimal allocation on Mondays because this amount mathematically minimizes underutilized and the more expensive overutilized time.

In this particular situation, with an 8 hr allocation, and 6 hr, 6 hr, 8 hr, and 10 hr of work on successive Mondays, there would be 2 hr, 2 hr, and 0 hr of underutilized time, respectively, for the first three Mondays, and 2 hr of overutilized

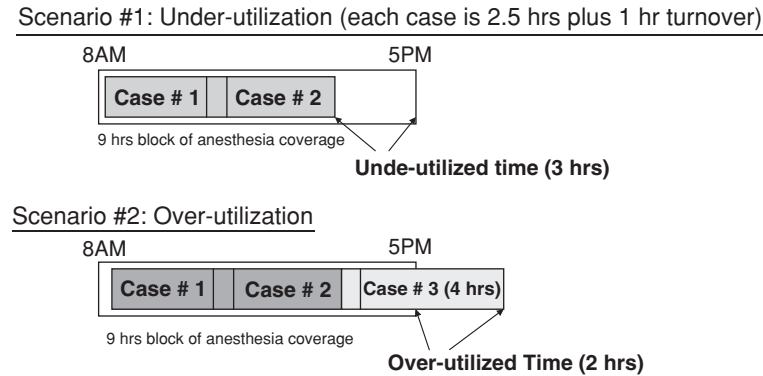


FIGURE 6.3. Scenario #1: Under-utilization (each case in 2.5 hr plus 1 hr turnover) Scenario #2: Over-utilization.

TABLE 6.2. *Example: Allocations of Two Ten-Hour Blocks per Day for Elective OOR Cases during Each Two-Week Cycle for One Hospital*

Monday: Adult cardiology; pediatric cardiac catheterization

Tuesday: Neuroradiology; MRI/CT

Wednesday: Adult cardiology; open overflow time

Thursday: Interventional radiology; MRI/CT

Friday: Adult cardiology; pediatric cardiac catheterization

CT, computed tomography; MRI, magnetic resonance imaging; OOR, outside of the operating room.

time, multiplied by 2, for the fourth Monday, for a total of 8 inefficiency hours. No other OR allocation (e.g., 7 hr, 10 hr, 13 hr) gives a lower amount of inefficiency hours. This efficiency hour analysis would be repeated to calculate optimal allocated time duration for each day of the week. Any additional caseload can be covered by the overflow anesthesia time.

ENTERPRISE-WIDE SCHEDULING ENABLES CONTROL OF OOR SCHEDULING TO BE DISTRIBUTED TO EACH OOR SERVICE

Inherent problems to OOR scheduling include that OOR cases are often written on paper calendar, whereas OR cases are typically scheduled electronically, so it is difficult to assess demands for anesthesia staff. Also, rebookings/cancellations for OOR anesthetics may not get passed on to the anesthesia scheduler if a paper scheduling system is used.

Computer-based enterprise-wide patient scheduling systems permit clerks, nurses, physicians, or patients (e.g., via the Internet) to schedule patient appointments throughout a multiple-specialty physician group and/or health care system. An application of these systems is to coordinate patient scheduling in surgeons' clinics with patient scheduling in surgical suites or with OOR areas. Better synchronization of such

schedules is an important objective. Just as some radiology departments allow clerks at physicians' offices to schedule radiological procedures via a Web browser, and some clinics allow patients to schedule their own appointments, the anesthesia department can allow clerks and nurses in other departments to schedule directly into OOR anesthesia time.

Advantages to scheduling OOR anesthetics using an enterprise-wide scheduling system include the following:

- Clinic nurses and radiology schedulers do not have to phone the anesthesia department and wait to see if someone answers.
- Anesthetics can be coordinated with other appointments the patient may have on the same date. For example, a patient's schedule for the day might include preanesthesia evaluation at 9 a.m., anesthetic starting at 11 a.m., CT machine at 11:30 a.m., and oncology clinic at 3:00 p.m.

Deciding when patients should arrive for their OOR case is also a major challenge. If patients are told to arrive too early in the morning for a procedure scheduled in the afternoon, they risk waiting several hours and the unpleasantness of remaining nil per os (NPO) for most of the day. On the other hand, if patients do not arrive early enough, they may not be ready in the event an earlier case is cancelled or finishes early.

Asking patients to arrive a fixed number of hours, such as 2 hr, before their scheduled OOR procedure should be replaced by statistical methods which compute the earliest time that their scheduled case could begin. Patient waiting times must be balanced against patient availability and staff waiting times. A good general rule is that if the preceding case is cancelled or finishes early, the patient should be ready and waiting 19 times out of 20. Thus, OR staff should wait only 5% of the time. Mathematically, the earliest possible start time is calculated from the scheduled and actual start times of historical cases performed by the same suite, service, and day of the week. While 99 historical cases by the same suite, service, and day of the week are desirable, a minimum of 19 suffices.

Knowledge of "the earliest possible start time" for each case, in conjunction with revised NPO guidelines, allows some patients to eat or drink on the morning of a procedure

TABLE 6.3. *Dates and Number of Anesthesia Hours, Including Turnovers for OOR Location XYZ*

Mondays	4/2/2007	6	4/9/2007	6	4/16/2007	8	4/23/2007	10
Tuesdays	4/3/2007	4.5	4/10/2007	8.67	4/17/2007	18.94	4/24/2007	7.25
Wednesdays	4/4/2007	7.75	4/11/2007	11.02	4/18/2007	6.13	4/25/2007	5.8
Thursdays	4/5/2007	9.42	4/12/2007	0	4/19/2007	4.48	4/26/2007	0
Fridays	4/6/2007	6.32	4/13/2007	8.37	4/20/2007	0	4/27/2007	0.67

Normally, the minimum amount of data to make this determination would be 2–3 months worth of Mondays, with 9 months being preferred.

Efficiency of use of OOR time = [hours of underutilized time] + [hours of overutilized time multiplied by a fudge factor (usually assumed to be 2) to account for overtime/staff morale].

OOR, outside of the operating room.

with little chance their case would have to be postponed because of food consumption. An example of a calculator that performs such analyses for one hospital is available online at <http://www.caseduration.com>, a site of the Division of Management Consulting of the Department of Anesthesia, University of Iowa.

CONCLUSION

Many anesthesia groups face large increases in demand for anesthesia outside the OR. Unfortunately, it is often difficult to keep an anesthesiologist working all day without gaps in his or her schedule. Providing a functional anesthesia service outside the security of the traditional OR is part of the reason that more and more hospitals have service agreements with anesthesia groups, usually including a stipend.

Involvement by a high-level member of the facility (e.g., hospital vice-president) is essential to bring together the budget, data analysis, staffing, and scheduling for OOR cases. Interpersonal skill and flexibility are needed by the anesthesiologist to work as part of a team in the ambiguity and stresses outside the OR.

Staffing and case scheduling for OOR anesthesia differ from that of ORs. From the start, anesthesia departments should establish a goal to provide coverage of OOR patients within a reasonable number of days (e.g., 2 weeks) by providing their procedural colleagues with open access to anesthesia-staffed OOR time. This may require the direct input of the specialists because it is difficult to predict the duration of OOR cases.

When an anesthesia group is perceived by surgeons, hospital managers, and OOR proceduralists as being “service oriented,” the anesthesia group will have an easier time negotiating hospital support.

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7 Procedural Sedation by Nonanesthesia Providers

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Although anesthesiologists and certified registered nurse anesthetists (CRNAs) are experts in sedation/analgesia outside of the operating room (OOOR), extensive demand in the face of limited resources has resulted in sedation being routinely performed by nonanesthesia health care providers. Sedation/analgesia is administered for minor office and hospital procedures in a variety of areas, including gastroenterology (GI), radiology, cardiology, dentistry, and the emergency room. Given the extreme diversity of settings, it is understandable that procedural sedation and analgesia evolved to meet the unique needs of each of these specialties. However, to improve patient safety, the Joint Commission and the American Society of Anesthesiologists (ASA) issued standards that unify and standardize the various approaches across specialties and institutions.^{1,2} This chapter will briefly review the essential elements needed to develop a safe policy for sedation by nonanesthesia practitioners.

CONTINUUM OF SEDATION/GENERAL ANESTHESIA

An essential component of standardization is the definition of the “continuum” of sedation/anesthesia from minimal sedation to general anesthesia (Fig. 7.1).² The continuum was developed to create unequivocal terminology for the sedation levels. Previously, three levels of sedation (conscious sedation, deep sedation, and general anesthesia) were recognized. The notion of “conscious” sedation was frequently misinterpreted and abused, in reality meaning “deep” sedation or even “general” anesthesia. Therefore, it has been replaced with the clearer term of “moderate” sedation, a well-demarcated clinical state that is safe and optimal in everyday OOOR practice. Furthermore, the definitions crystallize what the different stages of sedation/analgesia represent clinically and the expected physiologic consequences in each state.

Minimal sedation involves anxiolysis during which the patient responds normally to verbal commands. The patient maintains normal airway reflexes and ventilation, and normal cardiovascular responses. Types of sedative agents for this level include a single dose of sedative or analgesic administered orally for the purpose of alleviating anxiety or pain, and nitrous oxide less than 50% with no other sedatives or analgesics.

Moderate sedation involves the depression of consciousness, but during which the patient still responds to verbal commands, either alone or accompanied by light tactile stimulations. Spontaneous respiration is usually adequate and no interventions are required to maintain a patent airway. Cardiovascular function is usually maintained.

This type of sedation is the most common in OOOR procedures, and it is used for diagnostic and interventional procedures in the GI, radiology, cardiac catheterization laboratory, and other OOOR locations. Intravenous drugs such as midazolam and fentanyl are popular and safe for moderate sedation.

Deep sedation/analgesia involves significant depression of consciousness during which patients cannot be easily aroused but may respond purposefully following repeated or painful stimulation. Patients may require assistance in maintaining a patent airway, and spontaneous ventilation may be inadequate. Cardiovascular function is usually adequate. Higher doses of midazolam or fentanyl, as well as sedative doses of propofol, are commonly used for deep sedation.

General anesthesia is a drug-induced loss of consciousness during which patients are not arousable, even by painful stimulation. Patients often require assistance in maintaining a patent airway, and positive-pressure ventilation may be required because of depressed spontaneous ventilation or drug-induced depression of neuromuscular function. Cardiovascular function may be impaired. Propofol may fairly easily and unexpectedly result in general anesthesia. If the patient loses consciousness and the ability to respond purposefully, the anesthesia care is a general anesthetic, irrespective of whether airway instrumentation is required.

It is crucial to understand that sedation represents a cascade of events with progressive alteration (a continuum) in level of responsiveness, airway patency, and respiratory and cardiac function, as increased depths of sedation/anesthesia are achieved. The progression from minimal sedation to deep sedation/general anesthesia might represent a quick transition that lacks distinct separation between stages. In addition, the transition from one level of sedation to the next is often difficult to predict and varies from patient to patient, as well as with changing degrees of procedural stimulation and pain.

The sedation continuum is not drug specific, and levels from mild sedation to general anesthesia can be reached with virtually any commonly used sedative/analgesic agent. This is

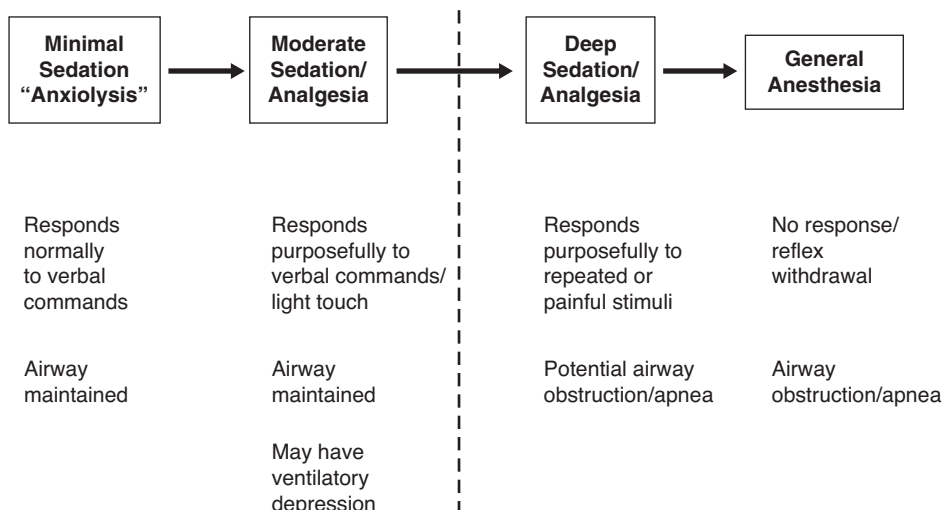


FIGURE 7.1. Continuum of conscious sedation (Adapted from Practice guidelines for sedation and analgesia by non-anesthesiologists: an updated report by the American Society of Anesthesiologists Task Force on Sedation and Analgesia by Non-Anesthesiologists. *Anesthesiology*. 2002;96:1004–1017).

particularly true when drug combinations are used such as a sedative plus an opioid, when the dosing interval is too short and drug accumulation occurs (this may be hard to predict), and during changes in intensity of painful stimuli during the procedure. While patients may breathe during painful parts of procedures, spontaneous respiration may be severely depressed when the stimulation subsides.

The Centers for Medicare and Medicaid Services (CMS) state that only anesthesia professionals (anesthesiologist, nurse anesthetist, and anesthesiologist's assistant) or other qualified nonanesthesiologist physicians (as well as dentist, oral surgeon, or podiatrist who is qualified to administer anesthesia under State law) are permitted to administer deep sedation and general anesthesia.³ Registered nurses, advanced practice registered nurses or physician assistants may not administer deep sedation per CMS. The 2010 ASA "Advisory on Granting Privileges for Deep Sedation to Non-Anesthesiologist Sedation Practitioners" was created to "assist health care facilities in developing a program" for the delineation of procedure-specific clinical privileges for nonanesthesiologist physicians to administer or supervise the administration of sedative and analgesic drugs to establish a level of deep sedation. The advisory outlines recommendations for education, training, licensure, performance evaluation and performance improvement. In contrast, mild to moderate sedation usually can be administered safely by nonanesthesia practitioners who have had specialized training.³ Knowledge of the pharmacologic profiles of sedation agents is necessary to maximize the likelihood that the intended level of sedation is targeted accurately. If cardiorespiratory compromise occurs, the nonanesthesia practitioners should possess the skills necessary to "rescue" a patient whose level of sedation is deeper than planned, and return the patient to the intended level. Therefore, one person must be available whose only responsibility is to monitor the patient,

identify cardiorespiratory compromise, and institute bag-mask ventilation and cardiopulmonary resuscitation if necessary. Backup emergency services, including protocols for summoning emergency medical services, must be established and maintained.

PERSONNEL AND TRAINING PROCEDURES FOR NONANESTHESIA PRACTITIONERS GIVING OR SUPERVISING MODERATE SEDATION

The Joint Commission requires that sedation providers have adequate training to administer the sedative drugs effectively and safely, the skills to monitor the patient's response to the medications given, and the expertise needed to manage all potential complications. This generally implies that sedation/analgesia at every location must be supervised by a competent physician who is appropriately trained and privileged. A qualified support person (nurse, respiratory therapist) should be present for the continuous monitoring of the patient. Such support persons must focus on the patient's status and not take part in the procedure. They should have "rescue capacity" to respond to a deeper level of sedation than intended, with expertise in airway management and advanced life support. They may assist with minor, interruptible tasks; however, they should have no other responsibilities that would interfere with the level of monitoring and documentation appropriate for the planned level of sedation. They should be free to monitor the patient from the start of the procedure through the completion of the recovery phase.

While the Joint Commission set forth standards for the procedural sedation care, the benchmarks of training required for privileges to perform procedural sedation actually depends

upon the individual institution or hospital. CMS recently issued revised interpretative guidelines for anesthesia services that require analgesia and sedation services in hospitals to be under the direction of one anesthesia service, under the direction of a qualified physician.³ The anesthesia service is responsible for developing policies and procedures governing the provision of sedation/analgesia, including the minimal qualifications for each category of practitioner who may provide sedation, for all patients having all levels of sedation in all facility locations.

In 2006, the ASA issued guidelines for privileging nonanesthesiologists to provide moderate sedation, which are found in entirety on the ASA Web site.⁴ This statement was created to give a foundation to any institution interested in developing sedation privileging policies. Included is specific training in administration of sedative/analgesic drugs, airway skills, resuscitation skills, patient presedation evaluation, monitoring and interpreting physiological variables, postprocedure transport and evaluation, and discharge criteria (Table 7.1).

PATIENT PREPARATION AND SELECTION

Table 7.2 illustrates patient preoperative factors that should prompt consultation of an anesthesiologist to evaluate the safety and provision of sedation. These factors include sicker patients (ASA status 4 and 5) as well as extremes of age, morbid obesity, sleep apnea, an anticipated difficult airway, chronic pain on opioid therapy, substance use disorder, history of difficult sedation, a prior adverse reaction to sedation/anesthesia, a long or complex procedure planned, and the prone position. Further details concerning preoperative patient selection and evaluation are described in Chapter 6.

FASTING GUIDELINES

A history of last oral intake is required before providing sedation/analgesia. Practitioners should follow the ASA fasting guidelines required for sedation/analgesia.² The concept behind these recommendations is that it is very difficult to predict the exact depth of sedation that will result from a dose of a sedative in a given patient. Therefore, it should be assumed that airway reflexes may be lost and steps to minimize gastric aspiration risk should be taken.

The ASA guidelines recommend at least 2 hours of fasting for clear liquids (fluids which light penetrates, not containing milk products), at least 4 hours for breast milk, at least 6 hours for a light meal, and 8 hours for a fatty meal (Table 7.3). These recommendations apply only to healthy patients undergoing elective procedures and do not guarantee that complete gastric emptying has occurred. They do not apply in many clinical situations, including for pregnant women beyond the first trimester of pregnancy; patients with severe pain on parenteral opioids; alcohol intoxication; patients with positional gastroesophageal reflux, nausea/vomiting, bowel obstruction, ascites, and other gastrointestinal disorders that

reduce gastric emptying; morbid obesity; diabetes; and numerous other conditions. In adults, some institutions have found it practical and safest to add an additional conservative margin with nil per os (NPO) status (such as at least 4 hours after clear liquids and 8 hours after a meal) due to frequent changes in schedules and the presence of patient medical conditions that may predispose to reductions in gastric emptying.

With the recommendations just outlined in mind, each practitioner will need to weigh the urgency of the procedure against the relative risk of pulmonary aspiration. Recognizing the lack of sufficient evidence pertaining to sedation/analgesia, the ASA in its Task Force on Sedation/Analgesia by Non-Anesthesiologists recommended that the potential for pulmonary aspiration of gastric contents should be considered in determining the target level of sedation, whether the procedure should be delayed, and whether the trachea should be protected by intubation.² Emergency room physicians routinely perform procedural sedations on patients noncompliant with the ASA fasting guidelines, and there is little indication that aspiration is a significant problem in this setting with mild/moderate sedation.^{5,6} Caution with the use of drugs that may more easily result in oversedation and loss of airway reflexes, such as propofol or fospropofol, should be carefully considered. Although not supported in the literature, administration of metoclopramide or H₂-blockers may be considered with the goal of decreasing injury should aspiration occur.

EQUIPMENT AND SUPPLY

Because sedation and analgesia may result in untoward events, including oversedation, respiratory depression, or cardiopulmonary arrest, having the appropriate emergency equipment in close vicinity to the sedation area is mandatory. Supportive equipment must include oxygen, suction, patient-monitoring devices, basic and advanced airway management equipment, a monitor/defibrillator/pacer, advanced life support medications, reversal or rescue agents, and vascular access equipment (Table 7.4).

MONITORING

Recommended Monitors

Chapter 4 describes monitoring techniques in detail. Guidelines that follow the ASA recommendations for monitoring patients during sedation/analgesia have been developed by several professional societies, including GI, emergency medicine, and radiology. There is general agreement that the patient should be continuously monitored from the start of moderate sedation until the time discharge criteria are met. Baseline vital signs, including blood pressure measurement, oxygen saturation by pulse oximetry, heart rate, rhythm, and level of consciousness are the minimum assessment parameters to be

TABLE 7.1. *Training and Credentialing in Procedural Sedation and Analgesia for Nonanesthesia Providers*

<i>Competency Category</i>	<i>Required Skills and Knowledge</i>	<i>Comments</i>
Administration of sedative/analgesic drugs	<p>Knows</p> <ol style="list-style-type: none"> Pharmacology: <ul style="list-style-type: none"> Appropriate drug selection Route of administration and dosage Time of onset, duration of action, maximum dose, side effects Treatment of oversedation: <ul style="list-style-type: none"> Airway, breathing, circulation (ABC) Reversal agents Vasoactive drugs and antiarrhythmics 	Written test recommended for verification of knowledge
Airway skills	<ol style="list-style-type: none"> Airway assessment: ability to examine airway and recognize potentially difficult airway <p>Physical examination:</p> <ul style="list-style-type: none"> Habitus: significant obesity (BMI >35); excessive facial hair; receding chin <ul style="list-style-type: none"> Head and neck: short neck; limited neck extension; decreased hyoid-mental distance (<3 cm in adults); neck mass, cervical spine disease; dysmorphic facial features (e.g., Pierre-Robin, Down syndromes) <ul style="list-style-type: none"> Mouth: small opening (<3 cm in adults); edentulous; protruding incisors; high arched palate; macroglossia, tonsillar hypertrophy; non-visible uvula <ul style="list-style-type: none"> Jaw: micrognathia, retrognathia, trismus, significant malocclusion Recognize signs of airway obstruction <ul style="list-style-type: none"> Stridor, noisy breathing, wheezing Rocking motion of chest and abdomen Ability to “rescue” a compromised airway <ul style="list-style-type: none"> Neck, head repositioning Perform jaw thrust, chin lift Insert oral/nasal airway Perform bag-mask ventilation 	<p>Airway skills training may include:</p> <ul style="list-style-type: none"> Airway workshops Airway simulator Supervised practice on patients in operating room
Resuscitation skills	<ol style="list-style-type: none"> Basic life support (BLS) required Moderate sedation: Advanced cardiac life support (ACLS) team available within 5 minutes Deep sedation: Individual trained in ACLS present during the procedure (deep sedation should be performed only by anesthesia providers) 	Institutions should conduct periodical “mock codes” to preserve and reinforce resuscitation skills and team response time.
Patient presedation evaluation	<ol style="list-style-type: none"> Obtaining consent <ul style="list-style-type: none"> Explanation of risks/benefits and possible alternatives Medical history <ul style="list-style-type: none"> Abnormalities of major organ systems Obesity with or without sleep apnea History of previous adverse reactions to sedation/analgesia, or regional or general anesthesia <ul style="list-style-type: none"> Drug allergies Current medications, including herbal products Time of last oral intake Tobacco, alcohol, or substance abuse Physical examination <ul style="list-style-type: none"> Body weight; Body Mass Index >35 Examination of the upper airway Level of consciousness 	Should be used for risk stratification and decision making for anesthesiology consult (see Table 7.1).

	<ul style="list-style-type: none"> • Baseline vital signs, including: blood pressure, heart rate, O₂ saturation via pulse oximetry • Heart/lung auscultation 	
	<p>4. Additional evaluation</p> <ul style="list-style-type: none"> • Diagnostic and laboratory testing guided by comorbid conditions and possible interference with the course of sedation/analgesia • American Society of Anesthesiologists (ASA) physical status classification 	
Monitoring and interpreting physiologic variables	<ol style="list-style-type: none"> 1. Vital signs that should be continuously monitored and recorded every 5 minutes: <ul style="list-style-type: none"> • Consciousness and level of responsiveness • Electrocardiogram (ECG) • Pulse rate • Blood pressure • Respiratory rate • Oxygen saturation via pulse oximetry • Capnography (end-tidal CO₂ monitoring optional) 2. Availability of resuscitative equipment and rescue drugs (see Table 7.4) 	<p>For moderate sedation there needs to be a designated person, other than the practitioner performing the procedure, who monitors the patient, and if necessary may perform minor, interruptible tasks.</p> <p>For deep sedation the monitoring person should not perform any other tasks.</p>
Postprocedure transport	<ol style="list-style-type: none"> 1. A trained person capable of managing complications (airway, hemodynamic) should accompany the patient to recovery. 2. Oxygen via face-mask administered 3. Emergency airway equipment and rescue drugs available 4. Pulse oximetry strongly recommended 	
Postprocedure evaluation	<ol style="list-style-type: none"> 1. Postsedation patients should be observed in an appropriately staffed and equipped area. 2. Consciousness and basic vital signs (oxygen saturation, blood pressure, respiratory rate, pulse rate) should be monitored until discharge criteria is reached. 3. Pain should be well-controlled before discharge. 	
Discharge criteria	<p>Guidelines for discharge:</p> <ol style="list-style-type: none"> 1. Patient alert and oriented 2. Vital signs stable and back to baseline 3. All patients who have received a reversal agent should be monitored for signs of re sedation up to 60–90 min. 4. A responsible person should be available to accompany the patient home. 5. Written discharge instructions regarding diet, medications, and activities should be provided. 	<p>Every hospital should have its own discharge policy. See standardized recovery scoring systems similar to those used in their surgical postanesthesia recovery areas (see Table 7.7)</p>

monitored, recorded, and documented prior to, throughout, and after sedation (Table 7.4). The ASA also recommends continuous electrocardiographic monitoring and use of supplemental oxygen during the administration of intravenous sedation.

Pulse oximetry has become undeniably the standard monitor for the detection of desaturation and hypoxemia during sedation/analgesia. However, pulse oximetry is far from the ideal in detecting ventilatory compromise, including hypoventilation, airway obstruction, or apnea. Significant respiratory compromise can occur despite normal oxygen saturation, particularly when supplemental oxygen is administered.⁷

According to the ASA standards for monitoring during sedation, the adequacy of ventilation during moderate or deep sedation shall be evaluated by continual observation of qualitative clinical signs and monitoring for the presence of exhaled carbon dioxide unless precluded or invalidated by the

nature of the patient, procedure, or equipment.⁸ Capnography is more sensitive than clinical assessment of ventilation in detection of apnea. In a recent study in which the anesthesia provider was blinded to capnography, 10 of the 39 patients developed 20 seconds of apnea, missed by clinical signs and pulse oximetry, but detected by capnography.⁹ Adverse outcomes from oversedation that may be potentially avoided by capnography are described in Chapter 3.

Although capnography is not currently a standard requirement for all procedural sedation/analgesia in OOR locations, its use in detecting adverse respiratory events associated with sedation has been the focus of multiple publications outside of the anesthesiology field.^{10,11} A recent randomized controlled trial using the combination of an opioid and benzodiazepine for elective endoscopic retrograde cholangiopancreatography (ERCP) found significantly fewer episodes of hypoxemia in patients monitored with capnography.¹²

TABLE 7.2. *Preoperative Factors That Prompt an Anesthesia Consult*

ASA Class	Medical Description	Examples	Presence of Anesthesiologist
1	Healthy patient	Healthy without medications	Not needed unless special indications*
2	A patient with mild systemic disease—no functional limitation	<ul style="list-style-type: none"> • Mild asthma • Medically controlled hypertension • Well-controlled diabetes mellitus 	Not needed unless special indications*
3	A patient with severe systemic disease—definite functional limitation	<ul style="list-style-type: none"> • Moderate to severe asthma • Poorly controlled hypertension • Poorly controlled diabetes mellitus with end-organ disease 	Consider anesthesia consultation. Special indications*
4	A patient with severe systemic disease that is a constant threat to life	<ul style="list-style-type: none"> • Morbidly obese with sleep apnea on oxygen therapy • End-stage renal failure requiring dialysis • Congestive heart failure 	Often needed
5	A moribund patient who is not expected to survive without the operation	<ul style="list-style-type: none"> • Septic shock • Polytrauma 	Needed

*Special indications for an anesthesia consult: Extremes of age (under 5 years of age or over 80 years), morbid obesity, sleep apnea, a difficult airway, chronic pain on opioid therapy, substance use disorder, history of difficult sedation, prior adverse reaction to sedation/anesthesia, a long or complex procedure planned, and the prone position.

ASA, American Society of Anesthesiologists.

Depth of Sedation Monitors

Depth of sedation may be monitored by processed electroencephalographic (EEG) activity; however, its usefulness is under debate. An example of this type of monitor is the bispectral index (BIS). The BIS is a continuously processed EEG parameter specifically developed to provide an estimate of the depth of consciousness. Sedation depth is scored on a unitless scale from 0 to 100. A BIS value of 100 is considered complete alertness, 0 is no cortical activity at all, and the range of 40 to 60 is believed to be consistent with general anesthesia.

Although this technology has been widely used to monitor depth of hypnosis in the operating room, its applicability for the purpose of sedation has yielded controversial data. It may be beneficial in preventing oversedation and reducing the time to discharge. Several investigations have suggested that its use may better guide the depth of sedation endpoint than traditional sedation scales, and it may have further benefit for sedation/analgesia in children as they frequently require deeper levels of sedation to prevent movement.^{13,14} Other studies have found unacceptably wide ranges of BIS values compared with the clinical assessment and no improvement in clinical outcomes.^{15,16} Although depth of sedation monitoring may have a beneficial role in the future for sedation/analgesia in the OOR setting, the findings indicate that more data are required before its possible uses and benefits can be defined.

DRUGS USED FOR SEDATION/ANALGESIA

A variety of drugs can be chosen to provide sedation and analgesia for adults and children for OOR procedures. In selecting agents, one should consider the requirements of the procedure (e.g., is the procedure painful, prolonged, or does

the patient need to be motionless?) and the risks and benefits for the individual patient and situation. Every clinician will prefer a drug or combination of drugs that grant analgesia, anxiolysis, amnesia, and minimal hypnosis, that are easily titratable and reversible, and that lack respiratory and cardiovascular depression and other side effects. Unfortunately, such drugs have yet to be discovered.

From a practical standpoint, if the procedure is not painful (e.g., noninvasive radiologic procedures such as computed tomography scanning and magnetic resonance imaging), pure sedation may suffice and benzodiazepines may be used alone. Analgesic agents (opioids) should be added to any procedure that demands pain relief. Ketamine may be an excellent single drug choice for painful or stimulating procedures in children and for restricted adult applications (e.g., fracture reduction). Most often a combination of drugs consisting of hypnotics and analgesics is a reasonable choice. However, the practitioner should be aware that with combinations of hypnotics/analgesics, drug side effects are frequently synergistic and can potentiate untoward side effects.

The specific agents for procedural sedation, amnestic and analgesic properties, dosage recommendations for adult patients, and side effects are listed in Tables 7.5 and 7.6 and are described briefly in the next section. See Chapter 6 and other chapters in this volume for more detail and more specific applications of these drugs in different OOR settings.

Common Drugs for Procedural Sedation/Analgesia

Benzodiazepines (BDZs) include *midazolam* (Versed®), *diazepam* (Valium®), and *lorazepam* (Ativan®). Benzodiazepines have antianxiety, anticonvulsant, sedative, muscle relaxant, and amnesic properties. However, they do not provide analgesia, and therefore, they are commonly coadministered with

TABLE 7.3. *Fasting Recommendations to Reduce the Risk of Pulmonary Aspiration*

Ingested Material	Minimum Fasting Period
Clear liquids*	2 hr
Breast milk	4 hr
Infant formula	6 hr
Nonhuman milk	
Light meal (toast and clear liquids)	
Fatty meal	8 hr

Note. These recommendations apply to healthy patients who are undergoing elective procedures. See text for other exceptions. Note that following the guidelines does not guarantee a complete gastric emptying has occurred, and patients with severe pain and those undergoing upper gastrointestinal procedures may have medical conditions that may place them at higher risk for aspiration of gastric contents.

*Examples of clear liquids include water, fruit juices without pulp, carbonated beverages, clear tea, and black coffee without milk.

TABLE 7.4. *Equipment Drugs for Procedural Sedation and Analgesia*

In the Procedural Room	Readily Available
1. High-flow oxygen source	Defibrillator/pacer
2. Suctioning apparatus	Emergency drugs
3. Airway management equipment	<ul style="list-style-type: none"> • Epinephrine • Ephedrine • Vasopressin • Atropine • Amiodarone • Lidocaine • Hydrocortisone • Glucose 50% • Diphenhydramine
<ul style="list-style-type: none"> • Face masks • Oral and nasal airways (different sizes) • Laryngeal mask airways (LMAs) • Laryngoscope handles (battery tested) • Laryngoscope blades (different sizes) • Endotracheal tubes cuffed and uncuffed for children • Stylet • Bag-valve-mask device (Ambu bag) 	<ul style="list-style-type: none"> • Esmolol or metoprolol
4. Vascular access equipment	
Gloves, tourniquets, alcohol wipes	
Intravenous catheters (24;20;18 gauge)	
Syringes and needles	
Intravenous fluids and tubing	
5. Basic monitoring equipment (ECG, pulse oximeter, BP cuff, capnometer strongly encouraged)	
6. Supplemental O ₂ during procedure	
7. Reversal agents	
<ul style="list-style-type: none"> • Naloxone • Flumazenil 	

BP, blood pressure; ECG, electrocardiogram.

opioids, which potentiate their effects. Doses should be reduced in patients with hepatic or renal disease, as well as elderly, critically ill, and obese patients. In these patients, the clearance of midazolam is halved, leading to prolonged half-life and excessive sedation.¹⁷ Adverse effects include pain on injection (diazepam and lorazepam), birth defects in first tri-

mester of pregnancy, paradoxical reactions (agitation), and dose-related hypoventilation, hypoxemia, and hypotension (especially midazolam).

In contrast to all other sedative-hypnotics, there is a specific drug to reverse the sedative effects of BDZs, namely *flumazenil* (Romazicon®). Its onset of action is rapid (1–2 minutes), peak effects in 5–10 minutes, and a half-life of 45–90 minutes. Because the duration of flumazenil is shorter than most BDZs, the possibility of re-sedation exists, and continuous respiratory monitoring is advised. It should be titrated in doses of 0.1 to 0.2 mg IV every 1 to 2 minutes to the desired effect. A dose of 1 mg is generally sufficient. Flumazenil should be used with extreme caution in patients with BDZ dependence or a history of seizures as it may precipitate life-threatening status epilepticus. Seizures have been reported after the reversal of BDZs even in non-BDZ-dependent patients. For this reason, routine reversal with flumazenil is not recommended.

Opioids (narcotics) are administered for their analgesic properties. In the context of procedural sedation, they are used to supplement other agents (e.g., sedative-hypnotics) to provide optimal conditions for painful procedures. These drugs share the ability to interact with opiate receptors located throughout the central nervous system and inhibit nociception. Although they differ substantially in potency, the opioids are equally effective for most OOR applications. The choice of one opioid instead of another is usually based on its onset and duration, or adverse effects. The clinically available agents range from the naturally occurring alkaloid morphine to synthetic compounds like *fentanyl* and *meperidine* (Demerol®). The most commonly used opioids by nonanesthesia practitioners in OOR procedures are fentanyl and meperidine.

Fentanyl is a synthetic opioid, 100 times more potent than morphine. Owing to its rapid onset, short duration of action, lack of histamine release, and stable cardiovascular profile, it is the preferred analgesic for procedural sedation/analgesia. It is highly lipid soluble and rapidly crosses the blood–brain barrier, causing analgesia in less than 90 seconds for durations up to 30 to 40 minutes. Administered in incremental small doses (e.g., 25 to 50 µg), it is very useful for short, painful procedures.

The drawback of fentanyl is respiratory depression that significantly overlaps its analgesic effects. The magnitude of respiratory depression can be greatly increased when fentanyl is used in combination with other sedatives such as midazolam.¹⁸ Supplemental oxygen and monitoring with pulse oximetry and capnography are strongly recommended with even small amounts of fentanyl. In small concentrations, fentanyl has limited effects on the cardiovascular function, although significant decreases in blood pressure may occur with fentanyl/benzodiazepine combinations,¹⁹ and in critically ill or hypovolemic patients.

As the first synthetic opioid, meperidine was often used to provide analgesia for procedures inside and outside of the operating room. With the advent of short-acting fentanyl, its popularity faded. Presently (in combination with a BDZ), it has some limited residual use in endoscopic procedures. It may be given in doses of 25–75 mg IV every 5 minutes. Peak effects occur in 5 to 7 minutes; however, the elimination

TABLE 7.5. Drug Dosage and Administration of Commonly Used Drugs for Procedural Sedation by Nonanesthesiologists

Drug	Sedation/ Amnesia	Anxiolysis	Analgesia	Route/Dose	Onset (min)	Peak (min)	Duration (min)	Comments
Sedative/hypnotics*								
Midazolam (Versed)	Yes	Yes	No	IV: 0.5–1 mg (titrate to effect up to 5-10 mg/hr)	0.5–1	3–5	10–30	– Minimal cardio-respiratory depression
				IM: 0.08 mg/kg	10–15	20–45	60–120	– Reduce dose when used in combination with opioids
				PO: 0.5 mg/kg	15–30	35–45	60–90	– Midazolam is benzodiazepine of choice for short procedures – Antagonist: flumazenil
Diazepam (Valium)	Yes	Yes	No	IV: 2–3 mg (titrate to effect up to 15 mg)	1–2	8–15	15–45	
				PO: 5–10 mg	30–60	45–60	60–100	
Lorazepam (Ativan)	Yes	Yes	No	IV: 0.25 mg (titrate to effect up to 2 mg)	1–2	15–20	60–120	
				PO: 2–4 mg	60–120	120	>480	
Opioids*								
Fentanyl	No	No	Yes	IV: 25–50 µg intermittent boluses	1–2	5	30–40	– Respiratory depression; decreased response to hypercarbia and hypoxia
Meperidine (Demerol)	No	No	Yes	IV: 25–75 mg	3–5	5–7	60–180	– Synergistic sedative and respiratory depressant effects (reduce dose with sedatives) – Nausea, vomiting – Meperidine: histamine release – Antagonist: naloxone
Reversal agents (antagonists)								
Flumazenil (Anexate)	No	No	No	IV: 0.1–0.2 mg (titrate to effect to max of 5 mg)	1–2	5–10	45–90	– Short-acting, repeat doses may be required – Avoid in patients receiving benzodiazepines for seizure control – Caution with chronic benzodiazepine therapy (withdrawal effect) or with tricyclic antidepressants

Naloxone (Narcan)	No	No	No	IV: 0.02–0.04 mg (titrate to effect)	1–2	2–3	30–60	– Short-acting, repeat doses may be required – May cause hypertension and tachycardia – Pulmonary edema reported
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*Alterations in dosing may be indicated based upon the clinical situation and the practitioner's experience with these agents. Individual dosages may vary depending on age and coexistent diseases. Doses should be reduced for sicker patients and in the elderly. When using drug combinations, the potential for significant respiratory impairment and airway obstruction is increased. Drugs should be titrated to achieve optimal effect, and sufficient time for dose effect should be allowed before administering an additional dose or another medication.

half-life is long, between 3–5 hours. Normeperidine, a toxic metabolite of meperidine, causes central nervous excitement and seizures. Meperidine has many drug interactions, but it is most notably contraindicated with monoamine oxidase inhibitors. Side effects include respiratory depression, hypotension, nausea, vomiting, and paradoxical agitation or anxiety.

Opioids can be reversed by *naloxone* (Narcan®). Naloxone antagonizes all of the central nervous system effects of the opioids, including respiratory depression, excessive sedation, and analgesia. Naloxone should be titrated slowly, in increments of 0.04 mg IV over 1–2 minutes to the desired effect (e.g., responsiveness to stimulation, and increase in respiratory rate over 8 breaths/minute). Absolute annihilation of analgesia may precipitate sympathetic discharge manifested by hypertension, tachycardia, and at extremis, ventricular fibrillation and pulmonary edema. The effects are seen in 1–2 minutes; however, the duration of reversal is rather short, 30–60 minutes, and re-sedation may occur if long-acting narcotics have been used. Because of naloxone's side effects, it is safest to administer appropriate doses of opioids in the first place. If naloxone is required due to an accidental overdose of an opioid, close monitoring of the reversed patient for 60–120 minutes is essential due to the possibility of late respiratory depression.

Drugs Used Less Frequently by Nonanesthesia Practitioners

Dissociative Anesthetics

Ketamine, a phencyclidine derivative, is unique because it possesses remarkable analgesic and amnesic properties, unlike other anesthetic-hypnotics. Ketamine causes disconnection between the thalamocortical and limbic systems, preventing the higher centers from perceiving sensory (auditory, visual) input, or painful stimuli. This leads to a cataleptic “dissociative” state, characterized by mental disconnection from the surroundings and deep analgesia. Although ketamine is usually administered by anesthesia personnel, ketamine in small doses (10–20 mg IV in an adult) has been used to enhance analgesia (Table 7.6), with minimal respiratory depression. Ventilatory drive is minimally depressed and protective airway reflexes including those of laryngeal muscles are well preserved. Ketamine has sympathomimetic effects and is a potent bronchodilator. Ketamine can increase blood pressure, heart

rate, and cardiac output, although these effects are blunted with concurrent administration of BZDs.

The major side effect of ketamine is emergence delirium. Hallucinations, nightmares, and agitation may occur at and after emergence in up to 15%–30% of adult patients who are administered ketamine without other sedative agents. It is rare among the pediatric population. Emergence reactions are blunted by concurrent administration of BZDs, such as midazolam.^{20,21} Ketamine stimulates oral secretions and may induce laryngospasm, particularly during light planes of anesthesia. Children might benefit from pretreatment with glycopyrrolate, 0.01 mg/kg given 10 minutes before the ketamine. Ketamine increases intracranial and intraocular pressure, and its use is limited in head trauma or open globe injury.

Other Anesthetic Agents

Propofol has potent sedative and hypnotic properties with minimal analgesic effect.^{22,23} Its high lipid solubility makes possible quick penetration into the central nervous system and rapid clearance from the blood, resulting in both rapid onset of action and quick recovery for doses used for procedural sedation. Propofol's duration of action is very short, between 2 and 8 minutes. The plasma concentration of propofol required for sedation depends on the targeted depth of sedation and is influenced by coadministration of other sedatives/analgesics. Usually, sedation will be achieved at a plasma concentration of 0.5–1.5 µg/ml, corresponding to continuous infusion rate of approximately 25–75 µg/kg per minute.¹⁷

Awakening is fast, even after prolonged infusion of propofol, requiring a 50% decrease in the plasma concentration of the drug.²² The pharmacokinetic parameters of propofol are altered by a variety of factors, including weight, sex, age, and concomitant disease; the presence of liver or renal failure does not significantly alter its pharmacokinetics. However, dose reduction is recommended in the elderly, as volume of distribution falls with age.²³

Propofol is an appealing drug for procedural sedation/analgesia due to its rapid onset/offset effect, clear-head recovery, and antiemetic effects. Nevertheless, propofol has many undesirable side effects, including respiratory depression,²⁴ severe hypotension,²⁵ and pain on injection, especially when administered through small peripheral veins. The most concerning property of propofol is that the therapeutic window of propofol is very narrow. After even a single dose of propofol, the depth of sedation may move quickly on the sedation

TABLE 7.6. Drug Dosage and Administration of Anesthetic Drugs for Procedural Sedation

Drug	Sedation/ Amnesia	Anxiolysis	Analgesia	Route/Dose	Onset (min)	Peak (min)	Duration (min)	Comments
Sedative/hypnotics*								
Ketamine (Ketalar)	Yes	No	Yes	IV: 0.2–0.5 mg/kg (titrate to effect)	1	1–2	10–20	– Dissociative anesthetic – Emergence reactions blunted with midazolam
				IM: 2–5 mg/kg	5	15	15–30	– Minimal respiratory depression, bronchodilator – Hypersalivation, laryngospasm – Cardiac stimulant (increase in blood pressure and heart rate) – Increase in intracranial pressure and intraocular pressure
Propofol (Diprivan)	Yes	Yes	No	IV: 0.5 mg/kg (intermittent boluses) or Infusion: 2.5–7.5 µg/kg/min	<1	1–2	5–8	– Cardio-respiratory depression – Pain on injection – Antiemetic properties
Fospropofol (Lusedra, formerly Aquavan)	Yes	Yes	No	IV bolus: 6.5 mg/kg; supplement with doses of 1.6 mg/kg as needed (interval 4 min)	4–7	4–13	20–40	– Provides antiemesis – Perineal itching lasting for a few min in up to 85% of patients – Respiratory depression and hypoxemia – Hypotension, bradycardia
Dexmedetomidine (Precedex)	Yes	Yes	Yes	IV loading dose: 0.5–1 µg/kg, slowly, over 10–20 min IV maintenance: 0.4–0.7 µg/kg per hour	5–10	60	Depends on infusion time: 4 min after 10 min infusion; 250 min after 8 hr infusion	– Minimal respiratory depression – Decreases blood pressure and heart rate – Potentiates the CNS effects of sedatives – Safe in elderly

*Alterations in dosing may be indicated based upon the clinical situation and the practitioner's experience with these agents. Individual dosages may vary depending on age and coexistent diseases. Doses should be reduced for sicker patients and in the elderly. When using drug combinations, the potential for significant respiratory impairment and airway obstruction is increased. Drugs should be titrated to achieve optimal effect, and sufficient time for dose effect should be allowed before administering an additional dose or another medication.

continuum scale and become deep sedation or general anesthesia. Furthermore, the Food and Drug Administration (FDA) restricts the use of propofol and fospropofol to practitioners trained in the administration of general anesthesia who are not involved in the conduct of the surgical/diagnostic procedure. Hence, in most OOR settings in the United States, propofol administration is limited to anesthesia professionals.

There is a growing interest in the use of target-controlled infusion (TCI) devices and patient-controlled systems (PCSs) for moderate sedation for endoscopic procedures. Advances in the technology of intravenous delivery devices combined with sophisticated pharmacologic modeling made possible the invention of computer-controlled infusion pumps. On the basis of age and weight of the patient, the TCI infusion system

calculates, by using a three-compartment pharmacokinetic model, the starting dose of propofol and the subsequent infusion rate required to achieve and maintain a desired target plasma concentration.²⁶ A recent prospective study found that a TCI of propofol in a range of 2 to 5 µg/ml provided adequate sedation for GI procedures of different degrees of difficulty without increasing the risk of drug-related side effects; the level of satisfaction with the sedation was high for patient, nurse, and endoscopist, and patients were discharged in about 30 minutes.²⁷

In a Patient Controlled Sedation (PCS) device, the medication is self-administered by the patient in response to pain; therefore, the patient has to be conscious enough to press the handheld button. Specialized pumps are used that deliver a preset dose of medication in response to a patient pressing a

handheld button. A lockout time is programmed into the pump to prevent the delivery of additional doses until the previous dose has taken its full effect. Results from a randomized, crossover trial comparing propofol administered by IV boluses with PCS and patient-maintained sedation using TCI of propofol found that the mean time for titration to adequate sedation was longer with TCI than with PCS (9 minutes vs. 6 minutes).²⁸ Although both techniques provided moderate sedation, two (9%) patients became oversedated during PCS.

SEDASYS (Ethicon Endo-Surgery, Inc, Cincinnati, OH) is a new propofol delivery system designed to provide moderate sedation in adult ASA 1 and 2 patients for colonoscopy and esophagogastroduodenoscopy. The device interfaces continuous monitoring of patient vital signs, including ECG, pulse oximetry, capnography, blood pressure, and patient responsiveness with computer-controlled propofol delivery to facilitate precise control of sedation. With signs of oversedation, it automatically decreases or stops the propofol infusion rate, while simultaneously increasing oxygen delivery through the nasal cannula attached to the patient. However, a practitioner can override the dose reduction and administer an additional propofol dose.

Recent studies conducted in the United States and Belgium demonstrated the feasibility of SEDASYS in administering minimal to moderate propofol sedation for endoscopic procedures by the GI team. The results were consistent with a low mean propofol dosage (65 mg) and a very rapid recovery time (29 seconds). Oxygen desaturation lasting less than 30 seconds occurred in 6% of patients, and 18 (38%) had at least one episode of apnea lasting more than 30 seconds. There was no need for airway support and there were no device-related adverse events.²⁹ In May 2009, an Advisory Panel to the FDA (U.S. Food and Drug Administration) recommended approval of the device with the following restrictions: use for colonoscopy and EGG procedures on adult patients under 70 years of age, develop a comprehensive training program, require a dedicated sedation delivery team, and require post-approval surveillance of adverse events. However, the device was rejected by the FDA in April 2010.

Fospropofol is a new intravenous sedative/hypnotic drug, approved by the FDA in 2008 for adults when administered by anesthesia professionals (MAC).³⁰ In contrast to propofol, which is a lipid emulsion, fospropofol is water soluble and does not produce pain during IV administration. The major concern with fospropofol is that it is metabolized to propofol, and therefore has all the cardiorespiratory risks associated with propofol. Six pharmacokinetic phase I and II studies of fospropofol were recently retracted due to an analytical propofol assay inaccuracy.³¹ Hence, pharmacokinetic data concerning fospropofol are lacking.

Fospropofol seems to be an effective drug for procedural sedation, although safety data regarding its use by nonanesthesia practitioners are limited.^{32,33} In a recent bronchoscopy study, 252 patients were randomized (2:3) to receive fospropofol 2 mg/kg or 6.5 mg/kg, after pretreatment with fentanyl, 50 µg.³⁴ The primary endpoint was sedation success, defined by the Modified Observer's Assessment of Alertness/Sedation score of 4 or less. Patients in the 6.5 mg/kg fospropofol group had significantly higher sedation success rates

than those in the 2 mg/kg group (89% vs. 28%, respectively; $p < 0.001$). The most frequent adverse events were transient and self-limited paresthesias and pruritus. Hypoxemia, mild per the investigators, was the most common sedation-related adverse event, and it occurred in 15% and 13% of patients, respectively, in the 6.5 and 2 mg/kg fospropofol dose groups.³⁴

Dexmedetomidine (Precedex®) is an alpha-2 receptor agonist drug. Dexmedetomidine interacts with both presynaptic and postsynaptic alpha-2 adrenergic receptors to decrease central sympathetic tone. It is rapidly distributed and extensively metabolized in the liver and eliminated in urine. Dexmedetomidine has many advantages over more commonly used hypnotics, especially in older patients. Although it produces sedative, analgesic, and anxiolytic effects, unlike other sedatives, it does not depress the ventilation. When dexmedetomidine is administered as a continuous infusion, it is associated with a predictable and stable hemodynamic response. Less stability is seen with bolus dosing. However, care should be taken when administered to patients who are hypovolemic or have severe heart block because dexmedetomidine can cause hypotension and bradycardia.³⁵

DISCHARGE CRITERIA

All patients receiving sedation/anesthesia should be monitored until they are no longer at risk for cardiorespiratory depression. To be discharged, they should be alert and ori-

TABLE 7.7. *Aldrete Scoring System*

Respiration	
Able to take deep breath and cough =	2
Dyspnea/shallow breathing =	1
Apnea =	0
Oxygen saturation	
SaO ₂ > 95% on room air =	2
SaO ₂ > 90%–95% on room air =	1
SaO ₂ < 90% even with supplemental O ₂ =	0
Consciousness	
Fully awake =	2
Arousable on calling =	1
Not responding =	0
Circulation	
BP ± 20 mm Hg baseline =	2
BP ± 20–50 mm Hg baseline =	1
BP ± 50 mm Hg baseline =	0
Activity	
Able to move 4 extremities =	2
Able to move 2 extremities =	1
Able to move 0 extremities =	0

Note: Monitoring may be discontinued and patient discharged to home or appropriate unit when Aldrete score is 9 or greater.

ented (or returned to age-appropriate baseline) and vital signs should be stable. Many hospitals have chosen to use standardized recovery scoring systems similar to those used in their surgical postanesthesia recovery areas (Table 7.7). Although there is no general agreement about the safe time to discharge, one large study performed in the emergency room found that in children with uneventful sedations using a variety of drugs, no serious adverse effects occurred more than 25 minutes after the final medication administration. The authors conclude that in most cases, prolonged observation beyond 60 minutes is rarely necessary.³⁶

CONTINUOUS QUALITY IMPROVEMENT EFFORTS

Patient safety during procedural sedation should be monitored by the development of a vigorous continuous quality improvement program (see Chapter 3 for further details). At the minimum, adverse events should be measured, such as O₂ desaturation below 85% for 20 seconds, apnea episodes, laryngospasm, need for positive-pressure ventilation, use of reversal agents, prolonged recovery stays, and serious adverse events such as aspiration of gastric contents, cardiac events, and unplanned admissions.

SUMMARY

In summary, safe administration of procedural sedation /analgesia by nonanesthesia professionals requires an understanding of the continuum of sedation/general anesthesia; extensive training and credentialing of personnel performing these procedures; proper patient preparation and selection, with an anesthesia consult for higher risk patients; adherence to fasting guidelines; standard equipment and monitoring procedures; and a thorough knowledge of the pharmacologic and physiologic properties of sedative and analgesic drugs. Due to the severity of adverse effects of sedative/opioid/anesthetic drugs and the potential for unexpected progression along the continuum to deep sedation or anesthesia, anesthesiologists should design the curriculum/training procedures and supervise credentialing of nonanesthesia health care practitioners who administer sedation/analgesia in the OOR setting.

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8 Anesthesia and Sedation Outside of the Operating Room: Outcomes, Regulation, and Quality Improvement

JULIA METZNER, MD and KAREN B. DOMINO, MD, MPH

Providing anesthesia care in areas outside the operating room (OOOR) has numerous challenges, including an unfamiliar environment; inadequate anesthesia support; deficient resources; cramped, dark, small rooms; and variability of monitoring modalities. In addition, sicker patients are undergoing more complex procedures in areas that may be physically located far from the OR environment. To improve safety of patients undergoing procedures in remote locations, practitioners need to be familiar with development of rigorous continuous quality improvement systems, national and regulatory patient safety efforts, as well as complications related to anesthesia/sedation in OOOR settings. This chapter will identify severe outcomes and mechanisms of injury in these remote locations, national patient safety and regulatory efforts that may be adapted to the OOOR setting, and quality improvement efforts essential to track outcomes and improve patient safety.

SAFETY OF ANESTHESIA AND SEDATION IN OOOR LOCATIONS

Good multi-institutional outcome data concerning complications of anesthesia and sedation in OOOR locations are lacking. The best data have been obtained in the pediatric population, perhaps because of greater involvement of safety-oriented pediatric anesthesiologists in the sedation of children for radiologic and other procedures.

Outcome Data in Pediatric Sedation/Anesthesia from Outside the Operating Room

There has been tremendous interest in outcomes of sedation and anesthesia in OOOR locations in the pediatric population. Cote et al.¹ used the Food and Drug Administration database to perform a critical incident analysis of sedation-related adverse events in children. Of the 95 cases investigated, 51 cases resulted in death and 9 in permanent brain injury.

These severe injuries occurred more frequently in nonhospital-based facilities, such as dental offices (93% vs. 37%, Fig. 8.1). Moreover, the majority of these deaths were judged to be preventable. Most were associated with failure to provide airway/ventilatory support in a timely fashion. Inadequate and inconsistent respiratory monitoring was another major factor contributing to poor outcome. Despite the lack of denominator data, this study was considered a breakthrough in the safety of pediatric procedural sedation.

In 2003, with the collaboration of 37 institutions around the world, the Pediatric Sedation Research Consortium database was created with the goal to share information on the current pediatric sedation practice outside the OR. In a prospective observational study, Cravero and colleagues² studied the incidence and nature of adverse events among the first 30,000 cases submitted to the registry. Data collection methods were standardized, and definitions were based on guidelines from professional societies. The most important findings were as follows: overall rate of complications was 5.3%; there were no deaths; major complications included one cardiac arrest secondary to hypoxia and one aspiration pneumonia (Table 8.1). The majority of complications were related to adverse respiratory events, including desaturation below 90% and lasting more than 30 seconds; stridor, laryngospasm, wheezing, or apnea that could progress to a poor outcome if not managed adequately; and airway and ventilation interventions, including bag-mask ventilation, oral airway placement, or emergency intubation (Table 8.1). Eighty percent of patients were in the American Society of Anesthesiologists (ASA) class 1 or 2, and 76% were younger than 8 years; sedation/anesthesia was provided mostly by anesthesiologists, intensivists, and emergency physicians; and most procedures (62%) were radiologic. The most frequently used sedatives and analgesic agents were propofol (50%), midazolam (27%), ketamine (14%), and pentobarbital (13%). Although severe complications were infrequent, the data from Cravero et al.² suggest that continued attention to prevention of adverse respiratory events is necessary to improve in patient safety in these low-risk procedures.

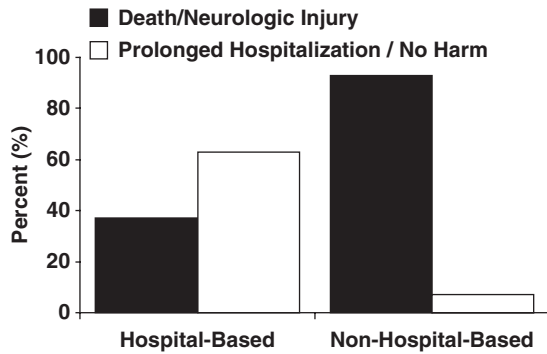


FIGURE 8.1. Outcome of adverse sedation-related events in children sedated in hospital-based compared with nonhospital-based facilities ($p < 0.001$). (Reproduced with permission from *Pediatrics*. 105:805-814, Copyright 2000 by the AAP.)

Outcomes of Anesthesia and Procedural Sedation in Adults

Pino³ reviewed outcomes in over 63,000 patients undergoing diagnostic or therapeutic procedures under sedation or anesthesia in one hospital. Forty-one percent were sedated by nonanesthesia providers, with anesthesiologists providing monitored anesthesia care in patients at extremes of age, ASA physical status 3–4, and in morbidly obese patients. There were 2 deaths and 17 cardiac arrests, but all were in the cardiac catheterization suite and were not related to sedation. It is important to note that respiratory events were likely to be underestimated because capnography, used to detect respiration and the presence of airway obstruction, was not used.

Closed Malpractice Claims in OOR Locations

Rare serious adverse outcomes have been studied by reviewing medicolegal records. We recently reviewed closed malpractice claims against anesthesiologists providing anesthesia care in remote locations using the ASA Closed Claims database.⁴ The Closed Claims Project is a detailed structured evaluation of adverse anesthetic outcomes obtained from the closed malpractice claim files of 37 professional liability insurance companies throughout the United States. Claims for dental damage are excluded. Patterns of injury and liability associated with claims from anesthesia in remote locations arising since 1990 ($n = 87$) were compared with claims from OR procedures ($n = 3287$).

The facilities most commonly involved in the remote location claims were the gastrointestinal suite (32%) and cardiology catheterization/electrophysiology laboratory (25%), followed by the emergency room, interventional radiology, and lithotripsy suite. Patients in remote locations were older (20% more than 70 years, $p < 0.01$) and sicker (69% ASA physical status 3–5, $p < 0.005$) than patients in operating room claims. There were also more children ($p < 0.01$) in remote locations. More than a third of remote location claims involved emergent procedures as compared with only 15% of

TABLE 8.1. *Complications of Pediatric Sedation/Anesthesia in OOR locations*

	Incidence per 10 000	n	95% CI
Adverse events			
Death	0.0	0	0.0–0.0
Cardiac arrest	0.3	1	0.0–1.9
Aspiration	0.3	1	0.0–1.9
Hypothermia	1.3	4	0.4–3.4
Seizure (unanticipated) during sedation	2.7	8	1.1–5.2
Stridor	4.3	11	1.8–6.6
Laryngospasm	4.3	13	2.3–7.4
Wheeze (new onset during sedation)	4.7	14	2.5–7.8
Allergic reaction (rash)	5.7	17	3.3–9.1
Intravenous-related problems/complication	11.0	33	7.6–15.4
Prolonged sedation	13.6	41	9.8–18.5
Prolonged recovery	22.3	67	17.3–28.3
Apnea (unexpected)	24.3	73	19.1–30.5
Secretions (requiring suction)	41.6	125	34.7–49.6
Vomiting during procedure (nongastrointestinal)	47.2	142	39.8–55.7
Desaturation below 90%	156.5	470	142.7–171.2
Total adverse events	339.6	1020	308.1–371.5
	(1 per 29)		
Unplanned treatments			
Reversal agent required (unanticipated)	1.7	5	0.6–3.9
Emergency anesthesia consult for airway	2.0	6	0.7–4.3
Admission to hospital (unanticipated; sedation related)	7.0	21	4.3–10.7
Intubation required (unanticipated)	9.7	29	6.5–13.9
Airway (oral; unexpected requirement)	27.6	83	22.0–34.2
Bag-mask ventilation (unanticipated)	63.9	192	55.2–73.6
Total unplanned treatments	111.9	336	85.3–130.2
	(1 per 89)		
Conditions present during procedure			
Inadequate sedation, could not complete	88.9	267	78.6–100.2
	(1 per 338)		

OOOR, outside of the operating room.

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OR claims ($p < 0.001$). These findings emphasize the high risk of many patients requiring care by anesthesia personnel as opposed to nonanesthesiologists for procedures outside the operating room.

Although the most frequently encountered anesthetic mishap in both remote and OR sites was of respiratory system origin, respiratory etiologies for remote location claims were double that of OR claims (44 vs. 20%, $p < 0.001$, Table 8.2). Inadequate oxygenation/ventilation was the most common single mechanism of injury in remote locations, occurring seven times more frequently than in OR claims (Table 8.2). Respiratory depression from oversedation was most common in the gastrointestinal suite during endoscopic retrograde cholangiopancreatography (ERCP) or upper gastrointestinal endoscopy. Propofol was most commonly used as the single agent or in combination with other drugs.

The severity of injuries for claims from remote locations was greater than those associated with the OR (Fig. 8.2). The proportion of death was almost double in remote location claims (54 vs. 29%, $p < 0.001$). The anesthesia care was judged by closed claims reviewers as substandard in more than half of remote location claims. In addition, a third of the claims in remote locations were judged by the reviewers as being potentially preventable by better monitoring, including pulse oximetry, capnography, or both. A capnograph was employed in only a minority of claims associated with oversedation.⁴

The most common anesthetic technique was monitored anesthesia care (MAC) in which the anesthesiologist administered sedation and monitored the patient, accounting for 50% of remote location claims. Respiratory depression due to an

absolute or relative overdose of sedative–hypnotic–analgesic drugs and deficient monitoring were deemed responsible for the complication. Monitored anesthesia care was the predominant technique in the gastroenterology suite, radiology, and cardiology catheterization laboratories.⁴

Bhananker et al.⁵ used closed claims methodology to examine patterns of injury and liability during MAC in other settings. Death or permanent brain damage occurred in 41% of claims for MAC, comparable to the severity of injury during claims associated with general anesthesia. The findings were similar to those in remote location claims in that respiratory depression secondary to oversedation was the leading mechanism of injury, as most of these injuries could have been prevented by adequate monitoring of ventilation, especially end-tidal capnography. “Polypharmacy,” including propofol in combination with other sedatives/opioids, was often involved in oversedation. These cases emphasize that pharmacokinetic features, changing levels of noxious stimulation, and variability in patient responses may contribute to accidental overdose.⁶ The findings point out that sedation is a continuum, and that moderate sedation may fairly easily become deep sedation. In addition, the findings point out the roles of attitudes of anesthesia and surgical personnel and delayed recognition of respiratory depression so that cardiac arrest may be the initial signaling event.⁶

It is important to remember that closed claims are biased by severe, permanent injuries and lack denominator data (the total number of anesthetics/sedation performed), as well as nominator data (the total number of adverse outcomes). Hence, estimates of risk or safety cannot be made from this type of data. However, the data provide excellent clinical details of rare, severe complications.

The conclusions that can be drawn from the analysis of ASA Closed Claims Project data^{4,5} are as follows:

- The most common etiology of death or permanent brain damage is inadequate oxygenation/ventilation.
- Respiratory depression from sedative agents is the leading cause of respiratory depression during sedation and MAC.
- Better monitoring of patient respiration, particularly end-tidal capnography, might prevent adverse respiratory events.
- General endotracheal anesthesia may be safer in some patients (e.g., morbid obesity with severe obstructive sleep apnea) and some procedures (e.g., ERCP and prone position procedures)

As a result of the Closed Claims findings, the ASA recently recommended use of end-tidal capnography to monitor adequacy of ventilation during propofol sedation, particularly since moderate sedation may quickly become deep sedation with this agent.⁷ Better assessment of adequacy of ventilation should improve the safety of patients undergoing anesthesia and sedation in OOR locations.

Other Adverse Events in Remote Location Claims

In addition to oversedation causing respiratory depression, the types of claims varied with the remote location.⁴ Most of

TABLE 8.2. *Mechanisms of Injury in Remote Location Claims*

	Remote Location (n = 87) n (%)	Operating Room (n = 3287) n (%)
Respiratory event	38 (44%) *	671 (20%) *
Inadequate oxygenation/ ventilation	18 (21%) *	94 (3%) *
Cardiovascular event	9 (10%)	526 (16%)
Equipment failure/ malfunction	12 (14%)	438 (13%)
Event related to regional block	2 (2%)*	283 (9%)*
Medication-related event	5 (6%)	256 (8%)
Other events †	21 (24%)	1113 (34%)

* $p < 0.001$ remote location versus operating room claims by z-test.

† Other events include surgical technique/patient condition, patient fell, wrong operation/location, positioning, failure to diagnose, other known damaging events, no damaging event, and unknown.

Source: Reprinted with permission from Metzner J, Posner K, Domino K. The risk and safety of anesthesia at remote locations: the US closed claims analysis. *Curr Opin Anaesthesiol.* 2009;22:502–508.

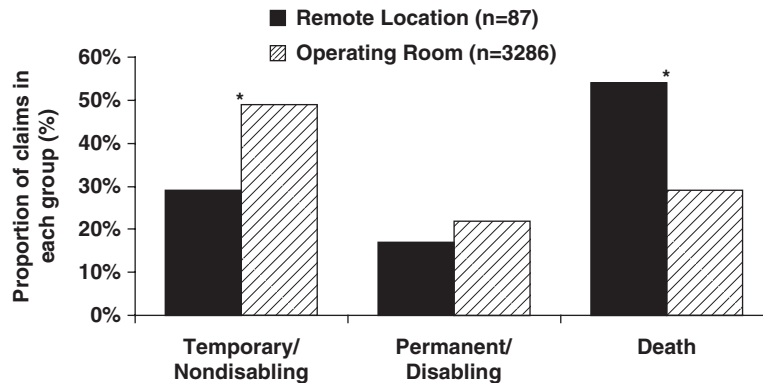


FIGURE 8.2. Severity of injury in remote location claims versus operating room claims. One claim with missing data excluded; $p < 0.001$ by Fisher's exact test. (Reprinted with permission from Metzner J, Posner K, Domino K. The risk and safety of anesthesia at remote locations: the US closed claims analysis. *Curr Opin Anaesthesiol.* 2009;22:502–508.)

the claims from radiology involved anesthesia in the magnetic resonance imager (MRI) scanner, resulting in oversedation, burns from non-MRI compatible electrodes, and a claim for brachioplexopathy in an obese patient whose arms were positioned above his head because he was too obese to allow arm positioning at his sides. Procedures in cardiology also had claims for difficult intubation with esophageal intubation during resuscitation, and a variety of events related to invasive procedures in patients with cardiac disease. Claims from the emergency room also involved complications of emergency endotracheal intubation and resuscitation, including central line placement.⁴

REGULATORY EFFORTS AT IMPROVING QUALITY OF CARE

Joint Commission and National Patient Safety Goals

In 2003, the Joint Commission, which accredits hospitals and health care organizations, began requiring health care organizations to comply with national patient safety goals (NPSGs) in an attempt to reduce medical errors and improve patient safety. The NPSGs are formulated based on the information provided by the Sentinel Event Advisory Group and should be viewed as a synthesis of the reported sentinel events (i.e., unexpected death or serious injury or potential for these injuries). The Joint Commission recommends program-specific (hospitals, ambulatory centers, offices) NPSGs for adoption and if the surveys show improvement in a specific area, the goals will be implemented into the accreditation standards. Each year, the Joint Commission revises and updates the NPSGs and removes some goals while identifying new goals and requirements. The goals are found on the JCAHO Web site (<http://www.jointcommission.org/>).

The NPSGs in 2009, relevant to anesthesia and sedation, focused upon ways to improve the accuracy of patient identification, effectiveness of communication among caregivers

and during transfer of care, medication safety, and reduction of iatrogenic infections and surgical fires (Table 8.3).⁸

Recently, the Joint Commission has focused attention on the application of the “Universal Protocol for Preventing Wrong Site, Wrong Procedure, and Wrong Person” to correctly identify the patient, the appropriate procedure, and correct site of the procedure. Although distinct from the NPSGs, the Universal Protocol was inspired by the NPSGs and is particularly relevant to patient safety when anesthetized or sedated patients are undergoing procedures.

The protocol is based on three intertwined elements: conducting a preprocedure verification process, marking the procedure site (involve the patient directly if possible), and performing a timeout before the procedure. The timeout is standardized; initiated by a designated member of the procedure team (e.g., either the anesthesiologist or the surgeon); involves the immediate members of the procedure team; team members agree about the patient identity, correct site, and procedure to be performed; and the timeout is documented. The surgical timeout has recently been expanded to improve team communication concerning equipment readiness, patient conditions, and anticipated intraoperative or postoperative concerns (Fig. 8.3). Implementation of a 19-time surgical safety checklist designed by the World Health Organization's (WHO) Safe Surgery Saves Lives Program reduced death and complications after noncardiac surgery in a multi-institutional international study.⁹ Adaptation of this checklist to procedure units in OOR settings may be helpful to improve team communication and consistency of care.

In summary, as the Joint Commission continues to gather sentinel event statistics and correlate them with past and current NPSGs, new goals will emerge and new patient safety questions will be addressed. Although the purpose of most of the goals seems clear, there are some concerns about the challenges some goals might represent in their applicability in the clinical care. The Joint Commission is reviewing current NPSGs and, as a result, there will be no new NPSGs developed for 2010.

TABLE 8.3. 2009 National Patient Safety Goals Relevant to Anesthesiology

Goal 1: Improve the accuracy of patient identification
Use two patient identifiers, such as the individual's name, an assigned identification number, telephone number, or other person-specific identifier.
Prior to the procedures, mark the surgical site, and use timeout to identify the patient and confirm the right procedure on the right side.
Eliminate transfusion errors related to patient misidentification. Before initiating a blood or blood component transfusion, match the blood or blood component to the order, match the patient to the blood or blood component, and use a two-person verification process.
Goal 2: Improve the effectiveness of communication among caregivers
Report critical results of tests and diagnostic procedures on a timely basis.
"Readback" of the critical lab/diagnostic results.
Use standardized abbreviations, acronyms, and symbols.
Use a "standardized" approach of hand-off communication; allow clinicians to ask and answer questions pertinent to patient's care.
Goal 3: Improve the safety of using medications
Prevent errors with look-alike/sound-alike medications.
Label medications and solutions; discard unlabeled medications.
Reduce harm from anticoagulation therapy. Use approved protocols for the initiation and maintenance of anticoagulant therapy; use international normalized ratio for Coumadin therapy; use programmable infusion pumps for IV heparin therapy.
Goal 4: Reduce the risk of health care-associated infections
Improve compliance with hand hygiene guidelines.
Implement policies and practices aimed to reduce the risk of central-line-associated infections and surgical site infections.
Goal 5: Reconcile medications across the continuum of care
Complete a list of the patient's medications and communicate that information to the next provider of care.
Goal 6: Reduce the risk of surgical fires
Currently is applicable only to the Joint Commission's ambulatory care and office-based surgery accreditation programs
Educate staff members, including licensed independent practitioners and anesthesia care providers, in how to control heat sources, manage fuels, and provide enough time for patient preparation.
Guidelines to minimize oxygen concentration under drapes

Source: Based on The Joint Commission 2009 National Patient Safety Goals (NPSGs).

Never Events

In 2002, the National Quality Forum (NQF) published a report, *Serious Reportable Events in Healthcare*, which identified a list

of 27 adverse events that should never happen in a safe hospital practice, defined as "never events."¹⁰ In publishing this report, the NQF's goal was to provide the basis of systematic reporting of the most alarming health care errors and associated adverse events, and ultimately to increase public accountability and stipulate a safer health care. To be included in NQF's list of "never events," an event must be: of concern to both the public and health care professionals; clearly identifiable and measurable; serious, resulting in death or significant disability; usually preventable; and important for public credibility or accountability.¹¹ Over time, the list has been revised and expanded, and it now includes 28 never events (Table 8.4).¹²

Events relevant to anesthesia practice include procedures performed on the wrong body part or wrong patient, the wrong procedure performed, patient death from medication error, administration of incompatible blood or blood products, and intraoperative or immediately postoperative death in an ASA class I patient. Over 25 states require hospitals to report all or several of the NQF-endorsed adverse events. Minnesota, the first state to implement an open adverse events reporting system and to perform root-cause analysis (RCA; to be described later in this chapter), reported 154 adverse events that occurred between 2005 and 2006 (Fig. 8.4).¹³ The events that were reported most often (55%) were pressure ulcers and objects retained in a patient's body after an invasive procedure. Twenty-three percent of adverse events resulted in no harm to patients, while 20% led to either death or serious disability. Of the 24 deaths reported during this time period, 12 were due to falls, 3 were the result of suicide, 2 were related to the malfunction of a product or device, and 2 were related to medication errors. There were 23 cases of surgery on the wrong body part, 3 on the wrong patient, and 5 cases in which the wrong procedure was performed.

In an effort to improve patient safety, the Centers for Medicare and Medicaid Services and other major insurers moved to ban payments for certain adverse events that may be preventable with better care. Some of the selected events overlap with NQF's never events list and include surgery on the wrong body part, foreign body left in a patient after surgery, mismatched blood transfusion, major medication error, severe "pressure ulcer" acquired in the hospital, and preventable postoperative death. Other never events, like urinary tract infections and hospital-acquired pneumonia, are particular to the Medicare policy and contribute to the escalation of health care costs, as well as patient harm.

The Leapfrog Group

Hospitals also are facing increasing financial pressure from private stakeholders to do more to avoid never events. The Leapfrog Group was one of the leading organizations to adopt a never events policy and to ask hospitals to apologize to patients, report unexpected adverse outcomes to various safety agencies (such as the Joint Commission), perform root-cause analyses, and waive all related costs when a preventable, serious adverse event occurs within their facility.¹⁴

** RETURN WITH PREFERENCE LIST TO MAIN OR PAVILION FRONT DESK**

<p>PLEASE PLACE PATIENT STICKER HERE OR WRITE IN PATIENT NAME:</p>	<p>SURGICAL SAFETY CHECKLIST WHO / SCOAP - SAFE SURGERY SAVES LIVES GLOBAL PATIENT SAFETY CHALLENGE</p> <p><i>Directions: Please place a check mark in the box for actions performed</i></p>
<p>SIGN IN – PRIOR TO INDUCTION OF ANAESTHESIA, VERIFY:</p> <ul style="list-style-type: none"> <input type="checkbox"/> PATIENT CONFIRMED IDENTITY, SITE, PROCEDURE AND CONSENT <input type="checkbox"/> SITE MARKED/NOT APPLICABLE <input type="checkbox"/> ANAESTHESIA SAFETY CHECK COMPLETED <input type="checkbox"/> PULSE OXIMETER ON PATIENT AND FUNCTIONING <p>DOES PATIENT HAVE A:</p> <ul style="list-style-type: none"> KNOWN ALLERGY <ul style="list-style-type: none"> <input type="checkbox"/> NO <input type="checkbox"/> YES DIFFICULT AIRWAY/ASPIRATION RISK <ul style="list-style-type: none"> <input type="checkbox"/> NO <input type="checkbox"/> YES, AND NEEDED EQUIPMENT AND ASSISTANCE AVAILABLE 	
<p>TIME OUT – PRIOR TO SKIN INCISION (ATTENDING SURGEON BEGINS CHECKLIST HERE):</p> <ul style="list-style-type: none"> <input type="checkbox"/> CONFIRM ALL TEAM MEMBERS HAVE INTRODUCED THEMSELVES BY NAME AND ROLE <input type="checkbox"/> SURGEON, ANAESTHESIA PROFESSIONAL AND NURSE VERBALLY CONFIRM PATIENT, SITE, PROCEDURE, POSITION <p>ANTICIPATED CRITICAL EVENTS</p> <ul style="list-style-type: none"> <input type="checkbox"/> SURGEON REVIEWS: WHAT ARE THE CRITICAL OR UNEXPECTED STEPS, OPERATIVE DURATION, ANTICIPATED BLOOD LOSS? RISK OF >500CC BLOOD LOSS (7CC/KG IN CHILDREN)? <input type="checkbox"/> NO <input type="checkbox"/> YES, AND ADEQUATE IV ACCESS AND FLUIDS PLANNED <input type="checkbox"/> ANAESTHESIA TEAM REVIEWS: WHAT ARE CRITICAL RESUSCITATION PLANS, PATIENT-SPECIFIC CONCERNS, IF ANY? <input type="checkbox"/> NURSING TEAM REVIEWS: WHAT ARE THE STERILITY INDICATOR RESULTS, EQUIPMENT ISSUES, OTHER PATIENT CONCERNS? <input type="checkbox"/> ANTIBIOTIC PROPHYLAXIS GIVEN IN LAST 60 MINUTES <input type="checkbox"/> NOT APPLICABLE <input type="checkbox"/> ANTIBIOTIC REDOSING PLAN IN PLACE <input type="checkbox"/> NOT APPLICABLE (CASE < 3 HOURS) <input type="checkbox"/> ESSENTIAL IMAGING DISPLAYED <input type="checkbox"/> NOT APPLICABLE <input type="checkbox"/> ACTIVE WARMING IN PLACE <input type="checkbox"/> NOT APPLICABLE (CASE < 1 HOUR) <input type="checkbox"/> GLUCOSE CHECKED FOR DIABETICS <input type="checkbox"/> INSULIN STARTED FOR GLUCOSE > 125 <input type="checkbox"/> NOT APPLICABLE <input type="checkbox"/> BETA BLOCKER PLANNED POSTOPERATIVELY <input type="checkbox"/> NOT APPLICABLE (NOT ON PREOP BETA BLOCKER, NO INDICATIONS) <input type="checkbox"/> VTE PREVENTION PLAN IN PLACE <input type="checkbox"/> NOT APPLICABLE <p>LAST YEAR THERE WERE 58 SHARPS INJURIES IN THIS OR-</p> <ul style="list-style-type: none"> <input type="checkbox"/> THE OPERATING TEAM HAS AN AGREED PLAN TO PREVENT SHARPS INJURY? <input type="checkbox"/> NOT APPLICABLE (NO SHARPS) 	
<p>SIGN OUT – PRIOR TO WOUND CLOSURE:</p> <ul style="list-style-type: none"> <input type="checkbox"/> SURGEON CONFIRMS INSTRUMENTS & SPONGES ARE OUT OF INCISION (SURGEON) <p>SIGN OUT – AT COMPLETION OF THE CASE & PRIOR TO THE PATIENT LEAVING THE OPERATING THEATRE:</p> <p>NURSE VERBALLY CONFIRMS WITH THE TEAM:</p> <ul style="list-style-type: none"> <input type="checkbox"/> INSTRUMENT, SPONGE AND NEEDLE COUNTS CORRECT <input type="checkbox"/> WHAT PROCEDURE WAS PERFORMED? <input type="checkbox"/> HOW IS THE SPECIMEN LABELLED (INCLUDING PATIENT NAME)? <input type="checkbox"/> ARE THERE ANY EQUIPMENT MALFUNCTIONS OR ISSUES TO BE ADDRESSED? <p>SURGEON, ANAESTHESIA PROFESSIONAL AND NURSE REVIEW:</p> <ul style="list-style-type: none"> <input type="checkbox"/> WHAT ARE THE KEY CONCERNS FOR RECOVERY AND MANAGEMENT OF THIS PATIENT AND WHAT COULD HAVE BEEN DONE BETTER? 	

Return with PL
to
Main or Pavilion Front Desk.

SIGNATURE (ON BEHALF OF ENTIRE TEAM)

DATE

FIGURE 8.3. World Health Organizations’s Safe Surgery Saves Lives checklist used at University of Washington Medical Center, Seattle, Washington, one of the participating hospitals in the Haynes et al. study.⁹

TABLE 8.4. *Never Events, 2006: Serious Reportable Events in Health Care*

Surgical events
Surgery performed on the wrong body part
Surgery performed on the wrong patient
Wrong surgical procedure performed on a patient
Unintended retention of a foreign object in a patient after surgery or other procedure
Intraoperative or immediately postoperative death in an American Society of Anesthesiologists Class I patient
Artificial insemination with the wrong sperm or donor egg
Product or device events
Patient death or serious disability associated with the use of contaminated drugs, devices, or biologics provided by the health care facility
Patient death or serious disability associated with the use or function of a device in patient care, in which the device is used for functions other than as intended
Patient death or serious disability associated with intravascular air embolism that occurs while being cared for in a health care facility
Patient protection events
Infant discharged to the wrong person
Patient death or serious disability associated with patient elopement (disappearance)
Patient suicide, or attempted suicide resulting in serious disability, while being cared for in a health care facility
Care management events
Patient death or serious disability associated with a medication error (e.g., errors involving the wrong drug, wrong dose, wrong patient, wrong time, wrong rate, wrong preparation, or wrong route of administration)
Patient death or serious disability associated with a hemolytic reaction due to the administration of ABO/HLA-incompatible blood or blood products
Maternal death or serious disability associated with labor or delivery in a low-risk pregnancy while being cared for in a health care facility
Patient death or serious disability associated with hypoglycemia, the onset of which occurs while the patient is being cared for in a health care facility
Death or serious disability (kernicterus) associated with failure to identify and treat hyperbilirubinemia in neonates
Stage 3 or 4 pressure ulcers acquired after admission to a health care facility
Patient death or serious disability due to spinal manipulative therapy
Environmental events
Patient death or serious disability associated with an electric shock or electrical cardioversion while being cared for in a health care facility
Any incident in which a line designated for oxygen or other gas to be delivered to a patient contains the wrong gas or is contaminated by toxic substances
Patient death or serious disability associated with a burn incurred from any source while being cared for in a health care facility
Patient death or serious disability associated with a fall while being cared for in a health care facility
Patient death or serious disability associated with the use of restraints or bedrails while being cared for in a health care facility
Criminal events
Any instance of care ordered by or provided by someone impersonating a physician, nurse, pharmacist, or other licensed health care provider
Abduction of a patient of any age
Sexual assault on a patient within or on the grounds of the health care facility
Death or significant injury of a patient or staff member resulting from a physical assault (i.e., battery) that occurs within or on the grounds of the health care facility

Source: Reproduced with permission from the National Quality Forum, © 2007.

Established in 2000 by a small number of health care purchasers, today the Leapfrog Group comprises more than 65 employers and agencies that purchase care for more than 30 million people. Since its inception, the group's vision was to exert its leverage toward improving health care quality,

optimizing patient outcomes, and ultimately lowering health care costs nationwide. More information can be found at <http://www.leapfroggroup.org>.

The goals of the Leapfrog Group are to reduce preventable medical mistakes and improve the quality and affordability

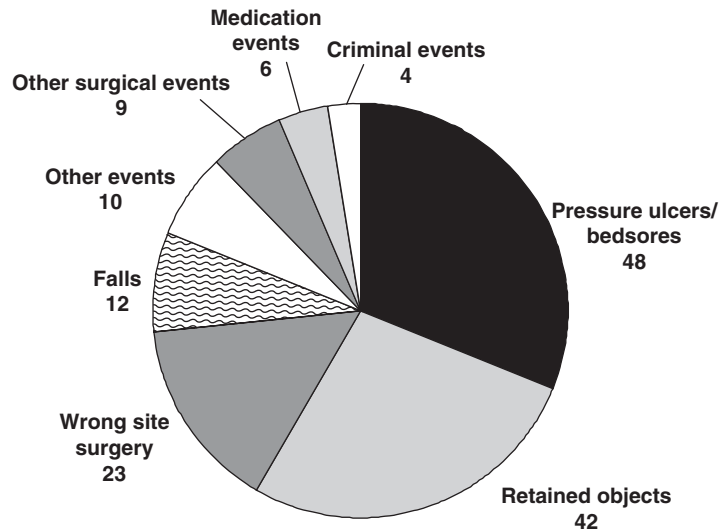


FIGURE 8.4. Reported adverse health events (154) by category in Minnesota, 2005–2006. (Reprinted with permission from Adverse Health Events in Minnesota 2007 Public Report, Overview of Reported Events, page 5. Copyright Minnesota Department of Health 2007.)

of health care; encourage reporting of quality and outcomes so consumers can make informed health care choices; reward doctors and hospitals for improving the quality, safety, and affordability of health care; and help consumers reap the benefits of making smart health care decisions.

To achieve this goal, the Leapfrog Group proposed specific patient safety measures (leaps) to be implemented in hospitals across the United States. In order to evaluate the hospital's compliance with these safety measures, the Group conducts periodical surveys and releases the data for the public on its Web site. Financial incentives and rewards are allocated to the well-performing sites.

The Leapfrog Group's "patient safety leaps" include intensive care specialist coverage in the intensive care unit, computerized physician order entry systems, referral to high-volume centers for high-risk procedures, and a good Safe Practices Score.¹⁵ The Leapfrog Safe Practices Score is based upon 13 safe practices audited by the Group using voluntary hospital surveys. These safe practices include a safety culture, adequate nursing workforce, pharmacist involvement in medication use, patient readback of informed consent, documentation of end-of-life directives, prevention of mislabeled radiographs, anticoagulation and deep venous thrombosis prevention, prevention of central line sepsis, hand-washing procedures, prevention of aspiration, and computerized medical record systems.¹⁶ Based on the obtained data, hospitals are ranked by quartiles and the information is displayed on the Leapfrog Group Web site. To be rewarded for high-quality care, a hospital must score on the top quartile and show evidence of continuous improvement in the safety process.

To date, the impact of these initiatives on the quality and cost of health care have been discussed extensively in the literature, and whether they represent a real breakthrough is still under debate. A recent study analyzing the first initiatives collectively showed that hospitals performing according to

the Leapfrog Group standards had lower mortality rates and better quality of care scores for acute myocardial infarction, pneumonia, and congestive heart failure.¹⁷ Another study found that hospitals in California that met referral criteria for high-volume surgery for abdominal aortic aneurysm repair had a 51% reduction of in-hospital mortality compared with those who did not adhere to standards.¹⁸ Moreover, a report published by the Leapfrog Group in 2008 indicated that implementing these leaps in nonrural hospitals could save more than 57,000 lives and save up to \$12.0 billion each year.¹⁵ Although a recent review did not show any significant improvement in risk-adjusted inpatient mortality rate in hospitals that completed the 2006 Safe Practice Score survey,¹⁹ it is likely that the Safe Practice Score represents a major step to improving overall patient safety in hospitals.

CONTINUOUS QUALITY IMPROVEMENT IN THE OOR SETTING

Structure, Process, and Outcome: The Building Blocks of Quality

Quality improvement programs are generally guided by requirements of the Joint Commission. These programs are oriented toward improvements in the structure, process, and outcome of health care delivery.²⁰ *Structure* refers to the setting in which the process of care takes place and describes the organizational characteristics that facilitates delivery of care. Examples include organization and ownership of the facilities, ratio of practitioners to patients, qualifications of medical staff, and technological complexity. Structural characteristics are considered necessary but insufficient elements in the delivery of health services. They are considered indirect measures of quality in that their presence enables the provision of quality health services but does not ensure it, whereas

the absence of these structural characteristics decreases the probability of quality outcomes.

Process encompasses all the medical activities performed for “good” patient care but also includes prevention, continuity of care, and physician–patient interaction. In the actual practice, process measures often imply compliance with standards of care, such as: Was the patient consented prior to procedure? Was the antibiotic timely administered? Was central venous access obtained under strict sterile technique? Although process characteristics are considered more proximal indicators of quality than the structural ones, they cannot guarantee a quality outcome; they can only increase its probability.

Outcome refers to the impact of treatments on patient status at the end of the care, including mortality, morbidity, length of hospital stay, and patient satisfaction. Continuous quality improvement programs focus on measuring and improving these basic components of care.

Quality Improvement Strategies

Episodic outcome assessment has a well-rooted tradition in medicine in the form of mortality and morbidity (M&M) conferences. Since the 1990s, continuous quality improvement (CQI) systems have taken a systems approach to identifying and improving quality of care, rather than the traditional medical approach of blaming the individual.

In the Joint Commission standards, routine tracking of outcomes requires analysis when trends exceed acceptable performance limits, performance or outcome varies excessively, and special adverse events occur such as adverse drug reactions, adverse events related to anesthesia and sedation, and sentinel events. The goal is to identify and correct latent errors, effect change, and reassess to determine effect (Fig. 8.5).²¹

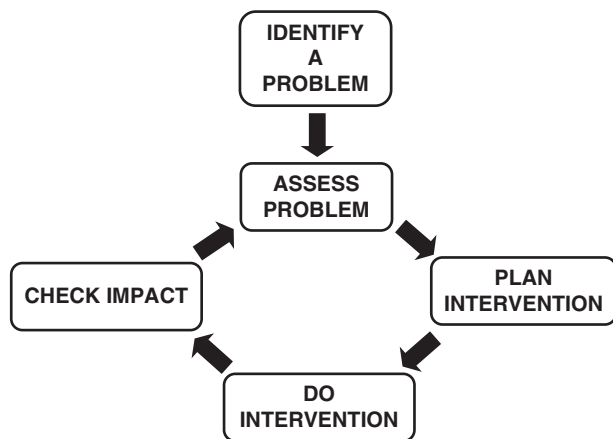


FIGURE 8.5. Continuous quality improvement (CQI) process. (Reprinted from Campion FX, Rosenblatt MS. Quality assurance and medical outcomes in the era of cost containment. *Surg Clin North Am.* 1996;76:139–159. Copyright 1996, with permission from Elsevier.)

Sentinel Event Monitoring

Hospitals and health departments use the reporting of sentinel events to focus on interventions and structural engineering that can prevent subsequent patient injury and death. Sentinel events that mandate reporting, review, and a planned response mechanism include wrong site or wrong patient surgery, hemolytic transfusion reactions due to major blood group incompatibility, and awareness during general anesthesia if it results in significant psychological harm. Although reporting sentinel events to Joint Commission is voluntary, root-cause analysis (RCA) is mandatory within 45 days if the Joint Commission determines that an organization has had a reviewable sentinel event. Failure of the institution to conduct an RCA can result in the organization being placed on accreditation watch.

Root-Cause Analysis

Root-cause analysis is a system-based approach to investigate the causal or contributing factors underlying adverse events or critical incidents. Initially developed to analyze aviation and industrial accidents, RCA is now widely implemented as an error analysis tool in health care. The goal is to determine what happened, why it happened, and what can be done to prevent it happening again. The fundamental theory of RCA is not to “name and blame” individuals for a mistake, but rather identify the underlying problems and sequence of events in which the incident was rooted. A typical RCA process follows a structured approach, which begins with data collection and reconstruction of the event through record review and participant interviews. A multidisciplinary team analyzes the sequence of events with the goal to spot why and how the incident occurred. Although identification of “active” errors is important, the major goal of RCA is to uncover “latent” errors (i.e., system weaknesses) hidden in a faulty operating system.

The RCA method helps to determine the factors causing variation from the expected outcome. For example, a published RCA investigated the case of a patient who was mistakenly taken for another patient’s invasive electrophysiology procedure.²² A traditional analysis might have focused on assigning individual blame, perhaps to the nurse who sent the patient for the procedure despite the lack of a consent form. However, the subsequent RCA discovered at least 17 distinct errors, no single one of which could have caused this adverse event by itself. The case illustrates how these specific “active” errors interacted with a few underlying latent conditions to cause harm. The most remediable of these were absent or misused protocols for patient identification and informed consent, systematic faulty exchange of information among caregivers, and poorly functioning teams. This led the hospital to implement a series of systematic changes to reduce the likelihood of a similar error in the future.

The U.S. Department of Veterans Affairs²³ and the Joint Commission pioneered RCA in the early 1990s; each developed its own programs, replacing older review methods with a more systematic approach. The Joint Commission now

TABLE 8.5. *Root Cause Analysis (RCA)*

A root cause analysis has the following characteristics:

1. Interdisciplinary, involving experts from the frontline services
2. Involving of those who are the most familiar with the situation
3. Continually digging deeper by asking why, why, why at each level of cause and effect
4. A process that identifies changes that need to be made to systems
5. A process that is as impartial as possible

To be thorough, a root cause analysis must include the following:

1. Determination of human and other factors
2. Determination of related processes and systems
3. Analysis of underlying cause and effect systems through a series of why questions
4. Identification of risks and their potential contributions
5. Determination of potential improvement in processes or systems

To be credible, a root cause analysis must do the following:

1. Include participation by the leadership of the organization and those most closely involved in the processes and systems
2. Be internally consistent
3. Include consideration of relevant literature

Source: U.S. Department of Veterans Affairs National Center of Patient Safety (NCPS).

requires organizations to perform a RCA for every sentinel event.²⁴ In the Veterans Affairs system, facilities submit RCA reports for serious adverse events to the National Center for Patient Safety. Currently, 25 states require reporting of adverse events to the state health department. Although these institutions teach standard methods and have developed tools to help standardize reports, best practices have not been established for recommendations for action, follow-up, and analyzing results (Table 8.5).²⁵ Furthermore, there are no studies in peer-reviewed literature on the effectiveness of RCA in reducing risk or improving safety in medical care, and there are no evaluations of the cost or cost effectiveness of the procedure compared with other tools to alleviate hazards.

Continuous Quality Improvement Systems in OOR Locations

To improve patient safety by making system changes in anesthesia/sedation practices in OOR procedure areas, a robust CQI system should be adopted. In addition to adherence to regulatory standards and measurement of “best practice” process indicators (e.g., performance of timeout, antibiotic administration, etc.), outcomes must to be measured and compared over time and to national standards. Outcome measurements for anesthesia and sedation practices need to include patient injuries, as well as escalation of care and identification of process problems (see Table 8.6 for outcome

TABLE 8.6. *Continuous Quality Improvement (CQI) Anesthesia Outcomes*

<i>Major Injuries</i>	<i>Escalation of Care</i>
Death	Prolonged intubation
Brain damage	Prolonged stay in postanesthesia care unit
Nerve damage	Prolonged hospital stay
Respiratory system injuries	Unscheduled admission of an outpatient
Airway trauma	Unscheduled intensive care unit admission
Adult respiratory distress syndrome/acute lung injury	Extra tests
Aspiration pneumonitis	Postoperative consult
Pneumothorax	Change in anesthetic plan
Prolonged ventilatory support	Naloxone
Pulmonary edema	Rule out myocardial infarction
Respiratory arrest	Reintubation
Other respiratory system injury	Extra drugs
Cardiovascular system injuries	Other escalation of care
Myocardial infarction	Process problem
Prolonged arrhythmia	Delay in procedure
Stroke	Time out problem
Cardiac arrest	Cancellation of procedure
Localized vascular insufficiency	Patient arrived needing further tests, labs
Other cardiovascular system injury	Antibiotic administration
Other injuries	Equipment problem
Burn (thermal)	Other process problem
Skin inflammation	
Eye injury	Quality assurance (QA) concern scores for outcomes:
Dental injury	0. No QA concern
Seizure	1. QA concern—no effect
Awareness/recall	2. QA concern—escalation of care
Pain	3. QA concern—temporary injury
Other patient injury	4. QA concern—permanent injury
Other soft tissue	5. QA concern—death

TABLE 8.7. *Continuous Quality Improvement (CQI) Management Areas*

Airway	Instrumentation
Airway obstruction	Central line
Aspiration of gastric contents	Equipment
Bronchospasm	Arterial line
Difficult intubation	Instrumentation (miscellaneous)
Endobronchial intubation	IV infusion
Esophageal intubation	Disconnect
Inability/difficult to ventilate	Infiltration
Accidental extubation	IV infusion (miscellaneous)
Inadequate ventilation/ oxygenation	Metabolic
Laryngospasm	Hypoglycemia
Premature extubation	Hyperglycemia
Airway (miscellaneous)	Peripheral nerve
Circulatory	Peripheral nervous system
Air embolism	Position
Excessive blood loss	Hyperextension
Hypertension	Pressure
Hypotension	Position injury (miscellaneous)
Inadequate/inappropriate fluid therapy	Pulmonary
Ischemia, cardiac	Pneumothorax
Circulatory management (miscellaneous)	Pulmonary management (miscellaneous)
Central nervous system	Thermoregulation
Central nervous system (miscellaneous)	Hypothermia
Medication	Other
Wrong dose	Preop evaluation
Wrong drug	Turnover
Allergic reaction	Miscommunication
Neuromuscular block management	Personnel delay
Drug action/interaction (miscellaneous)	Failure to diagnose/misdiagnosis
Hematologic	Failure to treat/wrong treatment
Hematologic	Inadequate monitoring
	Document issue
	Other

measurements).²⁶ Identification of management areas (Table 8.7) from which these adverse outcomes arose helps focus attention for improvement in various systems. For more severe quality indicators that result in unexpected temporary injuries, permanent injuries, or death, a root-cause analysis should be performed to determine system conditions which may have contributed to the adverse event, and to make process changes to prevent the event from occurring in the future. In addition to determination of rates of adverse events, current CQI systems also review production issues as well as patient satisfaction with their care.

SUMMARY

Providing anesthesia and sedation in procedure areas outside of the OR is increasing in popularity, but it is associated with risks that may be greater than when provided to similar patients in the OR setting. Patient safety can be improved by adherence to respiratory monitoring (e.g., pulse oximetry and capnography), sedation standards/guidelines and national patient safety and regulatory efforts, and development of vigorous CQI systems to measure outcomes and effect system changes.

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9 CT and PET/CT-Guided Interventional Radiology Procedures

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Over the last several decades, computed tomography (CT) has become a critical imaging modality for the diagnosis of a wide range of diseases.^{1,2} CT has also become a valuable guidance modality for a large number of percutaneous interventions that are generally divided into diagnostic and therapeutic categories.³

Common diagnostic CT-guided interventions include biopsies, aspirations, and drainages. Needle biopsies can be used to obtain cellular material for cytologic assessment or tissue cores for histological assessment from almost any anatomical region of the body. Special bone biopsy needles allow for penetration and sampling of bone lesions. Needle aspiration of fluid collections can be performed to obtain samples for microbiology, cytology, chemistry, and other tests. Some of the additional diagnostic interventions that can be accomplished under CT guidance include spinal discography and wire localization procedures, for example, to localize small peripheral lung nodules prior to video-assisted thoracoscopic surgery (VATS).^{3,6}

Drainage procedures address diagnostic and therapeutic indications. Catheter drainages are often performed to definitively manage fluid collections, both infected and uninfected, and are an attractive alternative to surgery in many cases.⁷ Types of fluid collections that can be drained include bilomas, hematomas, seromas, urinomas, cysts, pseudocysts, pleural effusions, and empyemas. Cysts or parasitic cysts can be drained and even treated with sclerosing agents using CT guidance. Catheter drainage of a viscus, such as percutaneous cholecystostomy, can also be used to temporize or palliate extremely ill patients until their condition allows definitive surgical therapy. CT-guided gastrostomies and cystostomies can also be performed.³

A variety of tumor ablation technologies, including radiofrequency ablation, cryoablation, microwave ablation, percutaneous ethanol ablation, and others can be performed under CT guidance for curative or palliative intents. CT-guided neurolysis procedures, local anesthetic injections, vertebroplasties, and ablation procedures can be performed for pain management purposes.^{3,8}

COMPUTED TOMOGRAPHY: HISTORICAL BACKGROUND AND RECENT ADVANCES

Computed tomography was introduced in the early 1970s. It was the first technology to incorporate computer reconstruction of images. The spatial and temporal resolution of CT scanners has improved dramatically over the last few decades. With the introduction of spiral CT in the early 1990s followed by multidetector CT (MDCT), rapid acquisition of volume data became possible, paving the way for the development of three-dimensional (3D) image processing techniques such as multiplanar reformation (MPR), maximum intensity projection (MIP), surface-shaded display (SSD), and volume-rendering techniques (VRT), all of which have become a vital component of medical imaging today. These new features have led to the application of CT imaging to a wide spectrum of clinical indications, including CT myelography, CT angiography, coronary calcium scoring, perfusion imaging, and virtual endoscopy.^{1,2,9}

CT fluoroscopy also represents a substantial technologic advance, combining the cross-sectional imaging capability of CT with real-time image display.¹⁰⁻¹² A foot pedal that initiates image acquisition, sterile drapes over the gantry table controls, and an image display monitor in the scanner room permit the radiologist to stand alongside the patient during the procedure, affording more radiologist control and faster procedure times. This is especially useful for interventions in less compliant patients.¹³⁻¹⁵

THE INTERVENTIONAL CT SUITE: PLANNING AND SETUP

Any CT scanner can be used for CT-guided interventions; however, multidetector CT scanners are generally preferred, since multiple detectors allow faster coverage of the entire intervention site in three dimensions. This not only permits easy recognition of needle deviations in the craniocaudal

direction but also permits adaptation to organ shift during the intervention.³ Selection of a scanner with a large-bore gantry may also be helpful for certain procedures where longer instruments are used, as well as for obese patients (see Fig. 9.1). There should be enough space in the scanner room for the radiologist, one or two assistants, a sterile table with the required instruments, monitoring devices, and possible additional equipment such as a ventilator or ablation device. The location of wall gases and suction should be accessible from either side of the scanner. The scanner gantry and table control buttons are typically duplicated on both sides of the scanner. Anesthesia equipment and personnel are usually positioned on the side of the patient opposite from the interventional radiologist.⁵

PREPROCEDURAL CONSIDERATIONS

Radiation

A relative disadvantage of CT guidance is exposure of the patient, the interventionalist, and support personnel to ionizing radiation.¹⁶⁻¹⁸ As with all medical imaging, the goal is to utilize CT to the extent necessary for safely and efficaciously accomplishing the procedure while minimizing radiation exposure under the ALARA (as low as reasonably achievable) principle. Since prior imaging studies are usually available at the time of the procedure, the planning and postprocedure scans should be limited to the organ or region of interest, including the planned approach and adjacent critical structures. The CT scanning technique parameters (kV, mAs, and collimation), the number of sequential scans, and the total CT fluoroscopy time during a procedure should be optimized to



FIGURE 9.1. Computed tomography (CT)-guided percutaneous ablation: The wide-bore CT gantry depicted is a potential advantage in large patients because it allows comfortable scanning of the patient and the positioned percutaneous devices during the procedure.

reduce patient radiation yet allow identification of important structures and monitor for possible complications. Intermittent rather than continuous usage of CT-fluoroscopy can reduce the overall radiation exposure. It is particularly important to be aware of a potentially high patient skin dose from repeat scanning of the same area during the course of an intervention.¹⁹⁻²⁰

When CT fluoroscopy is used, the interventionalist and other in-room personnel are also exposed to radiation. The interventional radiologist's hand should never extend into the primary X-ray beam. When continuous fluoroscopy is necessary, plastic needle holders are available that remove the hand from the primary beam.^{13,14,20} The beam is well collimated; therefore, scattered radiation from the patient's body is the dominant source of exposure to personnel in the procedure room. Scatter can be limited by placing a lead drape over the region of the patient's body closest to the interventionalist but not infringing on the scan coverage area.¹⁴ Radiation protection measures for the interventional radiologist are similar to those for other fluoroscopic interventions. A lead apron with 0.35 mm lead equivalent must be worn. A thyroid shield and protective goggles are recommended. Personnel should maximize their distance from the patient during scan acquisitions to the extent possible, since radiation levels decrease in proportion to the inverse-square of the distance from the radiation source. This means that even small increases in distance from the patient result in large decreases in radiation exposure to personnel. When possible, stepping out of the CT suite during scanning eliminates radiation exposure to personnel.^{13,14,20}

Bleeding Risk

Bleeding is a potential complication of percutaneous interventions, and it is of particular concern in patients receiving anti-coagulants or with bleeding disorders. Periprocedural management of these patients can be complex due to the wide range of procedural techniques, patient medications, and comorbidities.^{21,22}

Guidelines for optimizing coagulation parameters prior to imaging-guided procedures exist, but they are controversial.²¹ In general, the international normalized ratio (INR) should be below 1.5, the partial thromboplastin time (PTT) close to normal, and the platelet count above 50,000/mm³ for most procedures. When possible, warfarin should be discontinued 5–7 days prior to the procedure. Clopidogrel and aspirin should be withheld for 5 days before the procedure and fractionated heparin should be held for 12 to 24 hours. Nonsteroidal anti-inflammatory (NSAIDs) may be less critical but are preferentially withheld for 1–2 days. Heparin should be stopped 4–6 hours before the procedure, with recheck of the PTT, and can generally be resumed 12 to 24 hours after the procedure if necessary.²¹ The use of closure devices, smaller diameter catheters and biopsy devices, and adjunct hemostatic measures such as postbiopsy tract occlusion may also reduce the incidence of periprocedural bleeding complications.²⁴

Large Patients

Several challenges can exist when planning a procedure in a large patient. Needles and catheters used in interventional radiology are designed with variable lengths, usually ranging up to 20 or 25 cm. In large patients, the skin-to-target distance may exceed the maximum length of available instruments. In this case, preprocedural planning becomes even more important; reviewing available imaging studies can help determine the optimal patient position and approach to achieve the shortest possible distance from the skin to the target lesion. Pillows, splints, foam pads, bolsters, and other devices may be used to position the patient optimally on the CT scanner table. These devices allow the patient to remain securely and comfortably positioned for the duration of the procedure.

Large patients have an increased incidence of diabetes and heart disease, and they are more prone to complications, including wound infections, pressure ulcers, myocardial ischemia, and respiratory compromise. Some large patients have obstructive sleep apnea or are at high risk for airway compromise. In such cases, the expertise and participation of the anesthesiologist is critical in managing these patients appropriately.²³

Oral Contrast Material

When precise bowel visualization is necessary, oral contrast material can be administered prior to CT scanning. Oral contrast material allows better differentiation of bowel loops from adjacent structures and can assist in planning a targeted approach to avoid bowel injury. We selectively utilize oral contrast material prior to procedures in patients requiring intravenous sedation. Barium and iodine-based contrast material are both used commonly; iodinated oral contrast agents are preferred when gastrointestinal perforation is suspected.^{1,19} When monitored anesthesia care (MAC) or general anesthesia is planned, oral contrast material may be withheld due to the potential risk of aspiration. However, when oral contrast material is necessary, special intubation techniques may be helpful in reducing the risk of aspiration.^{1,19}

Intravenous Contrast Material

Intravenous (IV) contrast material administration is used in some cases to better delineate the target lesion or to better visualize surrounding anatomy, including arteries and veins. IV contrast material also can help characterize hypervascular tumors or vascular malformations, which may represent relative or absolute contraindications for biopsy procedures.¹⁹

IV contrast material can be nephrotoxic, and it is therefore typically not administered to patients with renal insufficiency. Although cutoff values vary by institution, at our hospital, IV contrast material is avoided in patients with an estimated glomerular filtration rate (eGFR) of less than 30 ml/min, unless they are on chronic dialysis. If IV contrast material administration is necessary in patients with reduced renal function, a reduced amount of contrast material and aggressive hydration may decrease the risk of contrast-induced nephropathy.²⁶

Adverse reactions to contrast material can occur, and they can range in severity. Symptoms of contrast reaction may be mild, such as sneezing, vomiting, or a few hives, or severe, such as hypotension, hypertension, extensive urticaria, laryngeal edema, wheezing, shortness of breath, and anaphylaxis. IV contrast material is generally avoided in patients with a previously documented anaphylactoid reaction. Patients at risk for a reaction include those with active asthma, multiple allergies, and those with previously documented reactions to contrast material. Premedication with corticosteroids reduces the risk of a contrast material reaction.²⁶ Both radiologists and anesthesiologists are trained to treat contrast material reactions, although details of treatment regimens are beyond the scope of this chapter.

IV contrast material may be injected by hand, but it is better delivered using a power injector that allows for more precise volume, rate, and timing of injections. A 20-gauge IV access is usually adequate. Central venous catheters and peripherally inserted central catheters (PICC lines) are usually not injected by power injector, unless specifically designed for this purpose. Attention should be paid to compatibility of IV contrast material with other drugs being administered through the same line.

Anesthesia Considerations

Most CT-guided biopsies and drainages can be performed under intravenous sedation. In addition to relieving patient anxiety and discomfort, the reduction in respiratory rate and tidal volume with sedation can be very helpful for thoracic and abdominal procedures, where target lesions move with respiratory motion. At the same time, however, reproducible breath holds may be necessary to allow accurate targeting of lesions. In contrast, oversedation can negatively affect patient cooperation.²⁷ Although IVCS can be administered or supervised by an appropriately certified radiologist, consultation with an anesthesiologist may be helpful in patients with significant comorbidities, a history of difficult intubation, chronic pain issues, sleep apnea, morbid obesity, or patients with abnormal head and neck anatomy or movement. For more invasive procedures such as tumor ablations, deeper sedation or even general anesthesia may be required. For these patients, a full outpatient preprocedural assessment by an anesthesiologist is typically performed 1 week prior to the procedure.

INTERVENTIONAL CT PROCEDURES

CT-Guided Biopsy

CT-guided percutaneous biopsies provide a minimally invasive method of obtaining a definitive cytologic or histologic diagnosis of lesions throughout the body. As with other image-guided procedures, CT-guided percutaneous biopsies are performed using sterile technique. Antibiotics are not routinely administered prior to biopsy. Needle size can vary widely, although the majority of tissue samples are obtained

using needles ranging from 18 to 25 gauge. Multiple samples are usually obtained. In some institutions, a cytotechnologist or cytopathologist is present in the CT suite at the time of biopsy to evaluate for sample adequacy before the needles are removed; this immediate feedback can reduce the number of nondiagnostic procedures. Additional information regarding image-guided biopsy technique can be found in Chapter 10.

Patient positioning is usually determined by the shortest, safest route to the lesion. Liver mass biopsies are typically performed in the supine or slightly obliqued position. Retroperitoneal mass and vertebral biopsies are most often performed with the patient prone or in a lateral decubitus position. Pain can vary with the anatomic site and depth of needle penetration. Most biopsies are performed using a combination of local anesthesia and intravenous sedation. The level of sedation required tends to be relatively constant throughout the procedure. For liver and kidney lesions in particular, as well as other lesions near the diaphragm where respiratory motion can be significant, it is preferable to begin sedation before the initial planning CT scan. Once sedated, visceral organs are in a more stable position for the duration of the procedure. This facilitates selection of an optimal skin entry site and trajectory. The majority of CT-guided biopsies can be completed in under 1 hour.

For some biopsies, a craniocaudal angled approach may be necessary, making the procedure technically more difficult. In these cases, reproducible breath holds or shallow respirations are even more important, as the most significant anatomic shifts with breathing will be in the craniocaudal direction. Multiplanar reformats may be helpful during the biopsy to assist needle guidance, but they can prolong procedure time.

Although most biopsies are straightforward, some patients require additional preprocedural planning. A transpleural path should generally be avoided to prevent pneumothorax or spread of infection or tumor from the abdomen into the thorax. Traversing the stomach, small bowel or colon with needle biopsies can be done when necessary to biopsy a solid structure. We typically avoid traversing small bowel and colon with large needles. The small bowel and colon should not be transgressed with fine needles when targeting a fluid-containing structure.^{6,24}

Catheter Drainages

Over the last 20 years, image-guided abscess drainage has become common practice, replacing open surgical drainage in the vast majority of cases. Catheter drainage provides a rapid and simple means of therapy with high success rate and few complications. CT is often the imaging modality of choice for guidance of abscess drainage procedures, due to its excellent anatomic detail, including the ability to clearly differentiate bowel from surrounding structures.^{31,32} In general, deeper collections or those requiring transluteal drainage or other access routes traversing large muscles tend to cause more pain and discomfort. Although the majority of abscesses are readily accessible and can be drained percutaneously, alternative access routes, such as transrectal or transvaginal approaches,

may be necessary to facilitate the drainage of deep pelvic fluid collections.¹¹

There are two general techniques used for drainage catheter placement. In the modified Seldinger technique, the catheter is placed into the collection over a guidewire after dilation of the tract. In the trocar technique, the catheter is placed into the collection in a single step. In either case, the dilation or catheter insertion steps may be painful. Additional information regarding techniques of catheter drainage can be found in Chapter 10.

Alcohol Ablation

Percutaneous alcohol ablation may be used to treat tumors, such as small hepatocellular carcinomas, as well as symptomatic, recurrent cysts in the liver or kidney. Initial needle or small-diameter (6 French) catheter placement is usually well tolerated, but the actual ethanol injection can produce considerable pain. Large volumes of alcohol or inadvertent intravascular injection can lead to toxicity, including symptoms of coughing, choking sensation, tachycardia, and respiratory depression.^{34,35} Communication and coordination between the interventional radiologist and anesthesiologist is therefore needed.

Thermal Ablation

Percutaneous tumor ablation procedures are performed to manage malignant lesions, most commonly in the liver, kidney, adrenals, lung, or bone. A variety of technologies are currently being used, including radiofrequency (RF) ablation, cryoablation, microwave ablation, and others (see Fig. 9.2).⁸ Although some ablation procedures are completed in about 1 hour, other cases may require up to 3 or 4 hours.



FIGURE 9.2. Manufacturers of radiofrequency and cryoablation applicators have designed flexible and right-angle handles in order to clear the gantry during scanning. Right-angle cryoapplicators are pictured here.

Ablation procedures require the precise placement of one or more ablation applicators into the target organ or tissue. Some radiofrequency ablation devices allow placement of a single applicator with subsequent deployment of an expandable array of tines or electrodes into the target area.³⁶⁻³⁸

Radiofrequency ablation applies an alternating electric current to tissues around the applicator probe, which produces ionic agitation and frictional heating. Coagulative necrosis occurs when temperatures exceed 50°C. A 2–6 cm diameter thermal ablation zone can be produced with each radiofrequency ablation.⁸ Reproducible levels of breath holding are often important in facilitating optimal and safe probe placement, and they can be accomplished either with a degree of intravenous sedation that allows patient cooperation or with general anesthesia and same-level interruption of ventilation. Analgesia is particularly important just prior to turning on the radiofrequency generator, since the heating process may trigger significant pain. Radiofrequency ablation tends to produce more pain than other ablation methods such as cryoablation. Cryoablation is discussed in more detail in Chapter 10.

Pain Management

Nerve blocks can be used for pain management and involve CT-guided placement of the needle adjacent to a nerve or nerve plexus that is responsible for pain. Although the ultimate goal is pain management, the procedure itself can be quite painful, and sedation is often required. Chemical ablation can be performed using the percutaneous injection of alcohol (95%) or phenol (6%) to induce neurolysis, analogous to its use as a destructive agent in tumor therapy. Various neurolysis procedures that can be performed may target the pterygopalatine ganglion, stellate ganglion, celiac plexus, pudendal nerve, and interiliac sympathetic plexus and ganglion. Injection of steroids for local pain management and anti-inflammatory effects may target various joints such as the facet joints, sacroiliac joints, and others.

SPECIAL CONSIDERATIONS

Percutaneous Biopsy of Carcinoid Tumor

Carcinoid crisis has been described in association with surgery and anesthesia, as well as other stresses. Stimulation of hormone release can result in hypertension or profound hypotension that is difficult to reverse. Although reports of complications from biopsy of carcinoid tumors are rare, symptoms of carcinoid syndrome have occurred with transbronchial biopsy, resulting in acute facial flushing and hypertension. A fatal case of severe flushing, nausea, faintness, followed by generalized seizure activity, profound hypotension, and cardiopulmonary arrest after percutaneous biopsy of a carcinoid liver metastasis has also been described in the literature.²⁸ Anesthesia consultation and premedication may be considered for interventional procedures involving carcinoid tumor.

Biopsy of Adrenal Masses

Catecholamine-induced hypertensive crisis is a specific problem encountered with adrenal and extra-adrenal pheochromocytoma that can lead to labile blood pressures during biopsy. When pheochromocytoma is suspected, pharmacologic pretreatment strategies should be considered in conjunction with the anesthesiologist, although pretreatment does not necessarily prevent such crises from occurring. Both the radiologist and anesthesiologist should be prepared to treat a catecholamine-induced crisis when performing adrenal mass biopsies. Although historically there has been concern over IV contrast material administration in patients with suspected pheochromocytoma, it is extremely rare for IV contrast material alone to induce a crisis.^{29,30}

Echinococcal Cysts

Percutaneous needle aspiration of hydatid cysts caused by Echinococcal disease has long been discouraged because of potential complications, such as anaphylactic shock and the spread of daughter cysts into the peritoneum. Although anaphylactic shock from rupture has been documented, its frequency and mechanism of action have not been well detailed. Recent data indicate that hydatid cyst aspiration and ethanol ablation may be safer than originally described.^{31,32} Despite the lack of conclusive documentation of the risks of percutaneous drainage, the procedure is ideally performed with an anesthesiologist available to treat any potential acute complication.

Postprocedural Considerations

After completion of a CT-guided percutaneous interventional radiology procedure, the skin entry site is sterilely bandaged. A CT scan of the target region is performed after the procedure if necessary, to exclude immediate complications and to document the position of drainage catheters or other devices. Outpatients are placed at bed rest for 1 to 6 hours, the duration depending on the type of procedure. During that time, vital signs and pain levels are monitored. After thoracic interventions, a chest X-ray is generally performed to exclude a pneumothorax. Following thermal ablations, patients are admitted overnight for observation, laboratory value assessment, and a follow-up CT or MRI to evaluate the ablation site.

Mild hemoptysis following lung biopsies can occur and should significantly decrease in volume over a period of a few hours. Massive hemoptysis (more than 200 ml in 1 hour) requires immediate intervention. After percutaneous interventions, signs or symptoms of hemorrhage generally warrant a CT scan. Large or active hemorrhage may necessitate angiographic embolization.⁴

Postprocedural pain control is sometimes a significant issue in patients after tumor ablation procedures performed adjacent to sensitive areas, such as peritoneal surfaces, liver capsule, and pleura. Ablations involving the diaphragm may lead

to referred shoulder pain that can persist for days or even weeks after the procedure, but it tends to subside slowly over time.

PET/CT

Historical Background and Recent Advances

Positron emission tomography (PET) is being increasingly used for the diagnosis, staging, and follow-up of various malignancies. By far, the most common radiopharmaceutical employed in PET and PET/CT imaging is ^{18}F -fluoro-deoxyglucose (FDG), a radiolabeled glucose analog. Various other radiopharmaceuticals are currently under investigation for their role in tumor imaging, including radiolabeled amino acids for the evaluation of cell proliferation. Malignant cells often have increased glucose metabolism, reflecting increased cell membrane facilitated transport and upregulation of intracellular hexokinase activity, among other factors. FDG is taken up by tumor cells but, unlike glucose, is not fully metabolized, thereby becoming trapped inside metabolically active cells.³⁹ FDG-PET has been used in the evaluation of solitary pulmonary nodules, non-small cell lung carcinoma, lymphoma, melanoma, breast cancer, colorectal cancer, and many other malignant and inflammatory conditions. FDG-PET can aid in the differentiation of malignant from benign lesions, assist in the staging of malignancies, and provide a means of monitoring response to therapy. PET can be especially useful when there is a complicated appearance on CT or MR imaging due to postoperative changes or scar tissue. PET/CT incorporates the cross-sectional anatomic information provided by CT and the metabolic information provided by PET in a single scanner. PET/CT offers several advantages over PET alone, the most important of which is the ability to accurately localize increased metabolic activity to specific anatomic locations or structures.⁴⁰

PET/CT-Guided Intervention

PET/CT is beginning to see application in interventional radiology. PET/CT enables direct targeting of metabolically active portions of tumors, which are more likely to yield viable cells for diagnosis (see Fig. 9.3). This is particularly useful with partially necrotic tumors or tumors such as chronic lymphocytic lymphoma, in which more than one clonal population of cells may exist. Incorporation of metabolic targeting capabilities also improves the ability to target lesions that are not visible or poorly visible on CT, MRI or ultrasound (US). The CT component of the PET/CT is critical for determining a safe interventional approach.

Patients fast for approximately 4–6 hours prior to PET/CT to enhance FDG uptake by tumors as well as to minimize cardiac and muscle uptake. Before the injection of FDG, a blood glucose level of less than 150 mg/dl is preferred, as cellular FDG uptake is competitive with glucose. There are no contraindications to FDG administration other than the



FIGURE 9.3. Positron emission tomography (PET)/computed tomography (CT)-guided liver biopsy. The PET/CT image shown is the result of gray-scale CT and color PET image fusion. The arrow indicates the tip of a biopsy needle entering the metabolically active liver metastasis in this patient with known breast cancer.

relative contraindication of pregnancy. Imaging is initiated approximately 60 minutes following the injection of FDG. PET/CT scans are acquired as a series of sequential bed positions with each bed position providing at least 15 centimeters of coverage along the patient long-axis. For interventional purposes, a single bed position may suffice in terms of anatomic coverage. A single bed position PET/CT scan can be completed in 2–6 minutes depending on equipment and imaging protocol.

Potential radiation exposure to operating personnel from positron-emitting radiopharmaceuticals should be considered, but it is not prohibitive.⁴¹ Standard lead aprons are not useful in reducing exposure from the high-energy photons produced by PET radiopharmaceuticals and therefore strategies of maintaining distance from the patient and minimizing close contact periods are most helpful.

Another potential limitation of PET/CT-guided interventions is that of misregistration of the two image datasets. Although PET/CT images are acquired on a dedicated PET/CT scanner, the PET and CT hardware is actually configured in-line, with a long gantry passing through both scanners. The PET and CT images are obtained sequentially. As a result, there is potential for patient motion between the two scan acquisitions, either due to shifts in body position, or more commonly due to differences in respiratory phase. For anatomic locations that do not move with respiration, such as many portions of the skeleton, the neck, the pelvis, and extremities, respiratory motion is rarely a significant problem.

For structures close to the diaphragm, strategies are needed to minimize image misregistration, such as adequate sedation to reduce the rate and depth of inspiration.⁴² Breath-hold techniques may be feasible in some cases and is a strategy currently under investigation at our institution.

PET/CT scanners resemble MRI scanners, with a long gantry that can limit access to the patient by the medical team. As with procedures performed in a closed-bore MRI, tubing and monitoring leads must be long enough to allow free travel of the patient all the way into the scanner gantry. A video camera system can be installed on the far end of the gantry to provide constant visual monitoring of the patient. Wall-mounted gas supplies, suction, and monitoring equipment should be considered when planning the layout of a PET/CT suite that may be used for interventional procedures.

In conclusion, CT is a well-established guidance modality for interventional procedures, and PET/CT is an emerging guidance modality for similar procedures. The anesthetic considerations are quite variable depending on the procedure, the patient, and the interventional radiologist. Close communication between the radiologist and the anesthesiologist will help ensure an uneventful procedure and an optimal outcome for the patient.

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10 | Magnetic Resonance Imaging and Ultrasound-Guided Percutaneous Interventional Radiology Procedures

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The need for procedural sedation and anesthesia for minimally invasive procedures continues to grow as the number of procedures and interventional applications increases. This trend will continue as the population ages and the complexity and array of imaging-guided interventional procedures expand. Minimally invasive procedures performed with imaging guidance both supplement and in some situations replace traditional open surgeries. In cases where patients cannot tolerate open surgery, imaging-guided percutaneous procedures offer an attractive alternative.

Although imaging-guided procedures are less invasive than surgery, they still have potential complications and can result in patient anxiety, pain, and discomfort. Accordingly, there is an important role for monitored and general anesthesia for patient safety and comfort, as well as for facilitating the technical success of the procedure. Anesthesiologists are often present throughout the entire procedure or may be consulted in cases where intravenous sedation is administered by the interventional radiologist. To select appropriate sedation and analgesia strategies, the anesthesiologist must assess the patient's current status, underlying medical conditions, and details of the procedure, including the type of the procedure, the expected duration and complexity of the procedure, patient's position, breath-holding concerns, the anticipated amount and type of pain, and potential complications. Frequent communication before, during, and after the procedure between the interventional radiologist and anesthesiologist is important for delivering sedation and analgesia in a safe, effective manner. This chapter focuses on the various types of interventional procedures performed with ultrasound (US) and magnetic resonance imaging (MRI) guidance.

MAGNETIC RESONANCE IMAGING

Magnetic resonance imaging is used principally as a diagnostic tool, and it has been used infrequently to guide interventional radiology procedures. The principal advantages of MRI

during intervention include high intrinsic soft tissue contrast resolution and its ability to provide images in any anatomic plane without the use of ionizing radiation. While the physics of MRI is beyond the scope of this chapter, MRI, in basic terms, utilizes magnetic fields and radio waves to generate images. The strength of the magnetic field is an important determinant of image contrast.¹ The magnetic field strength is measured in Tesla (T). The field strength can range from low (0.1–0.5 T), medium (0.5–1.0 T), or high (1.5–3.0 T), to ultrahigh (>3.0 T).^{2,3} The specific information depicted in MRI images can be manipulated or emphasized by altering the sequence parameters selected. For example, image sequences can be selected to help distinguish tissue types based on fat or water content, presence or absence of iron or hemosiderin, and degree of vascularity or perfusion. Magnetic resonance imaging may depict pathology and provide functional information that is not readily discernable with US or computed tomography (CT).

There are some limitations with MRI that affect diagnostic and interventional applications. For instance, evaluation of dense bone or heavy calcification is characterized by a signal void. Long image acquisition times can result in motion artifacts from respiratory motion, patient movement, bowel peristalsis, or cardiac and vascular pulsations. This motion artifact can degrade image quality, making both interpretation of images and interventional procedures difficult. Steady progress over the years has led to improvements in signal-to-noise ratio while decreasing the length of MRI sequences and maintaining anatomic coverage.^{4,5} Nevertheless, MRI-guided procedures are usually more time consuming than those performed with CT or US.

ADVANTAGES OF MAGNETIC RESONANCE IMAGING-GUIDED PROCEDURES

Unlike CT scanning, MRI does not utilize ionizing radiation. Magnetic resonance imaging provides direct multiplanar

imaging. Acquiring images in any plane allows the entire needle path to be visualized regardless of needle angulation.⁶ The excellent soft tissue contrast resolution of MRI is advantageous when a biopsy or ablation is required for lesions that cannot be discerned and targeted optimally with US or CT. Similarly, ablation zones, treatment responses, complications, thermal effects on adjacent structures, and tumor recurrences can often be imaged with superior tissue contrast resolution by MRI as compared to other imaging modalities.⁷⁻⁹ The use of specially tailored sequences such as temperature-sensitive imaging during the procedure and subtraction contrast-enhanced imaging^{10,11} after the procedure increase inherent contrast resolution.

Choice of Apparatus

Both open and closed MRI systems can be used for interventional procedures, and each has its advantages and disadvantages.⁷ Most diagnostic MRI examinations are performed in closed-bore magnets of 1.5 to 3.0 T. These systems allow for greater signal-to-noise ratios and scan speeds that are sufficient for diagnostic imaging. However, closed-bore MRI systems can only be used to guide interventions intermittently because the patient must be repetitively moved in and out of the magnet for manipulation of the instruments. The confined space of the closed-bore MRI system limits access to the patient. Furthermore, the confined space limits the length of incrementally advanced biopsy needles or ablation applicators that can remain partially outside the patient's body during imaging. Newer wide-bore (70 cm or larger) high-field systems have been developed that help increase access during interventional procedures and allow for instruments to be advanced incrementally between imaging acquisitions¹² (Fig. 10.1).



FIGURE 10.1. Closed-bore magnetic resonance imaging (MRI) interventional suite. All equipment in the MRI interventional room is MRI compatible. This particular system has a magnet bore diameter of 70 cm, which is comparable to that of many computed tomography (CT) scanners.

Open MRI systems have been designed to image large or claustrophobic patients. Relative to closed systems, open MRI systems provide greater access to patients not only when manipulating the needle but also while acquiring images in near real time. However, open magnets are usually of lower field strength (0.2–1.0 T), which results in lower signal-to-noise ratio and decreased spatial resolution. In addition, the image acquisition times may be longer, which results in patients having to hold their breath for extended periods of time. The available access to the patient, space limitations, and duration of image acquisition provided by the different systems will affect the anesthesiologist's management of the patient during the procedure.

Patient Factors

Magnetic resonance imaging–guided procedures are contraindicated in patients who have cardiac pacemakers, insulin pumps, cochlear implants, bone growth stimulators, implantable infusion pumps, and neurostimulators.^{13,14} Cardiac arrhythmias and burn injuries can be caused by radiofrequency-induced electrical currents or heating within intracardiac pacing wires and other indwelling metal-containing catheters or leads. Care should be taken when imaging patients with metallic objects (ferromagnetic or otherwise), which are susceptible to significant heating as compared with normal biologic tissues. Certain devices that are ferromagnetic, such as some cerebral aneurysm or vascular clips, can be dislodged. Similarly, metallic foreign bodies, such as bullets and other metallic fragments, can potentially move while being imaged.^{15,16}

If MRI is to be performed in a patient with an implanted device, the documentation of the specific model implanted should be reviewed and assessed for safety.¹⁷ An increasing number of implants and devices have been confirmed to be MRI compatible, including nonferromagnetic vascular clips, staples, and orthopedic implants or prostheses. In addition, many cardiac prosthetic valves can be scanned safely. Patients who may have intraorbital metal, such as welders, or patients with a history of penetrating eye injury should be screened with radiographs of the orbits because metallic foreign bodies can dislodge and cause ocular injury and blindness.

Device Factors

For most interventional procedures, continuous electrocardiogram (ECG) monitoring is required, especially when general anesthesia is used. Cardiac monitoring, however, can be affected by magnetic field-induced distortion of the ST and T wave components of the ECG.¹⁸ This prevents monitoring for silent cardiac ischemia in the MRI environment. Consequently, patients with known active ischemic heart disease should not have their procedures performed in the MRI suite until this technical problem is solved.

All equipment in the interventional MRI room must be MRI compatible. This means that the equipment is MRI safe (will not cause harm to the patient), will not affect image

quality,¹⁹ and will not be affected by the MRI scanner. Access to the interventional MRI procedure room should be strictly controlled to prevent inappropriate objects and devices from entering. Conventional interventional and surgical instruments as well as anesthesia equipment, including gas cylinders, are often made with stainless steel, which is strongly attracted by the magnetic field. Regardless of size, any of these objects can become hazardous projectiles, accelerating within the magnetic field into the patient gantry.⁶ Special care must be taken to ensure that all devices used during an MRI procedure will not pose a risk to the patient from current induction, heating, or magnetic attractive forces.²⁰ For instance, the radiofrequency pulses from the MRI scanner can induce electrical currents within standard ECG leads, potentially resulting in burns from contact.¹⁹

Equipment used during the procedure may adversely affect the image quality and scanner performance by interference with the magnetic field or radiofrequency signals.⁶ Patient monitoring equipment, such as pulse oximetry sensors, can produce radiofrequency interference that affects image quality.¹⁹ A number of MRI-compatible interventional instruments, such as scissors, blades, needles, carts, and ablation equipment, have been developed. In addition, MRI-compatible anesthesia equipment, such as patient monitors, infusion pumps, gas cylinders and respirators are available.¹⁹ Further information on MRI safety is available in the references.^{15,16}

MAGNETIC RESONANCE IMAGING–GUIDED BIOPSY

Magnetic resonance imaging is not used as commonly as CT or US to guide percutaneous biopsies; however, MRI guidance may be advantageous in situations where lesions are not visible or are poorly visualized with the other imaging modalities. Because of its multiplanar capability, MRI is useful in guiding biopsies of lesions in the superior abdomen where angulation of the needle is required to avoid diaphragmatic injury and pneumothorax.⁶ In these cases, the entire length of the needle path can be visualized.

Magnetic resonance imaging is particularly helpful in guiding breast and prostate gland biopsies. It is a sensitive imaging tool for detecting cancers that are not visible with other imaging modalities.^{21,22} For example, relative to mammography, MRI has been shown to detect additional breast cancer foci in up to 10% of cases.²³ Magnetic resonance imaging–guided breast biopsies are performed with the patient in a prone position using a dedicated breast surface coil. Large-needle biopsy and wire localization are procedures usually performed in a closed MRI system.^{22,24} Magnetic resonance imaging–guided biopsy (up to 9 gauge) with vacuum assistance has been accepted as a safe and accurate technique allowing for sampling of lesions as small as 1 cm with a success rate of 95% to 100%.^{6,22} During these procedures, gentle compression is applied to the breast. Local anesthesia and a small skin incision are usually sufficient.⁶

Magnetic resonance imaging–guided prostate gland biopsies can be performed in an open MRI system using a transperineal

approach or a closed system via a transgluteal approach.^{25,26} Magnetic resonance imaging–compatible spring-loaded transrectal biopsy devices have also been developed.²⁷ Local anesthesia may be sufficient with some patients requiring the addition of intravenous sedation.

TUMOR ABLATION

Radiofrequency ablation is the most commonly used percutaneous tumor ablation technology; however, the use of radiofrequency ablation with MRI guidance is limited by the interaction between radiofrequency signals and MRI signals.²⁸ Cryoablation, on the other hand, can be performed in the MRI suite without interference. With the recent development of thin applicators (17 gauge), cryoablation is increasingly performed percutaneously under CT, US, or MRI guidance. All percutaneous thermal ablation techniques are minimally invasive alternatives to surgery, allowing patients with significant comorbidities or unresectable disease to be treated.¹²

Cryoablation destroys the targeted tissues through a freezing and thawing process resulting in cellular dehydration, intracellular disruption, cell membrane damage, local ischemia due to small vessel injury, and other factors.^{12,29} The distal end of the cryoablation applicators can reach temperatures as low as -185°C .³⁰ The critical temperature for complete tissue destruction ranges between -20°C and -50°C , depending on the tissue.³¹

Typically one or more needle-like cryoablation applicators are placed into the targeted tissue, depending on the size of the tumor. During the cryoablation process, an ice ball is formed around the distal end of the cryoprobe as the heat is removed from the surrounding tissues. The ice ball can be visualized and monitored by MRI, CT, or US.³⁰ Ultrasound is limited in that the entire ice ball cannot be visualized due to acoustic shadowing that hides the distal portion of the ice ball. Computed tomography can be used to visualize the entire ice ball, but MRI provides better contrast between frozen and unfrozen tissues.⁶ In addition, MRI can provide near real-time monitoring of the dynamic formation of ice and can visualize the irreversible effects in targeted tissues after the thawing process.¹² Optimal visualization of the ice ball allows for improved tumor coverage while reducing the risk of injury to adjacent organs (Fig. 10.2).⁶ Magnetic resonance imaging–guided percutaneous cryoablation has been shown to be effective and safe for a variety of oncologic applications in the liver, kidney, breast, prostate, and musculoskeletal system.³²⁻³⁵ In addition, cryoablation can be used to treat uterine fibroids.³⁶

Cryoablation tends to cause less pain than the heating of radiofrequency ablation, a factor that affects sedation and anesthesia decisions.³⁷ Whether radiofrequency ablation or cryoablation is performed, reproducible levels of breath holding are often important for optimal and safe probe placement, particularly if the target organ is subject to respiratory motion. When general anesthesia is used, breath holding can be accomplished with same-level ventilation interruption.

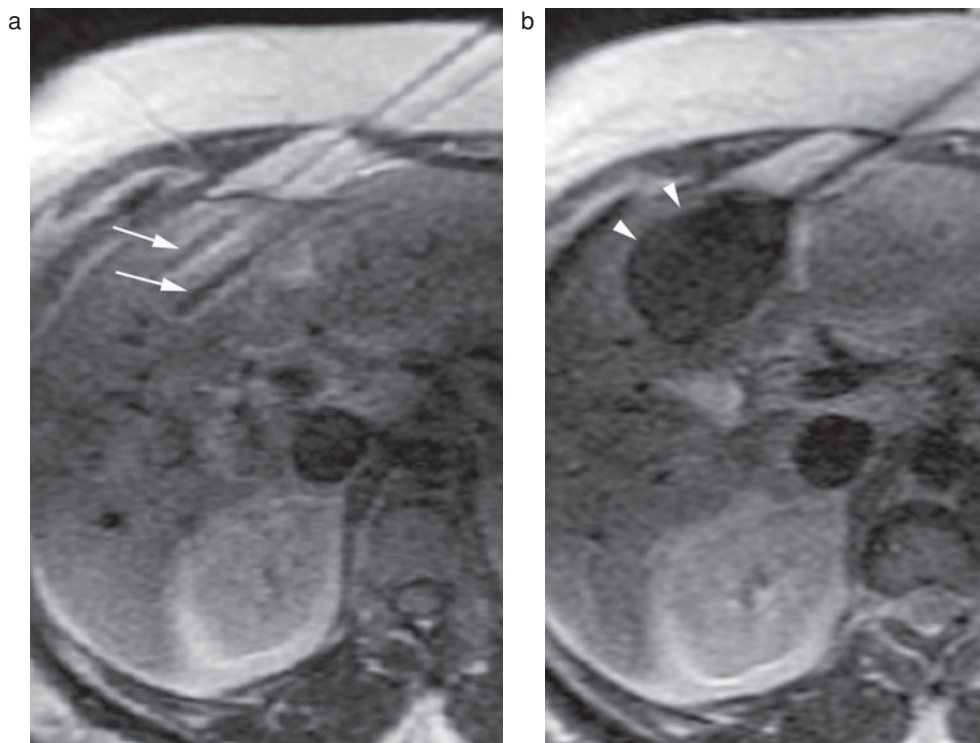


FIGURE 10.2. (a) Cryoablation. An axial magnetic resonance imaging (MRI) image (0.5 T; T2-weighted) demonstrates a hyperintense breast cancer metastasis in the liver with two percutaneous cryoprobes positioned in the lesion (arrows). (b) An axial MRI image obtained during cryoablation demonstrates a hypointense ice ball (arrows) that completely surrounds the metastasis.

When intravenous sedation is used, it is often helpful to use smaller doses of sedatives and analgesics to control patient discomfort while still allowing the patient to hold his or her breath on command. Once the ablation probes are in place, increased doses of medications may be appropriate during the actual heating or freezing periods of the procedure. Monitored anesthesia care, instead of intravenous sedation without anesthesia personnel, is often preferred for patients with comorbidities, and those who cannot tolerate any discomfort or being in a restricted position for 2 to 4 hours.⁶ At our institution, ablation procedures are most often performed with monitored anesthesia care.

Typically when intravenous sedation is used the patient is discharged the same day. If monitored anesthesia care or general anesthesia is used, patients are admitted overnight and observed for complications. Bleeding is the most common complication. Rarely, severe thrombocytopenia can occur after extensive liver cryoablations and may require platelet transfusions for management.⁶ Extensive ablations also can induce myoglobinemia and myoglobinuria. When severe, myoglobinuria can lead to acute renal failure.³³ Management of myoglobinemia and myoglobinuria may require hydration with normal saline and alkalinization of urine with sodium bicarbonate.⁶

A specific problem that is encountered when performing cryoablation of the adrenal gland or structures near the adrenal

gland is catecholamine-induced hypertension. This complication is more likely to occur when residual normal adrenal tissue is present and is less likely to occur when the adrenal gland is completely replaced with nonhormonally active tumor.³⁷ During cryoablation procedures, the hypertension occurs during or following thawing and not during freezing. This is in contrast to radiofrequency ablation procedures, which are more likely to induce hypertension during the application of heat.³⁷ Pretreatment medication should be considered in high-risk procedures, although this does not necessarily prevent a hypertensive crisis.³⁷

MAGNETIC RESONANCE IMAGING-GUIDED, HIGH-INTENSITY FOCUSED ULTRASOUND THERAPY

The use of focused ultrasound for ablation of tumors was limited before the use of MRI because of difficulty with precise target definition and inability to control beam dosimetry without a temperature-sensitive imaging method.¹¹ Magnetic resonance imaging has the ability to satisfy both of these requirements, allowing for accurate real-time treatment monitoring.³⁸ The use of transcutaneous focused ultrasound as a thermal ablation technique is less invasive than previously described percutaneous methods.³⁹ With this procedure,

high-frequency ultrasound beams penetrate through the soft tissues and are focused to a specific target site. Temperatures in the range of 55°C to 90°C can be generated in the targeted tissues.⁶ To date, focused ultrasound has been shown to be a safe and effective treatment method for certain symptomatic uterine fibroids.⁴⁰ Clinical trials are being performed to assess the potential of this technique for treating various malignant tumors.^{41,42} For the treatment of uterine fibroids with focused US, patients are placed prone on a special MRI table that contains an embedded set of ultrasound transducers. During the procedure, intravenous sedation is used to ensure patient comfort and immobility while maintaining verbal communication throughout the procedure.⁶ It is important to search for scars on the anterior abdominal wall because these can absorb ultrasound energy, resulting in skin burns and discomfort. Hair removal may also be required to ensure optimal contact between the transducer and skin.⁶ To avoid bladder filling during the procedure, a Foley catheter is placed. Once the target is localized and a safe pathway is established, therapeutic focal sonications are administered, each lasting 20 to 40 seconds.⁶ Temperature-sensitive MR images are used during the procedure to monitor the dose delivered. After the procedure, intravenous gadolinium-enhanced images are performed to assess for adequate treatment response.

Magnetic Resonance Imaging–Guided Brachytherapy

In the treatment of low-risk prostate cancer, brachytherapy has been shown to be effective.^{43,44} Brachytherapy also has lower rates of long-term complications when compared to external beam radiation therapy.⁴⁵ Brachytherapy can be performed with ultrasound guidance using a perineal approach. Ultrasound guidance has limitations due to the poor visualization of the prostate gland margins, neurovascular bundles, urethra, and rectal wall.⁶ As with other MRI-guided procedures, the superior contrast resolution of MRI allows for optimal visualization of the prostate and surrounding structures.⁴⁶ This allows for better targeting, which can maximize tissue destruction while reducing injury to adjacent normal structures.⁴⁷

Appropriate patient selection criteria for MRI-guided brachytherapy are based on prior biopsy and imaging results and are further detailed elsewhere.⁶ The procedure has been described in an open vertically configured MRI system with the patient in a lithotomy position and under general anesthesia.⁶ When the treatment plan and trajectory have been determined, the perineum is prepared in a sterile fashion and the needles used to deliver the iridium seeds are placed under near real-time MRI. The correct location of the needle tips are confirmed in multiple planes before delivering the seeds.

In summary, MRI offers advantages in a variety of interventional applications and is likely to be used more often in the future for an increasing array of interventional procedures. MRI may make possible or facilitate minimally invasive procedures previously not possible or difficult to accomplish with CT or US guidance. Many issues such as MRI-safe and MRI-compatible equipment, room safety,

patient monitoring, and appropriate anesthesia levels require special consideration in the MRI environment.

Ultrasound

Ultrasound has been a valuable method of imaging the body for decades and is currently one of the most widely used and versatile imaging modalities in radiology. Ultrasound poses no known risks to the patient and does not use ionizing radiation.⁴⁸ It does, however, have the potential to deposit enough energy into the tissues that local heating can occur. Limitations on energy settings and time of scanning are therefore appropriate in certain settings such as obstetrical US.⁴⁹ Another advantage of US is that it provides real-time assessment of moving structures such as the heart, blood vessels, and fetus. The ability to visualize respiratory motion of viscera during interventional procedures is extremely helpful. The multiplanar and real-time imaging capabilities of US allow for the rapid assessment of spatial relationships, a great advantage for interventional applications. When compared to other imaging modalities such as CT or MRI, ultrasound has the added advantage of being portable and relatively inexpensive. Superficial structures and many deep structures can be readily assessed with satisfactory spatial resolution and tissue contrast. Finally, US offers various types of Doppler imaging that can be used to make qualitative and quantitative assessments of blood flow.

There are some limitations with US imaging that affect diagnostic and interventional applications. Sound energy is nearly completely absorbed or reflected at interfaces between soft tissue and bone such that structures deep to bone cannot be visualized. Bowel gas also strongly reflects the US beam, which limits visualization of deeper structures. In these situations, repositioning the patient or scanning from different approaches may avoid these structures and allow visualization. Finally, very large patients can present a challenge because sound waves must traverse greater depths to provide imaging of anatomical regions of interest.

INTERVENTIONAL APPLICATIONS

Ultrasound-guided interventional procedures can range from quickly performed procedures requiring minimal patient cooperation and sedation to more prolonged, difficult cases requiring controlled breathing, patient cooperation, and adequate pain control. The most commonly performed US-guided interventional procedures include percutaneous biopsies of organs or masses and fluid aspirations or drainages, all of which can be performed in almost any body region (Fig. 10.3).

ULTRASOUND-GUIDED MASS BIOPSIES

Pain from US-guided needle biopsies varies with the anatomic site and depth of needle penetration. Unlike catheter placements,

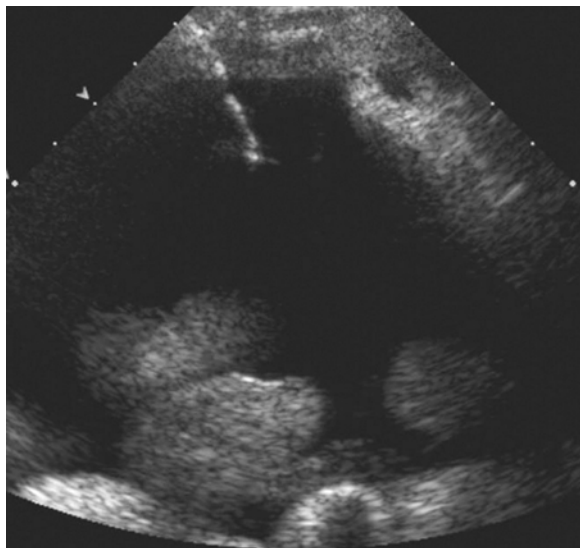


FIGURE 10.3. Ultrasound-guided paracentesis. The percutaneously inserted needle is seen as a thin linear bright (echogenic) structure within the ascites. Loops of small bowel are seen in the inferior aspect of the image and are easily avoided.

the level of sedation required tends to be relatively constant throughout the procedure.

Fine-needle aspiration biopsy (FNAB) is a minimally invasive and safe method for obtaining a tissue diagnosis. Fine-needle aspiration biopsy is usually performed with 20- to 25-gauge needles. The procedure can be performed with syringe aspiration or capillary action techniques. While these techniques usually obtain cellular material suitable for cytopathology analysis, these techniques can, on occasion, obtain tissue cores suitable for histopathology analysis as well. Large-needle biopsies, commonly using spring-loaded side-cutting needles, are also commonly employed and are more likely to yield an actual core of tissue for histopathology evaluation than FNAB techniques. Although spring-loaded core biopsy devices are available in sizes as small as 22 gauge, most such biopsies are performed with 18-gauge or larger systems. Although the diagnostic yield attained from core biopsies may be higher than FNAB,⁵⁰ the potential for complications may be increased.

Ultrasound-Guided Liver Parenchymal Biopsy

Liver parenchymal biopsies are usually performed on an outpatient basis with core biopsy devices. Parenchymal biopsies can be performed to evaluate for transplant rejection, treatment response, abnormal liver function tests, and unexplained jaundice. For hepatic parenchymal biopsies an 18-gauge biopsy is usually obtained. Relative contraindications to the procedure include uncorrectable coagulopathy, with INR >1.5 and platelets less than 50,000/ μ l.⁵¹ Patients with chronic liver disease may have persistent abnormal coagulation parameters; these cases should be evaluated on a case-by-case

basis. The presence of ascites is itself not a contraindication to liver biopsy. The procedure is usually performed with local anesthesia and intravenous sedation. If the right lobe is targeted, the patient can be scanned through an intercostal or subcostal approach in the right anterior oblique position. If the left lobe is targeted, an epigastric approach in the supine position can be used. With interventions performed near the diaphragm as in liver biopsy, intermittent breath holding is helpful for needle visualization and to prevent inadvertent injury to the target organ or surrounding structures. Even though it is important to maintain patient comfort during the procedure, oversedation can interfere with the patient's ability to follow breathing instructions. Potential complications include bleeding, infection, and bile duct injury. Rare complications may include gallbladder injury, pneumothorax, or bowel perforation.

Ultrasound-Guided Renal Procedures

Both renal parenchymal and renal mass biopsies can be performed with US guidance. To decrease the risk of bleeding during parenchymal biopsies, a subcostal, posterolateral approach is preferred for targeting of the renal cortex in the upper or, more commonly, lower pole of the kidney.⁵² Ultrasound can also be used to help guide percutaneous renal abscess drainages or facilitate percutaneous nephrostomy access. Accessing the renal collecting system allows for percutaneous nephrostomy tube insertions, ureteral interventions, stone manipulations, or even for fiberoptic endoscopy.

Renal interventions require local anesthesia administration and often intravenous sedation. Reproducible breath holding is important because the location of the kidney is dependent on the phase of respiration. Complications may include subcapsular or perinephric bleeding, hematuria, urinoma, and infection.⁵² With renal biopsies performed with large needles, there is a small risk of arteriovenous fistula formation. These patients can present with renin-mediated hypertension induced by relative hypoperfusion distal to the fistula. Preexisting hypertension is thought to be a risk factor for developing a fistula following a renal biopsy. Arteriovenous fistulas can also present with hematuria, renal colic secondary to blood clots, or hypotension from bleeding. Large fistulas have been reported to cause congestive heart failure.

TRANSRECTAL ULTRASOUND APPLICATIONS

Endocavitary transducers with biopsy guide attachments can be used for transrectal biopsies and drainages. One of the most common applications with this approach is the prostate biopsy. The patient is placed in a left or right lateral decubitus position, which allows for easy probe insertion and manipulation. Pain encountered during the procedure can increase patient anxiety and result in pelvic muscle contraction, making the procedure more difficult. Administration of a local anesthetic in the periprostatic margins blocks the capsular nerve fibers.⁵³ Potential injury to the neurovascular

bundles is reduced with real-time needle visualization. Ultrasound-guided prostate biopsy has frequent minor and rare major complications. Immediate complications include hematuria (most common complication), rectal bleeding, and vasovagal episodes. Delayed complications, which may occur up to 7 days after the biopsy, include persistent hematuria, dysuria, vague pelvic discomfort, hematospermia, and hematochezia.

Transvaginal Ultrasound Applications

Endovaginal US guidance is a useful alternative for needle biopsies of pelvic tumors if the transabdominal route is not feasible or safe. A transvaginal route may be less painful and difficult than a posterior approach through the sacroscliac notch, where multiple nerves and vessels are located. The transvaginal route is also an option for needle aspiration of pelvic fluid collections because they are often in close proximity to the vaginal fornices. Fluid collections, including sterile fluid collections (urinomas, seromas, lymphoceles, endometriomas, hemorrhagic cysts, loculated ascites, and peritoneal inclusion cysts), should generally be aspirated completely to minimize the risk of secondary infection.⁵⁴

The lithotomy position is employed and intravenous antibiotics may be given for prophylaxis. The procedure can be painful as the needle passes through the vaginal wall musculature, particularly if dilators and catheters are placed. For this reason, transvaginal catheter drainages are uncommonly performed. Intravenous sedation and analgesia are desirable. An 18-gauge needle of adequate length can be inserted through the attached needle guide and local anesthetic can be applied before fully traversing the vaginal wall.⁵⁴ Complications can include bleeding and bowel injury.

Ultrasound-Guided Thoracentesis

Ultrasound is capable of detecting as little as 3 ml of fluid in the pleural space; however, even with US guidance, thoracentesis is usually indicated and more safely performed when larger amounts of fluid are present.⁵⁵ Ultrasound guidance is particularly helpful in targeting small or loculated effusions or when previous attempts without imaging guidance have failed.

The ideal position for the patient is sitting upright and leaning slightly forward. A lateral decubitus or supine oblique position can be used in patients who cannot sit upright. Local anesthesia often suffices for these procedures and is applied from the skin to the parietal pleura. For anxious or uncooperative patients or when technical challenges are anticipated, intravenous sedation or even general anesthesia may uncommonly be required. Potential complications include re-expansion pulmonary edema, pneumothorax, bleeding, lung or diaphragm injury, and even injury to upper abdominal viscera such as the liver or spleen. These risks are lower when using US guidance as compared to localization by physical examination.⁵⁵

Ultrasound-Guided Paracentesis

Ultrasound-guided paracentesis is a common procedure performed for both diagnostic and therapeutic indications. Complicated ascites may demonstrate echogenic debris or septations and may be difficult to completely drain. Relative contraindications include uncorrectable coagulopathy, an acute abdomen requiring immediate surgery, numerous intra-abdominal adhesions, abdominal wall cellulitis at the site of puncture, and pregnancy. Although large volumes of ascites, up to 10 l, may be safely drained in many patients, lower volumes should be removed in patients with hypotension, hypoalbuminemia, or tenuous cardiovascular status. Albumin can be infused intravenously prior to paracentesis when appropriate.⁵⁶

Desirable preprocedure coagulation parameters at many institutions are similar to those described previously for thoracentesis.⁵¹ Local anesthesia applied from the skin to the peritoneal layer often suffices for these procedures with only the exceptional patient requiring sedation or general anesthesia. The patient is typically placed in a supine position. Variations in positioning may facilitate the accumulation of a larger pocket of fluid in a safely accessible peritoneal location. Care is taken to avoid abdominal viscera and inferior epigastric vessels during needle/catheter placement. Real-time US visualization during needle placement is most helpful when targeting small or loculated collections and when critical structures are in close proximity to the fluid collection.

This is a relatively safe procedure with a low incidence of complications. Potential complications include persistent fluid leak from the puncture site, abdominal wall hematoma, and introduction of infection. Complications such as perforation of bowel and major blood vessel laceration are reduced with real-time image guidance.⁵⁷

Ultrasound-Guided Needle Aspiration and Catheter Drainage of Abscesses

Percutaneous catheter drainages of abscesses yield high success rates with relatively low complication rates and are often preferred to open surgical drainage.⁵⁸ Percutaneous abscess drainage is often performed for definitive management but also used as a temporizing measure in some cases prior to surgery.^{59,60} Surgical drainage is still performed in cases where safe percutaneous access is not available and in cases where fluid collections are expected to be too viscous or multiloculated for effective percutaneous drainage. Similarly, when underlying conditions such as tumor, large-caliber bowel perforation, bowel necrosis, pancreatic necrosis, and other situations mandate surgical intervention, percutaneous drainage may not be appropriate.

Ultrasound is often an excellent method for detecting abscess collections in the neck, extremities, abdomen, and pelvis. Pulmonary abscesses may even be visible if they are contiguous with the pleura such that no air-containing lung intervenes. Once the collection is located with US, a pathway is selected for approach. Usually the shortest distance that

avoids structures such as bowel or large vessels is chosen. Uninvolved solid organs are usually avoided but may be traversed if necessary and depending on the procedure. Traversing more than one body cavity is avoided when possible in order to avoid cross-contamination. If the collection is small or only a diagnostic sample is needed, US-guided needle aspiration may suffice. For larger collections and commonly for therapeutic purposes, percutaneous catheter drainage may be indicated.

Local anesthesia may suffice for superficial fine-needle aspiration procedures, just as with simple paracentesis or thoracentesis procedures. On the other hand, needle aspirations of deep collections and in particular catheter drainage procedures typically require intravenous sedation. Monitored anesthesia care and general anesthesia are rarely needed. For the interventional radiologist, having a relaxed and comfortable patient can mean the difference between a rapid, uncomplicated procedure and a prolonged, difficult procedure. For procedures near the diaphragm, such as liver abscess drainages, respiratory motion can also be a significant issue. Sedation may be helpful in decreasing the respiratory rate and tidal volume, resulting in less motion of the target organ or region. On the other hand, having the patient adequately sedated but not oversedated will provide the advantage of being able to have the patient suspend respirations when needed during critical points in the procedure. For procedures away from the diaphragm, such as pelvic or extremity drainages, respiratory motion is usually not a factor. Generally, the most painful portions of catheter drainage procedures are the serial dilation and catheter insertion steps. Certain access routes are more likely to cause significant pain for the patient, including approaches through the sacrosclatic notch for deep pelvic fluid collection drainages.

Ultrasound-Guided Percutaneous Cholecystostomy

Ultrasound-guided percutaneous cholecystostomy is generally reserved for critically ill patients with acute cholecystitis who cannot undergo surgical cholecystectomy. As the patient's condition improves, definitive treatment with cholecystectomy can be performed. In acalculous cholecystitis, percutaneous drainage may be adequate alone. A transhepatic approach is preferred for gallbladder drainages in order to reduce the risk of bile leakage into the peritoneum. Complications of percutaneous cholecystostomy include bile peritonitis, hemobilia, gallbladder perforation, and vagal effects due to catheter placement.⁶¹ A mature fibrous tract should be allowed to form along the peritoneal catheter tract prior to catheter removal in order to decrease the risk of bile peritonitis. This may require leaving the catheter in place for 4–6 weeks.⁶² Percutaneous cholecystostomy may require an intercostal approach and will most commonly traverse the liver capsule in addition to entering the gallbladder. Small amounts of bile may leak into the peritoneum. When this occurs, bile is irritating to the peritoneum and can cause considerable pain. Adequate sedation and analgesia are therefore important; however, some of these patients may already be in the intensive care unit, medicated and intubated.

Ultrasound Guidance in Regional Anesthesia

Ultrasound guidance can significantly improve the quality of nerve blocks in many types of regional anesthesia.⁶³ Ultrasound may allow for direct visualization of the nerve or surrounding anatomic structures and even of the local anesthetic solution during injection. It is important to ensure that the local anesthetic is administered around the nerve structures for successful regional anesthetic blocks.⁶³ Most nerve block procedures require high-frequency transducers in the range of 10–14 MHz. The majority of peripheral nerves can be visualized over their entire course and are described to have a fascicular pattern with ultrasound.⁶³ Many potential complications can be avoided with US guidance as compared to traditional block techniques which rely on anatomic landmarks.⁶⁴ In particular, complications such as intraneuronal or intravascular injection are reduced with US guidance. A more complete description of specific nerve blocks is available.⁶³

Ultrasound-Guided Vascular Interventions

Vascular access can be challenging in volume-depleted or large patients. Intravenous drug users or patients with aberrant venous anatomy may also present difficulties in vascular access. This can be particularly problematic in the emergency setting or critical care setting. Traditional vascular access relies on anatomic landmarks, arterial palpation, or visible pulsations. These clinical clues, for example, during jugular vein access, can be limited or difficult to assess, resulting in multiple needle passes and complications such as pneumothorax or hemothorax. Ultrasound guidance provides real-time visualization of the needle and vessel and can distinguish between arteries and veins, allowing for successful first-attempt access and shorter procedure times. Veins such as the basilic, cephalic, and subclavian veins may be difficult to see or access without US guidance.

Ultrasound can also be used for percutaneous embolization of pseudoaneurysms.⁶⁵ Traditionally, the management of pseudoaneurysms has been surgical resection. Ultrasound embolization is relatively safe, simple, and quick to perform. Pseudoaneurysms can be occluded with transducer-applied direct pressure to interrupt blood flow through the pseudoaneurysm neck. This method, however, can take 30–60 minutes for successful completion. An alternative method is percutaneous US-guided thrombin injection into the pseudoaneurysm sac. Thrombosis is usually observed within seconds, and complications related to this technique are low.

Ultrasound can be used to guide many other types of interventions, which are beyond the scope of this chapter. Fine-needle aspiration biopsy of thyroid nodules and large-needle breast lesion biopsies are common procedures usually performed on an outpatient basis. Ultrasound can be used to facilitate and assist in brachytherapy seed placements for pelvic neoplasms and to guide uterine dilatation and curettage procedures.⁶⁶ In conclusion, US is a versatile and practical imaging modality for use in a wide range of imaging-guided interventional procedures.

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1 | 1 | Interventional Neuroradiology

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Interventional neuroradiology — also known as endovascular neurosurgery — evolved as a new medical subspecialty in the 1980s and focuses on the treatment of cerebrovascular, head and neck, and spinal diseases by using endovascular or other percutaneous routes to reach the target. Rapid technical improvements in each successive generation of medical devices and materials (catheter technology, coils, and stents) brought interventional neuroradiology to the forefront in the management of aneurysms and various vascular malformations.

In 1927, Egas Moniz, professor of neurology in Lisbon, Portugal, pioneered the radiographic imaging of the intracranial vasculature in a living human subject.¹ The only approach at the time was Dandy's method of introducing air into the ventricular system to localize space-occupying lesions of the brain by the distortion of the ventricles.² Egas Moniz injected bromide into the surgically exposed carotid artery of a 48-year-old patient with postencephalitic Parkinson disease and took angiographic images.¹ However, the patient died 8 hours later from carotid thrombosis. The field of neuroangiography has since tremendously expanded as a result of improved imaging capabilities, technical equipment, and safer contrast media. In the era of noninvasive imaging such as computed tomography (CT) angiography and magnetic resonance (MR) angiography, cerebral angiography still remains the gold standard for visualizing the cerebral vasculature given its unique high spatial resolution, high-speed real-time image acquisition, high-resolution road mapping, and indispensable information on hemodynamics. Cerebral angiography carries a very low risk when performed by experienced neurointerventional staff.³⁻⁵ Besides the technical competences, a thorough understanding of pertinent anatomy and pathology is essential. The indications must be reviewed in light of all previous imaging studies, prior surgical procedures, and evolution of the anatomic pathology. Excellent diagnostic skills with noninvasive neuroimaging modalities are necessary to identify the presence of cerebrovascular diseases, identify potential candidates for neurointerventional procedures, provide routes of endovascular access, and to define the scope of treatment options.

NEURORADIOLOGY TECHNIQUES

Digital Subtraction Angiography and Road Mapping Technique

In angiography, images are acquired by exposing an area of interest with time-controlled X-rays while injecting contrast

medium into the blood vessels. To remove the overlying structures besides the blood vessels in this area, first a mask image is acquired before contrast injection that is then subtracted from subsequent images obtained during and after contrast injection. By doing so, contrast reduction from bone and soft tissues surrounding the vasculature is vastly reduced and vessel detail greatly enhanced (Fig. 11.1). Digital subtraction angiography (DSA) requires that the patient ideally remains almost motionless during image acquisition. Roadmap fluoroscopic imaging has allowed interventional neuroradiologists to superimpose angiographic images of the vascular anatomy on the live fluoroscopic image by injecting a small amount of contrast medium during acquisition of a mask image to enable safe device navigation (Fig. 11.2). Roadmap imaging in particular is easily degraded by patient movement.

ESSENTIALS OF RADIATION PROTECTION AND X-RAY IMAGE PRODUCTION

A basic understanding of radiation physics is essential to minimize the neuroanesthesia team's radiation exposure. Most nonpatient exposure is the result of scattered radiation produced as the primary X-ray beam passes from the tube through the patient and into the image intensifier. A common cause of exposure of anesthesiologists to the primary X-ray beam is reaching into the beam without alerting the operator. During fluoroscopy, the interventionalist is looking at the video monitors and will not see the anesthesiologist approaching the patient. Therefore, the anesthesiologist and interventionalist should coordinate any adjustments on the patient, his or her leads, and vascular accesses during nonfluoroscopy periods whenever possible. During DSA runs, both the anesthesiologist and interventionalist should step out of the neuroangiographic suite whenever possible. Hand injection technique requires that the operator stays near the patient to inject the contrast in a manually controlled fashion in unfavorable vascular anatomies during DSA. The benefit of hand injections in lieu of using a power injector is the immediate feedback and ability to stop the injection in cases of catheter movement or malposition. The anesthesiologist, however, can step away from the table, therefore reducing his or her exposure to scattered radiation. This might not be justifiable in exceptional cases such as unstable patients that require continuous attendance. Protective devices such as pull-in and ceiling-mounted lead acrylic window shields and lead aprons

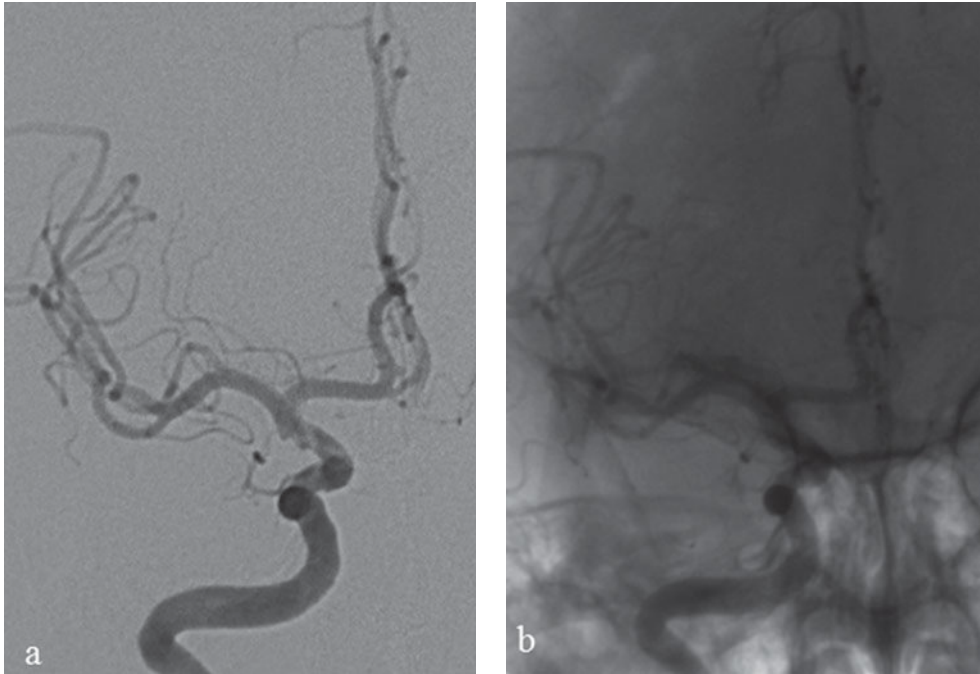


FIGURE 11.1. Right internal carotid artery injection (frontal plane) in a 38-year-old female patient with (a) and without (b) computer-generated subtraction. The vascular details become apparent during injection once the bony anatomy and soft tissue are digitally subtracted.

as well as increasing the distance from the primary beam should be used to protect from radiation exposure.⁶⁻⁹

CONTRAST MEDIUM AND SIDE EFFECTS

Acute adverse reactions occur in 5%–8% of patients in whom conventional, ionic, higher osmolality contrast agents are administered intravascularly.¹⁰ Nonionic contrast media (such as Omnipaque, Ultravist) are usually used in neuroangiography because of their lower osmolality and lesser side effects. Adverse reactions to intravascular contrast media are generally classified as either anaphylactoid (idiosyncratic) or nonidiosyncratic.¹⁰ Anaphylactoid reactions occur independently of the dose or concentration of the agent. Their acuity and symptoms (vomiting, hot flushes, urticaria, pruritus, and diaphoresis) typically make them appear as allergic or hypersensitivity reactions; however, they do not result from an antigen–antibody interaction. Nausea/vomiting and scattered hives are usually minor, self-limited reactions. They should, however, be watched closely for other systemic symptoms because they might indicate early signs of a more severe reaction. Severe reactions are laryngeal edema, bronchospasm, pulmonary edema, hypotensive shock, respiratory arrest, or convulsions. For bronchospastic reactions without hypotension, oxygen (3 l/min), 0.1–0.2 ml (0.1–0.2 mg) of 1:1000 solution of epinephrine subcutaneously or inhaled bronchodilators are recommended.¹⁰ In severe anaphylactoid reactions,

oxygen (3 l/min), intravenous (IV) fluids (normal saline or Ringer’s solution), 0.1 mg epinephrine of 1:10,000 solution IV, 50 mg diphenhydramine IV, and 200 mg hydrocortisone IV are recommended. In patients with a history of previous radiocontrast media reaction, pretreating with prednisone and diphenhydramine reduces the risk to 9%.¹¹ Using low-osmolality radiocontrast media further reduces the risk to 0.5%.¹¹ In patients with a history of mild to moderate contrast reactions, the American College of Radiology recommends a regimen of prednisone 50 mg PO 13 hr, 7 hr, and 1 hr prior to contrast administration as an acceptable premedication regimen.¹²

Chemotoxic reactions are due to specific physiochemical effects of the injected agent on the organ or vessel it perfuses. They are directly dependent on the dose and concentration of the administered agent. Patients should be screened for the presence of clinically significant conditions (e.g., renal dysfunction, cardiovascular disease, seizures) that may place them at higher risk. In such patients, alternate diagnostic imaging modalities that do not require intravascular administration of a radioopaque contrast medium should be investigated first. If found inconclusive and administration of contrast medium is necessary, a lower osmolality agent should be used. From et al. showed that contrast-induced nephropathy is associated with increased mortality. This risk is higher in patients in whom the contrast medium is administered intravenously as opposed to intra-arterially.¹³ For patients with renal insufficiency, prehydration with sodium bicarbonate (130 mEq/l IV solution at 3.5 ml/kg bolus over 1 hour,



FIGURE 11.2. Left internal carotid artery injection in frontal (*a*) and lateral (*b*) plane in an 83-year-old female patient who presented with a subarachnoid hemorrhage from a ruptured left-sided posterior communicating artery aneurysm measuring 11 x 8.9 mm with a daughter dome at its posterior and superior aspect representing the likely rupture site (*c*, arrow). The patient also had a medial variant clinoid aneurysm on the same side. Once the best trajectory was chosen, a roadmap (*c*) was used to guide the catheter to the proper location within the blood vessel so that coils can be deployed to treat a cerebral aneurysm. Complete obliteration of the aneurysm was confirmed on postembolization angiography (*d*, frontal; *e*, in lateral plane; *f*, roadmap with * indicating catheter tip and ** coils).

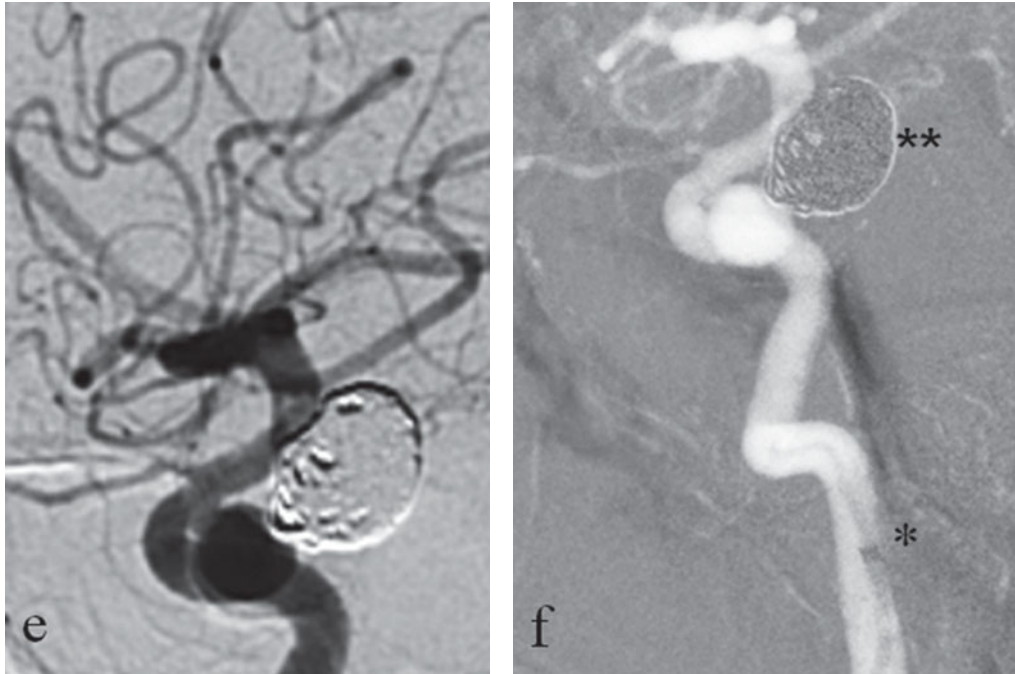


FIGURE 11.2. *Continued.*

then 1.2 ml/kg per hour during the procedure and for 6 hours after the procedure) and administration of N-acetylcysteine (600 mg orally at 24 and 12 hours before and after the procedure) can prevent contrast-induced nephropathy.^{14,15}

NEURORADIOLOGY-NEUROANESTHESIA TEAM: GENERAL CONSIDERATIONS

Whereas diagnostic cerebral angiography is generally performed using intravenous sedation or local anesthesia only, many of the interventional procedures require general anesthesia given their longer duration and the sensitivity of digital subtraction angiography and roadmap imaging to patient motion rather than significant pain associated with these procedures. However, certain procedures such as the retrieval of an intracerebral intravascular clot using the MERCI device can be very painful and potentially result in sudden increases in heart rate and blood pressure. The operator should alert the neuroanesthesiologist prior to such maneuvers. Certain procedures, such as carotid stenting or tumor embolizations, benefit from the patient being kept awake and cooperative to evaluate neurological function throughout the procedure unless the risk of patient injury, such as arterial dissection, or inability to visualize the embolization process safely because of patient motion rises above a safe threshold. Many other procedures (e.g., kyphoplasty) can be performed safely using either method, and the choice of anesthesia relies highly on operator and patient preference and has to be decided on an individual basis.

To obtain a high-quality DSA cerebral angiogram, the patient must be able to refrain from moving, swallowing, or breathing for the duration of 10–15 seconds during each injection of contrast. Most patients can undergo diagnostic cerebral angiography without any sedation or with minimal to moderate sedation using fentanyl (25–200 μ g) and midazolam (0.5–2 mg).

Uncooperative patients (i.e., any patient unable to refrain from moving, swallowing, or breathing on command because of impaired level of consciousness or neurological deficits such as global aphasia or neglect) may require general anesthesia and paralytics to adequately control movement and respiration. Particularly for the performance of urgently required cerebral angiography, such as for evaluation of subarachnoid hemorrhage, the threshold for use of general anesthesia will be low because diagnostic angiography in such cases is often followed by an intervention to treat the offending source of hemorrhage. In the absence of a neurological exam in the anesthetized patient, a bolt or external ventricular drainage should be in place in patients with radiographic and clinical evidence of or potential for increased intracranial pressure (ICP). This can be easily performed in the angiography suite. This is particularly important in the angiography suite because the patient has to be positioned supine with no head elevation to stay in an isocenter position within the biplane radiographic environment. This may have a negative effect on the ICP and require additional pharmacological measures other than cerebrospinal fluid drainage to help with ICP control.

Neuropsychological monitoring allows for the assessment of the functional state of specific regions in the brain throughout

a procedure, and it provides an indirect measure of regional ischemia while the patient is under general anesthesia. These techniques include electroencephalography (EEG), somatosensory or motor evoked potentials, as well as brainstem evoked potentials and are routinely performed in carotid endarterectomy, cerebrovascular surgery, and complex spinal surgery. Liu et al. described its use also in 35 patients undergoing 50 endovascular procedures (balloon test occlusion [$n = 19$], coil embolizations [$n = 22$], and permanent vessel occlusion [$n = 9$]).¹⁶ He reported an alteration in management in 14% of the patients based on changes in EEG, somatosensory evoked potentials, and/or brainstem auditory evoked potentials. Neuropsychological monitoring is relatively insensitive in detecting ischemic changes in the cerebellum or posterior cerebral artery territories. Other limitations include confounding anesthesia-related effects that may mimic cerebral ischemia.¹⁷ The implications for the neuroanesthesiologist are to use opioids intraprocedurally for analgesia and to avoid inhalational agents for their negative impact on EEG activity and evoked potentials.

As in the surgical operating room, to bring the case to a safe conclusion, both the neuroanesthesiologist and the neurointerventionalist need to have a good understanding of each other's procedural requirements within the neuroangiographic suite. Depending on the neuroangiographic suite layout, the neuroanesthesiologist will have to adapt the usual setup to this unique setting. The position of the anesthesiologist and anesthesia equipment relative to the patient is altered by the confines of the room and angiographic apparatus (Fig. 11.3). Due to the size and proximity of the neuroangiography apparatus to the head, access to the patient is more limited than in the regular operating room. Modern dedicated neuroangiography systems have simultaneous biplane (i.e., anteroposterior and lateral) imaging using paired X-ray tubes and image intensifiers that almost completely surround the patient's head and require large degrees of freedom of motion around the head allowing for projectional adjustments. In addition, the relatively fixed positions of the interventionalist and the videofluoroscopy monitors further limit access to the patient. Although unrestricted direct access to the patient's head and airway is generally desired by the neuroanesthesiologist, this is clearly not possible during most open or endovascular neurosurgical procedures. Whenever general endotracheal anesthesia is used, ventilator tubing and other support lines must be carefully positioned and extended not to get accidentally caught during movements of the fluoroscopy equipment. Although adjustments can always be made and access to the airway obtained, this usually requires temporary withdrawal of the X-ray machines from the head. This may not matter during noncritical parts of a procedure, but it could cause serious interference during more critical parts of an intervention, when continuous visualization of the anatomy is required. At our institution, the dedicated biplane neuroangiography suites allow best access to the patient, when the neuroanesthesiologist and the ventilation machine are located to the patient's left side to minimize interference with the interventionalist and the imaging system (Fig. 11.3). Anesthesia is induced before imaging equipment is brought



FIGURE 11.3. The GE Innova biplane angiography suite at the authors' facility provides images in two planes at the same time, thus allowing better visualization, fewer injections of contrast, and shorter procedure time. The technology features rotational angiography and 3D reconstruction, and it is also capable of producing cross-sectional images like a computed tomography (CT) scan. The neuroanesthesiologist and the ventilation machine are best located to the patient's left side given the confines of the angiography apparatus.

into its working position, which allows unrestricted, direct access to the patient during induction. After the airway has been secured and the patient stabilized, the imaging equipment is brought into its working position. The interventionalist on the patient's right side must assist the neuroanesthesia team to position equipment and arrange convenient airway and vascular access. While approaching the arch with the catheter, the operator can easily verify the correct position of the endotracheal tube and central venous lines and communicate this with the anesthesia team.

During monitored (MAC) or standby anesthesia care cases, rapid airway access is more critical than it is in cases performed under general endotracheal anesthesia because the patient's airway is not protected. In these cases, the neuroanesthesiologist's need for immediate airway access takes precedence and requires good communication with the interventionalist.

Patient Monitoring

Once the patient is brought to the neuroangiography suite and placed in the supine position, an 18- or 20-gauge intravenous line is started. Continuous monitoring of heart rate and

rhythm, blood pressure, breathing rate and pattern, as well as peripheral oxygen saturation are mandatory for every procedure whether under local anesthesia, intravenous sedation, monitored anesthesia care, or general anesthesia. An arterial line is inserted for procedures requiring strict blood pressure monitoring and control, including patients with acute subarachnoid hemorrhage (SAH) or cardiovascular instability. In acute stroke patients, time is of essence, and although desirable, insertion of a radial arterial line may cause an unnecessary delay for the revascularization attempt. Blood pressure control in both directions will frequently have to depend on the skillful administration of vasoactive medication based on frequently updated cuff pressures. Invasive blood pressure measurement including mean arterial pressure (MAP) and ICP monitoring via a bolt or an external ventricular drainage (EVD) is mandatory in patients with raised ICP to monitor cerebral perfusion pressure (CPP). That is of paramount importance in patients with high-grade SAH during aneurysm embolization or vasospasm therapy. If the ICP rises, the level of the EVD and thereby the amount of drained cerebrospinal fluid has to be adjusted in close coordination with the operator. If ICP cannot be controlled to maintain adequate cerebral perfusion in the angiography suite setting, the procedure may have to be aborted to allow for optimized ICP management, including head elevation, a simple but highly effective maneuver.

Vascular Access Sites

For a right-handed operator, the right common femoral artery is the preferred access point. However, both groins are prepped and draped in case the right common femoral artery cannot be accessed for anatomic reasons or if bilateral access is required. In case the anesthesiologist cannot put in an arterial line either because of limited time in acute stroke cases or for anatomic reasons, the operator can introduce a sheath that is 1 French larger in size than the intended one, which may allow transduction of the blood pressure via the femoral sheath. This increases the risk of injury to the femoral artery, particularly in stroke cases, in which the use of already very large access sheaths (9 French) is common. Complications of the transfemoral approach include groin hematoma, retroperitoneal hemorrhage, arteriovenous fistula and pseudoaneurysm formation, dissection, and femoral nerve injury.¹⁸ The transbrachial approach obviates the need for prolonged bed rest and eliminates the risk of occult hematoma formation. This alternate approach is sometimes necessary when transfemoral access is impossible because of peripheral vascular disease or aortic occlusion (Fig. 11.4). For diagnostic catheterization, a 4 or 5 French sheath is used, whereas 6 or 7 French sheaths are routinely used for embolizations. For revascularization procedures, 8 or 9 French sheaths are required. Once the sheath is in place, it is connected to continuous pressurized heparin saline flush (3000 IU of heparin in 1000 ml of normal saline). Access site hemostasis following sheath removal can be achieved by simple or assisted manual (FemoStop System) compression or by the use of a closure

device (Perclose, VasoSeal). Due to the increased risk of access site complications from the use of such devices,¹⁹ our preferred method is manual compression whenever possible. The presence of peripheral pulses distal to the arterial puncture site should be ascertained before the patient leaves the neuroangiographic suite and monitored afterwards.

The timing and method of sheath removal needs to be discussed with the anesthesia team because this may impact on the postextubation care of the patient, who must stay in a horizontal position for a prolonged period of time.

Anticoagulation

To prevent embolic complications, interventions are performed under systemic heparinization that should be initiated after sheath placement. An 80 IU/kg loading dose is administered to target an activated clotting time (ACT) of two or three times baseline. The ACT is checked in intervals during the procedure and additional heparin boluses are given to ensure targeted anticoagulation. At the end of the procedure, the patient's anticoagulation is allowed to correct spontaneously, and the access sheath is removed at a later time when coagulation parameters have reached a safe level.

COMMON INTERVENTIONAL NEURORADIOLOGY PROCEDURES AND NEUROANESTHESIA CONSIDERATIONS

Endovascular Management of Cerebral Aneurysms

The permanent obliteration of aneurysms and their exclusion from the circulation is the main goal of aneurysm therapy (Fig. 11.2d,e). The choice of the appropriate endovascular technique depends on aneurysm size, location, and characteristics.

Intra-Aneurysmal Embolization

Direct *intra-aneurysmal embolization* of the aneurysm with preservation of the parent artery aims at complete exclusion of the aneurysm from the circulation analogous to surgical clip placement. In 1995, the Guglielmi Detachable Coil (GDC) (Target Therapeutics, Inc., South San Francisco, CA) achieved approval of the U.S. Food and Drug Administration for aneurysm *coiling*. This coil consists of soft platinum that is attached to a microguidewire by a thin, stainless steel junction. If the coil conforms to the confines of the aneurysm in the desired fashion, it is released by passing a tiny positive current through the guidewire. After electrolysis of the junction, the guidewire is withdrawn while the coil is left within the aneurysm. Most aneurysms require placement of several progressively smaller coils to achieve complete obliteration (Fig. 11.2). Since the original release of the GDC, numerous other coil designs from other manufacturers have entered the market while the basic principle remained the same. In a landmark study, endovascular treatment with coils was found to be associated with better

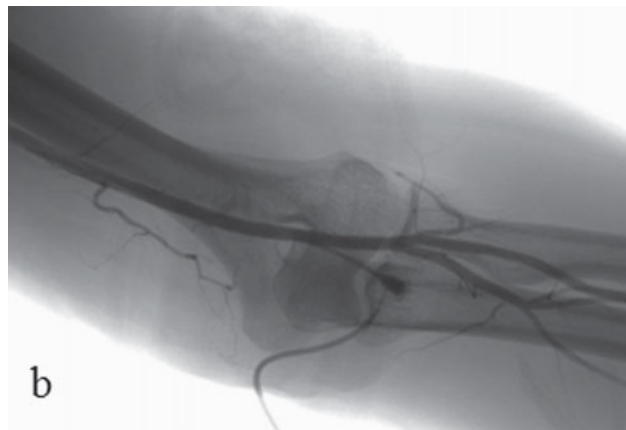
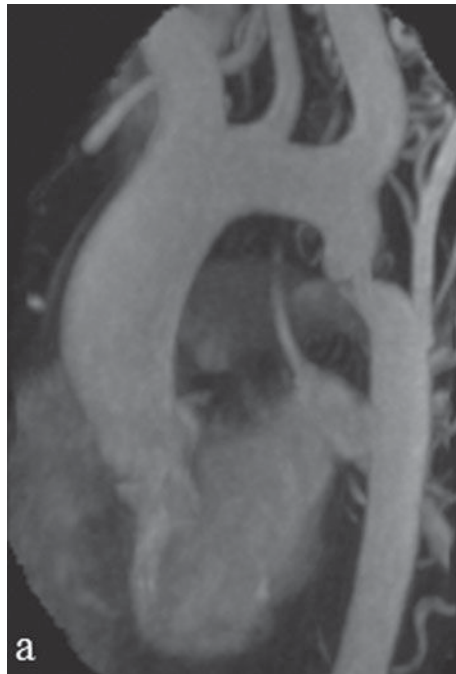


FIGURE 11.4. Coronal maximum intensity projection (MIP) (a) of magnetic resonance angiography (MRA) in a 51-year-old male patient with episodic left arm tingling and numbness. A cerebral angiography was requested to evaluate the moya-moya-like pattern of his cerebral arteries and the configuration of the basilar tip aneurysm seen on MRA of the brain. Initial angiography was unsuccessful due to the inability to navigate from the descending aorta to the arch. An MRA of the chest revealed coarctation of the aorta. In a second attempt, the left brachial artery was catheterized (b), and cerebral angiography was performed.

patient outcomes compared to surgical clipping in patients having suffered a subarachnoid hemorrhage from the aneurysm.²⁰ The prerequisite for aneurysm coiling without assist techniques is a relatively small aneurysm neck that allows retention of coils without encroachment on the parent artery. Compaction of coils with time and regrowth of the aneurysm are potential limitations of the technique. Although controversial, cranial neuropathies due to aneurysm pressure may be less likely to improve after coiling than clipping.

The endovascular treatment of wide-necked aneurysms has been revolutionized by the introduction of highly flexible self-expanding nitinol stents that can be navigated into the

tortuous cerebral circulation. The stent implantation requires premedication with aspirin (325 mg/day) and clopidogrel (75 mg/day) for 5 days before treatment and at least 12 weeks thereafter. Coil embolization through the stent struts can follow stent placement immediately or in a second stage after endothelialization of the stent (Fig. 11.5). As the required anticoagulation and antiplatelet therapy carry an excessively high risk for hemorrhagic complications, the stent-assisted technique is usually limited to unruptured aneurysms.

Complications during coil embolization include aneurysm rupture or thromboembolism. Aneurysm rupture during embolization is more common in recently ruptured and

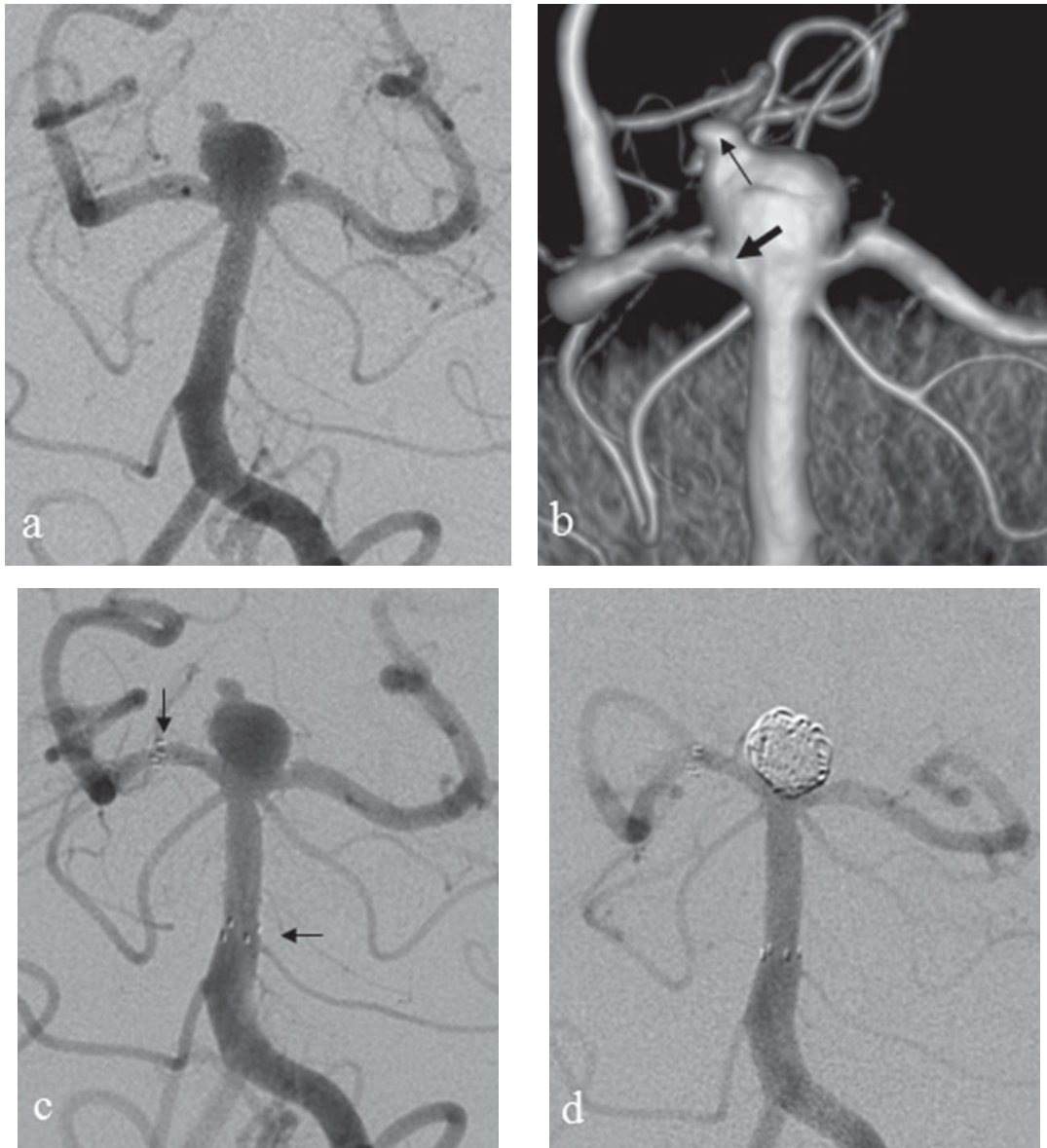


FIGURE 11.5. Left vertebral artery injection (frontal plane: *a*, before stent placement; *b*, after 3D reconstruction; *c*, after stent placement; *d*, after coiling) in a 68-year-old female patient with known basilar tip aneurysm that had been followed by magnetic resonance angiography (MRA) for 7 years and recently documented aneurysm growth. This broad-based, 7.4 x 7 mm basilar tip aneurysm (*b*) partially incorporated the right P1 segment (big arrow) and had a daughter dome (small arrow). A Neuroform III stent 3.5 x 20 mm was positioned in the right P1 and midbasilar segment bridging the aneurysm neck, thus preventing coil protrusion into the parent vessel during coil embolization 6 weeks later (arrows indicate proximal and distal stent markers).

small aneurysms.²¹ If a rupture is suspected, heparin should be immediately reversed using protamine sulphate (1 mg per 100 IU heparin) and an initial downward adjustment of the blood pressure by the anesthesiologist. The interventionalist will attempt to continue with obliteration of the aneurysm sac as quickly as possible. Usually, continued coiling results in cessation of the bleeding. If this fails, the outcome is likely to be catastrophic. Thromboembolic complications are typically platelet-derived events and occur during aneurysm coiling in

approximately 3% of cases, resulting in a permanent neurological disability in 1.7%–5% of the procedures.²² Heparin is commonly used as an anticoagulant in the prevention and treatment of thromboembolism during the procedures. However, heparin has almost no effect on platelet aggregation and therefore may not always be able to prevent these complications. Once a thromboembolic complication has occurred and been recognized, various pharmacological agents or mechanical techniques may be used to dissolve or remove the clot.

This includes the use of additional heparin, or intra-arterial administration of a thrombolytic or antiplatelet agent.²³ For example, Abciximab (Rheopro) administered locally (2–10 mg) at the site of the thrombus has been successfully used to treat thromboembolic complications during coiling, even in cases with ruptured aneurysms.²⁴ Eptifibatid (Integrilin) is an alternative and binds to the platelet receptor glycoprotein (GP) IIb/IIIa of human platelets and inhibits platelet aggregation. The eptifibatid dosing regimen includes two systemic 180 µg/kg bolus doses given 10 minutes apart combined with a continuous 2.0 µg/kg per minute infusion.^{25,26}

Parent Vessel Occlusion and Provocative Testing (Balloon Test Occlusion)

In some cases, direct aneurysm obliteration without parent artery sacrifice may not be possible. The majority of aneurysms treated by *parent vessel occlusion* are cavernous/petrous/extracranial internal carotid artery (ICA) aneurysms, extracranial vertebral artery aneurysms, dissecting aneurysms of the internal carotid or vertebral artery, and giant aneurysms in the subarachnoid space with ill-defined neck or inaccessible location. The prerequisite for parent vessel occlusion is adequate collateral circulation as proven by balloon test occlusion to prevent subsequent cerebral infarction. This information is also critical for the neurosurgeon, if the aneurysm is treated surgically. A balloon is advanced to the target artery, either the internal or vertebral artery, at or near the site of proposed permanent vessel sacrifice, and a baseline neurological examination is obtained. After systemic anticoagulation to an ACT of 300–350 seconds, the balloon is inflated to occlude the artery, and continuous neurologic evaluation follows. Development of a new neurologic deficit indicates insufficient collateral blood supply. In our institution, cerebral blood flow evaluation by ^{99m}Tc SPECT is used to enhance the predictive value of the test. The radionuclide Tc ^{99m} hexamethylpropylene-amine oxime (HMPAO) is injected once the patient tolerates test occlusion for 10 minutes during a hypotensive challenge. After successful 20-minute balloon test occlusion, the balloon is deflated and the patient is transferred for nuclear imaging. If balloon test occlusion indicates adequate collateral circulation, permanent occlusion of the parent artery may be performed using microcoils. In patients with poor tolerance for parent artery occlusion, an extracranial-intracranial bypass has to be done surgically before parent artery occlusion.

TREATMENT OF VASOSPASM

The intraarterial (IA) infusion of vasodilators has been proven beneficial for catheter-induced vasospasm and vasospasm following subarachnoid hemorrhage.²⁷ Verapamil is a phenylalkylamine calcium channel blocker that inhibits voltage-gated calcium channels in the arterial wall smooth muscle cells and results in vasodilation (Fig. 11.6).^{27,28} Nimodipine

and nicardipine, dihydropyridine agents, also improve the distal microcirculation and have a longer half-life than verapamil.^{29,30} On selective catheterization of the targeted vessel, 5 mg Verapamil diluted in 10 ml sterile water is slowly infused over 2 minutes while close attention is paid to cardiac side effects such as hypotension and bradycardia. The neuroanesthesiologist has to anticipate these effects since untoward elevation of ICP or reduction of systemic blood pressure by vasodilators can exacerbate the neurological injury. The infusion of the vasodilator can either be done via the proximal guide catheter, thus not requiring general anesthesia, or via superselective catheterization of the target vessel. In case of severe flow limitation, urgent angioplasty may be necessary to avoid incipient infarction. Transluminal balloon angioplasty should be performed under general anesthesia using a high-resolution digital roadmap imaging to avoid catastrophic vessel rupture or dissection. The pathophysiology underlying transluminal balloon angioplasty includes disruption of smooth muscle cells and extracellular matrix, thus causing smooth muscle and endothelial cell flattening.³¹ Transluminal balloon angioplasty of the spastic segment is more durable for vasospasm therapy;³² however, the intraarterial administration of Verapamil runs a significantly lower risk of vessel injury and allows treatment of distal and small artery vasospasm not amenable to balloon angioplasty.

EMBOLIZATION OF CEREBRAL ARTERIOVENOUS MALFORMATIONS

In brain arteriovenous malformations (AVMs), arterial feeders are directly connected to the venous system without intervening capillaries, resulting in high-flow arteriovenous shunts (Fig. 11.7). The risk of treating a brain AVM must be weighed against its natural history. Intracranial hemorrhage is the most common form of clinical presentation with a quoted annual risk of 2%–4%.^{33,34} The angiographic evaluation of patients with an AVM also includes superselective catheterization of the feeding arteries to rule out flow-related aneurysms or angiopathies. In patients with hemorrhage, it has to be determined which lesion, the AVM itself or an associated aneurysm, is responsible for the hemorrhage. The AVM should be addressed initially, when identified as the source of hemorrhage. Aneurysms associated with AVM present an increased risk of hemorrhage and may regress spontaneously following AVM treatment.³⁵ Current therapeutic options for brain AVMs include embolization, microsurgical resection, stereotactic radiosurgery, and various combinations. The goal of any combined therapy is to decrease the overall morbidity and mortality of AVM treatment. Preoperative AVM embolization is indicated to facilitate surgical excision of the AVM by reduction of the intraoperative bleeding. Embolization prior to radiosurgery aims at reducing the size of the nidus so that stereotactic radiosurgery can target the remainder with a higher dose and a better chance of cure. In selected cases, small AVMs may be completely obliterated by embolization alone. Embolization of AVMs requires a special armamentarium

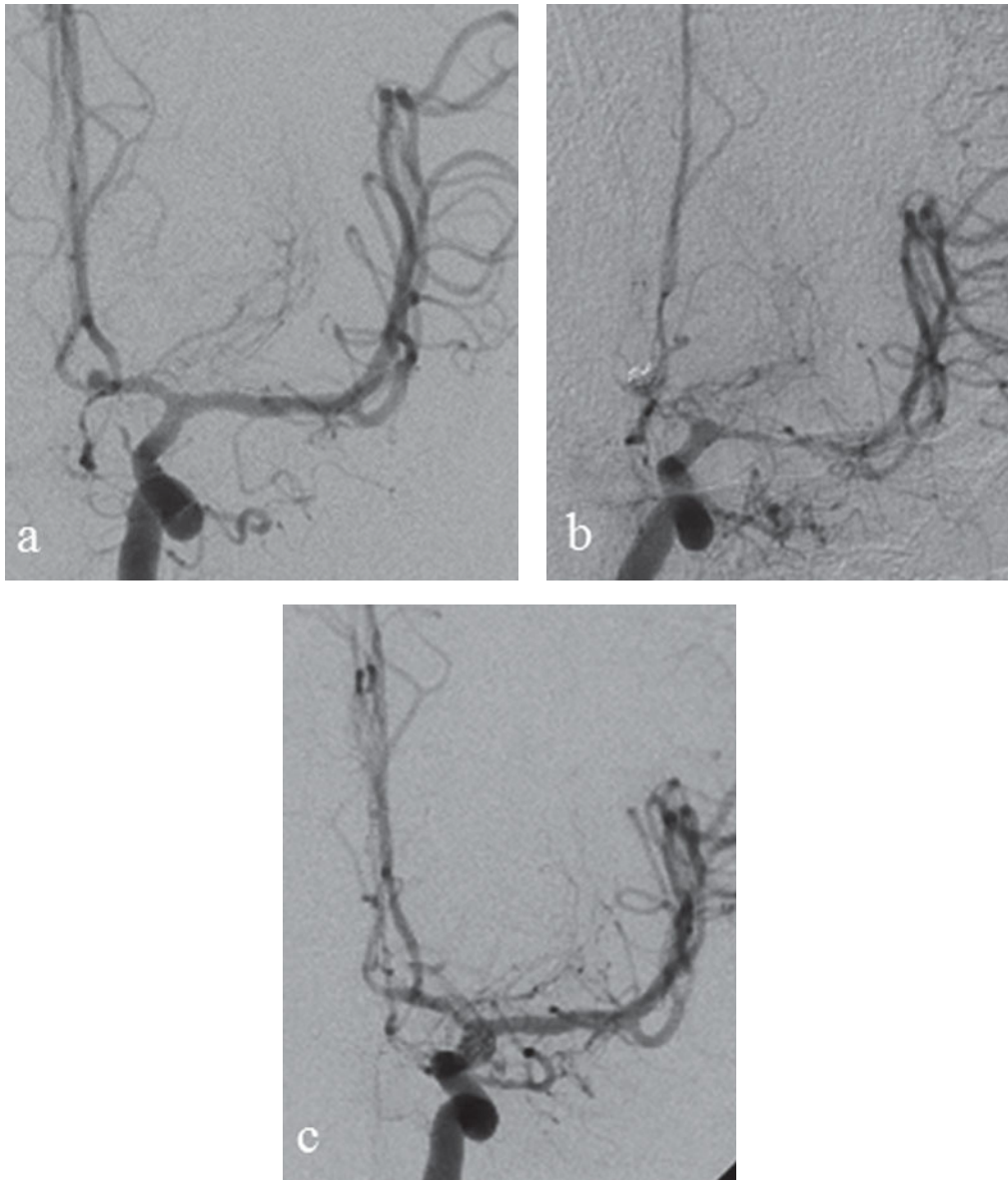


FIGURE 11.6. Left internal carotid artery injection in frontal plane on days 0 (*a*), 6 (*b*), and 9 (*c*) after subarachnoid hemorrhage. This 43-year-old patient presented with a subarachnoid hemorrhage from a ruptured anterior communicating artery aneurysm and underwent successful coil embolization of the aneurysm. On day 6 after coiling, he became somnolent and was found to have severe vasospasm in the left A1 and both A2 segments as well as in the left M1 segment treated with intra-arterial infusion of Verapamil into the left internal carotid artery on four consecutive days. The patient was also subjected to triple H therapy (induced hypertension, hemodilution, and hypervolemia). The vessel diameter of the spastic segments gradually improved and the mental status change subsided.

such as flow-directed microcatheters for a safe and reliable navigation into the very distal aspects of an arterial feeder. Flow-directed navigation uses arterial blood flow to drag the very flexible distal microcatheter segment forward into the vessel with the highest flow, which is usually the desired feeder. In very high-flow AVMs, flow-guided microcatheters rapidly achieve very distal, often intranidal positions at very low risk of vessel injury. Intravenous heparin is administered on an individual basis to prevent microemboli if there are

small feeders or if there is slow flow. For embolization, either solid occlusive devices (coils, balloons), particulates (polyvinyl alcohol particles [PVA particles], or liquid embolic agents such as Onyx or N-butyl cyanoacrylate (NBCA) are used. Complications associated with the liquid embolic agents include passage through the nidus before solidifying and lodging in veins draining the AVM, which can lead to AVM rupture if not yet completely embolized. Other complications include passage of embolic material into the pulmonary circulation.

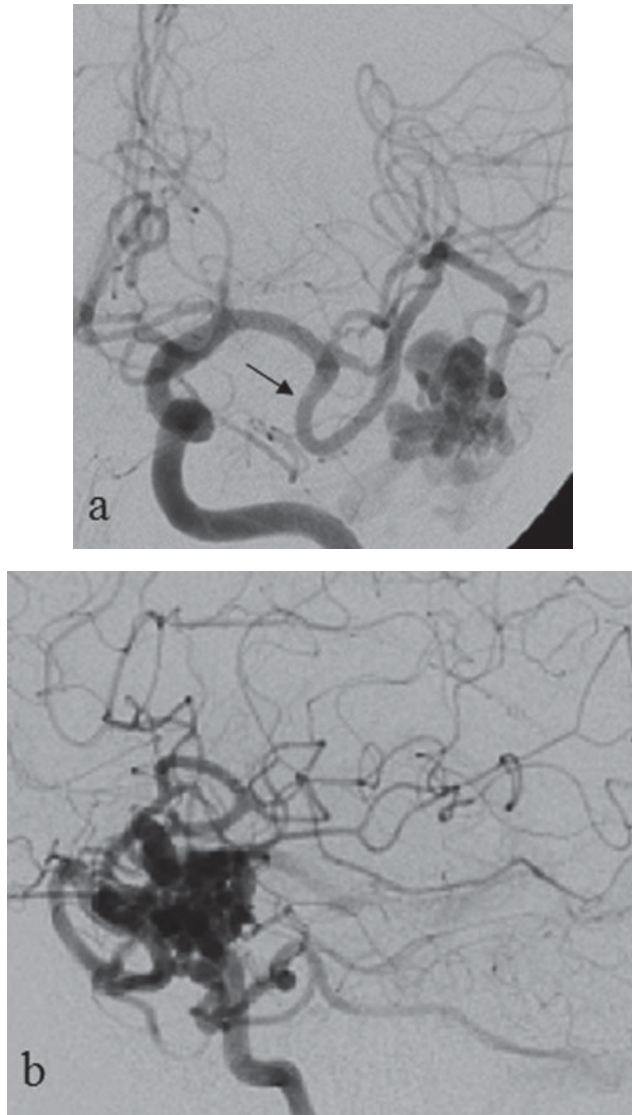


FIGURE 11.7. Left internal carotid artery injection (*a*, frontal; *b*, lateral plane) of a 67-year-old male patient who presented with seizures and was found to have a 1 cm left anterior temporal arteriovenous malformations (AVM) fed by the left anterior temporal artery (arrow) draining into the vein of Rosenthal and vein of Labbé.

In case of microcatheter entrapment, cutting the catheter at the access site and leaving it in place, although not a desirable outcome, may be safer than continued or overly aggressive pulling on the device, which could lead to brain hemorrhage or catheter fracture.

Anesthetic considerations during cerebral AVM embolization primarily consist of a tight control of arterial blood pressure. Once the microcatheter is in position, the patient's blood pressure is transiently lowered to slow flow through the AVM and allow a more controlled embolization. Embolization can markedly reduce flow through the nidus, causing stagnation in the draining veins with subsequent thrombosis, hemorrhage,

or venous ischemic infarct.³⁶ Another reason for hemorrhage may be normal perfusion pressure breakthrough. The chronically low perfusion pressure in the parenchyma adjacent to an AVM impairs cerebrovascular autoregulation. After removal of the shunt, parenchymal hyperperfusion can cause edema and hemorrhage.³⁷ Approximately 10% of brain AVM embolizations cause a permanent neurological deficit.³⁸ These deficits are often caused by embolization of branches arising from an AVM feeder that supply normal brain parenchyma.

ACUTE STROKE INTERVENTION

Intravenous administration of recombinant tissue plasminogen activator (rt-PA) within the first 3 hours of stroke onset was the first Food and Drug Administration (FDA)-approved therapy for acute ischemic stroke based on two phase III National Institutes of Neurological Disorders and Stroke (NINDS) tissue plasminogen activator (tPA) trials completed in 1995.³⁹ In angiographic controlled pilot trials of IV rt-PA, the rate of recanalization of major arterial occlusions with IV rt-PA is low, with partial or complete recanalization of only 10% of occluded internal carotid arteries and 25% of occluded proximal middle cerebral arteries.⁴⁰ An intra-arterial approach allows extension of the treatment time window, a higher concentration of lytic agent delivered to the clot target, a lower systemic exposure to the drug, higher recanalization rates, salvage therapy for IV rt-PA nonresponders, and combined use with other endovascular techniques. On the other hand, intra-arterial thrombolysis requires additional time to initiate therapy, is only available at specialized centers, and represents mechanical manipulation within potentially injured vessels. Intra-arterial thrombolysis (IAT) is considered if patients treated with IV rt-PA had no neurological improvement or worsening of the neurological deficit without hemorrhagic changes on repeat CT scan, and an occlusion of the M1 or M2 segment, internal carotid artery, vertebral artery, or basilar artery on CT angiogram, allowing initiation of treatment *within 6 hours* of the onset of symptoms.

At first, a detailed angiographic examination of the vascular anatomy, including the collateral circulation at the circle of Willis and the leptomeningeal levels is performed. A microcatheter is then passed over the microguidewire to the level of occlusion. Contrast is injected into the microcatheter to locate the clot. Prior to infusion, the microguidewire is passed several times through the clot to increase the surface area for thrombolysis. Two milligrams of rt-PA is injected through the catheter starting beyond the thrombus while the microcatheter is then retracted into the thrombus.

If there is no significant response or persisting occlusion after repeated administration of rt-PA on control angiography, or as a primary revascularization technique, mechanical clot disruption or retrieval by one of the following interventional techniques, alone or in combination, is considered:

- Aggressive microcatheter/microguidewire clot maceration
- Percutaneous transluminal angioplasty (PTA)

- Stent deployment
- Use of a clot extraction device such as the MERCI (mechanical embolus retrieval in cerebral ischemia) retrieval system (Concentric Medical, Inc.) or the Penumbra system

The MERCI device is a flexible, helical-shaped, tapered tip made of nitinol wire with arcading filaments in its second and third generation (V series) to enhance friction between the device and the clot to increase capture rate (Figure 11.8) This technique is used in conjunction with simultaneous flow reversal in the affected artery during retrieval. First-generation MERCI devices achieved recanalization rates of 48% and, when coupled with intra-arterial thrombolytic drugs, recanalization

rates of 60% have been reported.⁴² Multi MERCI was an international, multicenter, prospective, single-arm trial of thrombectomy in patients with large-vessel stroke treated *within 8 hours* of symptom onset.⁴³ Treatment with the L5 Retriever resulted in successful recanalization in 75 of 131 (57.3%) treatable vessels and in 91 of 131 (69.5%) after adjunctive therapy (intra-arterial tissue plasminogen activator, mechanical). Favorable clinical outcomes (modified Rankin Scale 0 to 2) occurred in 36% and mortality was 34%; both outcomes were significantly related to vascular recanalization. Symptomatic intracerebral hemorrhage occurred in 16 patients (9.8%).

The Penumbra system (PS; Penumbra, Alameda CA) is a new embolectomy device that removes the thrombus in

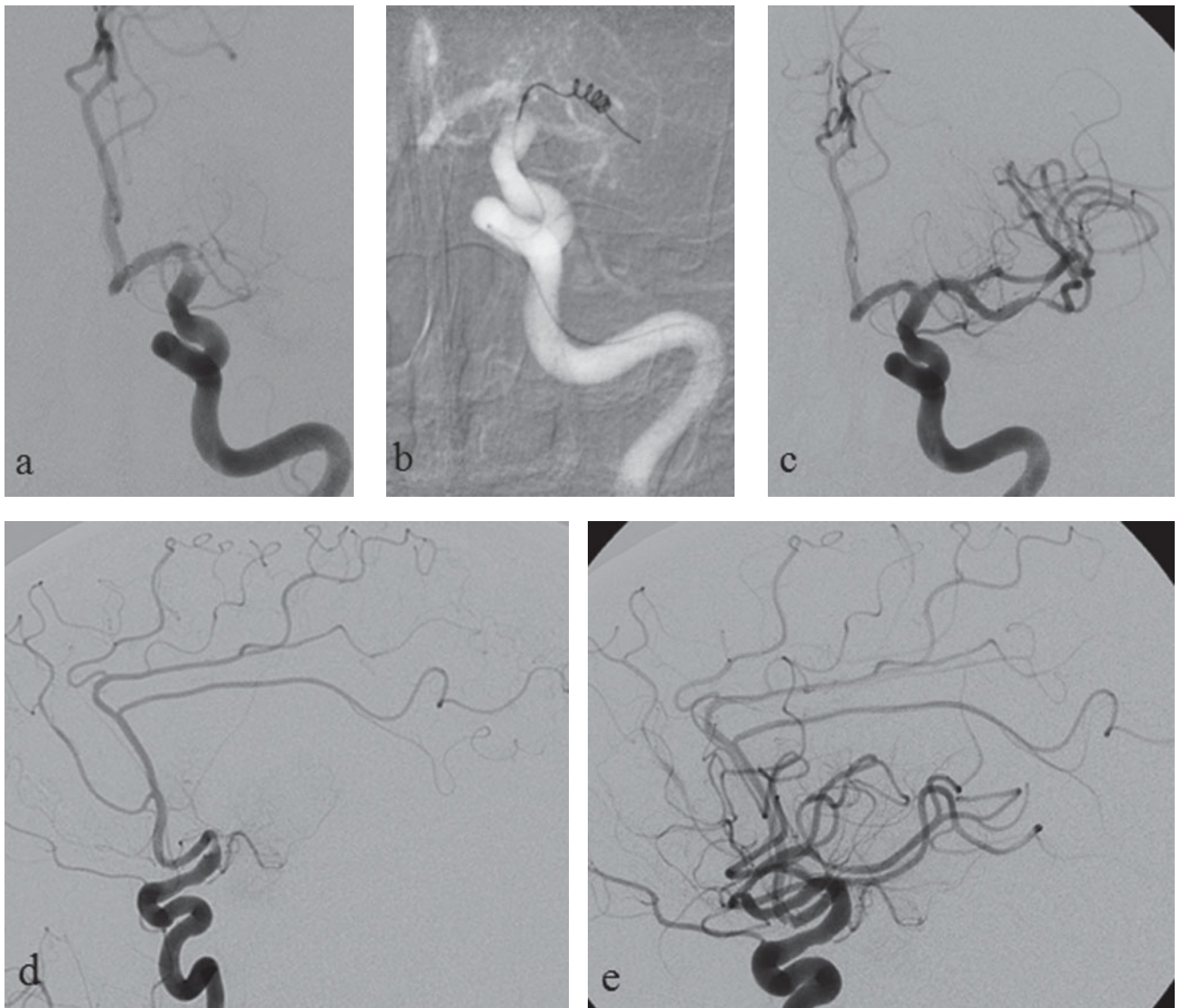


FIGURE 11.8. Left internal carotid artery injection (*a* and *c*, frontal plane; *b*, roadmap; *d* and *e*, lateral plane) in an 83-year-old male patient who presented with a 4–5 hour history of aphasia and right-sided hemiplegia. The patient had received intravenous tissue plasminogen activator (tPA) in an outside hospital and was found to have a proximal M1 occlusion with clot partially extending into the A1 origin (*a* and *d*). After clot retrieval using the MERCI device (*b*), complete recanalization of the M1 segment and the superior and inferior division of the M2 segments was achieved (*c* and *e*).

large-vessel thromboembolism via aspiration and extraction.⁴¹ For aspiration, a reperfusion catheter is used in parallel with a microguidewire with a bulbous tip (“separator”) and an aspiration source to break up the thrombus from proximal to distal and aspirate it from the occluded vessel. This is accomplished by slowly advancing the aspiration catheter into the clot while continuously moving the bulbous separator tip in and out of the distal end of the microcatheter.

Although data are limited, angioplasty and stenting have been used in the emergency treatment of intracranial lesions in patients with acute ischemic stroke either as primary technique or after other methods have failed.

Anesthesia considerations in the management of patients with acute stroke include a rapid response by the anesthesia provider to decrease the time from onset of symptoms to the onset of treatment given the limited therapeutic window for intra-arterial thrombolysis (6 hours after patient was last seen normal) or aggressive mechanical clot disruption (8 hours after patient was last seen normal). In addition, there is evidence that earlier recanalization improves the chance for a good outcome. Therefore, it is critical to proceed expeditiously, even though a complete medical history or other circumstances may not be fully known or retrievable at the time of induction. For example, not infrequently, the patient may have arrived at our institution by airlift, while family has not arrived yet or other caregivers cannot be reached to obtain more detailed information. At the author’s facility, general anesthesia is advocated in all patients based on significantly altered level of consciousness and the inability to communicate and cooperate because of aphasia and/or neglect in the majority of patients. Communication between the interventionalist and neuroanesthesiologist regarding the optimal blood pressure management in each individual case is essential to enforce good perfusion of the collaterals but to avoid hemorrhage into the reperfused brain tissue.

OTHER NEUROINTERVENTIONAL PROCEDURES

Other neurointerventional procedures that may involve specialized anesthesia care include preoperative embolizations of head, neck, and spinal tumors; embolization of dural fistulae of the brain and spine; elective intracranial and extracranial stent/angioplasty; sclerotherapy of vascular malformations of the head and neck; and others. A detailed discussion covering all of these procedures is beyond the scope of this chapter. Similar principles of neuroanesthetic considerations as outlined earlier, however, apply to a great extent to these procedures as well.

CONCLUSION

As the scope of endovascular neurosurgery continues to expand, so does the need for anesthesia support outside the normal operating room environment. A close cooperation and familiarity with the endovascular procedure by the neuroanesthesiologist is required for optimal results.

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12 | Interventional Radiology Procedures

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Since the beginning of Interventional Radiology (IR) as we currently know it, the specialty has suffered somewhat from a recognition problem. The specialty has been known under many different names and acronyms, and most of these still persist today. Examples include:

1. Interventional Radiology
2. IR
3. Cardiovascular & Interventional Radiology
4. CVI
5. CVIR
6. Angio
7. Special Procedures
8. CVI/R
9. Vascular Radiology

Even the specialty's major society, the Society of Interventional Radiology (SIR, sometimes pronounced as in "Yes, Sir") has gone through name changes. Formerly, it was known as the Society of Cardiovascular and Interventional Radiology (SCVIR, pronounced "skiver," rhymes with "shiver"). Before that, the society began in 1973 as the Society of Cardiovascular Radiology or SCVR.¹

To this day, when asked, "What do you do?" many practitioners of interventional radiology will simply reply, "I am a physician." If the questioner persists, the next question will often be, "What type of practice?" When the words "Interventional Radiology" come out in response, too many of us are confronted with a relatively blank stare, all due to the recognition problem of IR.

This chapter is an effort to correct some of that recognition problem and to offer a summary, albeit incomplete, of the scope of practice of interventional radiologists. Clarification of the spectrum of IR cases is appropriate before later discussions in subsequent chapters of the anesthetic needs for such cases. Please note that lists of indications and contraindications are not intended to be exhaustive. Discussions of complications will center on those acute complications that will be of particular interest to providers administering off-site anesthesia for these cases. Specific anesthetic considerations for radiology procedures are discussed in Chapter 13.

Before describing the practice of IR physicians, some details about these practitioners themselves might be helpful. A survey

of radiologists in 2003 with a special focus on interventional radiologists was performed by the American College of Radiology, and was published in 2005.² Some interesting findings from that study included:

- About 10% of radiologists call themselves *interventional radiologists* (IRs).
- Less than one-half of those who call themselves IRs actually do IR cases >70% of the time.
- IRs work more hours than their non-IR counterparts.
- Fewer than 6% of IRs are female.
- The average age for IRs is the mid to late 40s.

Another important point is that the percentage of practitioners who perform IR procedures *and who are radiologists* continues to decrease. Cardiologists, vascular surgeons, general surgeons, neurosurgeons, as well as some nephrologists, urologists, and even neurologists today perform some cases previously performed almost exclusively by interventional radiologists. That fact may have ramifications to those providing anesthesia for some of these cases, since the operators' expectations of those providing anesthesia may vary based on their backgrounds.

To return to the initial focus of this chapter, the question must be asked: What kinds of procedures are in fact performed in Interventional Radiology? To sum it up simply: In IR, we perform a vast array of diagnostic and interventional procedures, mostly through *very small holes*.

Examples that will be expounded upon in the coming sections of this chapter include:

- Abscess drainage
- Arterial procedures and interventions
- Biliary procedures and interventions
- Gastrointestinal (GI) procedures and interventions
- Genitourinary (GU) procedures and interventions
- Intraoperative cases (e.g., thoracic and abdominal aortic stent grafts)
- Noninvasive vascular imaging
- Percutaneous oncologic interventions
- Percutaneous biopsies
- Venous procedures and interventions
- Venous access

ABSCESS DRAINAGE

An abscess is a collection of pus that has formed in a confined space in the body in response to an infection. The confined space can be an organ or simply body tissue, and abscesses can arise in almost any location in the body. The contents of abscesses can include varying amounts of fluid, bacteria (usually), dead and dying tissue, live and dying neutrophils, and other debris. Abscesses can be related to disease processes (e.g., appendicitis and diverticulitis) or trauma, or they may be postoperative.

Postoperative abscesses are more common with contaminated surgical procedures, but even “clean” procedures can occasionally result in abscess formation. Treatment includes antibiotics (which do not readily penetrate the abscess cavity but do treat the surrounding inflammation and infection) and drainage.

Some abscesses need no image guidance (Fig. 12.1) to allow effective drainage. Surgical incision and drainage is in many cases the preferred method, and when open drainage is performed, it is usually done so by providers other than interventional radiologists.

Suitable anesthesia (this can be local, regional, general, or some combination) is needed regardless of the method of drainage. From an IR standpoint, abscesses can be drained using several modalities, including:

- Computed tomography (CT) (Fig. 12.2)
- Ultrasound
- Fluoroscopy (Fig. 12.3)
- Magnetic resonance (MR)
- Some combination

In all cases, the target area needs to be localized and identified. Also, important nontarget structures (e.g., large vessels, bowel, lung, and other viscera) must be identified and avoided in the planned path of access. Imaging aids greatly in both identifying the target and avoiding undesired structures.

The use of a disposable metallic grid in CT scan can help identify positioning. In ultrasound and fluoroscopy, structures



FIGURE 12.1. Superficial cutaneous abscess for which no imaging is needed for incision and drainage (I &D).

are visualized in real-time during access. Magnetic resonance is used less frequently because special (translation: *expensive*) nonferromagnetic equipment must be employed. In some cases, a procedure may be begun with one modality (e.g., CT or ultrasound) and, once access is established, the procedure may be completed with fluoroscopic guidance.

Acute complications from abscess drainage include:

1. Acute infection/sepsis from disrupted abscess
2. Injury to undesired target, which can lead to bleeding, bowel injury, peritonitis, or pneumothorax

ARTERIAL PROCEDURES AND INTERVENTIONS

Arterial procedures can be performed purely for diagnostic purposes or they may be therapeutic in nature. Most purely diagnostic procedures do not require more than sedation and analgesia (moderate sedation). Some of the more complex procedures may indeed require a more intensive level of anesthesia support.

Arteriography represents the purely diagnostic arterial procedures. In these procedures, the patient is generally placed supine on the angiography table. The planned site of entry is prepped and draped using sterile technique. After the administration of local anesthesia, access into the arterial system is gained with a needle and a wire. Most commonly, access is gained via the common femoral artery, but other access sites can be used as well. The most common alternate site is the brachial artery, left preferable to right (fewer great vessel origins are crossed from the left). Radial artery access is used in coronary angiography, but the small vessel size and distance to common arterial targets frequently preclude its use in peripheral arterial procedures.

A sheath with a hemostatic valve may be inserted at the operator's discretion. Reasons to use a sheath are listed below. Catheters of varying shapes, sizes, materials, and hole configurations (some have only a single end hole, while others have many additional side holes) are inserted and navigated to the desired locations. Contrast is injected, either by hand or using a power injector, while imaging is acquired. In many institutions, much diagnostic arteriography has been replaced with CT angiography (CTA), which will be discussed later.

Some reasons to use a vascular sheath (Fig. 12.4) include:

1. Planned frequent catheter exchanges
2. Planned intervention (reduces injury to the vessel or damage to devices)
3. Scarred access site (when in the common femoral artery, it is known as the “hostile groin”)
4. When the sheath is needed for arterial pressure monitoring during the case
5. When the operator is working alone
6. A deep groin in an obese patient
7. Heavily calcified vessels (minimizes trauma with catheter exchanges)
8. Planned repeat intervention in the near future (e.g., thrombolysis)

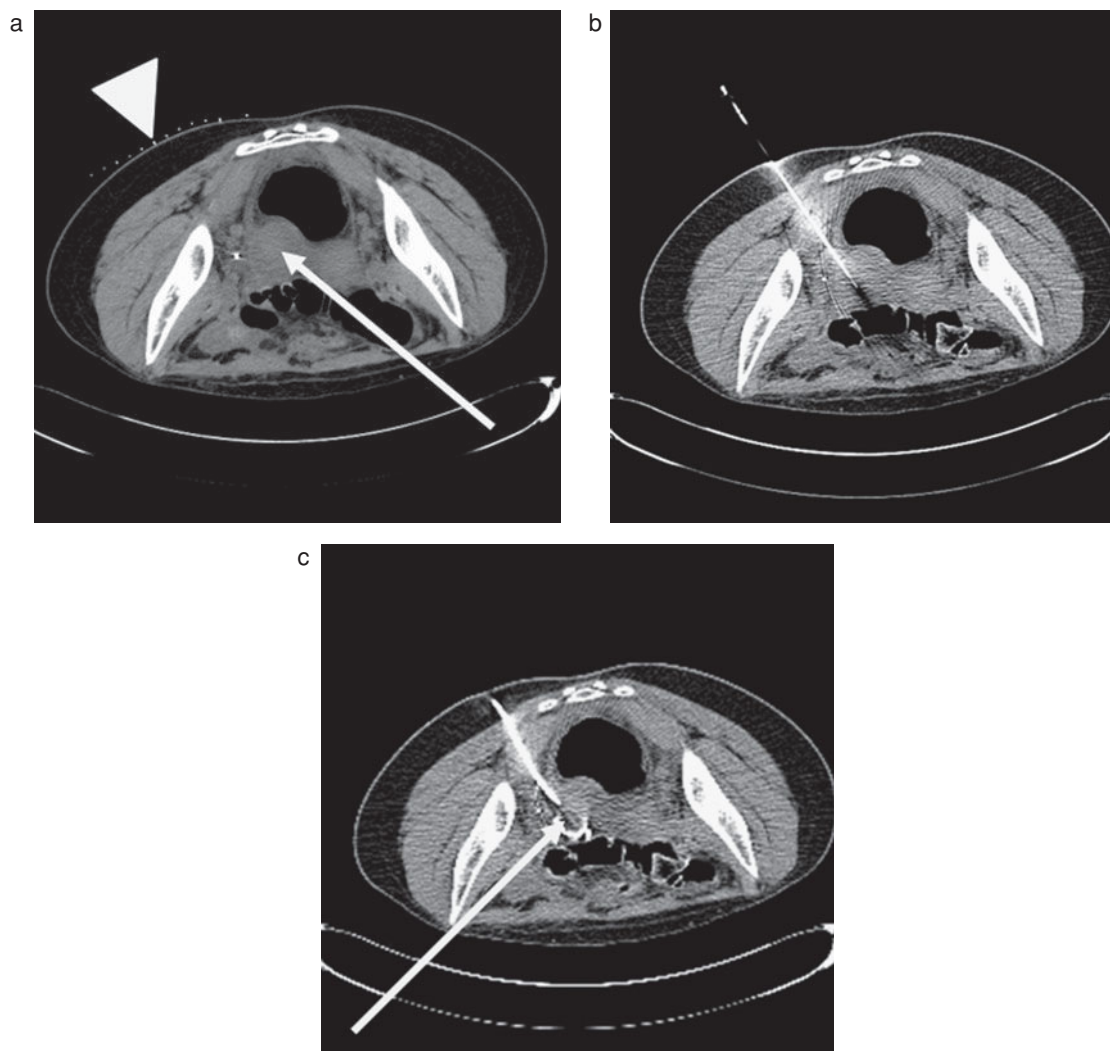


FIGURE 12.2. Computed tomography (CT)-guided abscess drainage. (a) Prone CT scan with metallic grid (arrowhead) in place; the abscess is identified (arrow). (b) Prone CT scan with narrow-gauge finder needle in place. (c) Prone CT scan demonstrating drain within abscess collection; the Cope loop (arrow) of the drainage catheter has been formed.

Cut-film imaging has largely been supplanted by digital subtraction angiography (DSA). When acquiring images during DSA, one or more images are acquired before the introduction of contrast material to serve as a “mask.” Then, the contrast is injected while the patient remains motionless. Using a noncontrast image as a mask, its findings are digitally subtracted from the findings on the postcontrast imaging. The difference in the before and after images results in a depiction of the newly contrast-filled arteries. This technique can be quite accurate with excellent resolution; however, it can be negatively affected by patient motion.

There are many indications for diagnostic arteriography, including:

1. Evaluation of the extent of atherosclerotic disease
2. Evaluation of ischemia

3. Evaluation of the arterial supply to a neoplasm or vascular anomaly
4. Evaluation for presence and extent of arterial trauma

In some instances, the diagnostic information obtained will serve as a preoperative guide for the surgeon. In other cases, the intervention will be performed percutaneously, either at the same time or at a separate sitting.

Contraindications to diagnostic arteriography include gross hemodynamic instability, uncorrectable bleeding diathesis, prior severe reaction to iodinated contrast material, and significant renal insufficiency (unless dialysis is planned). A patient who cannot control his or her breathing or remain still may be imaged, but anesthesia support may be required.

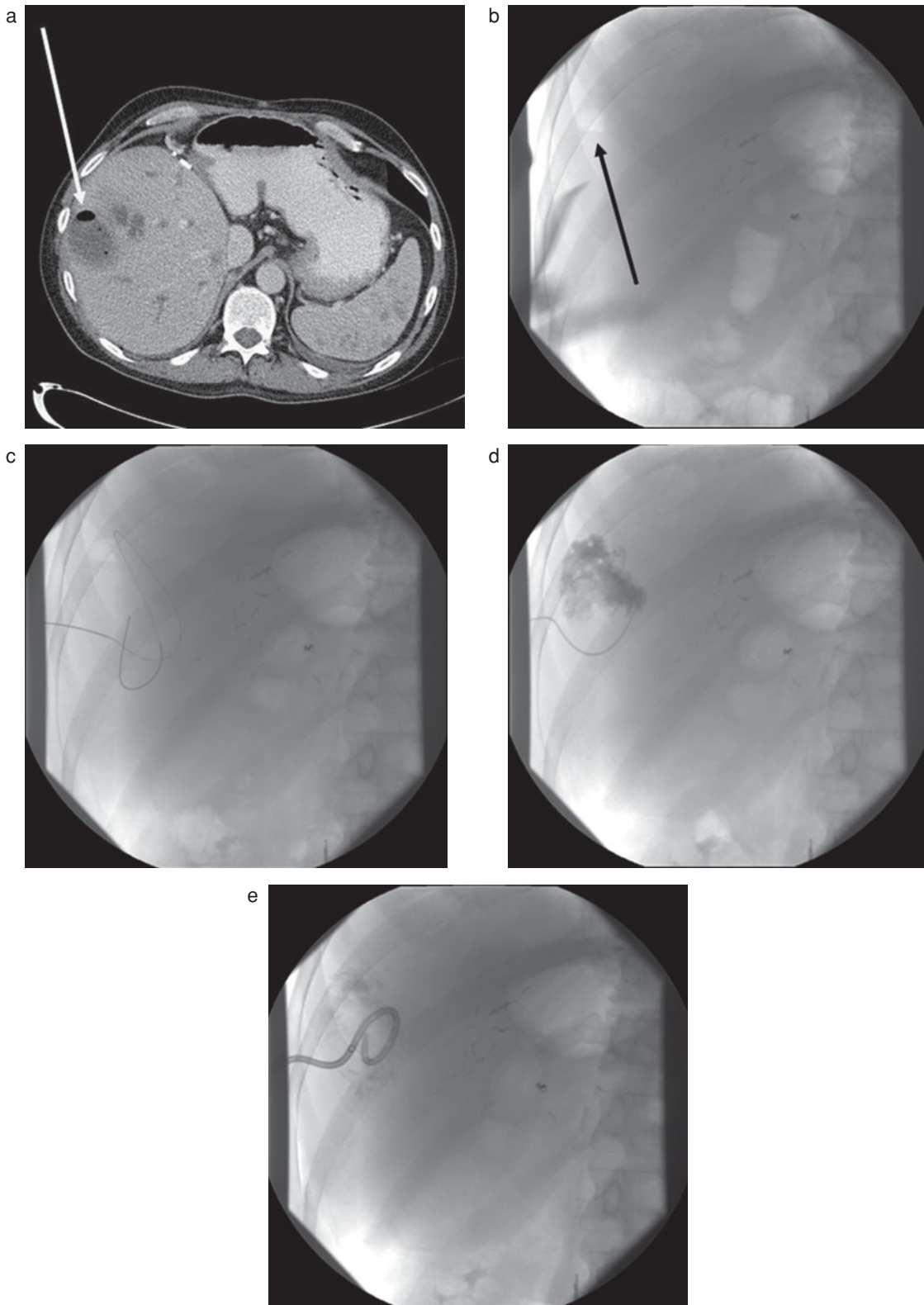


FIGURE 12.3. Fluoroscopy-guided abscess drainage. (a) Supine computed tomography (CT) scan identifying intrahepatic abscess with air (arrow). (b) Supine fluoroscopic image demonstrating same air pocket (arrow). (c) Fluoroscopic image demonstrating needle into fluid collection below air with wire (through a needle) coiled in collection. (d) Contrast injected through micropuncture catheter confirming positioning within abscess. (e) Drainage catheter (with Cope loop coiled) within abscess.

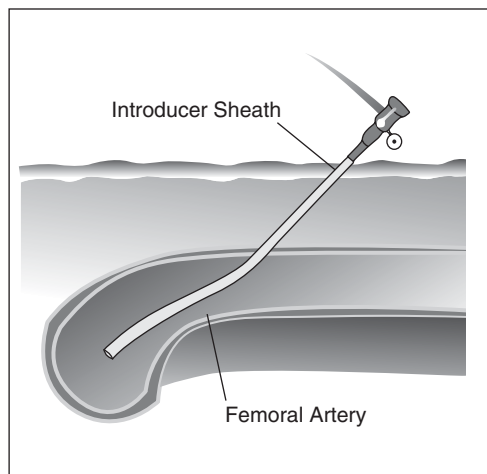


FIGURE 12.4. Vascular sheath. (Used with permission from Vascular Solutions, Inc.)

Arterial interventions can include:

- Percutaneous transluminal angioplasty (PTA)
- Arterial stenting
- Thrombolytic therapy
- Embolic therapy

Percutaneous transluminal angioplasty (Fig. 12.5) and arterial stenting are mechanisms to dilate arteries that have become stenotic or even occluded. In these techniques, the precise location of the significant stenosis to be treated is identified angiographically, and its significance may be confirmed with hemodynamic (pressure) measurements. Intravenous heparin is usually administered prior to crossing the stenosis. Next, a catheter and wire are passed through and beyond the stenosis. In the case of an occlusion, the occluded segment may actually be recanalized (this can be through the occlusion or in a subintimal plane) with a small catheter and wire.

The catheter is removed leaving the wire in position. Over this wire, an angioplasty balloon (generally about 20% larger than the native vessel) or a stent (equal to or up to about 10% larger than the native vessel) of appropriate size is positioned. The balloon is inflated and held in position, usually for 1 to 2 minutes. In the case of a stent, it is deployed at the correct site. If it is a “self-expanding” stent, it is allowed to open and then angioplastied with a balloon as needed; if it is a “balloon-mounted” stent, then inflation of the included balloon deploys and expands the stent to the desired size. In all cases, follow-up arteriography is mandatory to evaluate the result.

Thrombolytic therapy (Fig. 12.6) is utilized to dissolve or lyse thrombus in blood vessels, and these vessels can be arteries, veins, or artificial conduits. Thrombus is most readily and successfully treated early during its course. Many thrombolytic agents available today are enzymes that work by converting plasminogen to the natural fibrinolytic, plasmin. Plasmin lyses clot by breaking down the fibrinogen and fibrin contained in a clot. Various agents are currently utilized,

among them alteplase (recombinant tissue plasminogen activator or r-tPA), urokinase, tenecteplase, and reteplase. Streptokinase is not used much in the United States.

With thrombolytic therapy, higher success rates are achieved when a wire can be passed through the clotted segment, a technique known as the *wire traversal test*. Once the wire is confirmed to be intravascular and beyond the thrombosed segment, a special catheter designed for thrombolysis is positioned just into the clot with its infusion segment spanning as much of the clot as possible. Thrombolytic agent is infused at specified rates and for specified durations, after which additional angiography is performed. These subsequent results guide whether catheter repositioning, continuation of thrombolysis, cessation of thrombolysis, or additional treatment (e.g., angioplasty, stenting, or surgical intervention) is warranted.

Indications for thrombolytic therapy include:

1. Thrombosis of native vessel (arterial or venous)
2. Thrombosis of conduit vessel, including venous bypass graft, prosthetic bypass graft, or dialysis graft
3. Embolization of thrombus occurring during percutaneous thrombolysis or open surgical procedure

Contraindications to thrombolytic therapy include:

1. Active bleeding (e.g., GI bleeding, bleeding ulcer) or uncorrected bleeding diathesis
2. Recent bleeding (e.g., recent surgery or trauma, recent hemorrhagic stroke)
3. Pregnancy
4. Previous allergic reaction to thrombolytic agent
5. Known intracranial neoplasm or vascular malformation
6. Suspected aortic dissection
7. A nonviable extremity

With embolization therapy, (Fig. 12.7) various agents can be used to effect either permanent or temporary occlusion of blood vessels, more commonly of arteries but also of veins. Among the agents that have been used are:

- Permanent agents
 - Polyvinyl alcohol (PVA)—particles or spheres
 - Absolute alcohol
 - Sodium tetradecyl sulfate (Sotradecol®) (Angiodynamics, Queensbury, NY)
 - Coils (platinum or steel)
 - Balloons
 - Glue (n-Butyl Cyanoacrylate or n-BCA, known as TRUFILL®) (Cordis Neurovascular, Miami Lakes, FL)
 - Onyx® liquid embolic system (ev3, Inc., Plymouth, MN)
 - 50% Glucose
 - Boiling contrast
 - Silk thread
- Temporary agents
 - Gelfoam (as a slurry or as “torpedoes”)
 - Autologous blood

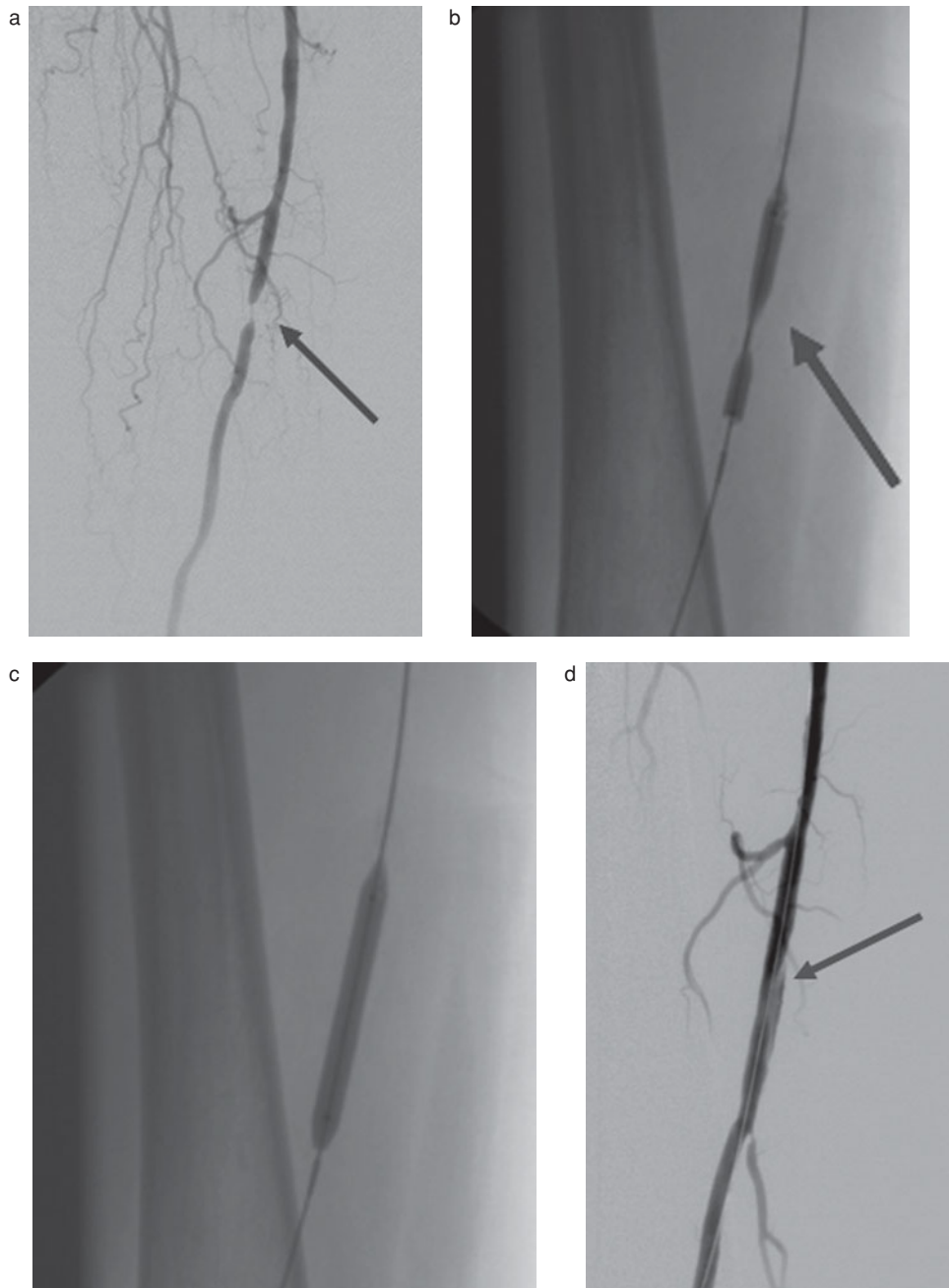


FIGURE 12.5. (a) Digital subtraction angiography (DSA) image of the distal right superficial femoral artery (SFA) with high-grade stenosis (arrow). (b) Angioplasty balloon partially inflated demonstrating stenosis at the “waist” (arrow). (c) Angioplasty balloon fully inflated demonstrating no residual stenosis. (d) Follow-up post-angioplasty image showing resolution of stenosis; a small dissection flap (arrow) was not flow-limiting.

Sites/reasons for embolization therapy may include:

- Trauma
- GI hemorrhage
- Bronchial artery embolization
- Vascular anomalies
- Varicoceles/pelvic congestion
- Uterine arteries for fibroids
- Aneurysms
- Chemoembolization or radioembolization for cancer treatment.

Arterial embolization techniques involve arteriography to identify the artery or arteries to be treated. A catheter is

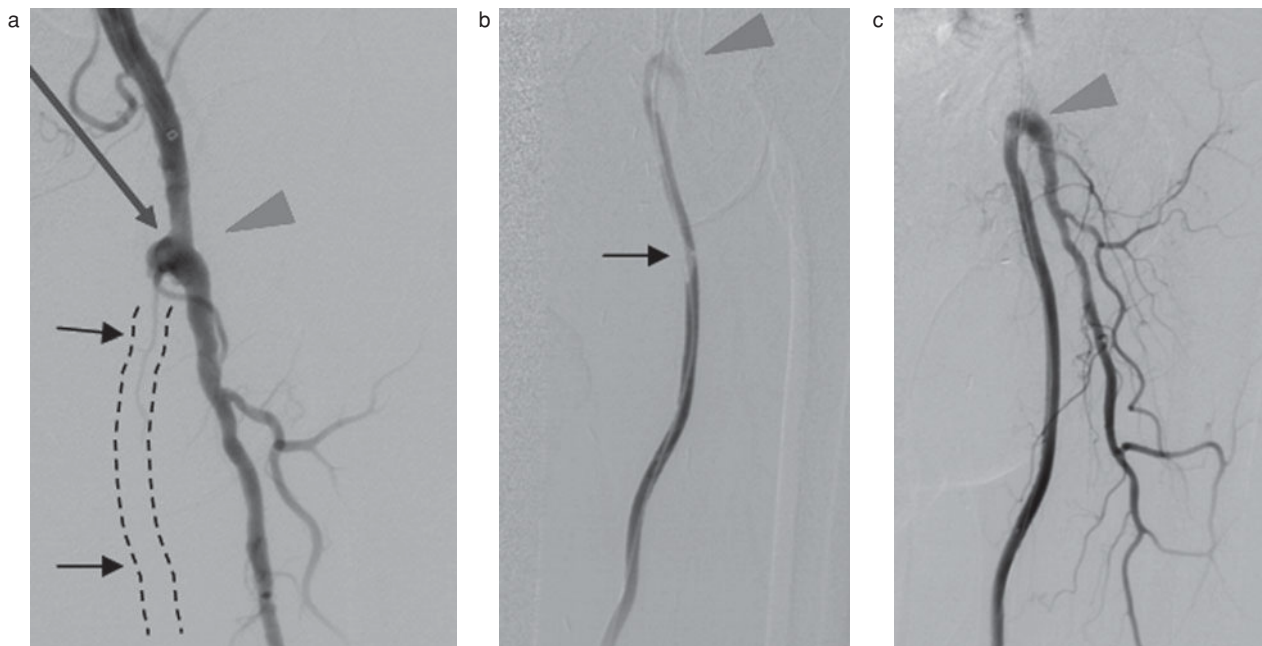


FIGURE 12.6. (a) Occluded femoral-to-distal graft (short arrows and dashed lines show path of the occluded graft); stump of occluded graft (long arrow) guides placement of the thrombolysis catheter. (b) Partial thrombolysis noted after 7 hours; some clot still present (short arrow). (c) After 24 hours, graft is now completely eradicated of clot; a distal lesion (not shown) was treated with angioplasty. Note that the arrowhead points to the same anatomic location in each image.

positioned as close to the desired site as is feasible. Embolic agent is carefully administered, taking care to avoid reflux into uninvolved vessels or embolization of undesired vessels (“nontarget embolization”). As with other arterial interventions, follow-up arteriography is mandatory to evaluate efficacy. Venous embolization is carried out similarly.

Acute complications for diagnostic arterial procedures are relatively infrequent, but they can include:

1. Bleeding from the entry site or other vessel
2. Thrombosis at the entry site or other vessel
3. Embolus from thrombus
4. Dissection (which may be flow-limiting)
5. Contrast reaction

With the addition of interventions to the diagnostic arterial procedure, the complications include those just listed, as well as:

1. With thrombolysis, unrelated bleeding may ensue (e.g., intracranial, GI).
2. With embolization procedures, nontarget embolization may occur.
3. Angioplasty or stenting can result in vessel disruption.

BILIARY PROCEDURES AND INTERVENTIONS

The biliary system may be accessed via direct puncture through the liver, or diagnostic information related to the biliary system may be obtained by a transvenous route. Biliary

procedures performed by direct puncture include percutaneous transhepatic cholangiography and percutaneous transhepatic biliary drainage.

Indications for diagnostic percutaneous biliary procedures include:

1. Evaluation for source of obstructive jaundice (including stone, mass, or stricture)
2. Evaluation of medically treatable jaundice
3. Determination of the etiology of cholangitis
4. Determination of the location of a bile duct leak (if ERCP cannot do so)
5. Evaluation for presence and extent of biliary ductal system abnormalities (e.g., choledochal cysts or atresias)

Contraindications to percutaneous biliary procedures include:

1. Uncorrectable bleeding diathesis
2. Previous severe reaction to iodinated contrast
3. Hydatid disease, documented or suspected
4. Large vascular hepatic lesions (tumors or vascular malformations)
5. Extensive undrained ascites
6. Severe contrast reaction that has not been pretreated

The technique of biliary drainage (Fig. 12.8) involves placing the patient supine on the angiography table. The right arm should be placed above the head. Intravenous sedation (or general anesthesia, if indicated) is administered. A suitable lateral location in the mid axillary line at or below the 10th intercostal

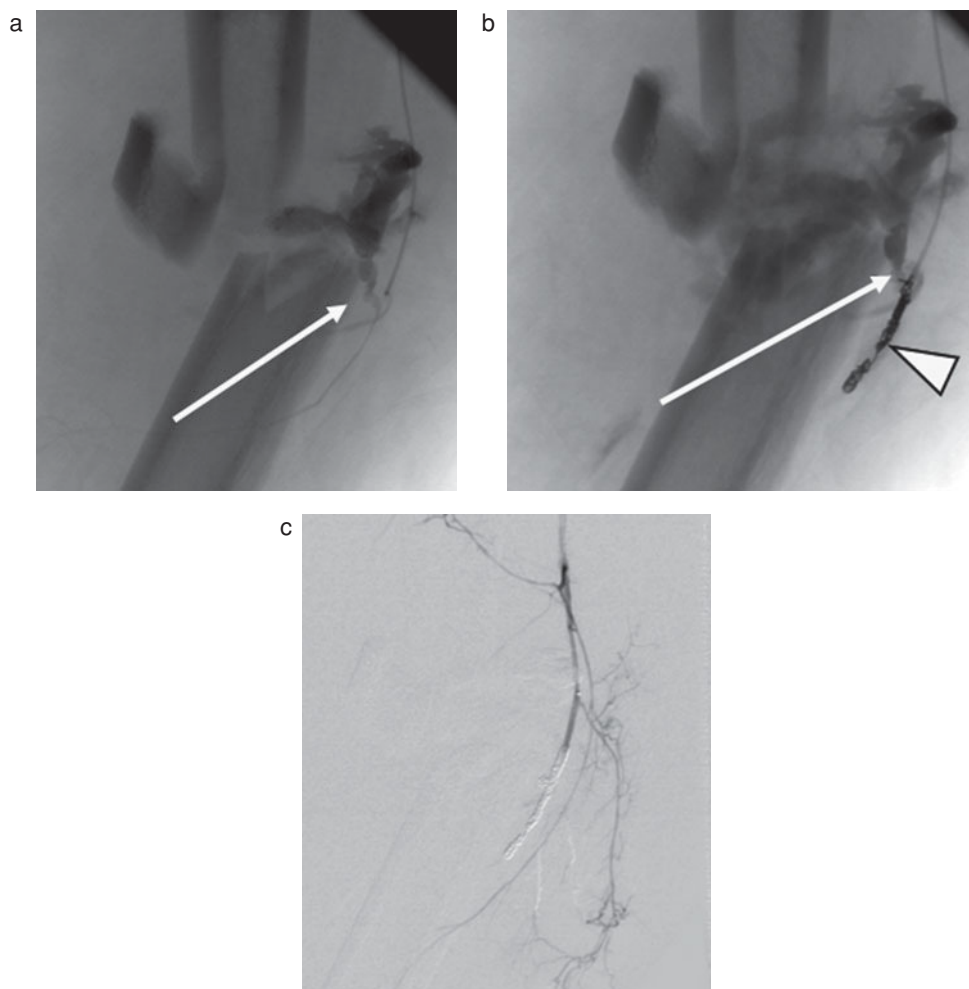


FIGURE 12.7. (a) Extravasation (arrow) from injured artery near site of femur fracture; image is unsubtracted. (b) After deposition of some coils (arrowhead), there is still extravasation (arrow) from injured artery near site of femur fracture; image is unsubtracted. (c) After completion of coil embolization, no further extravasation is seen on this digital subtraction angiography (DSA) image.

space (to minimize pleural transgression) is identified using fluoroscopy. Local anesthesia is instilled. A long 22-gauge Chiba needle is inserted obliquely into the hepatic parenchyma. With magnified fluoroscopic visualization, contrast is gently instilled as the needle is slowly withdrawn.

The goal is to opacify a bile duct, and then the entire biliary ductal system. Structures other than bile ducts that may be opacified include hepatic parenchyma, portal vein branches, hepatic vein branches, hepatic arterial branches (not particularly common), the gallbladder, lymphatics, and even extrahepatic structures (inferior vena cava [IVC], aorta, peritoneal cavity, and right kidney). If the first attempt is unsuccessful, additional attempts with slightly altered angulations are performed until a bile duct is opacified.

Once a bile duct is opacified, additional contrast is instilled while multiple images are acquired. If intervention is warranted, a suitable duct (assuming the duct entered for the initial

cholangiogram was not suitable) for definitive access is identified. Using complex angulation, that duct can be entered with a separate needle stick. A guidewire is carefully advanced into the ductal system. The needle is exchanged for a transitional dilator set or a directional catheter, as indicated. Conversion to a drainage catheter can follow.

Another percutaneous biliary procedure is cholecystostomy tube placement. In patients with acute cholecystitis who are unsuitable for operative intervention, gallbladder drainage can be performed with temporary amelioration of symptoms. The patient is placed in a position similar to the position for biliary drainage. The gall bladder is identified with imaging (ultrasound is commonly used, but CT or fluoroscopy alone can be used). The gallbladder is accessed with a needle (which should traverse some hepatic parenchyma to allow closure of the tract when the tube is removed) and then a guidewire. Over the wire, an appropriate drainage catheter is placed and secured.

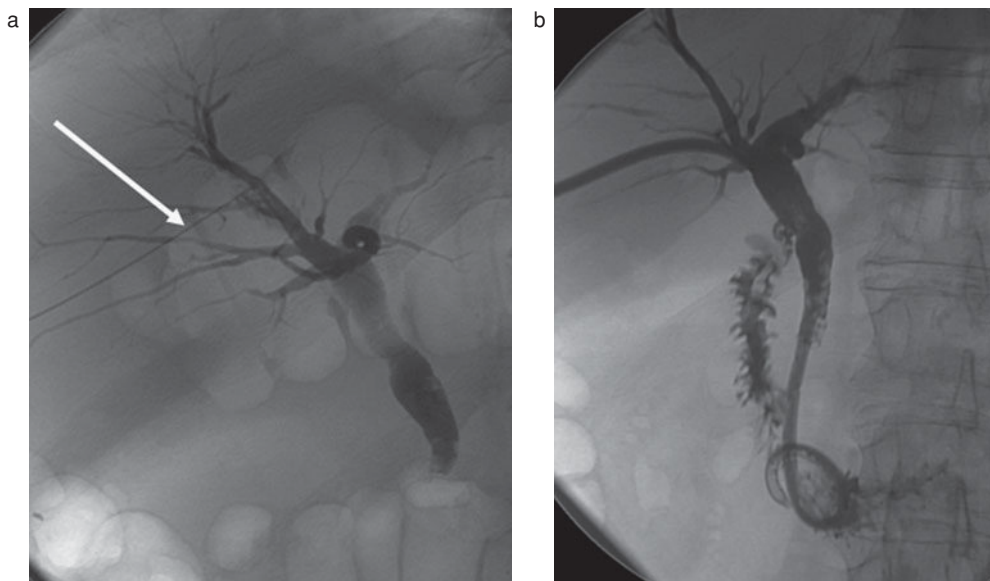


FIGURE 12.8. (a) Chiba needle (arrow) has been used to access and opacify the biliary ducts; the point of entry is in a right anterior duct. (b) After separate access into a right posterior duct, this access was converted to a drainage catheter (its Cope loop is coiled in the duodenum).

Transvenous (usually transjugular, but the transfemoral route can sometimes be used as well) hepatic and biliary procedures include hepatic venography, hepatic hemodynamic pressure measurement, liver biopsy (these three are often performed at one sitting, referred to by some as a “hepatic triple package”), and transjugular intrahepatic portosystemic shunt (TIPS) creation.

Indications for hepatic venography and hemodynamic evaluation include suspicion for hepatic venous pathology (e.g., Budd-Chiari syndrome) and determination of the presence and severity of portal hypertension. Random liver biopsies can be obtained at the same time.

For most cases, sedation and analgesia (moderate sedation) is sufficient. With the patient supine and head slightly to the left, ultrasound is used to identify and subsequently access the right internal jugular vein. Through the access needle, a wire is inserted with fluoroscopic guidance. Ultimately, a long vascular sheath is inserted. Through this sheath, access through the right atrium into the IVC is gained. An angled catheter is used to engage a right or middle hepatic vein (the left can be chosen as well). Contrast hepatic venography is performed. Simultaneous right atrial (via the sheath) and free (i.e., not yet wedged) hepatic (via the catheter) pressures are measured.

Next, the catheter is advanced over a wire to a wedged position in the periphery of the hepatic vein. The wedged position allows an indirect estimate of the portal venous pressure in a manner similar to the way pulmonary capillary wedge pressure approximates left atrial pressure. The sheath can either remain positioned in the right atrium or be advanced into the free hepatic vein position. Additional hemodynamic measurements are made. The corrected sinusoidal pressure (CSP), which is the difference between wedged and free pressures, determines the presence and severity of portal hypertension.

Creation of a portosystemic shunt can be performed percutaneously via the transjugular route. Indications and contraindications are listed below.

Indications for TIPS creation can include (Fig. 12.9):

1. Repeated episodes of esophageal variceal bleeding
2. Upper GI bleeding due to esophageal varices that have failed endoscopic treatments
3. As a “bridge” to liver transplantation to prevent variceal bleeding
4. Intractable ascites or hepatic hydrothorax

Contraindications to TIPS creation include:

1. Pre-existing hepatic encephalopathy
2. Failure of cessation of alcohol use (precluding subsequent liver transplantation)
3. Younger patients who may require years of portal decompression (although many of these are now managed with transplantation)
4. Significant heart failure, valvular disease, or pulmonary hypertension

Technically, the procedure begins similarly to the hepatic venography described earlier. However, these cases are generally longer and more painful. In our institution, we use general endotracheal anesthesia. Once access to the right hepatic vein (preferred) is obtained, the position of the right portal vein is estimated. Experience and cross-sectional imaging are helpful here; alternatively, injection of CO₂ or contrast from a wedged hepatic vein position may yield images of the portal vein.

A special needle for this purpose is thrust anteriorly out of the right hepatic vein, through the hepatic parenchyma, and hopefully into the portal vein (a maneuver sometimes jokingly referred to as the “poke and hope”). Aspiration is

performed, and, if venous blood is returned, contrast is instilled to confirm successful entry into the portal venous system. If not, the technique is repeated using slightly different angulations (requiring more pokes and more hope) until entry into the portal venous system is obtained.

Once the portal venous system has been engaged, a guide-wire and catheter are advanced into the portal vein. Hemodynamic measurements are made before creation of the portosystemic communication. The parenchymal tract is predilated with an angioplasty balloon. Ultimately, a metallic stent or a combined covered/uncovered stent is inserted spanning from the portal venous end, through the parenchymal tract, and to the hepatic venous end near the IVC. Hemodynamic measurements are again made determining

reduction of the portosystemic gradient. Final contrast images should be obtained.

Another newer biliary procedure is portal vein embolization (PVE). Portal vein embolization is performed in patients who are scheduled to undergo hepatic resection, but in whom insufficient liver volume would be left behind after resection. In these cases, the portal vein branches to the segments that contain the tumor are embolized. With the decrease in blood flow to those segments, the remaining segments that were not embolized are thereby stimulated to hypertrophy. In a matter of weeks, sufficient hypertrophy can occur so that the resection can proceed as planned, now leaving adequate hepatic parenchyma for sufficient postoperative liver function and patient survival.

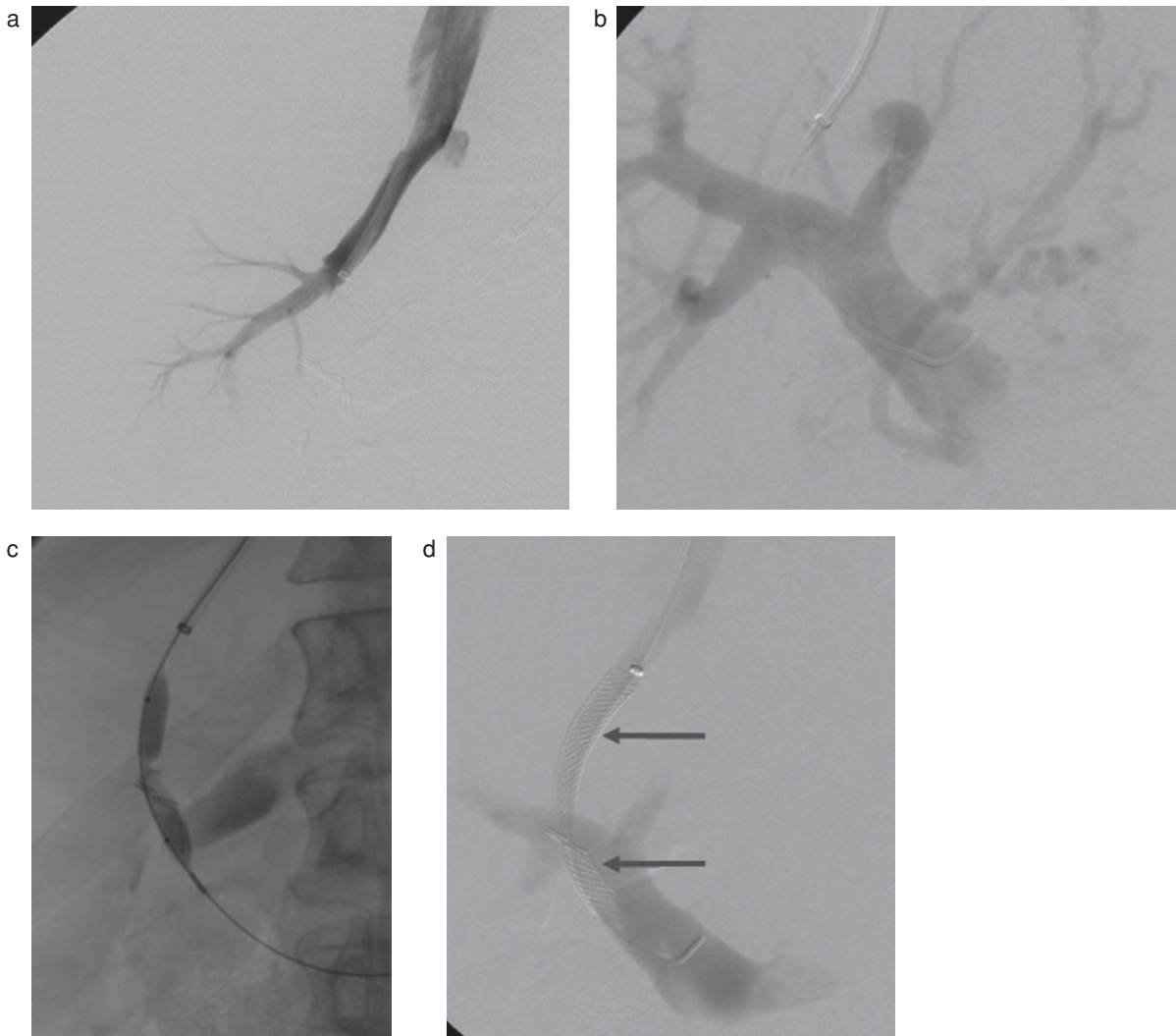


FIGURE 12.9. (a) A right-sided hepatic vein (later proven to be the middle hepatic vein) is injected with digital subtraction angiography (DSA) imaging. (b) After probing with the needle from the hepatic vein, a portal vein branch is identified; the portal system is opacified by a catheter passed into the main portal vein. (c) The hepatic parenchymal tract is dilated with an 8 mm x 4 cm angioplasty balloon. (d) The metallic stent (arrows) has been inserted spanning from the portal vein inferiorly, through the parenchymal tract, and into the hepatic vein more superiorly.

Technically, PVE is initially prepared like a percutaneous biliary drainage. With adequate sedation and local anesthesia, passes through the liver are made with a long needle. Contrast is gently injected until portal vein branches, rather than bile ducts, are opacified. Once a portal vein branch is entered, a wire is advanced. Catheters and wires as appropriate are used to engage the desired portal vein branches. Embolization is then performed with PVA and coils.

Acute complications from biliary interventions include:

1. Bleeding into the tube tract from portal venous injury (more commonly than from hepatic arterial injury)
2. Bile leak
3. Bleeding from the liver capsule or skin
4. Pleural transgression (can result in hemothorax, pneumothorax, or bile in the thorax)
5. Contrast reaction

GASTROINTESTINAL PROCEDURES AND INTERVENTIONS

Gastrointestinal (GI) interventions by interventional radiologists mostly consist of access procedures. The most common of these is percutaneous gastrostomy, although percutaneous gastrojejunostomy, percutaneous cecostomy, and direct percutaneous jejunostomy are performed as well.

Gastrostomy placement (Fig. 12.10) usually requires distention of the stomach with air (by an existing or a temporarily placed nasogastric tube). Once the stomach is distended, fluoroscopy is used to identify a path that will avoid important adjacent structures (particularly colon and lung).

Some practitioners perform gastropexy with specially designed gastropexy anchors, while others choose not to do so. Next the stomach is entered with a needle, then a wire. Over the wire, the tract can be dilated and then an appropriate tube is placed.

Cecostomy and direct jejunostomy are performed similarly, but without the nasogastric tube. Another variation of GI procedures includes CT-guided gastrostomy into the distal gastric remnant after gastric bypass procedure, since the remnant is often already distended with air or fluid.

Acute complications from GI procedures include:

1. Bleeding (from access site or from the entered viscus, usually stomach)
2. Peritonitis (from leak of gastric or other contents)
3. Transgression of undesired structures (e.g., colon, pleura, liver, spleen)

GENITOURINARY PROCEDURES AND INTERVENTIONS

Genitourinary (GU) interventions can be safely performed in the IR suite, usually with sedation and analgesia. Most commonly, direct access into the renal collecting system is requested. Access down the ureter into the bladder can be performed as well, leaving behind either an internal/external nephroureteral tube or abandoning external access and leaving only an internal double-J nephroureteral tube. Direct access into the bladder, via suprapubic cystostomy, is another GU procedure performed by IR practitioners. Balloon ureteroplasty can be performed for strictures, although subsequent

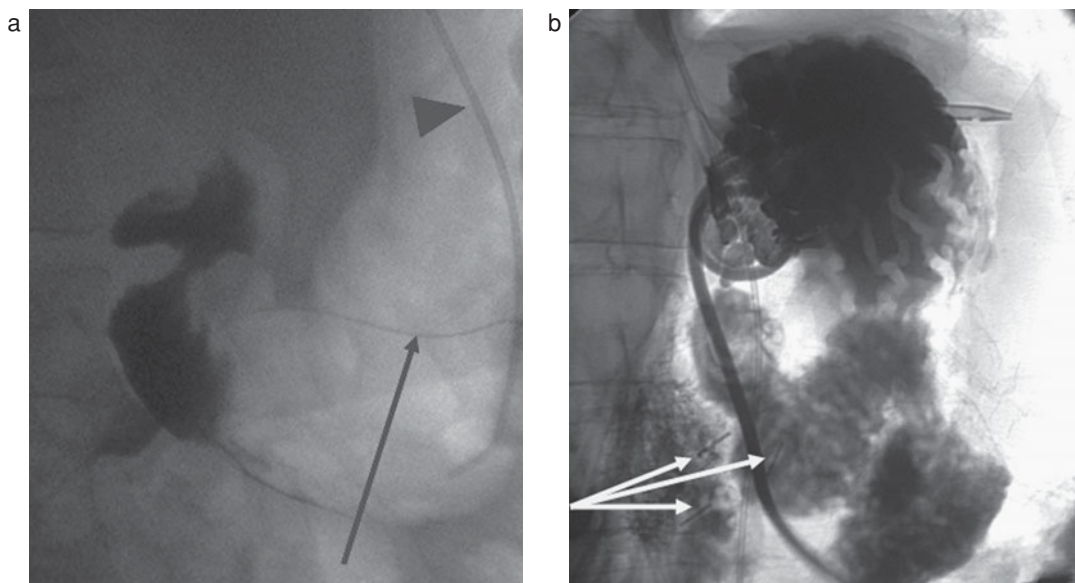


FIGURE 12.10. (a) The stomach has been distended with air delivered via a nasally placed 5 French catheter (arrowhead); a wire (arrow) has been inserted through a needle (not seen). (b) Three metallic gastropexy anchors (arrows) have been placed as has a gastrostomy tube; there is contrast in the stomach and peristalsis has brought contrast into small bowel loops as well.

prolonged stenting of ureters treated this way is required. Lastly, reverse nephroureteral tube placement or exchange via an ileal conduit (following cystectomy) can be performed.

With the exception of cystostomy and reverse nephroureteral tube procedures, most GU procedures performed in the IR suite require that the patient be prone. This positioning presents its own anesthetic and airway management issues which will be discussed elsewhere.

The most common indication for nephrostomy tube placement is to divert urine in the face of obstruction, most commonly related to nephrolithiasis. Other less common indications for nephrostomy tube placement include:

- Access for other procedures such as nephrolithotomy
- Diversion of urine and stenting of the ureter to allow healing after ureteral injury
- Treatment of complications related to renal transplantation
- Access for medication infusion, including chemotherapy and antimicrobial agents
- Treatment of urinary tract obstruction related to pregnancy

From a technical standpoint, percutaneous nephrostomy tube placement (Fig. 12.12) requires the patient to be prone. The three major steps can be reduced to: *opacify/identify*, *access*, and *drain*.

To *opacify* the collecting system, contrast must be given. This can be done by administering intravenous contrast and waiting for the pyelographic phase of the intravenous urogram (usually 3 to 5 minutes) to identify the renal pelvis. Alternatively, direct puncture over the suspected region of the renal pelvis can be performed with a 22-gauge Chiba needle, using fluoroscopic guidance and bony (or calcified) landmarks. Ultrasound may help. Once the renal pelvis is entered, aspiration on the needle will result in the return of urine.

At this point, a small amount of contrast and air are injected. The contrast outlines the collecting system and, since

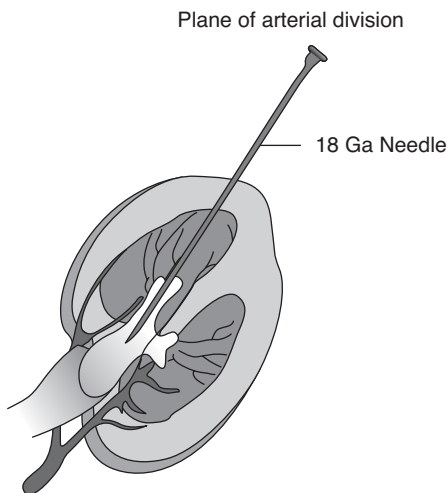


FIGURE 12.11. Needle through the avascular plane of Brödel.

the patient is prone and the air will rise (which in this case is posteriorly), a suitable posterior calyx can be *identified* for definitive access.

To *access* the posterior calyx, oblique lateral angulation is preferred. This technique allows passage of the second needle through the relatively avascular plane of Brödel (Fig. 12.11).

Once the needle is deemed to be in line with the desired calyx, fluoroscopic imaging is performed at a 90-degree angle so the appropriate depth to the desired calyx can be ascertained. Once the needle enters the calyx, probing with a guidewire is performed to confirm positioning within the calyceal system. From this point, conversion to a catheter (for navigating down the ureter if needed) is carried out and ultimately, placement of the *drainage* tube of choice is performed. Tubes can be secured using a number of securement devices; in our institution, we prefer 2-0 Nylon suture.

Acute complications from GU procedures include:

1. Bleeding (can cause hematuria or retroperitoneal bleeding)
2. Pneumothorax (risk is lowest when access is below the 12th rib)
3. Contrast reaction

INTRAOPERATIVE CASES (e.g., THORACIC AND ABDOMINAL AORTIC STENT GRAFTS)

In some facilities, intraoperative cases (Fig. 12.13) are no longer performed by the interventional radiologists. In other facilities, such as ours, the vast majority of these cases are performed as a combined effort with vascular and/or cardiothoracic surgeons working jointly with IR physicians. Inasmuch as these cases are performed either in the Operating Room or in a hybrid endovascular suite (quite analogous to an operating room), they often do not constitute an “off-site” location. They are mentioned here only to be included among the varied scope of procedures in which IR physicians may be involved.

Acute complications of intraoperative cases include:

1. Access site complications
2. Stent malposition or migration
3. Vessel injury with bleeding
4. Contrast reaction

NONINVASIVE VASCULAR IMAGING

Noninvasive vascular imaging has greatly expanded in the last decade or so. Formerly consisting only of duplex ultrasound, noninvasive imaging now also includes peripheral CT angiography (CTA), cardiac CT with coronary CT angiography, MR angiography (MRA), and cardiac MRI.

Again, interventional radiologists are involved in these modalities in varying degrees, depending on institutional practices. For most of these procedures, anesthesia support is not needed, with the occasional exception of some of the MR

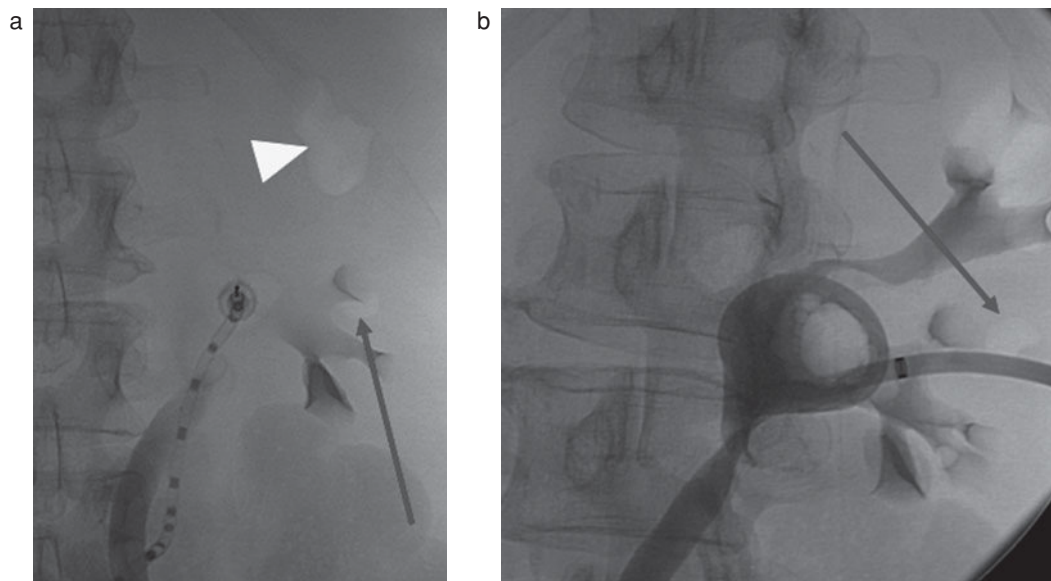


FIGURE 12.12. (a) The collecting system has been entered with a needle and both contrast and air have been instilled; a posterior upper pole calyx (arrowhead) overlies the 12th rib, so a smaller posterior mid pole calyx (arrow) was chosen for final access. (b) The posterior mid pole access (the arrow points to the air in the calyx) was converted to the nephrostomy tube; the Cope loop of the tube is coiled in the renal pelvis.

studies in patients who cannot adequately control motion, respirations, or both. Diagnostic and interventional procedures in CT, MR, and ultrasound are covered in more detail elsewhere in this text.

The most significant complications from noninvasive studies are related to contrast reaction (much more common with iodinated contrast for CT than with gadolinium-based contrast for MR) and IV site problems.

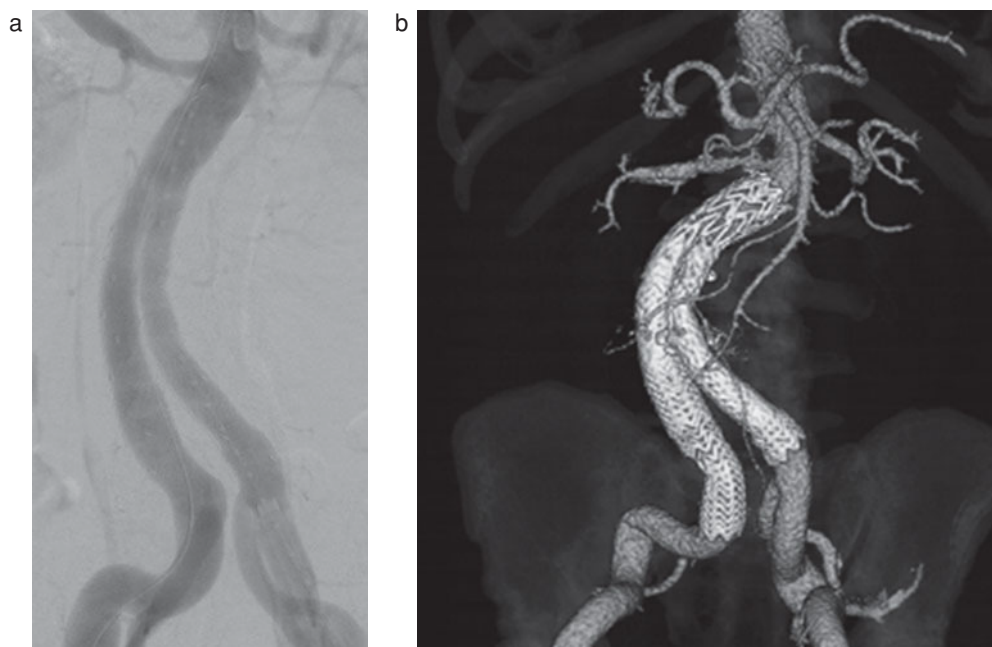


FIGURE 12.13. (a) Intraoperative DSA imaging of AAA endograft repair. (b) Postoperative CTA of the same patient demonstrating stable position of the endograft at almost 6 months postop.

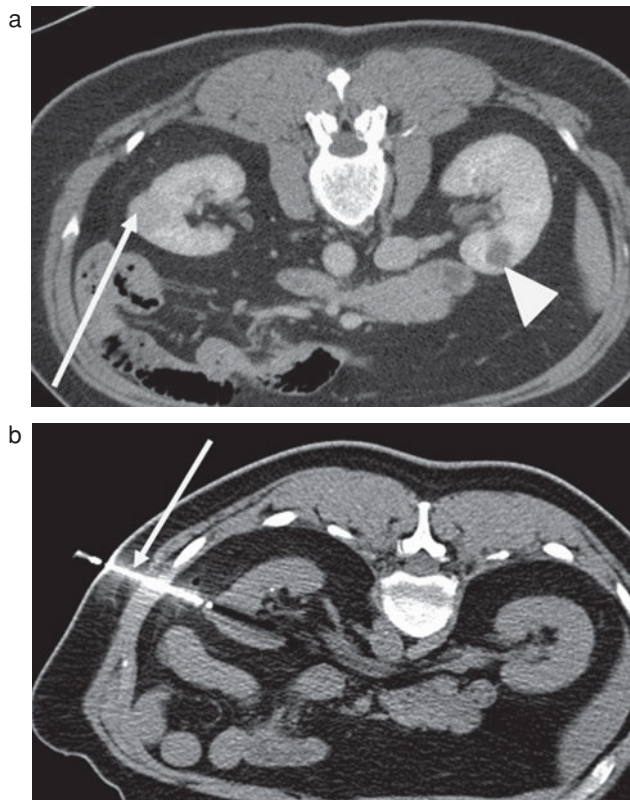


FIGURE 12.14. (a) Prone contrast CT shows a hyperdense lesion (arrow) representing a left renal cell cancer; the hypodense right kidney lesion (arrowhead) represents a cyst. (b) The cryotherapy ablation probe (arrow) has been positioned into the left renal mass on this noncontrast prone CT scan.

PERCUTANEOUS ONCOLOGIC INTERVENTIONS

This field has experienced rather rapid expansion in the last few years with many significant advances having been made. Examples of these interventions include:

1. Percutaneous transarterial chemoembolization (TACE)
2. Percutaneous ablation using radiofrequency waves, microwaves, laser, cryoablation, alcohol instillation, or acetic acid instillation (Fig. 12.14)
3. Image-guided insertion of radioactive agents, such as hepatic arterial insertion of Yttrium spheres

Some of these procedures can be done with sedation and analgesia, but in selected patients, general anesthesia may be warranted (claustrophobic patients, those who cannot remain still for extended periods, and those with questionable airways).

Percutaneous ablation treatments may be discussed in more detail elsewhere. Briefly, image guidance (usually CT or ultrasound, but fluoroscopy can be used as well) is used to safely gain access into the lesion(s). Lesions to be treated are most commonly in the liver (hepatocellular carcinoma or metastases), but treatment of lesions in kidney, lung, and adrenal

have been performed. Once the location is ensured, treatment begins by either using specialized devices to deliver ablation energy (radiofrequency, laser, microwave, or cryoablation) or by instilling a measured amount of liquid ablation agent (alcohol or acetic acid).

Transarterial chemoembolization and Yttrium spheres are delivered after arteriography identifies the vessel or vessels supplying the lesion(s). Once access as peripheral as desired is obtained, either chemotherapeutic agent combined with embolic agent or the radioactive spheres are delivered via the catheter through the selected hepatic arterial branches. Postprocedure care is according to established protocols.

Acute complications from oncologic interventions are dependent on the type of access:

1. If percutaneous access is used, then the acute complications are similar to other percutaneous procedures, including bleeding, injury to nontarget structures, and transgressing pleura. Also, injury (from heat or cold) to nontarget structures may occur.
2. If transarterial access is used, acute complications are similar to other transarterial embolization cases.

PERCUTANEOUS BIOPSIES

Interventional radiologists perform percutaneous biopsies at some facilities whereas at other institutions, body imagers and others perform these procedures. These interventions will be discussed in more detail elsewhere. Suffice it to say that the maxim from Samuel Shem's book, *The House of God*, which states that "there is no body cavity that cannot be reached with a #14 needle and a good strong arm" is not far from true. One alteration is that it is wiser to use a smaller needle (e.g., 22-gauge) in case undesired targets are encountered. Some representative images are shown (in Fig. 12.15).

Acute complications from biopsies are generally site-specific and can include:

1. Bleeding
2. Acute injury to nontarget structures (including pneumothorax and pancreatitis)
3. Inadequate specimen

VENOUS PROCEDURES AND INTERVENTIONS

Apart from venous access (discussed later), venous procedures are less common than arterial procedures. However, the breadth of venous procedures is greater than that of arterial procedures. Some venous procedures have already been discussed in the section "Biliary Procedures and Interventions," including hepatic venography with hemodynamic evaluation, transjugular liver biopsy, and TIPS.

Other venous procedures include:

1. Venography
2. Angioplasty (Fig. 12.16)

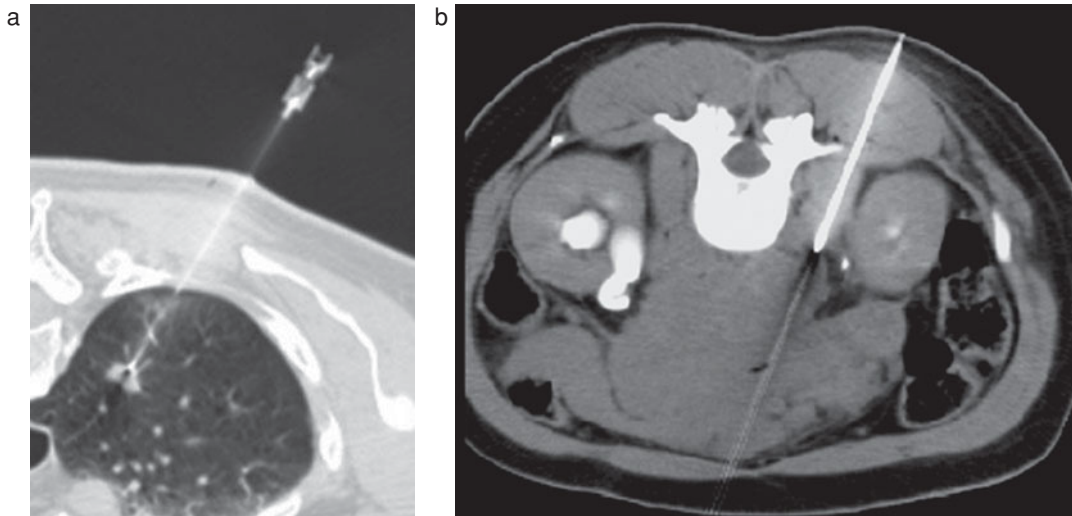


FIGURE 12.15. (a) A fine needle has been advanced into a lung lesion with CT guidance. (b) Fine needle passed through enlarged paravertebral lymph nodes by CT; the needle will have to be withdrawn slightly before sampling.

3. Stent placement (Fig. 12.17)
4. IVC filter placement and retrieval
5. Minimally invasive treatment of varicose veins
6. Selective venous sampling (e.g., adrenal veins, renal veins, petrosal veins, and parathyroid)
7. Pulmonary arteriography (accessed via the venous system)
8. Embolization of pulmonary arteriovenous malformations (PAVMs)
9. Foreign body retrieval
10. Thrombolysis

Venography is angiography (the general term for imaging of the vessels) of the veins. The technical aspects are similar in many ways to arteriography. More often than with arteriography, ultrasound is used during access because the precise location of a vein is not as evident as the palpable pulse of an artery. Otherwise, sheaths, catheters, and wires are used to navigate to various areas for evaluation and/or treatment. Contrast is administered with DSA imaging to obtain venograms. For extremity venography, often a temporary tourniquet is applied to allow filling of deeper veins.

Angioplasty can be performed in the venous system similarly to the arterial system. Central venous angioplasty is often related to indwelling venous devices (e.g., ports, central lines, and pacer/defibrillator wires). Not infrequently, venous angioplasty needs to be repeated.

Stents can be placed in the venous system for stenoses refractory to angioplasty. Some promising results are reported, but the restenosis and occlusion rates for venous stents appear to be higher than for arterial stenting. In some cases, the stent can allow for antegrade flow long enough for sufficient collateral venous channels to develop before the stent occludes.

IVC filter placement is used to reduce the risk of emboli originating from lower extremity or pelvic deep vein thrombosis

(DVT) reaching the lung (pulmonary embolus, or PE). While most DVTs can be managed with anticoagulation, in certain instances, patients who cannot receive anticoagulation are treated with IVC filter placement.

Indications for IVC filter placement include:

1. Failure of anticoagulation (i.e., DVT or PE while adequately anticoagulated)
2. Allergy to anticoagulants (includes heparin-induced thrombocytopenia)
3. Contraindication to anticoagulation (recent surgery, active bleeding, recent trauma, known intracranial lesion, and others)
4. Patient at high risk for PE

Currently, both retrievable (also known as removable, temporary, or optional) and permanent filters are available. Most can be placed via either the transfemoral or transjugular routes. The technique involves access into the vein, performance of IVC venography, selecting an appropriate location (usually below the lowest renal vein and above the iliac confluence), deployment of the filter, and follow-up venography. On occasion, a suprarenal IVC filter can be placed; even less common is superior vena cava (SVC) filter placement, performed to prevent upper extremity DVT from embolizing centrally.

The procedures can be performed with little or no sedation. Before orthopedic surgery, the author personally had a retrievable IVC filter placed (Fig. 12.18) via the transjugular route (without sedation, so cases could continue to be performed by him immediately afterward); it was removed two months later (also without sedation) without incident.

Minimally invasive varicose vein procedures (Fig. 12.19) include endovenous ablation (by radiofrequency or laser) of incompetent superficial lower extremity veins (most commonly the greater and lesser saphenous veins), phlebectomy, and

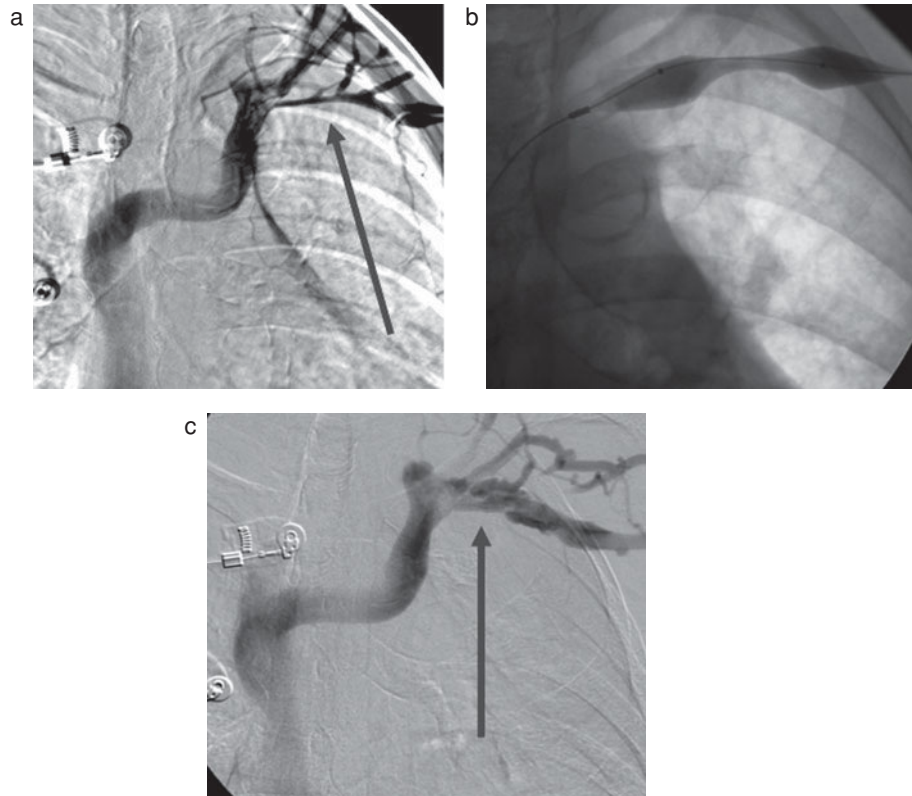


FIGURE 12.16. (a) Severe stenosis of the left subclavian vein (arrow). (b) Angioplasty balloon is partially inflated revealing the “waist” at the stenosis. (c) Angiographic improvement noted at the site of previous stenosis (arrow) after angioplasty.

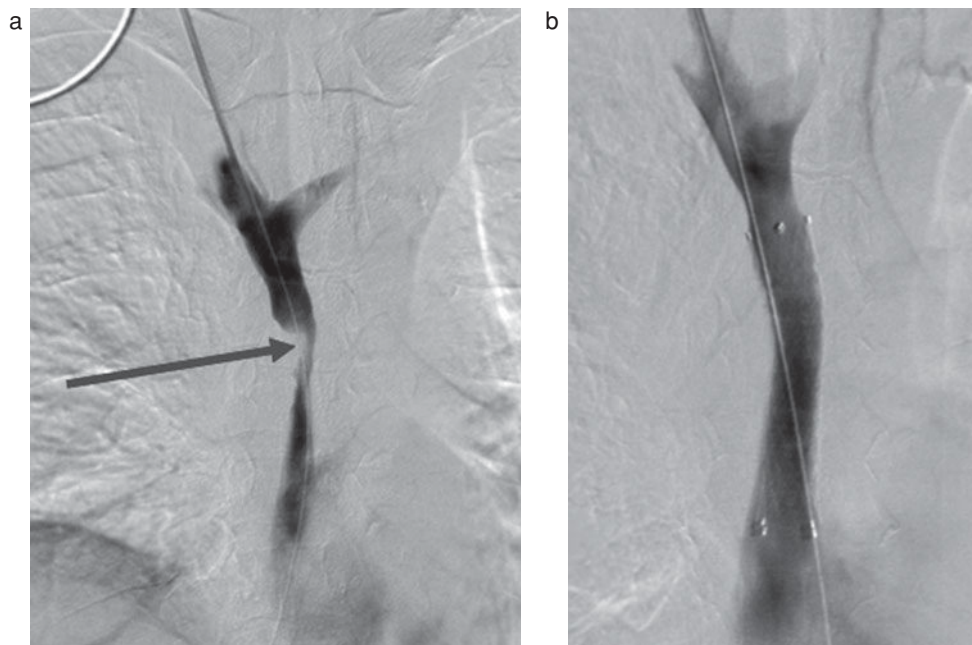


FIGURE 12.17. (a) High-grade stenosis in the mid superior vena cava (SVC) (arrow). (b) Successful resolution of stenosis in the mid SVC following stent placement; a stent was used because the compression of the SVC was caused by a large paratracheal neoplasm in a terminal patient.

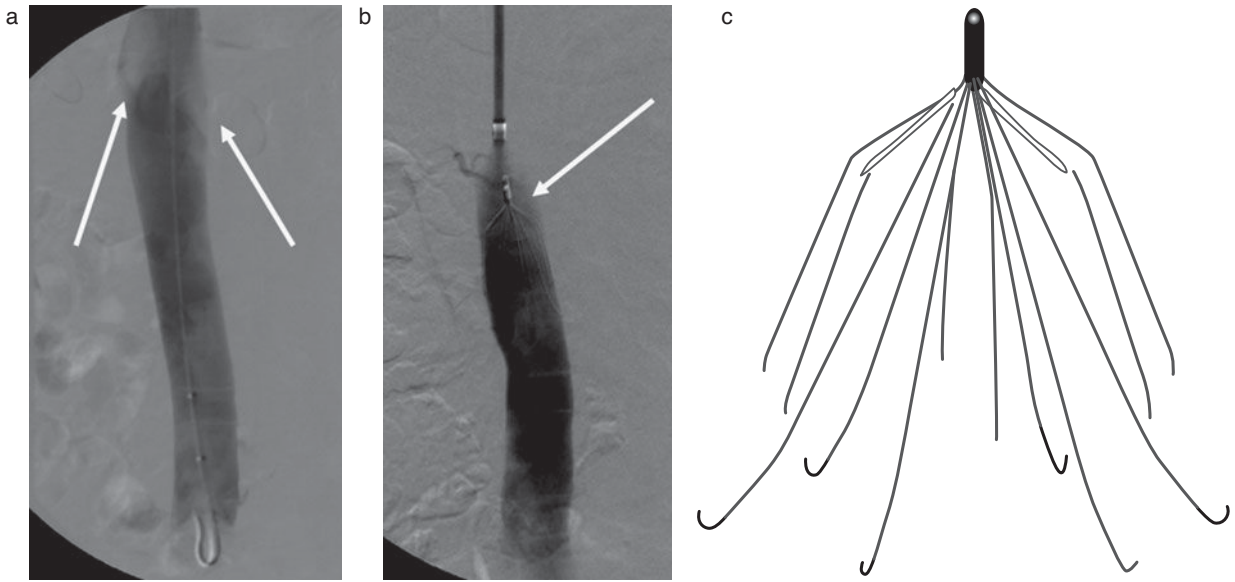


FIGURE 12.18. (a) Inferior vena cava (IVC) gram (the author's own) showing normal caliber; note inflow defects from unopacified blood from renal veins bilaterally (arrows). (b) The IVC filter has been successfully deployed. (c) Photo of an IVC filter.

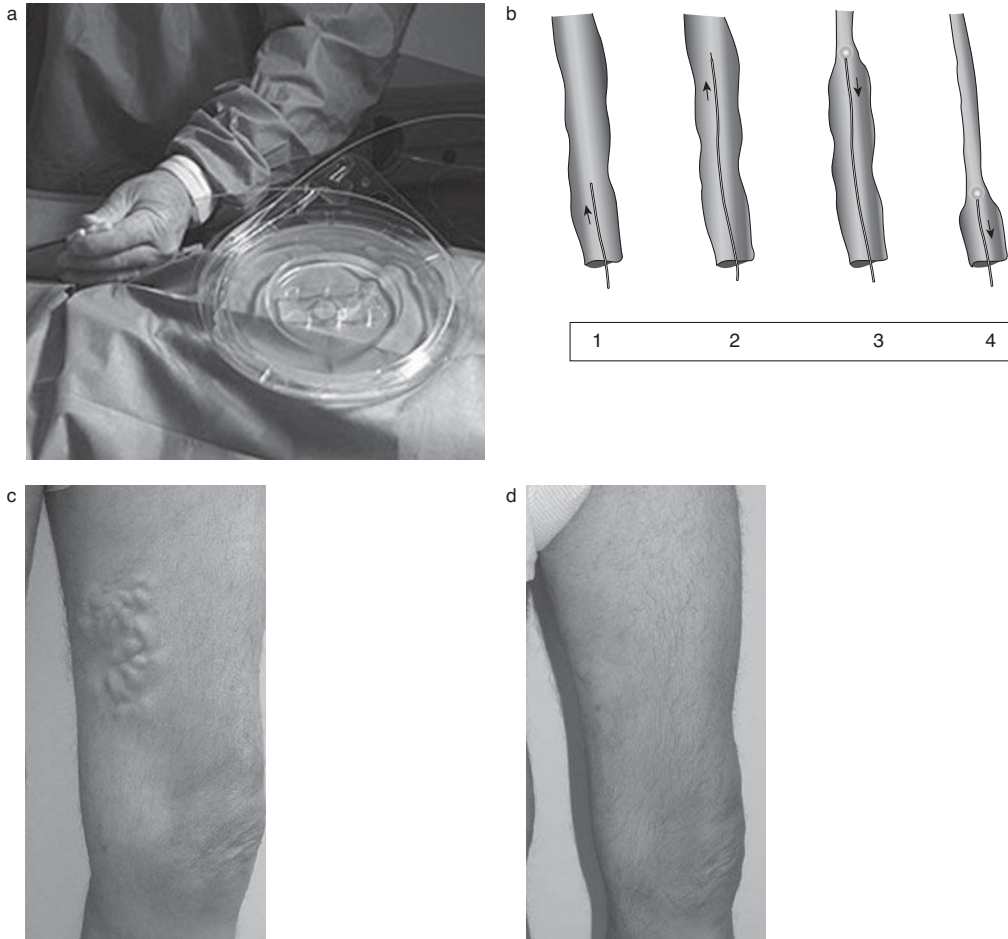


FIGURE 12.19. (a) A photo of an endovenous laser being used during a procedure. (b) The laser fiber is inserted and positioned (frames 1 and 2), then activated and withdrawn (frames 3 and 4), causing thermal damage to the lining of the treated vein, ultimately resulting in its occlusion (frame 4). (c) A “before” photo showing large medial thigh varicose veins following ablation of the incompetent source vein, in this case, the left greater saphenous vein. (d) An “after” photo showing resolution of the large medial thigh varicose veins following ablation of the incompetent source vein, in this case, the left greater saphenous vein. (All images used with permission from Vascular Solutions, Inc.)

injection sclerotherapy. These procedures can all be accomplished without sedation in many patients; in others, sedation and analgesia can be used. Imaging requirements usually consist only of ultrasound for access. A detailed description of the techniques is beyond the scope of this chapter.

Selective venous sampling (SVS) can be used to identify veins draining various organs. In some cases, establishing laterality of the abnormality is desired, such as adrenal vein sampling for aldosterone and cortisol, or renal vein sampling for renin. In other cases, SVS helps establish or refute a diagnosis. For example, bilateral simultaneous venous sampling for ACTH levels from the inferior petrosal sinuses after peripheral injection of CRH (corticotropin-releasing hormone) can confirm or refute a central (pituitary) source of ACTH. The diagnosis of Cushing disease is supported by detecting a significant gradient between the central (pituitary) and peripheral values of plasma ACTH. In parathyroid sampling, multiple veins that could potentially drain parathyroid tissue are accessed and sampled. An elevated parathyroid hormone level from one sample suggests the site of a parathyroid adenoma.

Pulmonary arteriography (Fig. 12.20) is used less frequently than in the past given the speed, availability, and excellent results of pulmonary CT angiography. Nonetheless, it remains a procedure that IRs are at times requested to perform. In some cases, it is used to evaluate for PE in the presence of a high clinical suspicion but a negative or equivocal noninvasive test (pulmonary CTA or nuclear medicine test). Other indications include evaluation for chronic PE, evaluation and treatment of pulmonary arteriovenous malformations or pseudoaneurysms, or evaluation of pulmonary hypertension.

Technically, either the jugular or femoral venous approach can be employed. Once access is gained to the right atrium, one of several catheters can be used to navigate through the tricuspid valve, through the right ventricle, and into the pulmonary outflow tract. The left and right pulmonary arteries are selected and power-injected as needed. Control of the patient's respirations is mandatory here. Digital subtraction angiography imaging is acquired in the AP projection and at least one obliquity.

If pulmonary AVMs are identified, they can be embolized with coils or metallic occlusion devices, taking care to avoid passage of the embolization device through the fistula and to the left atrium, left ventricle, and ultimately, the systemic arterial circulation.

Foreign body retrieval (Fig. 12.21) most commonly consists of retrieving a broken venous catheter fragment. These fragments often reside in the heart or pulmonary arterial tree. Many are asymptomatic, identified on unrelated chest radiograph. Retrieval via the transfemoral route is most commonly attempted using one or more of a variety of snare products to grab the fragment and pull it out through a sheath in the access vein.

Venous thrombolysis is less commonly employed than arterial thrombolysis, but the principles are similar. For lower extremity DVT thrombolysis, sometimes the patient must remain prone while access via the popliteal vein is gained and maintained during infusion of thrombolytic.

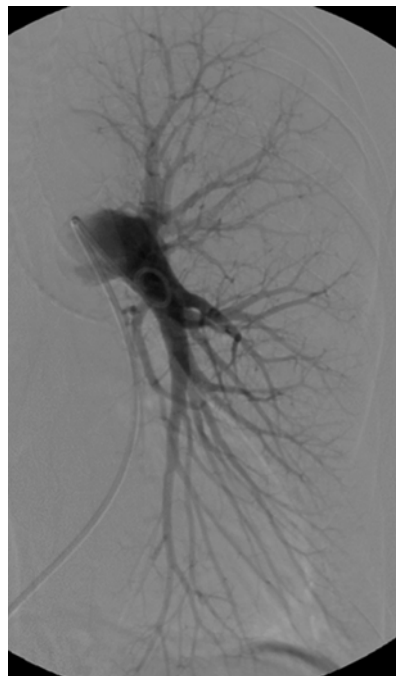


FIGURE 12.20. Normal left pulmonary arteriogram obtained with DSA imaging.

Acute complications from venous procedures include:

1. Access issues (bleeding, thrombosis, pneumothorax)
2. Contrast reaction
3. Vessel injury with bleeding
4. Thrombosis
5. Embolism (of thrombus or of the foreign body to be retrieved)
6. Device malposition (e.g., IVC filter)
7. Cardiac irritation with dysrhythmia

VENOUS ACCESS (INCLUDING HEMODIALYSIS ACCESS)

Central venous access (Fig. 12.22) encompasses a large portion of many Interventional Radiology practices. Access into the central circulation can be performed for infusion of medications (antibiotics, chemotherapeutic agents, blood products) or for withdrawal of blood for treatment (pheresis therapy or hemodialysis). Catheters can be partially tunneled under the skin (providing more comfortable access), implanted completely (subcutaneous ports), or inserted directly into the vein (nontunneled). Catheters range greatly in size, from 3 or 4 French to 16 French and potentially even more, based on patient size, vein size, and planned usage.

Ultrasound is frequently used to access the desired vein, both to identify a nonpalpable structure (the soft vein) and to avoid adjacent nontarget structures (including arteries and

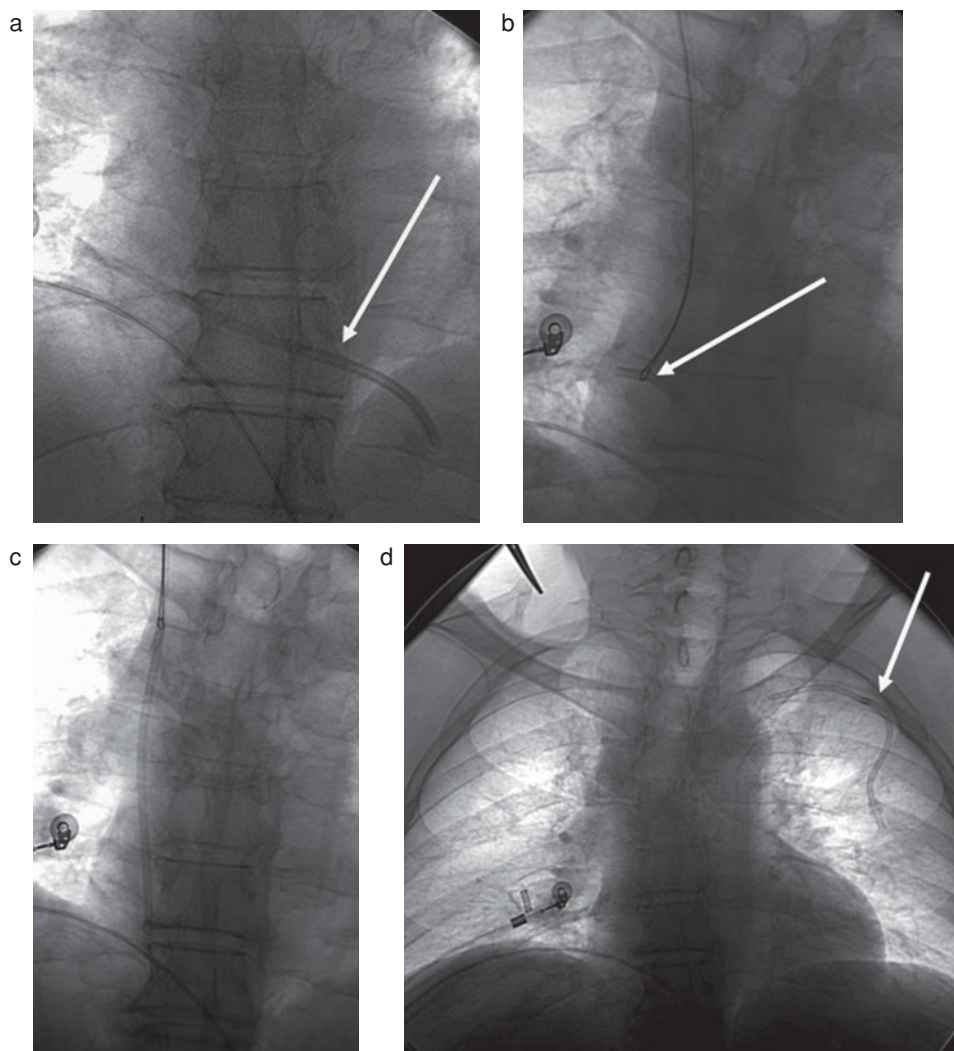


FIGURE 12.21. (a) Fragment of catheter (arrow) seen over lower chest, spanning right atrium and right ventricle. (b) One end of catheter fragment has been grasped with a snare (arrow). (c) Ensnares fragment is being removed via a right internal jugular (IJ) sheath. (d) The fragment has been completely removed; only the subcutaneous portion remains (arrow), and it can be easily removed externally.

lung). Fluoroscopy is used to follow the course of the wire once needle access into the vein is gained. Also, contrast can be given via the needle, and DSA imaging can be performed if the wire path is unusual in some respect.

Many different veins can be selected for access. In our institution, the internal jugular (IJ) is the route of choice, largely to reduce potential subclavian stenosis.³ For nontunneled catheters, there is evidence that the infection rate for subclavian access may be lower than for IJ puncture.⁴

Other less common and less preferable sites include:

1. Common femoral veins
2. Saphenous veins
3. Arm veins (basilic, cephalic, or brachial)
4. External jugular veins
5. Translumbar access into the IVC

6. Transhepatic access into the hepatic veins and then to the IVC

Along with catheter insertion, catheter exchange and removal are part of the array of central venous procedures performed by IR physicians. Additionally, management of noncatheter hemodialysis access (AV fistula and AV grafts) is frequently performed. These techniques include diagnostic contrast studies as well as angioplasty and sometimes stent placement. Peritoneal dialysis catheter (obviously not venous, but included here for discussion) positions can be manipulated percutaneously as well, although the success rate is not exceedingly high.

Acute complications from venous access procedures can be similar to any of those listed previously for other venous procedures.



FIGURE 12.22. A right IJ tunneled hemodialysis catheter has been inserted and is ready for use.

SUMMARY

The scope of procedures that are performed regularly by interventional radiologists has been outlined here to give the reader a summary of its breadth. Clearly, that list of procedures

encompasses many different indications, organ systems and body areas, techniques, and outcomes. As summed up earlier, we who work in IR do indeed perform a vast array of diagnostic and interventional procedures, mostly through *very small holes*.

Individual practices vary based on need and practice history of the particular institution and region. In many instances, the addition of sedation and analgesia (moderate sedation) is needed for comfortable performance of these procedures. In other cases, deep sedation or general anesthesia may be required to permit the successful performance of the procedures. The details of anesthesia involvement in IR procedures will be discussed in Chapter 13.

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13 | Anesthesia for Diagnostic and Therapeutic Radiologic Procedures

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Radiology procedures can be diagnostic, therapeutic, or both. Diagnostic procedures are anatomic or functional, minimally or noninvasive, cause little pain or discomfort, and seldom require anesthesia support. When anesthesia assistance is requested, it is typically because of the patient's physiological or psychological needs. Therapeutic techniques are often more invasive and more likely to require the services of an anesthesiologist because of the complexity of the procedure and the comorbidities and discomfort of the patient. All therapeutic procedures are to some degree interventional, but many diagnostic procedures are not, although an *interventional radiologist* may perform them.

Patient safety is paramount during any radiological procedure. For many patients, comfort can be achieved with as little as reassurance or local anesthesia. Patients having more complex or invasive procedures may benefit from the administration of sedative and/or analgesic medications (sedoanalgesia) titrated to effect, up to a regional or general anesthetic. Safety ensues from the judicious administration of sedoanalgesia to a patient in optimal medical condition by a trained and vigilant practitioner. The American Society of Anesthesiologists (ASA) defines the sedation continuum that derives from titrating medication and its concomitant impact on level of responsiveness and physiologic function (Table 13.1).¹

Noninvasive and many minimally invasive procedures (e.g., chest X-ray and breast needle localization, respectively) can be managed without medication, although some patients receive nominal sedation, anxiolysis, or analgesia. If the patient requests or requires moderate sedation (i.e., sedoanalgesia that might result in the loss of protective mechanisms such as the gag reflex, airway tone, and ventilatory drive), additional precautions are warranted to detect and mitigate its consequences. Among these are the evaluation and preparation of the patient, monitoring during the procedure, and postanesthesia care. Guidance can be found in the ASA Practice Guidelines for Sedation and Analgesia by Non-anesthesiologists.¹ If more than moderate sedation is planned (i.e., deep sedation or regional or general anesthesia) or for patients with significant comorbidities, a trained and dedicated provider should care for the patient.

Conducting anesthetics in the radiology department can be challenging because of the patient's comorbidities, the procedure,

the anesthetic, the radiology equipment, and the environment. The ASA Practice Advisory for Preanesthesia Evaluation² should be followed, and anesthetics should be administered by qualified and credentialed anesthesia personnel. After the anesthetic, the patient's recovery should be guided by the ASA Practice Guidelines for Postanesthetic Care.³ Remote locations often preclude immediate assistance, so thorough preparation, including access to a crash cart and defibrillator, is essential, and a system to provide reinforcements should be in place. Preparations must also be made for monitoring and support if the patient will be transported to another site for postanesthesia recovery. Patient safety is best ensured by following the Guidelines for Nonoperating Room Anesthetizing Locations promulgated by the ASA.⁴

Care delivered by anesthesia professionals can be one of three types: monitored anesthesia care (MAC), regional anesthesia, or general anesthesia. Selection depends on the procedure and the relative risks and benefits to the patient. Monitored anesthesia care, the least invasive anesthetic, is indicated when a procedure requires deep sedation or increased monitoring.¹ The anesthesiologist administers intravenous sedation and analgesia; the proceduralist may give an additional local anesthetic at the site. Monitored anesthesia care is a physician service that is distinct from moderate sedation because the anesthesia provider must be able to apply resources to support life and ensure patient comfort and safety during diagnosis or therapy.⁵ For regional anesthesia, the anesthesiologist performs a nerve block. Blocks may be central (neuraxial) blocks (e.g., spinal, lumbar epidural) or peripheral (e.g., brachial plexus, paravertebral). General anesthesia is used when the patient or procedure requires it. For all anesthetics, patient safety through selection and monitoring are critical components of an anesthesiologist's care.

DIAGNOSTIC RADIOLOGY

Contrast Media

Iodinated contrast media is frequently employed in both diagnostic and interventional radiology procedures and may result in adverse (anaphylactoid) reactions or renal dysfunction. Adverse reactions involve direct cellular effects, including

TABLE 13.1. *Continuum of Depth of Sedation: Definition of General Anesthesia and Levels of Sedation/Analgesia*

	<i>Minimal Sedation (Anxiolysis)</i>	<i>Moderate Sedation/ Analgesia (Conscious Sedation)</i>	<i>Deep Sedation/Analgesia</i>	<i>General Anesthesia</i>
Responsiveness	Normal response to verbal stimulation	Purposeful* response to verbal or tactile stimulation	Purposeful* response after repeated or painful stimulation	Unarousable, even with painful stimulus
Airway	Unaffected	No intervention required	Intervention may be required	Intervention often
Spontaneous ventilation	Unaffected	Adequate	May be inadequate	Frequently inadequate
Cardiovascular function	Unaffected	Usually maintained	Usually maintained	May be impaired

Note: Minimal sedation (anxiolysis) is a drug-induced state during which patients respond normally to verbal commands. Although cognitive function and coordination may be impaired, ventilatory and cardiovascular functions are unaffected. Moderate sedation/analgesia (conscious sedation) is a drug-induced depression of consciousness during which patients respond purposefully to verbal commands, either alone or accompanied by light tactile stimulation. No interventions are required to maintain a patent airway, and spontaneous ventilation is adequate. Cardiovascular function is usually maintained. Deep sedation/analgesia is a drug-induced depression of consciousness during which patients do not respond purposefully following repeated or painful stimulation. The ability to independently maintain ventilatory function may be impaired. Patients may require assistance in maintaining a patent airway, and spontaneous ventilation may be inadequate. Cardiovascular function is usually maintained. General anesthesia is a drug-induced loss of consciousness during which patients are not arousable, even by painful stimulation. The ability to independently maintain ventilatory function is often impaired. Patients often require assistance in maintaining a patent airway, and positive pressure ventilation may be required because of depressed spontaneous ventilation or drug-induced depression of neuromuscular function. Cardiovascular function may be impaired. Because sedation is a continuum, it is not always possible to predict how an individual patient will respond. Hence, practitioners intending to produce a given level of sedation should be able to rescue patients whose level of sedation becomes deeper than initially intended. Individuals administering moderate sedation/analgesia (conscious sedation) should be able to rescue patients who enter a state of deep sedation/analgesia, while those administering deep sedation/analgesia should be able to rescue patients who enter a state of general anesthesia.

*Reflex withdrawal from a painful stimulus is not considered a purposeful response.

Source: Reprinted with permission from American Society of Anesthesiologists Task Force on Sedation and Analgesia by Non-Anesthesiologists. Practice guidelines for sedation and analgesia by non-anesthesiologists. *Anesthesiology* 2002; 96(4):1005.

enzyme induction and activation of the complement, fibrinolytic, kinin, and other systems.⁶ Manifestations range from relatively benign itching to life-threatening cardiovascular or ventilatory collapse. Prophylaxis and treatment for the former include antihistamines and steroids. Anaphylaxis is quite rare and is probably not a result of the iodine in the contrast material.⁷

Patient risk factors for renal complications include chronic renal disease, diabetes mellitus, heart failure, older age, anemia, and left ventricular systolic dysfunction. Contrast risk factors are high osmolarity, viscosity, volume, and ionic media. For patients with renal disease, diabetes, proteinuria, hypertension, gout, or congestive heart failure, serum creatinine levels should guide the radiologist's administration of the contrast material. Adequate hydration, the use of bicarbonate, and low volumes of iso- or low-osmolar contrast are necessary in patients at risk. N-acetylcysteine or ascorbic acid may be of value in very high-risk patients.⁸ Diabetic patients with preexisting renal dysfunction who also take metformin have developed severe lactic acidosis after an iodinated contrast study. Thus, metformin should be discontinued at the time of or before the procedure, withheld for 48 hours subsequent to the procedure, and reinstated only after renal function has been re-evaluated and found to be normal.⁹

Intravenous gadolinium may be employed for magnetic resonance imaging (MRI) contrast studies and is not problematic during the anesthetic. The United States Food and Drug Administration (FDA) is evaluating gadolinium-containing contrast agents as the possible causative agent for

a disease known as nephrogenic systemic fibrosis or nephrogenic fibrosing dermopathy in patients with kidney failure.¹⁰

Although barium is an oral and not an intravenous contrast agent, it should be mentioned because it may pose an aspiration risk after ingestion if deep sedation or general anesthesia is necessary.

Ultrasound contrast is achieved through the intravenous administration of microbubbles, which are echogenic during an ultrasound examination. They carry an FDA warning that patients with pulmonary hypertension or unstable cardiopulmonary conditions should be closely monitored during and for at least 30 minutes after administration.¹¹

Anatomic Imaging

Magnetic Resonance Imaging

The MRI suite has been divided into four zones (Fig. 13.1),¹² and the ASA has issued a specific practice advisory¹³ emphasizing a location or position for optimal patient observation and vigilance during delivery of care in zones III and IV. The ASA promotes procedures for entering zones III and IV, with special emphasis on hazards in these environments, effects on monitoring capabilities, potential health hazards (e.g., high decibel levels and high-intensity magnetic fields), and the need for precautions to ensure the safety of MRI scanners. The American College of Radiologists and The Joint Commission have established standards, guidelines, and recommendations for the MRI suite.¹⁴⁻¹⁷

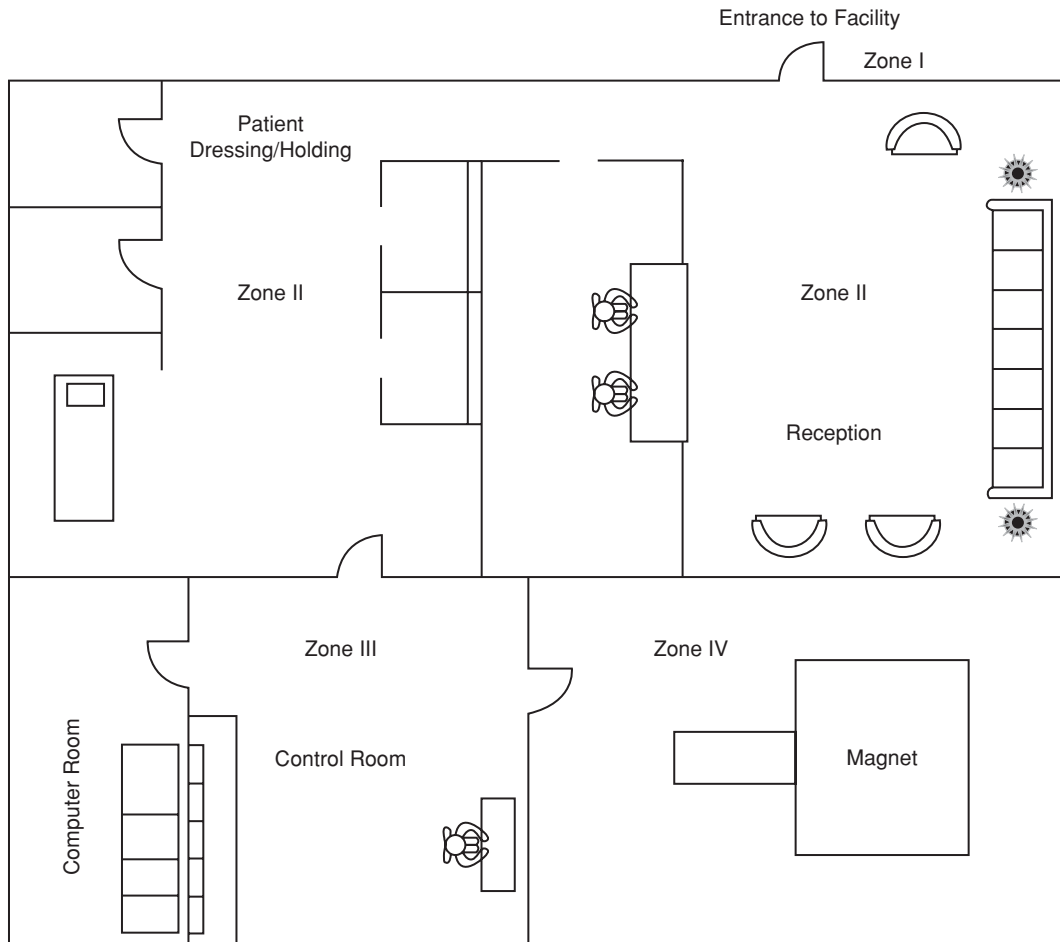


FIGURE 13.1. Layout of a typical magnetic resonance imaging (MRI) suite.

Patient monitoring and the administration of an anesthetic in the MRI suite can be difficult because the anesthesia provider is often physically separated from the patient during the study. The patient must be observed continually, either through a window into the scanner room or with a camera trained on the patient and a video monitor in the control booth. Vital signs must be monitored through a window or via a camera trained on a monitor in the scanner room or a slave monitor in the control room.

Monitor placement and the length and routing of leads, wires, and tubing should be considered to prevent entanglement or traction as the MRI tables moves. Coiling monitor wires (e.g., pulse oximeter, electrocardiogram) should be avoided because this has resulted in patient burns.¹⁸ Patient temperature should be monitored because it may increase from the heat of radiofrequency radiation within the magnetic field,¹⁹ or it may decrease by radiation, conduction, convection, and evaporation. Monitoring temperature intermittently instead of continuously may avoid the possibility of burns from the thermistor during long sessions or in critically ill patients.²⁰

Medical emergencies must be anticipated, and a plan must be in place to treat them. Although advanced cardiac life support may be instituted on a patient still in the scanner, prompt relocation outside the scanner room gives better access to the patient and is safer for the staff. If the magnet is shut down too quickly, called “quenched,”²¹ the liquid cryogen boils off rapidly and releases enormous amounts of helium vapor that may displace air, so an evacuation plan must be in place. The scanner is noisy and there have been reports of hearing loss following MRI scan, so some form of ear protection is advisable, even for unconscious patients.²² Positioning of patients can be difficult and care must be taken to prevent injury in obese patients or patients with preexisting neurologic disease.²³ The patient’s entrance into and exit from the scanner warrants vigilance as well.

Most MRI studies are associated with minimal patient discomfort. After assuring a patient’s safety, the primary goal is to keep the patient still. Frequently, patient cooperation is all that is required and little or no sedative or analgesic medication is needed. If medications are used, they should be titrated to effect. Doses that are too large may lead to confusion and disinhibition, resulting in an agitated and uncooperative patient.

TABLE 13.2. *Guidelines for Scheduling Imaging Studies as Awake, Sedated, or under Anesthesia*

Technique	Imaging Factors			Patient Factors		
	Study	Duration (min)	Position	Age (yr)	Developmental Status	Coexisting Disease
Awake	CT, NM	<30	Constant	<0.3, >3	Normal	Minimal or none
	MRI	<60	Constant	>7	Normal	Minimal or none
Sedate	CT, NM	>30	Changing	<0.3	Normal	Minimal or none
	MRI	<60	Changing	<4.5	Normal	Minimal or none
Anesthesia	CT, NM	Any	Any	Any	Severe delay	Any
	MRI	>60–90	Any	Any	Any	Any

Coexisting diseases include severe sleep apnea, refractory seizure disorders, preliver transplantation, patients unable to lie flat for extended periods of time, and American Society of Anesthesiologists physical status 3 or 4. In addition to changes, position may be an indication for sedation or anesthesia if it will be extremely uncomfortable for an extended period of time.

CT, computed tomography; MRI, magnetic resonance imaging; NM, nuclear medicine.

Source: Reprinted with permission from Taghon TA, Bryan YF, Kurth CD. Pediatric radiology sedation and anesthesia. *Int Anesthesiol Clin.* 2006;44(1):65–79.

An anesthesiologist should be consulted if the patient requires more than moderate sedation and is at risk for the loss of consciousness or protective reflexes. When a patient's medical condition is painful or if the procedure induces pain, regional²⁴ or general anesthesia may be chosen. If the patient is expected to be uncooperative during the procedure because of young age or claustrophobia, then general anesthesia is indicated. Table 13.2 lists the guidelines for selecting sedoanalgesia in pediatric patients based on age, developmental status,

position, study duration, coexisting disease, and type of imaging study.²⁵ A selective list of sedative, analgesic, and general anesthetic agents used in imaging studies is found in Table 13.3.²⁵

A general anesthetic requires inhalational gases or intravenous drugs. Airway management must be scrupulous and conservative because of the distance and barriers between the anesthesiologist and the patient. As with monitors, anesthesia devices, including airway equipment must conform to the

TABLE 13.3. *Medications Commonly Used in Radiology Sedation and Anesthesia*

Drug	Dosage Range	Radiology-Specific Sedation Comments	Class
Propofol anesthetic	150–200 µg/kg per minute 2 mg/kg per IV bolus	Potential for apnea and airway obstruction	General
Sevoflurane Anesthetic	2%–3% inhaled	Potential for airway obstruction and larygospasm	General
Choral hydrate	25–100 mg/kg orally	Potential for prolonged duration of action and toxicity with impaired liver function	Hypnotic
Pentobarbital	3–8 mg/kg IV or orally	Potential for paradoxical reaction: can use orally in infants and small children or intravenously	Barbiturate sedative
Midazolam	0.3–1 mg/kg orally	Adjunct; may be sufficient as single agent in severe neurologic disease	Benzodiazepine anxiolytic
Fentanyl	1–2 µg/kg	Painful condition exacerbated by position in scanner	Opioid
Morphine	0.1 mg/kg IV	Adjunct with pentobarbital or midazolam	Opioid
Meperidine	2 mg/kg IV or orally	Adjunct with pentobarbital may be particularly useful with adolescents	Opioid
Dexmedetomidine	2–5 µg/kg per hour 1 µg/kg per loading dose	Centrally acting alpha-1 agonist, with minimal respiratory depression; may be more commonly used in near future	Hypnotic

Source: Reprinted with permission from Taghon TA, Bryan YF, Kurth CD. Pediatric radiology sedation and anesthesia. *Int Anesthesiol Clin.* 2006;44(1):65–79.

TABLE 13.4. Study Durations, Case Turnover, and Incidence of Side Effects in Children Subjected to Magnetic Resonance Imaging (MRI) under Either General Anesthesia (GET Group) or Intravenous Anesthesia (MKP Group)

MKP	Group GET (n = 313)	Group MKP (n = 342)
Time to start scan (min)	9.6 (1.5)	4.2 (1.1)*
Duration of scan (min)	27.3 (7.9)	29.3 (11.4)
Emergence (min)	8.7 (5.5)	6.7 (4.1)
Time to discharge (min)	32.7 (10.9)	29.7 (9.7)
Case turnover	4–5 cases/5 hr	5–6 cases/5 hr
Side effects		
Discontinued	0 (0)	2 (0.6)
Repeat the scan	1 (0.3)	8 (2.3)*
Desaturation	10 (3.2)	16 (4.7)
Laryngospasm	8 (2.6)	0 (0)*
Shivering	4 (1.3)	0 (0)
Total	23 (7.0)	26 (7.7)

Note: Data are mean (SD) or n (%).

* $p < 0.05$.

Source: Reprinted with permission from Shorrab AA, Demian AD, Atallah MM. Multidrug intravenous anesthesia for children undergoing MRI: a comparison with general anesthesia. *Paediatr Anaesth*. 2007;17(12):1187–1193.

criteria of the American Society for Testing and Materials and the Food and Drug Administration. It may be best to secure the airway outside of the scanner room and then transport the patient into the room. For pediatric patients, sedation with ketamine, midazolam, and propofol is adequate, safe, and comparable to that used for general anesthesia with endotracheal intubation (Table 13.4).²⁶ Infants who are at increased risk for adverse effects (Table 13.5) may require an experienced and skilled practitioner.²⁶ When intravenous propofol, oral chloral hydrate, and intravenous pentobarbital were compared for anesthesia in infants, propofol produced the fastest induction and recovery (Table 13.6) and lowest failure rate (Table 13.7), although the incidence of respiratory events was high.²⁷ Total intravenous “light” general anesthesia with propofol and remifentanyl, but without airway instrumentation, has been used effectively for children,²⁸ as has intravenous propofol alone.^{29,30}

X-Ray, Fluoroscopy, and Computed Tomography

Electromagnetic waves (X-rays) have been incorporated into a number of different imaging modalities. The traditional X-ray refers to two-dimensional still images, although the same frequency of electromagnetic radiation is used for two-dimensional moving images (fluoroscopy) and “three-dimensional” computed tomography (CT). Concerns in these environments include the anesthesia provider’s radiation exposure and distance from the patient. The former is

TABLE 13.5. Side Effects in Patients Subjected to Magnetic Resonance Imaging (MRI) under Either General Anesthesia (Group GET) or Intravenous Anesthesia (Group MKP)

	Group GET (n = 313)			Group MKP (n = 342)		
	<1 year years	1–4 years	>4 years	<1 years	1–4 years	>4 years
No.	93	134	86	98	138	106
Discontinued	0 (0)	0 (0)	0 (0)	2 (2)	0 (0)	0 (0)
Repeat the scan	1 (1.1)	0 (0)	0 (0)	4 (4.1)	3 (2.1)	1 (0.9)
Desaturation	5 (5.3)	3 (2.2)	2 (2.3)	8 (8.1)	5 (3.6)	3 (2.8)
Total	6 (6.4) ^a	3 (2.2)	2 (2.3)	14 (14.2) ^b	8 (5.8)	4 (3.7)

Note: Data are n (%).

^a Significant ($p < 0.05$) compared with the older age strata within GET group.

^b Significant ($p < 0.05$) compared with the older age strata within MKP group and compared with the same age stratum of GET group.

Source: Reprinted with permission from Shorrab AA, Demian AD, Atallah MM. Multidrug intravenous anesthesia for children undergoing MRI: a comparison with general anesthesia. *Paediatr Anaesth*. 2007;17(12):1191.

addressed by distance, lead shielding, and radiation monitoring (personal dosimeter); the latter, by following protocols for monitoring similar to those in the MRI suite. The U.S. Occupational Safety and Health Administration has established limits for the exposure of individuals to radiation in restricted areas,³¹ and institutional guidelines should adhere to these standards. The presence of radiographic equipment (e.g., C-arm or CT aperture) can make airway management

TABLE 13.6. Mean (\pm SD) Values of Time in Minutes after Three Different Anesthetics

Times	Chloral Hydrate ^a (n = 101 ^b)	Pentobarbital (n = 66 ^b)	Propofol (n = 68)
Sedation ready	23.5 (13.4)	12.7 (8)	9.1* (6.7)
Procedure duration	48.11 (20.8)	49.3 (15.7)	58.5* (19.5)
Time to discharge	61.2 (31.9)	80.3 (39.2) [†]	53.9 (30.1)

^a Values in parentheses indicate \pm SD values.

^b One patient each in the chloral hydrate and the pentobarbital group was excluded due to sedation failure requiring transfer back to the induction room and assumption of care and further sedation with propofol by an anesthesiologist.

* $p < 0.05$, propofol versus chloral hydrate and propofol versus pentobarbital.

[†] $p < 0.05$, pentobarbital versus propofol and pentobarbital versus chloral hydrate.

n, number of cases.

Source: Reprinted with permission from Dalal PG, Murray D, Cox T, et al. Sedation and anesthesia protocols used for magnetic resonance imaging studies in infants: provider and pharmacologic consideration. *Anesth Analg* 2006;103(4):863–868.

TABLE 13.7. *Adverse Events after Administration of the Primary Sedative Drugs in Three Groups*

Adverse event	Chloral Hydrate (n = 102)	Pentobarbital (n = 67)	Propofol (n = 68)
Cardiorespiratory events	3* (2.9%)	9 (13.4%)	9 ^a (13.6%)
Gastrointestinal events	Emesis (2)	Hiccups (1)	0
Movement in scanner	23 (22.5%) [†]	8 (12.2%)	1 (1.4%)
Scan aborted completely	4 (3.9%)*	1 (1.4%)	0
Scan completed with additional/rescue sedation/Pedialyte	12 (11.7%)*	7 (10.4%)	1 (1.4%)
Scan completed with repositioning, bundling, etc.	7 (5.9%)	0	0

^a Significant respiratory event in two cases; referred to anesthesiologist.

* $p < 0.05$; [†] $p < 0.001$; n, number of cases.

Source: Reprinted with permission from Dalal PG, Murray D, Cox T, et al. Sedation and anesthesia protocols used for magnetic resonance imaging studies in infants: provider and pharmacologic consideration. *Anesth Analgesia*. 2006;103(4):863–868.

and access to the patient difficult, while the anesthesia machine and cart often compete for space with radiology equipment and supplies. The configuration of the table and other equipment means that patient positioning, especially lateral or prone, can be problematic. If the anesthesia provider remains in the procedure room, the anesthetic is performed with the encumbrance of a lead apron.

For diagnostic fluoroscopy procedures (Table 13.8) contrast material may be ingested (e.g., barium swallow), administered per rectum (e.g., barium enema), or injected intravenously (e.g., intravenous pyelogram) or intrarterially (e.g., aortogram). Many procedures can be performed without anesthesia support, unless a patient's comfort, comorbidities, or cooperation requires it. For example, diagnostic angiography is often performed with no or only light to moderate sedoanalgesia by cardiologists; percutaneous transhepatic cholangiography may be performed by a radiologist using the same regimen. Unstable or claustrophobic patients may require anesthesia assistance.

Computed tomography is a benign procedure for most patients and is relatively safe for personnel since the X-ray beam is tightly focused. Although studies are performed in a few seconds or minutes, they require a still patient, so cooperation must be assured either through patient education or pharmacologic intervention. A variant is computed tomographic angiography, in which thin-section CT and contrast material produce vascular maps that equal or exceed those provided by classic angiography.³²

TABLE 13.8. *Diagnostic Fluoroscopy Procedures*

Upper Gastrointestinal Series
Air contrast colon
Intravenous pyelogram (IVP)
Small-bowel enteroclysis
Fluoroscopic-guided biopsy
Arthrography
Myelography
Modified barium swallow
Hysterosalpingogram
Venogram
Arterogram
Barium enema
Percutaneous transhepatic cholangiography

Ultrasound

Like diagnostic X-rays, diagnostic ultrasound imaging is non-invasive and easily tolerated. In the absence of invasive techniques, anesthesia support is not warranted; if it is indicated, no encompassing techniques or precautions are necessary.

FUNCTIONAL IMAGING

Functional Brain Imaging

Functional brain imaging reveals blood flow, metabolism, or electrical activity. Electrical activity is demonstrated by the electroencephalogram (EEG), which directly measures the electrical potential between two scalp electrodes. Many anesthesiologists are familiar with this technology from its use in electroconvulsive shock therapy or intraoperative monitoring during carotid endarterectomy. Variants of the EEG used intraoperatively are the BIS[®], Narcotrend[®], PSI[®], Entropy[®], SNAPII[®], and Cerebral State Monitor[®]. The EEG is spatially limited by the number of electrodes, a limitation that has been improved by high-density arrays of over 120 electrodes.³³ Magnetoencephalography is a more sensitive technology that records local magnetic fields produced by neuronal electrical activity in the brain via extremely sensitive instruments such as superconducting quantum interference devices. It may be useful in multiple sclerosis, Alzheimer disease, schizophrenia, Sjögren syndrome, chronic alcoholism, and facial pain and has demonstrated efficacy in epilepsy.^{34,35}

Other functional brain imaging techniques rely on the remarkably consistent relationship between regional changes in the cellular activity of the brain and changes in the blood flow and metabolism of the region.³⁶ Blood flow is revealed by functional MRI (fMRI), positron emission tomography (PET), and single-photon emission computed tomography (SPECT). Functional MRI can use blood as a contrast medium because oxygenated hemoglobin is diamagnetic (negative magnetic susceptibility) and deoxygenated hemoglobin is paramagnetic

(positive magnetic susceptibility), resulting in distinct magnetic resonance signals. A less common technique uses arterial spin labeling to magnetically alter the protons in the water molecules of the arterial blood in the neck and then identify them as they perfuse the brain. Functional MRI has been useful in determining the functional relationship between tumors and surrounding tissues.³⁷ During a PET scan, a positron-emitting radionuclide molecule is injected that emits gamma rays that can be detected by a scanner. When the positrons emitted by the tracer annihilate with electrons up to a few millimeters away, two gamma photons are emitted; the amount of imaged tracer reflects blood flow and concomitant brain activity. It can also show regional metabolic activity if the radionuclide molecule contains [¹⁸F]-2-fluoro-deoxy-d-glucose (FDG), which concentrates in the more active areas. Positron emission tomography has been used in stroke patients to assess the magnitude of injury and the viability of areas at risk,^{38,39} in seizure patients to map brain areas to predict surgical morbidity and outcome, in Parkinsonian syndromes as an adjunct to clinical diagnosis, in dementia for early diagnosis and differentiation, and in the prognosis of, and efficacy of treatment for, brain tumors. Positron emission tomography is often combined with CT or MRI to provide an anatomic correlate for the functional image. Like PET, SPECT detects gamma rays, but the tracer material itself emits gamma radiation as it decays. More material indicates greater blood flow.

Metabolic activity can be directly revealed through magnetic resonance spectroscopy, which detects signals from hydrogen or phosphorous to determine the concentration of brain metabolites such as N-acetyl aspartate, choline, creatine, and lactate in tissue. Greater levels indicate greater metabolic activity. It is used in the diagnosis and treatment of certain neuropsychiatric disorders, such as schizophrenia, affective diseases, or autism; in the pathogenetic interpretation of some Parkinsonian neurodegenerative disorders;⁴⁰ in tumor diagnosis, prognosis, and therapeutic outcome; dementia diagnosis and prognosis; and in multiple sclerosis, infections, trauma, stroke, and perinatal ischemia.⁴¹ These procedures are often performed on awake individuals, although occasionally a patient's psychological or physical condition may require the use of sedation or general anesthesia.

Administering anesthetic psychotropes may result in artifacts that disrupt the remarkably consistent relationship between regional changes in the cellular activity of the brain and changes in its circulation and metabolism. For example, unresponsiveness induced with isoflurane was associated with a relatively uniform reduction in brain glucose metabolism during PET with FDG.⁴² Halothane resulted in a similar reduction. Propofol was associated with larger absolute metabolic reductions, a greater suppression of cortical metabolism than either inhalational agent, and significantly less suppression of basal ganglia and midbrain metabolism.⁴³ Propofol preferentially decreased cerebral blood flow in brain regions previously implicated in the regulation of arousal, performance of associative functions, and autonomic control and was more regionally than globally active.⁴⁴ With fMRI, morphine had a regional effect, decreasing the signal in cortical

areas as did propofol or midazolam. Activation was observed in endogenous analgesic regions such as the periaqueductal gray, the anterior cingulate gyrus (decreased signal), and hypothalamus (increased signal).⁴⁵ Midazolam impacts fMRI by significantly altering the signal in the brain's auditory and visual cortices.⁴⁶ Nonpharmacologic interventions can also influence imaging outcomes, such as increased mean airway pressure (e.g., continuous positive airway pressure) reducing the fMRI signal in the primary visual cortex.⁴⁷

There are no strong recommendations for anesthetic technique for these diagnostic procedures. Indeed, functional brain imaging techniques such as PET and fMRI have been used to *study* the effects of general anesthesia on the brain, and a systematic baseline response to anesthetics has not yet been developed.⁴⁸⁻⁵⁰ If an anesthetic is required, the anesthesiologist should consider the anesthetic's impact on cerebral blood flow, metabolism, and electrical activity and choose agents with minimal effect, combine agents to minimize their effects, and maintain steady-state anesthetic conditions.

THERAPEUTIC RADIOLOGY

Therapeutic radiology has grown from percutaneous procedures for aspiration/drainage to the more complex placement of arterial stents or embolization of arteriovenous malformations. Table 13.9 lists some common interventional therapeutic radiologic procedures and imaging methods. Biliary tube placement or exchange, tunneled catheter placement, vascular interventions, and other catheter insertions have been performed using moderate sedation for the patient, in which nurses, trained in critical care, monitor the patient and administer low-dose midazolam and fentanyl.⁵¹ Adverse events are few (Table 13.10) and minor without clinical impact.⁵¹ Tables 13.11 and 13.12 list various procedures and compare the utilization of different methods of anesthesia in Europe and the United States.⁵² Less rather than more sedation is the rule in Europe, although general anesthesia is more common in Europe. In one East Coast academic center, MAC or general anesthesia was used for only 10% of cases for interventional radiology.⁵³

As interventional radiology increases in volume and complexity, it is more often being performed in an emergency setting and includes high-risk patients who cannot tolerate a more invasive method, making an anesthesiologist necessary.⁵⁴ The conditions for performing an anesthetic for therapeutic radiology procedures include those for diagnostic radiology: monitoring from afar, avoiding radiation exposure, working around radiology equipment (Fig. 13.2), and prohibiting ferrous materials in the MRI suites. The choice of anesthetic technique for interventional radiology is procedure specific with wide variations, depending on the patient and the skill sets of the interventionalist and associated personnel. The anesthetic presents more challenges because the procedure is invasive and the patient may have several comorbidities. The requirement of a completely still patient, both for the success

TABLE 13.9. *Therapeutic Radiology Procedures and Imaging Techniques*

<i>Procedure Imaging</i>	<i>Arterial/Venous Interventions</i>	<i>Cancer Treatment</i>	<i>Ablation: Radiofrequency, Ethanol, Microwave, Cryo-Laser</i>	<i>Vascular Access</i>	<i>Vertebroplasty Kyphoplasty</i>	<i>Embolization</i>	<i>Percutaneous Procedures</i>
Fluoroscopy	Stenting, balloon angioplasty, catheter-directed thrombolysis, inferior vena cava filter, transjugular intrahepatic portosystemic shunt	Chemoembolization: Hepatic cancer		Artery, vein	Vertebral compression fractures	Brain aneurysm, uterine fibroids, arteriovenous malformation, varicocele, esophageal varices	Biliary drainage Nephrolithotomy Nephrolithotripsy
Computed Tomography (CT)		Cryotherapy: Prostate cancer, liver cancer, cervical cancer, retinoblastoma	Kidney, liver, lung		Vertebral compression fractures		
Ultrasound		Cryotherapy: Prostate cancer, liver cancer, cervical cancer, retinoblastoma	Kidney, liver, lung				
Magnetic resonance imaging (MRI)		Cryotherapy: Prostate cancer, liver cancer, cervical cancer, retinoblastoma	Kidney, liver, lung				

of the procedure and the safety of the patient, can be fulfilled by sedoanalgesia administered either by the proceduralist or an anesthesia professional. If a predictable ventilatory pattern in the patient is desired, it can be achieved by the judicious administration of sedoanalgesia to a cooperative patient or by

TABLE 13.10. *Frequency of Adverse Events Occurring in Five Common Interventional Radiology Procedures*

<i>Procedure Category (n = 539)</i>	<i>Respiratory Events (%)</i>	<i>Sedation Events (%)</i>	<i>Major Events (%)</i>
Biliary procedures (n = 183)	8.7 ^a (p = 0.044)	6.0 (p > 0.05)	2.2 (p > 0.05)
Tunneled catheters (n = 135)	3.0 (p > 0.05)	3.7 (p > 0.05)	1.5 (p > 0.05)
Diagnostic arteriogram (n = 125)	4.0 (p > 0.05)	4.0 (p > 0.05)	2.4 (p > 0.05)
Vascular interventions (n = 51)	2.0 (p > 0.05)	2.0 (p > 0.05)	2.0 (p > 0.05)
Other procedures (n = 45)	0.0 (p > 0.05)	2.2 (p > 0.05)	2.2 (p > 0.05)

^a Statistically significant for respiratory events (p = 0.044) and any adverse event (p = 0.015) during biliary procedures.

Source: Reprinted with permission from Arepally A, Oechsle D, Kirkwood S, et al. Safety of conscious sedation in interventional radiology. *Cardiovasc Intervent Radiol.* 2001;24(3):188.

general anesthesia with controlled ventilation. Some particularly painful procedures (e.g., radiofrequency ablation of osteoid osteomas) require a subarachnoid block or general endotracheal intubation by an anesthesiologist.⁵⁵ Other procedures associated with extreme fluid shifts (e.g., drainage of ascites fluid or blood loss during a uterine artery embolization) benefit from the presence of someone who is well versed in securing intravenous access and who knows how to use it. Some procedures may require anticoagulation and the means to measure its effects (e.g., activated coagulation time). Because interventional neuroradiology has virtually become a subspecialty unto itself, it will be discussed separately.

Fluoroscopy

Endovascular Stents

Fluoroscopy is the common imaging technique for stent placement. Anesthesiologists are requested for these procedures because of the potential for complications and because the patient population comprises patients who were previously considered “too sick for open surgery.”⁵⁶ Among the anesthetic techniques used for endovascular aortic repair are general, epidural, combined epidural/spinal⁵⁷ spinal, and continuous spinal.⁵⁸ Even when performed under MAC, one must be prepared for significant blood loss and invasive monitoring.⁵⁹ Mild hypotension, using nitroglycerin,⁶⁰ nitroprusside, nicardipine,

TABLE 13.11. Preferred Levels of Sedation for All Procedures

<i>Procedure</i>	<i>Awake/Alert</i>	<i>Drowsy/Arousable</i>	<i>Asleep/Arousable</i>	<i>Deep Sedation</i>	<i>General anesthesia</i>
<i>Vascular</i>					
Angiography	74% (163)	24% (53)	1% (2)	1% (2)	0.5% (1)
Pulmonary angiography	74% (136)	24% (45)	0.5% (1)	0.5% (1)	1% (2)
Angioplasty	62% (130)	33% (69)	3% (7)	2% (4)	0.5% (1)
Caval filter placement	67% (120)	29% (53)	3% (5)	1% (1)	0.5% (1)
Embolization	36% (71)	46% (91)	9% (18)	5% (10)	4% (8)
TIPSS	9% (11)	26% (32)	21% (26)	14% (17)	30% (37)
Thrombolysis	59% (118)	35% (70)	5% (9)	0.5% (1)	0.5% (1)
Atherectomy	58% (60)	36% (37)	5% (5)	0% (0)	1% (1)
Venous access	53% (78)	38% (56)	7% (10)	1% (1)	1% (2)
<i>Genitourinary</i>					
Nephrostomy	17% (26)	56% (85)	23% (35)	2% (3)	1% (2)
Nephrolithotomy	7% (5)	16% (11)	11% (8)	11% (8)	54% (38)
Stricture dilatation	11% (11)	33% (32)	39% (38)	7% (7)	9% (9)
Abscess drainage	33% (50)	52% (80)	12% (19)	2% (3)	1% (1)
<i>Abdominal/pelvic</i>					
Abscess drainage	36% (69)	49% (93)	13% (24)	2% (3)	1% (2)
Biliary drainage	12% (22)	38% (68)	32% (57)	11% (19)	8% (14)
Cholecystostomy	14% (15)	49% (53)	25% (27)	7% (8)	4% (4)
Thora/paracentesis	50% (54)	34% (37)	12% (13)	4% (4)	1% (1)
Tube procedure	47% (47)	37% (37)	13% (13)	3% (3)	1% (1)
Biopsy	62% (110)	32% (57)	5% (9)	1% (2)	0.5% (1)
Biliary dilatation	7% (10)	34% (49)	35% (50)	14% (20)	11% (16)
Gastro/jejunostomy	17% (16)	55% (53)	18% (17)	8% (8)	2% (2)
Stent placement	17% (31)	46% (83)	22% (39)	7% (12)	8% (15)
<i>Chest</i>					
Biopsy	67% (104)	29% (46)	3% (4)	0% (0)	1% (2)
Fluid drainage	61% (83)	31% (46)	6% (8)	0% (0)	2% (2)
Chest tube placement	45% (40)	42% (37)	11% (10)	1% (1)	1% (1)

Note: Figures in parentheses are the number of responders.

TIPSS, transjugular intrahepatic portasystemic shunts.

Source: Reprinted with permission from Haslam PJ, Yap B, Mueller PR, et al. Anesthesia practice and clinical trends in interventional radiology: a European survey. *Cardiovasc Intervent Radiol.* 2000;23:256–261.

or esmolol,⁶¹ and an immobile patient are important when deploying the stent. Spinal cord injury may be decreased by limiting hypotension, monitoring evoked potentials and cerebrospinal fluid (CSF) pressure, and measuring CSF proteins (S100 β) during thoracic aneurysm repair.⁶² An intrathecal drain may be beneficial for thoracic aneurysm repairs,⁶³ but it may also lead to catheter-related complications.⁶⁴

Carotid artery stenting may improve patient outcome compared with traditional carotid endarterectomy in patients who are at overall increased surgical risk.^{65,66} Aspirin and

clopidogrel are often administered before the procedure and heparin is given intraoperatively while activated clotting time is monitored. Stenting may be performed in a patient under MAC, with close attention paid to central nervous system changes and bradycardia,⁶⁶ or under general anesthesia. General anesthesia was found to depress baroreceptor reflex sensitivity and induce hemodynamic stability, potentially decreasing complications.⁶⁷

Stenting to improve blood flow through iliac, popliteal, subclavian, or renal arteries does not mandate the presence

TABLE 13.12. Preferred Level of Sedation for Selected Procedures and Comparison with U.S. Data

Procedure	Alert/Awake		Drowsy/Arousable		Asleep/Arousable		Deep Sedation		General Anesthesia	
	European	U.S.	European	U.S.	European	U.S.	European	U.S.	European	U.S.
<i>Diagnostic vascular</i>										
Vascular angiography	74	20	24	73	1	7	1	0	0.5	0
Pulmonary angiography	74	24	2	67	0.5	3	0.5	0	1	0
<i>Therapeutic vascular</i>										
Angioplasty	62	14	33	72	3	13	2	0	0.5	1
Caval filter placement	66	23	30	71	3	35	1	0	1	0
Embolization	35	7	47	60	9	29	5	2	4	2
Thrombolysis	59	15	36	68	5	17	0.5	1	0.5	0
Venous access	53	27	38	62	7	10	1	1	1	0
<i>Diagnostic visceral</i>										
Abdominal/pelvic biopsy	62	35–50	32	50–60	5	3–5	1	1	1	0
Chest biopsy	67	48	29	48	3	17	0	1	1	0
<i>Therapeutic visceral</i>										
Biliary drainage	12	0	38	25	31	48	10	22	8	5
Abdominal/pelvic										
abscess drainage	36	5–8	49	65	12	25	2	3	1	0
Nephrostomy	17	0–1	57	20–45	23	45	2	12	1	1–2
Biliary stent placement	17	3	47	50	21	37	7	42	8	1
Tube manipulation/change	47	30	37	57	13	12	3	1	1	0

Note: Data are presented as percentages. Each percentage is an approximation for that procedure at the level of sedation.

Source: Reprinted with permission from Haslam PJ, Yap B, Mueller PR, et al. Anesthesia practice and clinical trends in interventional radiology: a European survey. *Cardiovasc Intervent Radiol.* 2000;23(4):256–261.

of an anesthesiologist⁶⁸ unless the patient's condition warrants it. Stenting of venous outflow has been used for chronic nonmalignant or malignant obstruction of the femoroiliacaval vein,⁶⁹ and patients with neoplastic superior vena cava syndrome have received palliative stents without sedation.⁷⁰

A transjugular intrahepatic portosystemic shunt treats complications of portal hypertension (e.g., esophageal varices) by using an expandable metallic stent to create an artificial parenchymal channel between portal and hepatic vein branches. It may be performed under MAC or general anesthesia.⁷¹ The patient's mental status, ability to tolerate the procedure without moving, overall hemodynamic status, and ease of airway management dictate the type of anesthesia. Significant comorbidities can include pathological shunting in vascular beds, leading to increased cardiac output and heart failure. Ascites, pleural effusions, intrapulmonary shunting, pulmonary hypertension, hepatorenal syndrome, encephalopathy, and coagulopathies are common in these patients. Because of hepatic insufficiency, the anesthetic agents selected should not depend on the liver for clearance.⁷² A cirrhotic cardiomyopathy may be associated with a prolonged Q-Tc interval, which may deteriorate into a torsades de pointes arrhythmia.

Catheter-Directed Thrombolysis

Thrombolysis is accomplished by the local infusion of tissue plasminogen activators that create plasmin with ensuing fibrinolysis. Common agents include streptokinase, urokinase, and recombinant formulations. Thrombolysis is used in patients with myocardial infarction, ischemic stroke, pulmonary embolism, thrombosed dialysis access, portal vein thrombosis, and acute limb ischemia. Anesthesia is seldom required, but if it is, the anesthetic depends on the patient's comorbidities and avoiding trauma during airway maneuvers. Neuraxial regional anesthesia is contraindicated.⁷³

Inferior Vena Cava Filter

Inferior vena cava filters are placed in patients who have a history of, or who are at risk for deep vein thromboses in the legs that may then embolize to the right heart and lungs. Access is obtained through the right internal jugular vein or a femoral vein. The procedure may be performed without sedation, although sedoanalgesia may be administered by the interventional radiologist. General anesthesia or MAC is occasionally necessary after evaluation of the patient's comorbidities.



FIGURE 13.2. Picture of an interventional radiology suite.

Balloon Angioplasty

In balloon angioplasty, a narrowed or obstructed blood vessel is widened with a balloon-tipped catheter. Carotid angioplasty has been performed with deep cervical plexus blockade,⁷⁴ MAC, or general anesthesia. The same concerns apply to carotid stenting, which is commonly preceded by balloon angioplasty. Relatively minor procedures, such as percutaneous transluminal angioplasty of the infrarenal aorta, can be safely performed with local anesthesia by the interventionalist.⁷⁵

Chemoembolization

Chemoembolization is currently limited to hepatic tumors, either primary or metastatic. A catheter is inserted into the femoral artery and guided under fluoroscopy into the hepatic artery; contrast material is then injected to identify the arterial supply to the tumor. A chemotherapeutic agent such as doxorubicin is injected, followed by an embolic agent such as iodized poppy seed oil, which both limits the tumor's blood supply and traps the agent in close proximity to the tumor. Combination therapy with cisplatin, doxorubicin, and mitomycin C often enhances the tumor-specific toxicity.⁷⁶ The procedure is typically performed without an anesthesiologist. If anesthesia is requested, the primary anesthetic concerns are patient comorbidities, coagulopathies, and hepatic insufficiency.

Vascular Access

Vascular access refers to the placement of catheters in large veins for the infusion of medications (e.g., chemotherapy, parenteral feedings, antibiotics), dialysis, or blood sampling. Adults seldom require anesthesia care for catheter placement, but if anesthesia is needed, special attention is given to the patient's coexisting diseases and to the risk of air emboli through an open, large-bore catheter during spontaneous ventilation.

Vascular Occlusion Procedures

Uterine fibroids, varicoceles, esophageal varices, and arteriovenous malformations can be embolized under fluoroscopy. A catheter is inserted through a large artery or vein with the tip positioned near the structure to be embolized. Particles (e.g., gelfoam or particulate agents such as gelatin-impregnated acrylic polymer spheres), sclerosing agents (e.g., alcohols), metal coils, or liquid glue is used. The procedure is typically performed without an anesthesiologist. The primary concerns are patient comorbidities.

For the placement of balloon occlusion catheters in parturients at risk for hemorrhage, both general⁷⁷ and epidural⁷⁸ anesthesia have been utilized. An epidural catheter is placed before the balloon catheter is inserted to avoid displacement of the balloon when the patient is positioned and to provide analgesia should the patient undergo a cesarean section. Preparations should be in place for adequate intravenous access and invasive monitoring.

Percutaneous Procedures

In percutaneous nephrolithotomy, medium-sized or larger renal calculi are extracted from the urinary tract with a nephroscope. The patient is placed prone and a track is created through a small incision above the kidney, through which dilators and finally the nephroscope are inserted. If the stones are small, they may be removed directly. For larger stones, percutaneous nephrolithotripsy breaks up the calculi into manageable pieces and the procedure requires a neuraxial block or general anesthesia.⁷⁹ Attention is paid to fluid absorption, dilutional anemia, hypothermia, the potential for significant blood loss,⁸⁰ renal insufficiency, and the effects of placing the patient in the prone position. Potential complications include pneumothorax or hydrothorax, pneumonia/atelectasis, paralytic ileus, nephrostomy tube dislodgement, urine drainage from the flank lasting more than 1 week, infection, urinoma formation, renal pelvic laceration, ureteral avulsion, ureteropelvic or ureteral stricture, bowel injury, or escape of stone fragments into the retroperitoneum.⁸¹

Percutaneous biliary drainage may be performed with local anesthesia at the site of the drain tube and with supplemental intravenous sedoanalgesia. When pain is anticipated from large drainage catheters or dilatation of the transhepatic tracts, epidural or general anesthesia is recommended.⁸²

Hepatic insufficiency and the potential for blood loss should be considered in the anesthetic plan.

Computed Tomography, Magnetic Resonance Imaging, and Ultrasound Imaging

Ablation Procedures

Ablative therapies require cross-sectional images for accurate needle, probe, or catheter placement with the aid of CT, MRI or ultrasound imaging. The same general imaging-specific caveats apply to other therapeutic and diagnostic procedures. Thus, radiation exposure in the CT suite is monitored, and precautions against ferrous materials are taken in the MRI suite. The preanesthesia evaluation focuses on patient comorbidities.

Hyperthermic ablation includes radiofrequency (RFA), microwave, or laser ablation. In RFA, the most common procedure, electrical currents in the radiofrequency range heat an electrode that has been percutaneously or directly placed within a tumor. Because healthy tissue is better able to withstand heat, radiofrequency energy preferentially destroys the tumor and only a small edge of normal tissue around its perimeter. The heat also “cauterizes” small blood vessels and reduces the risk of bleeding. Kidney, lung, breast, bone, and liver tumors are common targets. Moderate sedation is often adequate for a percutaneous approach.⁸³ Radiofrequency techniques may be effective for hepatocellular carcinoma because ablation energy can be applied without pain.⁸⁴ General and epidural anesthesia are often used for RFA of renal cell tumors.⁸⁵ Since the process involves heat, precautions must be taken when the electrode is adjacent to critical structures. For example, during RFA for a mediastinal lymph node, a temperature probe was applied to the endotracheal tube cuff to monitor the tracheal temperature. When temperature rose, chilled saline was substituted for air in the cuff to prevent tracheal trauma.⁸⁶

Cryoablation is used for tumors in the lung, liver, breast, kidney, or prostate. Liquid nitrogen or gaseous argon destroys tissue by direct freezing, denaturation of cellular proteins, cell rupture, cell dehydration, and ischemia. Patient comfort and safety have been provided with local or general anesthesia.⁸⁷ In lung cryoablation, inflammation may result from the thawing phase of the ablated tissue. Cracking of a cryoablated liver may cause hemorrhage.⁷⁶

Interventional Neuroradiology

Interventional neuroradiologists use imaging techniques combined with catheters and other devices to treat vascular lesions in the central nervous system (CNS) and surrounding tissues by either occluding blood flow through abnormal vessels or by increasing blood flow in occluded vessels.⁸⁸ Cross-sectional imaging techniques assist in diagnosis, and the procedures are performed under fluoroscopy. Table 13.13 lists some procedures offered at a teaching hospital in the Midwest.⁸⁹

Anesthesiologists are often needed because of the complexity of the procedure, the medical status of the patient, or the

TABLE 13.13. *Interventional Neuroradiology Procedures*

1. Transarterial embolization of cerebral and spinal arteriovenous malformations and arteriovenous fistulae
2. Transarterial and transvenous embolization of cranial and spinal dural arteriovenous fistulae
3. Endosaccular embolization of intracranial aneurysms
4. Temporary and permanent balloon occlusion of intracranial and brachiocephalic vessels
5. Endovascular trapping of intracranial and extracranial aneurysms
6. Intracranial percutaneous transluminal angioplasty and stenting (e.g., internal carotid, middle cerebral, vertebrbasilar arteries)
7. Extracranial brachiocephalic percutaneous transluminal angioplasty and stenting (e.g., innominate, common and internal carotid, subclavian, and vertebral arteries)
8. Management of acute thromboembolic stroke with superselective intra-arterial chemical thrombolysis and percutaneous transluminal angioplasty
9. Chemical and mechanical angioplasty of intracranial vasospasm
10. Tumor embolization via transarterial and direct puncture
11. Embolization of congenital and acquired arteriovenous malformations and arteriovenous fistulae via transarterial, transvenous, and direct puncture
12. Direct puncture sclerotherapy of low-flow vascular malformations (e.g., venous, lymphatic, mixed)
13. Percutaneous vertebroplasty of benign and malignant vertebral compression fractures
14. Combined computed tomography and fluoroscopic-guided percutaneous biopsies, drainage procedures, and therapeutic embolization of spinal pathologies

need for immobility. The preanesthesia assessment focuses on the patient's neurologic status and comorbidities. An anesthetic plan must consider the potential for disease progression or iatrogenic complications. Consultation with a neuroradiologist determines whether the patient must be responsive for continuous CNS evaluation or whether rapid emergence from general anesthesia is preferred. Anesthetic medications for a responsive patient include propofol, dexmedetomidine, and fentanyl; for general anesthesia, propofol, sevoflurane, and desflurane.⁹⁰ Nitrous oxide should be avoided because of the potential for enlarging emboli. Laryngeal mask airways may be considered for airway management.

Among the intraprocedural concerns are elevated intracranial pressure, hemorrhage, blood pressure, and cerebrovascular occlusion. Control of carbon dioxide may be necessary for selected procedures. Hypercapnia has been used to vasodilate cerebral vessels for catheter entry, to enhance catheter propagation during superselective cerebral catheterization, and to increase cerebral venous outflow, thereby favoring movement of an embolizing agent away from intracranial drainage pathways.⁹¹ Hypocapnia may be used to decrease cerebral blood flow and lower intracranial pressure. Patient considerations include temperature, either warm for comfort or cool for

TABLE 13.14. *Interventional Neuroradiologic Procedures and Primary Anesthetic Considerations*

<i>Procedure</i>	<i>Possible Anesthetic Considerations</i>
Therapeutic embolization of vascular malformation	
Intracranial AVMs	Deliberate hypotension, postprocedure NPPB
Dural AVM	Existence of venous hypertension; deliberate hypercapnia
Extracranial AVMs	Deliberate hypercapnia
Carotid cavernous fistula	Deliberate hypercapnia, post-procedure NPPB
Cerebral aneurysms	Aneurysmal rupture, blood pressure control ^a
Ethanol sclerotherapy of AVMs or venous malformations	Brain swelling, airway swelling, hypoxemia, hypoglycemia, intoxication from ethanol, cardiorespiratory arrest
Balloon A&S of occlusive cerebrovascular disease	Cerebral ischemia, deliberate hypertension, concomitant coronary artery disease
Balloon angioplasty of cerebral vasospasm secondary to aneurysmal SAH	Cerebral ischemia, blood pressure control ^a
Therapeutic carotid occlusion for giant aneurysms and skull base tumors	Cerebral ischemia, blood pressure control ^a
Thrombolysis of acute thromboembolic stroke	Postprocedure ICH (NPPB), concomitant coronary artery disease, blood pressure control ^a
Intra-arterial chemotherapy of head and tumors	Airway swelling, intracranial hypertension
Embolization for epistaxis	Airway control

^a Blood pressure control refers to deliberate hypo- or hypertension.

A & S, angioplasty and stenting; AVM, arteriovenous malformation; ICH, intracranial hemorrhage; NPPB, normal perfusion pressure breakthrough; SAH, subarachnoid hemorrhage.

Source: From Young WL. Anesthesia for endovascular neurosurgery and interventional neuroradiology. *Anesthesiol Clin.* 2007;25(3):391-412. Copyright Elsevier 2007.

cerebral protection,⁹² padding, positioning, and bladder distention, the latter because intravascular volume/renal perfusion must be maintained in the presence of a dye load. Table 13.14 lists some anesthetic considerations for various interventional neuroradiologic procedures.⁹³

In addition to routine monitors, an arterial line may be needed if the procedure requires hypertension or hypotension. An arterial line enables the anesthesiologist to maintain the delicate balance between intracranial pressure and cerebral perfusion pressure or intravascular pressure if there is a potential for hemorrhage. If arterial monitoring will be needed after

the procedure, a peripheral site (e.g., radial artery) may be preferred to the side port of the introducer sheath. Intravenous access should always be adequate and blood products should be available as needed.

Before certain obliterative procedures, awake patients may undergo Wada testing, in which a barbiturate is selectively injected into each cerebral hemisphere via the internal carotid artery to determine the dominant side for speech and memory. The superselective anesthesia functional examination (SAFE) is a variant of Wada testing that improves the specificity of the test by positioning the tip of the catheter closer to the targeted region.

Procedures

Vertebroplasty and kyphoplasty are typically used to treat vertebral compression fractures in osteoporotic elderly patients with significant comorbidities, such as diminished pulmonary function associated with the vertebral fracture. The procedures may be performed with general anesthesia or local anesthesia with sedoanalgesia. In either procedure, after the patient is placed prone, trocars are inserted on each side of the vertebral body under fluoroscopic or CT guidance. Polymethylmethacrylate (PMMA) is injected via a trocar into the medulla of the vertebral body under direct visualization. In kyphoplasty, a balloon is inserted through the trocar to restore the intervertebral distance before PMMA is injected.⁹⁴ Risks of extravasations are increased by the presence of osteoporotic and osteolytic lesions. If PMMA leaks into perivertebral veins, it can cause radiculopathy, embolization, or interference with pulse oximetry readings. The most severe complication of PMMA leakage is spinal cord compression that requires immediate surgical decompression. Other complications associated with PMMA leaks are hypotension, hypoxemia, cardiac arrhythmias, and pulmonary embolism.⁹⁵

Anesthesia for the endovascular coiling of cerebral aneurysms ranges from none to general anesthesia. Many radiologists prefer general anesthesia to obtain optimal conditions for imaging and patient comfort and safety, even though general anesthesia may mask the clinical signs that guide the progress of the procedure.⁹⁶ Patients with subarachnoid hemorrhage caused by a leaking or ruptured aneurysm are at greater risk for increased intracranial pressure, cerebral ischemia, and hydrocephalus. Patients with a ventricular drain are at risk for transmural pressure changes and re-bleeding with elevated arterial pressure.⁹⁰

Patients with an arteriovenous malformation (AVM) often have a redistribution of blood flow from a steal phenomenon that may lead to the loss of autoregulation in the surrounding brain tissue as the chronic vasodilation compensates for the steal from the AVM. They may suffer spontaneous hemorrhage and have seizures or other neurological symptoms because of the ischemia resulting from this steal phenomenon or from venous hypertension.⁹⁷

General anesthesia is often preferred for embolization of an AVM because it facilitates visualization of structures and prevents patient movement. Blood pressure is controlled by reducing the anesthetic or administering vasoactive agents that may

help “float” a flow-directed catheter into the desired vessels. The most common AVM embolic agent is the fast-polymerizing liquid adhesive *n*-butyl cyanoacrylate (*n*-BCA), but a new liquid agent, Onyx, has recently been introduced.⁹⁸ During injection, Valsalva maneuvers and controlled hypotension may reduce the gradient across the AVM and diminish the amount of distal adhesive embolization.⁹⁹ When the AVM is embolized and the steal phenomenon ceases, the surrounding brain may suffer hyperperfusion injury unless the cerebral blood flow is aggressively controlled with nitroprusside or other agents.

Pial and dural arteriovenous fistulas (AVFs) are direct shunts between an artery and a vein and may be associated with extremely high blood flow. Clinical characteristics include bruit, neurologic symptoms or intracranial hemorrhage. Children may have concomitant high-output cardiac failure.¹⁰⁰ Transarterial embolization for high-flow, single-hole fistulas is performed with balloons, coils, stents, or *n*-BCA.⁹⁰

Cerebral thrombolytic procedures are most often performed on awake individuals, but their tenuous medical status may mandate an anesthesiologist's presence. Anesthesia concerns include altered mental status, airway protection, control of patient movement, and management of intracranial pressure.

Cerebral tumor embolization may be indicated for hemangioblastomas, intracranial metastases, meningiomas, hemangiopericytomas, neurogenic tumors (e.g., schwannomas), paragangliomas, juvenile nasopharyngeal angiofibromas, hemangiomas, esthesioneuroblastomas, benign bone tumors, malignant bone tumors, and extracranial metastases.¹⁰¹ As with an AVM, a steal phenomenon can result because of the hypervascular nature of these tumors. Hypotension should be avoided before embolization and hypertension should be avoided after it. Other concerns include greater intracranial pressure from brain edema, which may be treated with steroids.

Neurophysiologic monitoring helps gauge the progress of an intervention. In a patient under general anesthesia, it signals impairment so that the cause of the insult can be reversed promptly. The EEG, somatosensory evoked potentials (SSEPs), and brainstem auditory evoked potentials are valuable adjuncts to endovascular treatment of cerebral aneurysms under general anesthesia.¹⁰² Muscle motor evoked potentials can indicate spinal cord perfusion in the anterior spinal artery during endovascular procedures and complement SSEPs.¹⁰³ Transcranial Doppler ultrasonography directly measures regional cerebral blood flow (rCBF) in arteriovenous malformations, aneurysms, and arterial stenoses.¹⁰⁴ Other direct measures of rCBF include radionuclide CBF (e.g., technetium) studies and xenon CT.¹⁰² Since anesthetics often have an effect on measurements, the anesthesiologist must be in close communication with monitoring personnel to distinguish between anesthetic artifact and a new neurologic deficit.

Two serious complications of interventional neuroradiology procedures are intracranial hemorrhage and thromboembolic stroke.¹⁰⁵ The incidence of these two complications during coiling of cerebral aneurysms is 2.4% and 3.5%, respectively; during embolization of arteriovenous malformation it is 1%–8%.¹⁰⁶ Arterial pressure increases suddenly with acute

intracranial hemorrhage and should be controlled immediately. Heparin reversal may be necessary along with decreasing arterial pressure. Hyperventilation and mannitol should be considered to reduce intracranial pressure. Hemorrhage due to perforation can often be treated with coiling, although emergency craniotomy and clipping may be required if coiling fails.

Occlusive events can be thrombotic, embolic, or vasospastic. For all, the arterial pressure should be raised to increase collateral blood flow while normocarbica is maintained. Thrombi may be treated by mechanical lysis with a guidewire, normal saline, or thrombolytics. Misplaced coils may be retrieved endovascularly or via craniotomy. Vasospasm may be treated by increasing arterial pressure and volume while decreasing blood viscosity through hemodilution;¹⁰⁷ papaverine or nicardipine¹⁰⁸ or cerebral angioplasty¹⁰⁹ is also used. Maintaining hypotension with antihypertensive agents such as labetalol or esmolol may be beneficial after AVM embolization to prevent cerebral edema and hemorrhage. Using phenylephrine or norepinephrine can elevate mean arterial pressure 20%–30% above normal and maintain cerebral perfusion in patients with occlusion or vasospasm.⁹⁰

RECOVERY

Recovery of the patient is governed by the ASA standards for postoperative care.³ Nursing care should conform to the Standards of the American Society of Perianesthesia Nurses. The facilities and equipment for recovery should be commensurate with the complexity of the patient. Medically stable patients who have undergone innocuous procedures (MRI, inferior vena cava filter) under MAC can often recover en suite, provided that the nurses are trained and an anesthesiologist is available. Patients who have received regional or general anesthesia who are at risk for pain (e.g., radiofrequency ablation for hepatocellular carcinoma) or procedural complications (e.g., aortic stent graft) recover in a dedicated postanesthesia care unit or an intensive care unit. Resuscitation equipment, oxygen, and monitors should be available for transport from the radiology suite.

SUMMARY

As minimally invasive techniques in radiology suites become more common, the need for anesthesia support will increase. While recognizing and addressing a patient's comorbidities and other concerns are similar to what is already done in the surgical setting, the additional requirements and constraints of the imaging environment and the procedure are unique and call for specific solutions. Just as in the operating room, there is frequently no single best anesthetic technique for a given procedure. The anesthetic should be aligned with the demands of the procedure and the skill sets of the providers. Patient safety always takes precedence, and the location should never be permitted to compromise care.

The radiologist serves a critical function, for it is she who decides whether to consult the anesthesiologist or to do it alone. If the decision is to proceed with moderate sedation (administered by a nonanesthesia professional), the importance of vigilant clinical monitoring cannot be understated. In all cases, the patient deserves care that is consistent with the parameters, guidelines, and standards established by the various accrediting agencies and professional societies. There should be no exceptions.

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14 | Anesthesia in the Radiation Oncology Suite

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Cancer continues to be a leading cause of death in the developed world, with physicians and scientists constantly devising new weapons to combat it. Chemotherapy, surgery, nutrition, and holistic medicine all have a place in the multimodal approach that can prolong longevity and ameliorate quality of life. As part of this armamentarium, radiation therapy (XRT) has proven to be a safe and effective technique for the management of various malignant (and occasionally nonmalignant) lesions. XRT can be used for both curative and palliative purposes; in the latter case, patients benefit from decreased pain, preserved organ function, and the maintenance of lumen patency in hollow organs.¹ The medical team, led by a radiation oncologist, often includes a physicist, a dosimetrist, several radiation therapists (technologists), and the patient's primary care physician.² Anesthesiologists are increasingly being asked to join this team, as our services are recognized as a vital component for patient safety and comfort.

SELECTION CRITERIA

Because radiation therapy is a painless procedure, the vast majority of patients can complete their treatment without the use of anesthesia or sedation. Many others can be managed with small amounts of benzodiazepine sedation administered by a nurse certified in patient sedation. A small fraction of patients, however, will require the expertise of an anesthesia team. In general, the following populations may require anesthesia services:

1. *Children:* Surprisingly, many children are able to handle XRT without any medication. Parental reassurance, and possibly the promise of a small reward afterward provide enough motivation for many children to remain still. Clearly, babies and younger toddlers are not receptive to such enticement, and these are the patients that make up the vast majority of XRT anesthesia cases. Older children may be distressed by the absence of a parent next to them, but they often respond well to pictures attached to the ceiling within their field of view, or the presence of music in the room. Indicators that suggest the need for anesthesia include young age, anxiety, treatment complexity (e.g., prone position), emotional immaturity for age, and a history of noncompliance.³

2. *Patients with mental disabilities:* These patients may present as anxious, uncooperative, and combative. The application of physical restraints may only worsen the situation, and anesthetic intervention is often the only way to proceed. These patients may remain uncooperative throughout the entire course of treatment and are therefore some of the most challenging cases faced in the XRT suite.

3. *Patients with movement disorders:* Conditions such as tardive dyskinesia, choreiform disorders, and Parkinson disease make it difficult or impossible for these patients to remain still. Since effective treatment relies upon precise anatomical targeting, such movements may be detrimental to the patient's course of therapy. These patients may therefore require general anesthesia with skeletal muscle paralysis.

4. *Claustrophobic patients:* In general, these patients do not find XRT as disturbing as magnetic resonance imaging (MRI) or computed tomography (CT) scanning. However, if the head or neck is being treated, a plastic shield must be secured over the face. Many claustrophobic patients will not tolerate this unless they are deeply sedated.

5. *Procedures that are sufficiently painful:* Examples include treatment planning for prostate and cervical cancer, where MAC or general anesthesia may be required.

ANESTHESIOLOGY IN REMOTE LOCATIONS

The provision of anesthesia for patients undergoing radiotherapy procedures may present a deceptively simple challenge to the anesthesiologist. These cases are often very short in duration, sometimes lasting no more than 10 minutes. Furthermore, they can usually be accomplished without the use of general anesthesia. The patients themselves are typically young, and from a cardiopulmonary standpoint they are often healthy. There is no blood loss or fluid shift present. How then can we explain the discomfort that anesthesia providers experience when faced with performing cases in the radiation therapy suite?

In general, many clinicians experience a palpable sense of angst when asked to do cases anywhere outside of the "comfort zone" of the operating room. The personnel employed in the XRT suite are well trained in their field of expertise;

unfortunately for us, that field has little to do with anesthesiology. Assistance with lines, difficult airways, or anesthetic emergencies may be delayed or completely unavailable. Your colleagues and the anesthesia technicians might not be familiar with the location of the XRT suite, making it difficult and time consuming to acquire personnel support, extra drugs, or equipment. However, the greatest source of concern seems to be the physical distance that must be maintained from the patients. While many remote anesthetizing locations force the anesthesiologist to be a considerable distance from the patient, perhaps even in a different room (CT scanner, MRI suite,) the XRT area is unique in that there is no means of directly viewing the patient or the monitors. Instead, once the procedure has begun, we must rely solely upon the use of closed-circuit television monitoring. While “tele-anesthesia” has long been postulated as being a possible future direction of the field (see Chapter 33), few practitioners are excited about being the mavericks forced to incorporate this technology into their current practice.

FUNDAMENTALS OF XRT

Before anesthesiologists can feel more comfortable providing anesthesia in the XRT suite, they must first have a basic understanding of what is accomplished there. When the actual treatment room is first entered, the most obvious piece of equipment will be noticed is the linear accelerator (Fig. 14.1.)



FIGURE 14.1. The linear accelerator.

Inside of this machine, electrons are accelerated to very high energy states within a vacuum. The electrons are then forced to collide with a material such as tungsten, which releases energy in the form of X-rays.⁴ This energy is then focused at specific sites within the patient in an effort to degrade the genetic material within the tumor cells. The energy absorbed by the tissues is measured in terms of gray (Gy), which has replaced the more antiquated unit of rad. 1 Gy is equal to the deposition of 1 J/kg and is equivalent to 100 rad units.⁵ While most patients receive this type of X-ray therapy, other types of lesions respond better to bombardment with electron, proton, or neutron beam therapy. In any event, the anesthetic considerations are essentially identical despite the type of subatomic particle that is utilized.

SIMULATION

When a patient is accepted as a candidate for XRT, he or she must first undergo a treatment planning session, referred to as a simulation. The physical setup of the simulation suite is very similar to the XRT therapy room (Fig. 14.2.) However, the simulation machine is incapable of delivering therapeutic doses of radiation. Instead, it is used to provide radiographs of each treatment field which will aid the radiation therapy team in planning radiation doses and points of entry. Simulation serves several functions at the outset of therapy:

1. Simulation allows the radiation oncologist to prescribe the proper treatment by reproducing the exact conditions that will be encountered during the weeks of therapy. The number and location of anatomic fields that will need treatment will be decided; the radiation therapy team may typically treat anywhere from one to four fields, depending upon the type and size of the lesion. Ideal patient positioning will be also determined. Most patients can be treated in the supine position; however, craniospinal axis radiotherapy will necessitate the patient remaining in the prone position throughout therapy while two lateral whole-brain fields are supplemented with a posterior field of the spine.⁶ This adds another layer of challenge to the anesthetic management.

2. Once these sites are determined, the therapist will mark the skin with ink to denote targets for future treatment. These markings will remain on the patient for the duration of the therapy and may be reapplied by the therapist as necessary. The markings increase accuracy and greatly enhance the speed of the future therapy sessions.

3. Plaster immobilization casts of the head (Aquaplast RT, Q-Fix, Avondale, PA; Fig. 14.3) and/or body (Alpha Cradle, Smithers Medical Products Inc., North Canton, OH; Fig. 14.4) are made, depending upon the sites that are to be treated. These casts make certain that the patient will not move during the treatment sessions, ensuring that the radiation is directed at its target and not at normal surrounding tissue. Inadequate immobilization can result in treatment failure^{7,8} as well as damage to normal tissue.⁹

4. The radiation oncologist will determine whether blocks will be necessary during the treatment period. Blocks are



FIGURE 14.2. The simulation machine.

radio-opaque shields that are attached to the linear accelerator (Fig. 14.5) to shield radiosensitive organs (e.g., kidneys, eyes) from the ionizing radiation.

5. If the team is still questioning the need for anesthesia, the simulation offers an ideal trial, without the risk of radiation, to see whether the patient will be cooperative and can remain immobile during the session.

The simulation session takes anywhere from 20–90 minutes, depending upon the level of cooperation of the patient, and the number and location of the fields that need to be marked. Most patients who will require anesthesia for XRT will do well during the simulation with monitored anesthesia care (MAC). Since therapeutic radiation is not used, the anesthesia team can remain with the patient during the majority of the simulation. When conventional radiographs are taken, the anesthesia and radiation oncology teams can remain in the room while wearing lead shielding or can safely observe the patient through a panel of leaded glass from an adjacent room. Medications can be given freely throughout the procedure as dictated by patient anxiety and motion. If general anesthesia is required, the anesthesia machine must be placed in a location that will not interfere with the lateral X-ray fields. Circuit hose extensions may be needed to place the machine at an appropriate distance from the patient. At the conclusion of the simulation, patients may be recovered in the XRT suite, provided there is adequate nursing supervision. Alternatively, the patient can recover in the main postanesthesia care unit.

The simulation phase may immediately be followed by the first treatment, but it is more common for the patient to return within the next day or two to begin the actual radiation therapy. This gives the team adequate time to map the coordinates of the sites that will be irradiated and to decide upon dose and duration parameters. Total dose varies between 25 and 80 Gy, with a median value of 60 Gy. Lower doses are used for hematological cancers (leukemia, lymphoma) and seminomas; higher doses are reserved for solid tumors such as sarcomas and gliomas. The total dose of radiation is typically divided into 30 equal portions and administered once daily, 5 days per week, over a 6-week period. Certain patients may benefit from hyperfractionated irradiation or the administration of XRT more than once daily.¹⁰ Each field requires up to 90 seconds of irradiation; after this is completed the radiation therapists must adjust the couch, reset the coordinates of the linear accelerator, and change the blocks so that the next field can be treated. Depending upon the number of fields (typically no more than four), the entire process can be completed in anywhere from 5 to 20 minutes. At specified time intervals (usually once per week) the therapists will repeat the radiographs to ensure that the anatomic targeting of the radiation beam is still accurate. This should add no more than another 5 minutes to the procedure.

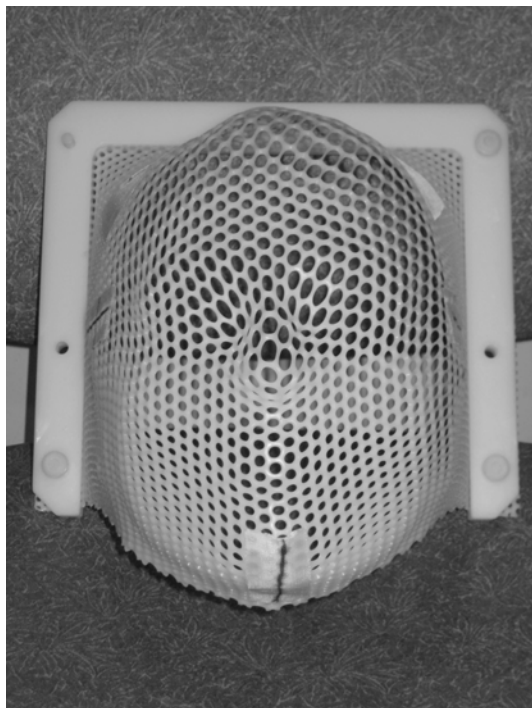


FIGURE 14.3. A premolded aquaplast.

ANESTHETIC MANAGEMENT OF XRT TREATMENT

The majority of patients who require anesthetic intervention can tolerate the daily therapeutic regimen with only MAC.



FIGURE 14.4. A premolded alpha cradle.

Even patients who may have required general anesthesia for the simulation typically do well with heavy sedation during the therapy phase, due to the brief time required for treatment. One significant exception is the patient being treated for retinoblastoma; in this case, the globe must be kept completely immobile. Monitored anesthesia care sedation, especially if ketamine is used (with a resultant lateral nystagmus), cannot accomplish this.¹¹ The room will be evacuated during the treatment period; however, it is safe to re-enter in between doses, and therefore it is unusual to be away from the patient for more than 3 minutes. Of course, any reasonable request to re-enter the room at any time should be honored by the radiation therapist; the treatment can be aborted before it is completed to allow safe entry into the room.

Patients are advised to follow fasting guidelines typical for all ambulatory patients. If the tumor or medical condition is impairing gastric emptying, stricter guidelines may need to be enforced. Parents are encouraged to allow infants and children to ingest solid food and breast milk up to 4 hours before the procedure, and clear liquids are generally permitted up to 2 hours beforehand.^{12,13}

The intravenous route is the preferred method of administering medication to these patients. While intramuscular drugs such as ketamine are effective, the repeated trauma of a painful injection daily for 6 weeks is often worse than the prospect of the XRT therapy. A large majority of these patients have either recently completed a course of chemotherapy or are receiving it concomitant with the XRT and will therefore have an intravascular port present. Typically the port can be

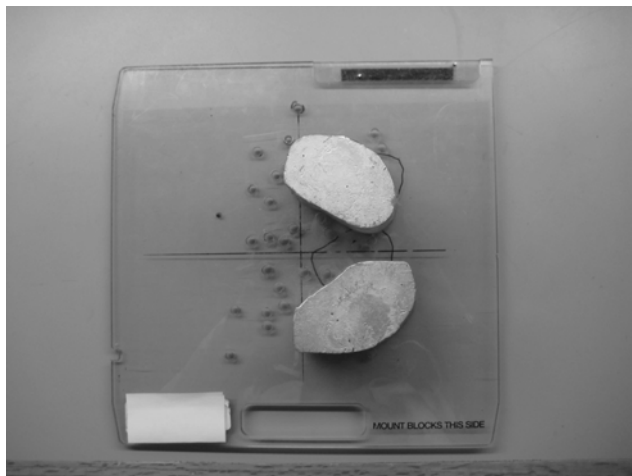


FIGURE 14.5. Blocks used to shield radiosensitive organs.

accessed with a Huber needle (Fig. 14.6) on the Monday morning prior to the first treatment, and the access can be left in place throughout the week and removed after the week's final treatment on Friday. The port remains dormant over the weekend, and the cycle repeats the following week. Parents can apply EMLA cream (AstraZeneca, London, UK) to the site 1 hour before arriving Monday morning to make the access less traumatic. Alternatively, if the patient does not have a port, intravenous access via a peripheral vein can be obtained Monday morning, left in throughout the week, and removed on Friday, thereby following the same schedule.¹⁴ Again, EMLA can greatly facilitate the process. In either case, the port or catheter should be flushed with a heparin flush solution (typically 300 units of heparin in 3 cc of normal saline) at the conclusion of each treatment to ensure continued patency throughout the week.

Aseptic technique is imperative when accessing a port or placing an intravenous catheter. These patients are typically neutropenic from the XRT and/or chemotherapy, as well as their disease state, and cannot tolerate the threat of bacterial infection. Large case series estimate the risk of sepsis between 7%³ up to 15%.¹⁵ The use of propofol, which can act as a potent culture medium for bacteria, may enhance the risk.¹⁶

Fortunately, the advent of short-acting sedative agents has replaced much of the use of such pediatric favorites as rectal methohexital,¹⁷ chloral hydrate, and the DPT cocktail (mep-eridine, promethazine, and chlorpromazine).¹⁸ Intravenous midazolam has been the cornerstone of pediatric sedation since its introduction into clinical practice. The anxiolytic and amnestic profile is so good that many patients can complete their entire series of treatments with the aid of only this drug. If this is the case, participation of an anesthesiologist is rarely warranted.¹⁹ The safety record of intravenous midazolam used in the absence of other sedative drugs is extensive. Since XRT is a painless procedure, it is unnecessary to supplement the benzodiazepine with narcotics. Therefore, with adequate

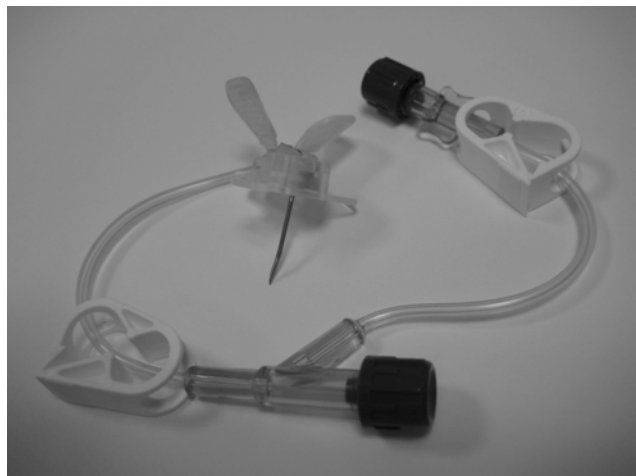


FIGURE 14.6. A Huber needle used to access an intravascular port.

monitoring of vital signs, the sedation can typically be managed by a registered nurse.

Patients who require more extensive therapy often still benefit from the use of midazolam. An initial dose of 0.05 mg/kg intravenously often provides enough sedation to allow for the placement of monitors. If ketamine is to be used, midazolam may decrease the incidence of postprocedure delirium.²⁰ After this initial dose of midazolam, the patient should be dosed with a more potent agent to allow for transfer to the treatment couch and placement of therapeutic restraining devices. If necessary, midazolam can be readministered; cumulative doses greater than 0.2 mg/kg are rarely necessary.

When benzodiazepine therapy is insufficient, propofol is usually the preferred drug of choice for most anesthesiologists in the XRT suite, especially when dealing with children. After benzodiazepine pretreatment as previously described, an initial propofol bolus in the range of 0.5–0.8 mg/kg has been shown to provide adequate sedation for positioning and manipulation on the XRT couch while still allowing for spontaneous respiration and airway control.²¹ This is followed by a continuous propofol infusion in the range of 7.4–10 mg/kg per hour throughout the treatment phase.^{22,23} Spontaneous eye opening was noted within 4 minutes of discontinuing the infusion.²² Initial concerns about tachyphylaxis to propofol²⁴ have been disproved by more recent studies.^{25–27} Thus, propofol, combined with midazolam, provides excellent therapeutic conditions throughout the entire course of treatment.²⁸

The infusion of the α_2 agonist dexmedetomidine in the XRT suite has been described,²⁹ although it has not been widely adopted. Likely reasons for its infrequent use include the prolonged time needed to administer the initial bolus (which can be as long as the entire case itself), and the fact that narcotic-mediated analgesia is not necessary in these painless cases.

Ketamine is another drug that is also used successfully, following midazolam pretreatment,³⁰ to manage patients in the XRT suite.^{31,32} Ketamine can be given as a continuous infusion (2.5 mg/kg per hour),³³ but the α -phase serum half-life of

11 min³⁴ and the short duration of these cases often makes this unnecessary. An initial dose of 0.5–0.75 mg/kg given at the start of therapy is often all that is required to accomplish the procedure. If the patient becomes agitated during the treatment, a supplemental dose of 0.25 mg/kg can be given to extend the period of cooperation. At some institutions, the use of ketamine has become so standardized that it is used in the XRT suite in the absence of an anesthesiologist.³⁵

Unlike propofol, it is not uncommon to witness tachyphylaxis develop to the effects of ketamine. By the fifth or sixth week of therapy, the patient may require twice the dosage to obtain the same effect as seen during the first or second week. Clinical experience has shown that recovery time is not prolonged in the latter phases of treatment, suggesting that the metabolism of the drug is also enhanced.

When general anesthesia is required, the brevity of the procedure must be kept in mind when choosing an induction agent. A muscle relaxant may not be necessary (the exception, as stated before, is XRT for retinoblastoma, which requires paralysis of the extraocular muscles.) The subglottic swelling that may develop with repeated daily intubations can be obviated by the use of a supraglottic airway such as the LMA (LMA North America Inc., San Diego, CA).^{36,37}

Antiemetic therapy is suggested at the conclusion of each day's treatment. The emetic effects of XRT can exacerbate the nausea from chemotherapy and stress and result in vomiting in the recovery area. Ondansetron 0.1 mg/kg is perhaps the agent of choice for most practitioners, but others report the use of steroids or phenothiazines with good results. Haloperidol, while showing some promise for the relief of postoperative nausea and vomiting, has been shown to be of little value in the XRT suite.³⁸

Some practitioners use psychosocial methods either in lieu of, or as a supplement to, pharmacologic sedation. These interventions work best among the pediatric population and may begin before the child enters the XRT suite. One center constructed an imitation linear accelerator in the children's playroom, complete with a large doll who received mock treatments. The children were allowed to act as the physicians and via transference were able to quell some of their apprehensions.³⁹ Other reports describe the use of music and videos,⁴⁰ gradually immersing the patient by slowly introducing him or her to what is expected and rewarding each successful step,⁴¹ and using an interactive Barney character⁴² in an attempt to keep patients calm and motionless. While the last study showed a statistically significant decrease in patients' heart rates, there was no difference in the incidence of observed behavioral distress or the need for sedation. Therefore, it is difficult to draw firm conclusions about the utility of these techniques. Furthermore, a busy XRT service might not be able to devote the necessary time and patience to foster the atmosphere necessary for such methods.

MONITORING DURING XRT

Remote monitoring of the patient receiving XRT therapy has progressed to the point where it is on par with technology

found in the operating room. The days of rigging together makeshift monitoring devices⁴³ have been supplanted by the use of crystal-clear, closed-circuit monitoring. The typical configuration (Fig. 14.7) uses two cameras to provide visual monitoring. Each camera is controlled by switches next to the television screens, allowing individual control of zoom and focus.⁴⁴ One camera is directed at the patient to observe for consistent breathing and the absence of other movements. The other camera is focused upon the monitors, which typically include (at minimum) the ASA standards of EKG, NIBP, and pulse oximetry, and qualitative end-tidal CO₂. If the patient is receiving general anesthesia, the field of vision can be widened to include the ventilator and anesthesia machine as well. A microphone is also present to transmit the pulse oximeter tone. Remote audio monitoring of an esophageal stethoscope has been reported⁴⁵ but is not widely practiced.

XRT IN REMOTE SITES

The provision of radiation therapy is not limited solely to the XRT suite; indeed, it has begun to make inroads into the operating room. Brachytherapy, or the intracavity implantation of radiotherapeutic material (e.g., radioactive prostate seeds, intrauterine isotopes) has been used successfully for years. Patient fears about “becoming radioactive” are largely exaggerated; because the radioactive material is sealed, only a small area around the site will be radioactive. The body as a whole will not emit radioactivity, and it is generally safe for the patient to resume contact with others. In contrast, a patient receiving external beam XRT will emit no radioactivity whatsoever. Patients who receive intravenous radioactive isotopes, however, will continue to discharge radioactive material in their saliva, sweat, and urine. The duration of this is dependent upon the half-life of the agent used.⁴⁶

Surgeons, radiation oncologists, and anesthesiologists can also work as a team to provide intraoperative radiation



FIGURE 14.7. A remote monitor bank.

therapy (IORT).⁴⁷ This is especially useful for tumors that cannot be fully resected or have a high probability of local recurrence. In these cases, the treatment begins in the operating room, where surgical exposure and debulking of the tumor occurs. The wound is then covered, and the patient is then transported to the XRT suite to receive high-dose external beam radiation directly to the exposed tissue. The patient is then returned to the operating room for closure of the surgical site. These cases, typically performed under general anesthesia, require a great degree of coordination between all parties involved. Transport of the patient with an open surgical site requires careful attention to maintaining a sterile field, as well as continued provision of anesthesia and analgesia. The patient should be stable from a cardiovascular standpoint prior to leaving the operating room; full monitoring, airway, and ACLS supplies should accompany the patient during the transit phase.⁴⁸

Stereotactic radiosurgery is another radiation therapy venue where anesthesiology services may be necessary. This procedure is used to treat conditions as diverse as malignancies, arteriovenous malformations, acoustic neuromas, and trigeminal neuralgia. The most widely used device, the Gamma Knife (Elekta Instruments Inc., Stockholm, Sweden) focuses 201 beams of gamma radiation (derived from cobalt-60) upon the lesion⁴⁹ (Fig. 14.8). In contrast to XRT derived from a linear accelerator, only a single session of radiotherapy is needed to treat the disease. (However, the patient may require several doses administered consecutively, each targeted to a different surface of the lesion.)

Anesthetic management is much like what has been described for traditional XRT. Monitored anesthesia care usually provides sufficient anesthesia, although general anesthesia may be required for very young patients and other special circumstances. The patient must first have the stereotactic frame placed, which involves having four anchoring screws placed into the soft tissue of the head. The neurosurgeon or oncologist applying the frame will use local anesthesia to numb the areas; however, a small dose of ketamine or propofol immediately beforehand will make the procedure less traumatic. The patient will then proceed to the MRI suite, where scans will be taken of the patient's brain with the external frame in place. It is imperative that all practitioners are aware of the hospital's protocols for MRI safety. The patient will likely be transferred to an MRI-compatible stretcher and all monitoring devices will be replaced with appropriate alternatives. Oxygen cylinders must be removed from the vicinity of the magnet. The patient must be interrogated about the presence of any metallic implants, and the medical staff must remove any objects that may become a projectile hazard. Since the frame will limit access to the patient's airway, it is imperative that the patient is transported with the appropriate tools to quickly remove the frame in case airway access is necessary. If a vascular lesion is present, the patient may also be taken to the neuroangiography suite for a diagnostic cerebral angiogram to further elucidate the anatomy. Afterward, the patient is permitted to rest while the physicians and physicists perform a 3D reconstruction of the MRI, plotting the coordinates that will most effectively target the intracranial

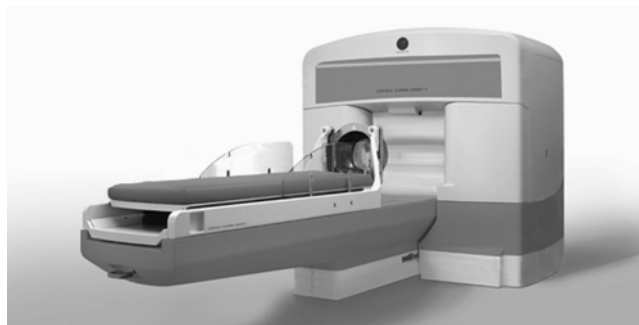


FIGURE 14.8. The gamma knife machine (courtesy of Elekta Instruments, Inc.).

pathology. The patient is then placed into the Gamma Knife unit where several doses of radiation are administered (each lasting from 4 to 10 minutes). Upon completion, the stereotactic frame is removed, antibiotic ointment is applied to the puncture sites left by the screws, and the patient is transported to the recovery area.

CONCLUSION

Remote site anesthesiology has become more routine over the last decade as hospitals realize they can reduce costs and increase efficiency by “outsourcing” some types of cases out of the operating room. While some clinicians still feel uncomfortable emerging from the “protection” of the operating room, others have embraced the chance to expand their practice beyond its traditional borders. XRT offers the anesthesiologist both a physical layout and a patient population that can be challenging initially, but ultimately extremely rewarding. The fact that these patients return daily, for up to 6 weeks, allows the anesthesia providers to develop a rapport with them more typical of a primary care practice. For the patient, the doctor with the scary needles gradually morphs into the trusted friend who has made the XRT possible; for the anesthesiologist, the room with the scary monitors and machines has become another conquered boundary.

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15 | Gastrointestinal Endoscopy Procedures

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A wide array of gastrointestinal (GI) endoscopy procedures are carried out in the GI endoscopy suite. Although the screening colonoscopy is the most one widely performed procedure (greater than 14 million procedures completed per year in the United States alone), other procedures are routinely utilized to diagnose and treat various GI pathologies.¹ Procedures range from minimally invasive, such as a routine screening colonoscopy, to much more invasive and complicated, such as endoscopic submucosal dissection (ESD). Sedation and anesthesia are integral parts of each GI endoscopy procedure. Adequate sedation and anesthesia optimize patient comfort and create a favorable environment for the physician to safely and efficiently carry out the necessary procedure. Understandably, levels of sedation and anesthesia vary with the invasiveness of the GI endoscopic procedure and the individual patient. Thus, cogent plans for sedation and anesthesia should be devised for each patient expecting a GI endoscopic procedure. Anesthetic considerations are discussed in detail in Chapter 16.

The aim of this chapter is to (a) briefly describe the most common endoscopic procedures and delineate events which are most stimulating during each procedure and (b) introduce the wide array of advanced GI endoscopic procedures that may be encountered by the anesthesia provider in the endoscopy suite.

COMMON PROCEDURES IN GASTROINTESTINAL ENDOSCOPY

A brief description of the most common GI endoscopy procedures will be provided, along with stimulating events within each procedure. The procedures covered herein are as follows:

1. Esophagogastroduodenoscopy (EGD)
2. Sigmoidoscopy/colonoscopy
3. Endoscopic retrograde cholangiopancreatography (ERCP)

Esophagogastroduodenoscopy

Esophagogastroduodenoscopy is the diagnostic and/or therapeutic examination of the upper GI tract using a flexible endoscope (see Table 15.1). This procedure provides the

possibility to obtain tissue specimens by performing a mucosal biopsy or staining of GI layers. Diagnostic EGD can be performed with light or no sedation, but potentially painful procedures such as esophageal dilatation, endoscopic mucosal resection (EMR) or endoscopic submucosal dissection (ESD) require increased levels of anesthesia.

Sigmoidoscopy/Colonoscopy

Sigmoidoscopy and colonoscopy is the diagnostic and/or interventional examination of the sigmoid or the entire lower GI tract up to the distal ileum, respectively, using a flexible endoscope. Endoscopy of the lower GI tract is considered less stimulating than the upper GI tract because there is no gag reflex involved (see Table 15.2). There are aspects of the lower GI tract examination, however, that are stimulating enough to require adequate sedation, including approach to right colon/cecum and retroflexion in the sigmoid region. Also, interventions such as the appropriation of biopsies, removal of polyps or other treatments are stimulation and require adequate sedation.

Endoscopic Retrograde Cholangiopancreatography

Endoscopic retrograde cholangiopancreatography is the radiographic examination of the biliary and/or pancreatic ducts via endoscopically-injected contrast through the major or minor duodenal papilla (see Table 15.3). Two-dimensional

TABLE 15.1. *Stimulating Events during Esophagogastroduodenoscopy (EGD)*

-
1. Intubation of the esophagus
 2. Passing the endoscope through the pylorus
 3. Endoscopic interventions:
 - a) Endoscopic hemostasis (APC, clips, injection, HP, etc.)
 - b) Esophageal/gastric/duodenal biopsy
 - c) Esophageal stenting
 - d) Dilatation of esophageal strictures
 - e) Endoscopic mucosal resection (EMR)
 - f) Endoscopic submucosal dissection (ESD)
-

TABLE 15.2. *Stimulating Events during Sigmoidoscopy/Colonoscopy*

1. Introduction of the endoscope
2. Air insufflation of the colon, causing distention of bowel
3. Advancement of the endoscope against the bowel wall and flexures, especially approaching the right colon/cecum
4. Looping of the colonoscope with concomitant distention of the bowel
5. Endoscopic interventions:
a) Mucosal biopsy
b) Polypectomy
c) Endoscopic hemostasis (APC, clips, injection, HP, etc.)
d) Endoscopic mucosal resection (EMR)
e) Dilatation and stenting of malignant strictures

black-and-white fluoroscopic images are produced using this technique, along with the possibility of a variety of interventional techniques, guided by the fluoroscopic information. ERCP requires a skillful delivery of sedation and analgesia. If the patients are too lightly sedated, they may gag, move or become agitated, which would be potentially dangerous considering the precise interventions that may be undertaken during an ERCP. If patients are too deeply sedated, they may develop airway obstruction, hypoventilation, hemodynamic instability and delayed emergence and recovery.

ADVANCED THERAPEUTIC AND DIAGNOSTIC TECHNIQUES

The following techniques will be discussed:

1. Endoscopic hemostasis
2. Capsule endoscopy
3. Double-balloon enteroscopy
4. Direct pancreaticobiliary visualization
5. Endoscopic mucosal resection
6. Endoscopic submucosal dissection
7. Endoscopic ultrasound (EUS)
8. Natural orifice transluminal endoscopic surgery (NOTES)

TABLE 15.3. *Stimulating Events during Endoscopic Retrograde Cholangiopancreatography (ERCP)*

1. Introduction of the endoscope
2. Passing the endoscope through the pylorus
3. Shortening the endoscope (to create critical view of the duodenal papillae)
4. Sphincterotomy
5. Cannulation of the common bile duct or pancreatic duct
6. Endoscopic interventions:
a) Stent placement
b) Balloon or basket extraction of biliary stones
c) Direct pancreaticobiliary visualization
d) Laser lithotripsy

Endoscopic Hemostasis

Acute and subacute GI bleeding may be treated with medical, endoscopic, or surgical approaches. There are a number of techniques and devices available for the endoscopic treatment of acute and subacute GI bleeding (AV malformations, diverticular bleed, postpolypectomy bleeding, etc.).² Current modalities fall into four broad categories, including: injection therapies (e.g., epinephrine), mechanical devices (e.g., endoclip), contact thermal therapy (e.g., heater probe), and noncontact thermal therapy (e.g., argon plasma coagulation), all of which are operable through the working channels of the endoscope. Endoscopic treatment of GI bleeding requires close monitoring of the patient and ongoing blood loss. The situation is complicated by a need for providing adequate sedation, especially that treatment modalities for hemostasis can be stimulating. Therapy may include more than one modality. For instance, endoscopists will often use both a mechanical device and an injection therapy for hemostasis purposes. All modalities increase the stimulation and pain associated with the procedure.

Injection Therapy

Injection/sclerosis needles allow the injection of hemostatic agents into the area of interest through a syringe attached at the handle of the endoscope. Hemostasis is achieved by the cytochemical mechanisms of the injected solution (e.g., epinephrine) and by mechanical tamponade.³

Mechanical Devices

Endoscopic clips create hemostasis via mechanical forces on the target lesion. The clipping device is composed of a delivery catheter with a handle to deploy the clip and a preloaded double- or triple-pronged metal clip.³

Band ligation systems, often used for the banding of varices, house rubber or latex stretched bands in a catheter. The lesion is captured and the band is deployed around the base, to create a tight compression that leads to hemostasis and subsequent necrosis and sloughing of the lesion.⁴

Direct Contact Thermal Therapy

The heater probe (HP) is a device that is composed of an inner heating coil surrounded by a Teflon-coated metal cylinder, which transfers direct heat to the specimen for tissue coagulation. A thermo-coupling device at the tip of the probe maintains a constant and precise temperature.³

The hemostatic grasper is similar to a rotatable biopsy forceps. Monopolar electrocautery desiccates tissue that is grasped with the tool.³

The multipolar electrocautery probe (MPEC) delivers thermal energy to tissue by creating a local electrical circuit composed of two electrodes on the probe and the viable tissue in between.³ With the multi-polar probe, electrical conductivity decreases as tissue desiccates, which limits maximum tissue injury potential and maximum temperature production.³

Noncontact Thermal Therapy

The argon plasma coagulator (APC) utilizes argon plasma as a conduit to deliver high-frequency monopolar coagulation to desired tissues, creating noncontact coagulation. When initiated, the argon plasma becomes electrically active, creating dessication of tissues at the tissue–argon interface. When the tissue becomes dessicated, it loses its electrical conductivity and is unable to transmit excessive energy. The plasma stream migrates to adjacent tissue that is electrically conductive.³

Additionally, the gas is only ignited when the catheter is near target tissue. These features limit the scope and depth of destruction of tissue.³ In addition to hemostasis, APC has been explored in other arenas, such as for the endoscopic ablation of Barrett's esophagus.⁵

Wireless Video Capsule Endoscopy

Video capsule endoscopy is a relatively new modality created to investigate suspected pathology within the small bowel, which is difficult to be accessed by either traditional upper or lower endoscopic examination.⁶ This noninvasive technology consists of a capsule ingested by the patient that records video as it passes passively through the digestive tract. The video is high resolution and provides excellent magnification. Primary indications for video capsule endoscopy are obscure bleeds, suspected small-bowel tumor, Crohn's disease, and small-bowel polyposis.⁷ Capsule endoscopy, however, does not afford the opportunity to perform biopsies or any therapeutic interventions. Wireless video capsule endoscopy requires no anesthesia.

Double-Balloon and Spiral Enteroscopy

Double-balloon enteroscopy is another diagnostic modality for the traditionally hard-to-reach regions of the small bowel. Unlike the video capsule endoscopy, the double-balloon enteroscopy allows for biopsy and therapeutic manipulation of small-bowel pathology. There are two balloons in the system, one at the end of the enteroscope and one at the end of a flexible overtube. By repeated and sequential inflation and deflation of the balloons, the loops of bowel may be examined and then reduced on the overtube in a pleated fashion, creating little stretch on the small bowel.⁸⁻¹¹ The balloons serve as anchors on the bowel, allowing the bowel to be withdrawn back onto the overtube and maintained in that pleated position.⁸⁻¹¹ The technique may be used in either an antegrade approach (initiating the sequence in the duodenum) or a retrograde approach (initiating the sequence in the terminal ileum). Indications for double-balloon enteroscopy include abnormalities identified on capsule endoscopy, obscure GI bleeding, and polyposis syndromes.^{7,12} A novel, yet similar, approach is spiral enteroscopy. This approach is similar to double-balloon or push enteroscopy, with the exception of small bowel being examined by coiling excess small bowel in an accordion style onto a special overtube system. Due to the

length of small bowel that must frequently be examined in enteroscopies, the procedure times are often prolonged. Most examinations are performed under intravenous sedation, but some physicians prefer general anesthesia.⁷

Direct Pancreaticobiliary Visualization

Direct pancreaticobiliary visualization is performed when a cholangioscope is inserted into the biliary tree after sphincterotomy and cannulation of the bile duct in a conventional ERCP procedure. As opposed to a purely fluoroscopic image in conventional ERCP, direct pancreaticobiliary visualization allows for real-time direct video imaging of the biliary tract while also providing the capability for directed diagnostic and therapeutic maneuvers. Direct pancreaticobiliary visualization has become more accessible as a single-operator procedure, due to recent technological innovations, such as the SpyGlass direct visualization system, which is a mother-daughter scope system that utilizes a fiber optic probe with a 0.8 mm diameter to achieve direct visualization of the biliary tree (Boston Scientific, Natick, MA, USA).¹³ In this system, directed biopsies may be performed with proprietary biopsy forceps, and there is capability for electrohydraulic lithotripsy.¹³ Indications include investigation and biopsy of suspected biliary malignancies and treatment of bile duct stones with lithotripsy. Complications are primarily related to the initial ERCP, but they may include a slightly higher incidence of postprocedural bacteremia, although there are little data on the newest imaging systems.¹⁴ Also, lithotripsy slightly increases the possibility of the rare complication of perforation of the bile duct.¹⁵ The antecedent ERCP procedure is already a significantly stimulating procedure that requires deep sedation. The direct pancreaticobiliary visualization, especially with interventions, further heightens the stimulation of the procedure.

Endoscopic Mucosal Resection

Both endoscopic mucosal resection and endoscopic submucosal dissection were developed primarily in Asia as a treatment for cancerous lesions in the upper GI tract, due to the overwhelming incidence of gastroesophageal cancers in that region.^{13,16} In addition to removal of early gastric cancer and treatment of Barrett's esophagus, EMR also has been utilized for removal of large colonic polyps, including flat and sessile polyps.^{17,18} In EMR, the mucosa in the area of question is resected and removed, predominantly with either a diathermic snare or band ligator, at the mucosal/submucosal plane.^{16,18} There are a variety of EMR techniques, including the "inject, lift and cut" method, EMR-cap technique, strip-off biopsy, and EMR with band ligation method.^{16,18} Usually, a fluid such as methylcellulose is injected into the submucosal layer to facilitate resection and to decrease the chance of perforation. One limitation of the EMR techniques is that they often result in piecemeal resections of large mucosal lesions. Both EMR and ESD are highly stimulating procedures, and are often performed in the anesthetic spectrum between deep sedation and general anesthesia.

Endoscopic Submucosal Dissection

Endoscopic submucosal dissection allows for en bloc mucosal resections, compared to the piecemeal resections of large mucosal lesions in EMR. In ESD, a region around the lesion in question is demarcated by electrocautery markings. A highly viscous solution such as hyaluronic acid or methylcellulose is then injected into the submucosal layer to separate the muscularis from the mucosa and to maintain a “safety cushion” to prevent unintentional perforation. An electrocautery knife is then used to perform an en bloc dissection of the previously demarcated lesion. The indications for ESD are similar to those for EMR.¹⁸⁻²⁰ Bleeding, pain, perforation, and stricture are the major complications for both EMR and ESD.¹⁸⁻²⁰ As with most advanced endoscopic procedures, the complication and efficacy rates do vary with the experience of the endoscopist.

Endoscopic Ultrasound

Endoscopic ultrasound has increased the diagnostic capability of endoscopy and has taken a prominent role in the staging of cancers in and around the GI tract.⁷ (Figure 15.1) Echoendoscopes have traditional direct imaging of standard endoscopes but also have ultrasonic capabilities by an ultrasound transducer mounted at the tip of the endoscope. Currently, there are two broad categories of echoendoscopes: radial and linear. Radial scanning echoendoscopes have an ultrasound transducer that rotates, creating an image of all tissue perpendicular to the long axis of the endoscope at the tip. Radial echoendoscopes, however, do not have the capability to perform a directed biopsy or fine needle aspiration (FNA). Linear array echoendoscopes provide images in an 80- to 105-degree arc along the long axis of the endoscope, which allows imaging of a needle as it is advanced into the ultrasonic field (and target lesion). This allows for ultrasound-guided



FIGURE 15.1: An EUS image of a mass adjacent to the stomach wall. (Photo courtesy of Mark Gromski, MD).

FNA and fine needle injection (FNI). From a diagnostic and prognostic point of view, EUS has emerged as a valuable tool in the staging of esophageal,²¹ gastric,^{22,23} rectal,^{24,25} and pancreatic cancers.^{26,27} From a therapeutic perspective, EUS-guided pseudocyst drainage,²⁸ celiac plexus neurolysis and block²⁹ and EUS-guided FNI for directed anti-cancer treatment³⁰⁻³² have emerged, in addition to a plethora of additional experimental approaches.

Natural Orifice Transluminal Endoscopic Surgery

Natural orifice transluminal endoscopic surgery (NOTES) is an experimental scarless approach to abdomino-pelvic pathology that combines expertise of endoscopy and minimally invasive surgery. This approach, currently being extensively explored in animal studies and in a few hybrid laparoscopic-NOTES human protocols, will likely drive further industry and academic research and development into minimally invasive approaches of GI pathologies. The NOTES approach is discussed in more detail in Chapter 18.

COMPLICATIONS AND SPECIAL POPULATIONS

Complications during GI endoscopy result primarily from interventional procedures. Hemorrhage following polypectomy, EMR, or ESD is encountered relatively frequently and is managed endoscopically, but it may require surgical intervention. Perforation from a variety of interventional procedures may lead to a distended abdomen, with resulting venous compromise and hemodynamic responses due to decreased preload. Variceal bleeding may lead to significant blood loss, which may lead to circulatory compromise and death. Complication profiles for more experimental techniques, such as NOTES, are not well characterized at this point in humans.

The complications of each endoscopic procedure must be known and there needs to be a backup plan should the complication occur. Depending on the invasiveness of the procedure, the complication profile of the procedure, and the level of sedation desired for the patient, health care personnel skilled in airway management and emergency resuscitative techniques should be present or immediately available during the procedure.

When determining endoscopic management, including sedation, the gastroenterologist and anesthesiologist must also take into account special populations, such as the elderly, obese, pregnant, and patients with comorbid conditions. For example, obesity is an independent risk factor for complications in ambulatory endoscopic procedures. A study by Qadeer and colleagues found increased body mass index (BMI) to be a risk factor for hypoxemia in subjects undergoing a variety of ambulatory endoscopic procedures.³³ In another study, BMI >28 was an independent risk factor for hypoxemia in subjects undergoing upper endoscopy.³⁴ Should endotracheal intubation become necessary during an endoscopic procedure, it is important to be aware that numerous studies correlated the difficulty of endotracheal intubation with obesity.³⁵⁻³⁷

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16 Anesthesia for Gastrointestinal Endoscopic Procedures

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Over the past several years, the number of endoscopic procedures performed by gastroenterologists in the United States has grown considerably. The escalating demand for endoscopic services can be attributed to an aging patient population, increased public awareness of cancer screening benefits, and the approval of Medicare reimbursement for surveillance colonoscopies.¹ In addition, the number and complexity of procedures that can be accomplished via endoscopy has risen. Patient wait times of 3 to 6 months are not uncommon at busy endoscopy centers.² Adequate sedation and anesthesia services are a crucial factor in maximizing efficiency and throughput at these centers.

Sedation for endoscopy facilitates the procedure, improves patient tolerance and satisfaction, and increases the likelihood that the patient will agree to further interventions.³ Historically, sedation regimens for endoscopy have consisted of a benzodiazepine combined with an opioid administered by nursing personnel under direction of the endoscopist. For screening colonoscopies in low-risk patients, this model usually proves successful. However, many modern endoscopic procedures are prolonged and complex, necessitating the need for deep sedation or general anesthesia. The sheer number of procedures being performed means many patients with significant comorbidities are undergoing gastrointestinal (GI) endoscopy. Along with an increasing volume of pediatric patients, these factors are altering sedation practices in the endoscopy suite. With increasing frequency, the expertise of anesthesia personnel is being employed to ensure safe and effective patient care.

The administration of anesthesia or sedation for endoscopy is associated with unique challenges that often differ from those encountered when providing anesthesia care in the operating room (OR). The location where procedures are performed (Figure 16.1), inconsistencies in preoperative preparation, postanesthesia recovery issues, and the management of complications are all areas requiring distinctive management strategies in the OOOR environment.

LOCATIONS

A recent survey of randomly selected members of the American College of Gastroenterology attempted to determine the locations

where endoscopy procedures are commonly performed in the United States as well as the types of sedation utilized for these procedures. The survey revealed that the majority (55.2%) of GI endoscopies are still being performed in the hospital setting, although a significant number are being performed in ambulatory surgery centers.⁴ Procedures performed in an office-based setting remain uncommon. Of note, there were significant regional differences in facility preference as well as sedation methods and percentage of cases in which an anesthesia professional administered the sedation (Table 16.1 and Fig. 2).⁴ While there have been several publications within the gastroenterology literature documenting and supporting the administration of propofol by nurses supervised by the gastroenterologist,⁵⁻⁷ this practice does not yet seem to have achieved widespread acceptance. A variety of factors likely explain this, including the recently reconfirmed restriction in the product labeling of propofol (which will be discussed later) as well as state-specific nursing regulations. Several state nursing boards do not allow registered nurses to administer propofol for procedural sedation.



FIGURE 16.1. Typical procedure room in GI endoscopy suite.

TABLE 16.1. *Geographic Variability in Sites of Endoscopic Service, Procedural Volume, and Sedation Agents*

	All Regions	Mid-Atlantic	North-East	South	Mid-West	West	South-West
Primary site of endoscopy (%)*							
Office	8.8	19.8	0.4	7.3	2.2	7.2	4.0
Ambulatory	35.8	26.4	28.3	42.7	30.7	46.8	42.6
Hospital	55.2	53.8	70.1	49.8	67.1	45.6	53.4
Other	0.2	0.0	1.2	0.2	0.0	0.4	0.0
Average number of procedures/week [†]							
EGD	12.3 (11.9–12.8)	11.6 (10.6–12.5)	9.2 (8.0–10.4)	13.0 (12.2–13.7)	13.3 (12.3–14.4)	10.8 (9.9–11.6)	15.6 (12.8–18.4)
Colon	22.3 (21.5–23.1)	20.6 (19.1–22.3)	21.5 (19.1–24.0)	24.5 (22.7–26.2)	23.2 (21.7–24.8)	19.9 (18.4–21.3)	23.2 (19.7–26.8)
Preferred sedation agent(s) (%)*							
Meperidine	56.0	48.1	56.3	59.6	59.8	41.9	66.3
Fentanyl	52.7	41.3	65.5	45.2	50.4	71.2	57.7
Midazolam	86.6	77.9	93.1	83.4	84.8	88.9	90.4
Diazepam	6.3	5.9	3.4	7.0	6.6	6.6	4.8
Propofol	25.7	42.8	6.9	30.6	15.2	12.6	11.5

* Data expressed represent responses for colonoscopy. The responses for EGD were comparable.

[†] Data expressed as mean (95% confidence interval)

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SEDATION VERSUS GENERAL ANESTHESIA

Sedation for every procedure in the endoscopy suite is not ubiquitous; indeed a small number of patients will tolerate simple GI endoscopic procedures without any sedation. While over 98% of colonoscopies and esophagogastroduodenoscopies (EGDs) are performed with sedation in the United States,¹

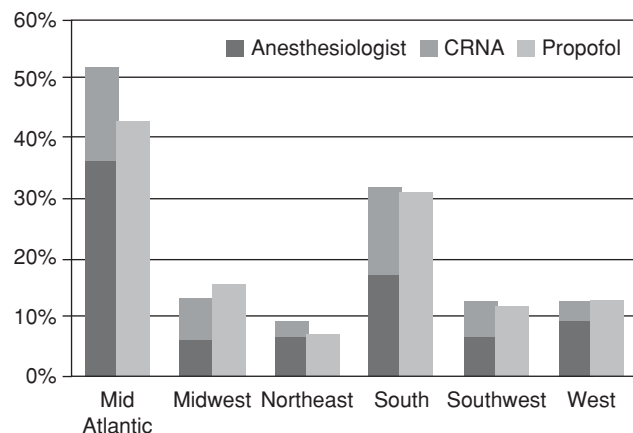


FIGURE 16.2. Prevalence rates for use of propofol and anesthesiologist/ certified registered nurse anesthetist (CRNA) for endoscopic sedation, analyzed by geographic region of the United States.

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unsedated examinations are more common in other countries. European studies have sought to elucidate patient factors that might predict poor tolerance of endoscopy without sedation.⁸ Apprehension about the procedure and elevated levels of anxiety as measured by the state trait anxiety inventory were both associated with poor patient tolerance. Although no formal studies have been done, it is likely that these same factors would help predict which patients may be more difficult to sedate.

Healthy patients undergoing simple procedures such as screening colonoscopies or EGDs will generally tolerate these procedures well with light to moderate sedation. While some centers will utilize anesthesia care providers for these cases, a majority of gastroenterologists will direct nurse-administered sedation for these routine procedures. Most GI endoscopy centers will consult anesthesiologists for specific patient groups (Table 16.2), such as pediatric patients, patients with a history of being difficult to sedate, mentally challenged patients, and patients with life-threatening medical conditions. In these more challenging situations, it is likely that deep sedation or general anesthesia will be required to achieve patient comfort and cooperation.

To choose the appropriate level of sedation for an endoscopic procedure, the anesthesia provider must consider several variables. The patient's medical status is paramount in this decision, including whether the patient is at risk for aspiration, thus requiring endotracheal intubation. The logistics of the procedure also come into play when formulating an anesthetic plan; namely the complexity and length of

TABLE 16.2. *Patients Likely to Require Sedation for Gastrointestinal Endoscopy*

Pediatric patients
Patients with a history of being difficult to sedate or history of difficult intubation
Substance abusers
Mentally challenged patients
Patients undergoing complex/long procedures
Patients with serious or life-threatening medical conditions

the planned procedure, positioning requirements, and proximity of the anesthesiologist to the patient's airway during the case.

SCHEDULING AND THE PRE-PROCEDURE EVALUATION

The same principles of preanesthetic evaluation for surgical cases should apply to GI endoscopic procedures. This may require significant coordination between the anesthesia provider and the endoscopist, especially when dealing with medically complex patients. While many patients are evaluated by the gastroenterologist in an office visit prior to the procedure, the open-access model has become increasingly popular.⁹ In this model, patients are referred by a primary care provider and scheduled for procedures without first being seen by the endoscopist. Most centers that employ an open-access scheduling system have a patient screening process in place. For example, the endoscopy scheduler will conduct a telephone interview and review the patient's medical history. Affirmative answers to specific questions (i.e., history of heart failure, coumadin therapy) trigger a preprocedure office visit with the physician who will be performing the endoscopy.

It is critical that the gastroenterologist and anesthesiologist communicate, and the expectations regarding preanesthetic evaluations are understood. A well-defined process of evaluating each patient preendoscopy for anesthetic risks helps to avoid the frustrating scenario in which the anesthesiologist is faced with an inadequately evaluated patient moments before the procedure is scheduled to begin.

An excellent example of a situation that requires preprocedure planning is that of managing antiplatelet medications and anticoagulants in preparation for endoscopic procedures where bleeding is expected, such as esophageal varices banding or endoscopic retrograde cholangiopancreatography (ERCP) with sphincterotomy. As the indications for long-term anticoagulant/antiplatelet therapy expand, the number of patients presenting to the endoscopy suite who are taking these medications also is increasing. This issue is of particular importance in patients who have drug-eluting coronary stents. As with surgical patients, the decision whether to withhold these medications during the periprocedure period is complex and must be made in collaboration with the gastroenterologist, cardiologist, and anesthesiologist. An approach that has

been studied and shown to be cost effective is to perform a primary diagnostic endoscopy while the patient remains on the usual anticoagulation regimen. An informed decision can then be made on how to manage the anticoagulants if a therapeutic procedure is deemed necessary.¹⁰ It is somewhat reassuring that a recent retrospective case-control study concluded that antiplatelet agents were not significantly associated with bleeding after endoscopic sphincterotomy.¹¹

An important aspect of the preanesthetic evaluation is determining whether the endoscopy suite is the most appropriate location for performing the procedure. Unlike other nonsurgical procedures requiring anesthesia services, the equipment necessary to perform many gastrointestinal procedures is relatively portable. From the anesthesiologist's perspective, the OR may be the safest environment for performing endoscopy in the most medically challenging patients. Specialized monitoring and airway equipment as well as additional anesthesiology personnel are more readily available if anesthesia complications arise.

REIMBURSEMENT

Payors do not typically provide separate reimbursement for sedation when a gastroenterologist both performs the procedure and oversees the sedation; the sedation component is included. As an increasing number of endoscopists have turned to anesthesiologists to provide sedation, charges to Medicare for anesthesia for colonoscopy have increased markedly. Between 2001 and 2003, the number of colonoscopies in which anesthesiologists provided sedation more than doubled, and charges to Medicare increased 86%.¹² This rapid growth has, of course, attracted increased scrutiny from commercial payors and Medicare contractors. Many carriers distinguish between anesthesia for low-risk and high-risk patients, allowing reimbursement for the latter only. Carriers have set guidelines to define a high-risk patient or procedure, and case-specific reasons that necessitate the participation of an anesthesia care provider must be documented accordingly. Payment policies are evolving. In early 2008, a major insurance company announced they would no longer pay for monitored anesthesia care during routine endoscopies in average risk patients. After protest from patients and physicians, they announced implementation of this policy would be delayed until more patient-friendly sedation alternatives that did not require the services of an anesthesiologist became available. In addition, significant regional differences exist. These regional disparities in reimbursement policies are a primary reason why anesthesia for endoscopy tends to be handled differently depending on geographic location. For instance, a 2004 survey showed that in the Northeast states, where carriers are generally unfavorable toward anesthesiologist involvement, only 7% of gastroenterologists used propofol sedation. In the mid-Atlantic states where more favorable policies exist, 43% of gastroenterologists utilized anesthesiologists to administer propofol.⁴ Economics will continue to drive practice, and issues such as nurse-administered propofol sedation will be at

the forefront of debates on resource utilization. On the other hand, CMS stated in the December 2009 revisions of the Interpretive Guidelines that propofol for endoscopy was an example of deep sedation, and Registered Nurses are not permitted to administer deep sedation.

MEDICATIONS FOR SEDATION AND ANALGESIA

The sedation regimen for the majority of GI endoscopic procedures consists of a benzodiazepine combined with an opioid titrated to mild to moderate sedation.¹³ As procedure numbers climb and techniques become more sophisticated, some limitations of this traditional sedation practice are discovered. There are patients who simply cannot be adequately sedated with a benzodiazepine/opioid combination, leading to failed procedural attempts and/or a poor experience for the patient. Onset of sedation can be prolonged with these two classes of drugs, and significant side effects are not uncommon in the recovery period, including nausea, vomiting, prolonged sedation, and respiratory depression. For these reasons, alternative drugs have been sought that offer improved pharmacodynamic profiles coupled with fewer side effects.¹⁴

PROPOFOL

While the issue of propofol administration by nonanesthesia personnel is controversial, there is little doubt that propofol is perhaps the most desired agent for endoscopic sedation.¹⁵ High patient satisfaction, quick onset, rapid recovery, and improved operational efficiency are all factors that have led to increased demand for propofol use in the endoscopy suite. Depending on the type and duration of procedure, it can be administered either as intermittent boluses or a continuous infusion. One of the drug's disadvantages, though, is its very narrow therapeutic window. Due to significant variation among patients, it is not uncommon for a dose that typically produces moderate sedation to lead to a level of deep sedation or even general anesthesia in some patients. As a result, the U.S. Food and Drug Administration (FDA) includes on propofol's product label a statement that it "should only be administered by persons trained in the administration of general anesthesia."¹⁶ In addition, both the American Society of Anesthesiologists Practice Guidelines for Sedation and Analgesia by Non-anesthesiologists¹⁷ and The Joint Commission state that practitioners providing sedation should be able to manage patients who reach a deeper level of sedation than was planned.¹⁸ In the case of propofol administration, therefore, the practitioner should be competent in managing airway obstruction and respiratory depression, which could include the need for endotracheal intubation, as well as cardiovascular side effects such as hypotension.

It is these positions by regulatory and accrediting agencies, which are supported by the American Society of Anesthesiologists, that have made the administration of propofol by

nonanesthesia professionals, including registered nurses under the supervision of an endoscopist, a controversial topic. The gastroenterology community has reported on at least 200,000 cases of nurse-administered propofol sedation (NAPS) for simple endoscopy procedures in which no mortalities occurred.¹³ The incidence of complications such as oxygen desaturation and airway obstruction associated with NAPS is not well defined, however. Some gastroenterologists are now reporting the use of NAPS for more complex endoscopic procedures, such as endoscopic ultrasound.^{19,20} In a retrospective study of more than 800 patients, 0.5% of patients required positive pressure ventilation during the procedure and oxygen saturation decreased below 90% in 0.7% of patients.¹⁹ This lead one proponent of NAPS for simple endoscopic procedures to caution about adopting this technique for more advanced procedures.²¹

Patient-controlled propofol sedation is another delivery model that has been investigated for use in endoscopic procedures as a way to provide adequate sedation while minimizing the problem of oversedation that can occur due to the drug's narrow therapeutic window.^{22,23} While it may not be clear which practitioners and delivery methods will be used most commonly in the future, it is certain that propofol will continue to be a popular drug administered with increasing frequency for sedation and anesthesia during endoscopic procedures.

FOSPROPOFOL

Recently approved by the FDA, fospropofol disodium (*LUSEDRA*; Eisai Corp. of North America) is a water-soluble prodrug of propofol. After intravenous administration, fospropofol is cleaved by alkaline phosphatase into propofol, formaldehyde, and phosphate. The liberated propofol exhibits a different pharmacokinetic profile from the standard lipid-emulsion propofol formulation. Studies have demonstrated a more predictable, gradual rise in serum levels along with a longer duration of pharmacodynamic effect.²⁴ Another advantage of fospropofol is the avoidance of side effects associated with propofol's lipid emulsion (potential for bacteremia, painful injection, etc.) Some disadvantages include the same steep concentration–response relationship as propofol and individual variability in the bioavailability of propofol from the prodrug.^{24,25}

A dose–response clinical trial of 127 patients compared the efficacy and safety of four different dosing regimens of fospropofol with that of midazolam for colonoscopy.²⁶ They examined rates of sedation success, time to sedation, requirements for adjuvant sedatives, assisted ventilation requirements, time to discharge, and physician and patient satisfaction. Adverse events were limited to hypotension in two patients as well as hypoxemia in two patients. Only one patient required airway assistance (verbal stimulation). They concluded the ideal dose of fospropofol for both patient safety and efficacy was 6.5 mg/kg followed by supplemental doses at 25% of the initial dose (1.6 mg/kg) as needed.

During fospropofol's development, it was expected by many (including insurance payors) that this drug would be approved for use by nonanesthesia providers and could possibly provide the benefits of propofol while eliminating the controversy associated with NAPS. However, it is now approved for marketing as "an intravenous sedative-hypnotic agent for monitored anesthetic care," because the FDA decided fospropofol should carry the same FDA warning as propofol in regard to who should administer the drug. The label warning states that only personnel who are trained in the administration of general anesthesia and are not involved in the conduct of the procedure can administer the drug. During the fospropofol approval process, formal comments to the FDA by the American Society of Anesthesiologists (ASA) requested such wording because it is their stance that, as a drug which leads to propofol release, fospropofol carries the same risk as propofol and thus should carry a similar "anesthesia training warning."²⁷ Cited as the primary concern in these comments by the ASA is the unpredictable individual patient response to propofol which can lead to a state of deep sedation or even general anesthesia.

DEXMEDETOMIDINE

Approved by the FDA in 1999 for sedation for intubated patients in the intensive care unit,²⁸ dexmedetomidine (*PRECEDEX*; Hospira, Inc.) is a highly selective alpha-2 adrenergic receptor agonist with sedative and analgesic effects.²⁹ Agonism at presynaptic receptors in peripheral sympathetic nerves inhibits the release of norepinephrine while stimulation at central postsynaptic receptors serves to inhibit sympathetic activity. As the drug's mechanism of action is unrelated to the gamma-aminobutyric (GABA) system, the quality of sedation is purportedly different.³⁰ Patients tend to appear quite sedated yet are more easily arousable than patients sedated by a GABA-potentiating agent such as midazolam or propofol. A relatively new agent in the anesthesiologist's armamentarium, dexmedetomidine's role in sedation for GI endoscopy has not been entirely established.

Few studies have been performed evaluating the use of dexmedetomidine specifically for endoscopic procedures. A Turkish study published in 2007³¹ compared dexmedetomidine and midazolam in a cohort of 60 ASA I and II adult patients undergoing esophagogastroduodenoscopy. Endoscopist satisfaction with sedation quality was higher and total side effects were lower in the dexmedetomidine group. Recovery time and hemodynamic parameters were comparable between the two groups.

A study from Poland evaluating dexmedetomidine for sedation during colonoscopy found it to be less than ideal and, indeed, the study was terminated due to adverse events in the dexmedetomidine group.³² Compared with patients receiving meperidine and midazolam or fentanyl as a single agent, patients receiving dexmedetomidine had the longest recovery time as well as significant bradycardia and hypotension not seen in the other groups.

KETAMINE

A synthetic phencyclidine derivative, ketamine is a rapidly acting anesthetic agent that produces rapid sedation, amnesia, and analgesia. Functioning as an N-methyl-D-aspartate (NMDA) receptor antagonist, ketamine acts to dissociate the limbic and cortical systems, producing a cataleptic state that does not resemble normal sleep patterns.³³

Airway reflexes are generally maintained, and cardiovascular and respiratory side effects are minimal.

Ketamine has been examined both as a sole agent for sedation and in combination with other sedatives in both adults and children. Most literature references center on its use in the pediatric population. Gigler et al. performed a retrospective analysis of 402 pediatric patients receiving various combinations of midazolam, meperidine, and ketamine for simple endoscopy procedures.³⁴ They concluded that the group which received midazolam and ketamine in combination had the lowest rate of complications as well as an equal rate of adequate sedation when compared with other sedation regimens. A study from Hong Kong sought to evaluate the effectiveness of intramuscular ketamine as a sole sedative agent in 60 children undergoing basic GI endoscopic procedures as well as bronchoscopy.³⁵ It was determined that a single intramuscular dose of ketamine (2–3 mg/kg) was safe and effective for children aged 7 years and older. A high failure rate was noted in children younger than 7 years, with the highest failure rates among infants. Kirberg et al. described their successful use of ketamine, primarily as an adjunct to other sedatives, in over 900 pediatric endoscopic procedures.³⁶ Ketamine use in difficult-to-sedate adult patients undergoing ERCP and endoscopic ultrasonography (EUS) has been explored.³⁷ In patients who were inadequately sedated with meperidine and diazepam, it was found that ketamine administration offered a better depth of sedation and shorter recovery time than additional dosing of meperidine and diazepam.

BENZODIAZEPINES

Long an integral part of sedation for endoscopy, early benzodiazepines, such as diazepam, were not water soluble, leading to problems with administration. Once water-soluble midazolam became available in the late 1980s, it quickly gained favor.³⁸ Early investigation of midazolam use for EGD found quicker onset, less thrombophlebitis, improved patient tolerance, and greater amnestic effects compared to diazepam.³⁹

The majority of intravenous sedation for endoscopy today involves administration of midazolam in combination with an opioid, usually by a nonanesthesia professional.¹ Serious side effects from midazolam are uncommon, although dose-dependent respiratory depression does occur. This respiratory depression is more likely in patients who have underlying respiratory disease and in those receiving concomitant opioids for sedation.¹³ A large prospective study of 2635 pediatric endoscopies at The Children's Hospital of Philadelphia found only 2 serious adverse events (apnea) and concluded

that administration of midazolam and fentanyl is safe for pediatric endoscopy.⁴⁰

OPIOIDS

The second component of the conventional sedation combination for endoscopy is an opioid. Twenty years ago, meperidine was the primary choice.³⁸ Today, the use of meperidine and fentanyl is nearly equal.¹ Alternative opioids have been investigated for use in the sedation, such as the ultra-short-acting remifentanyl. One study examined the use of remifentanyl combined with a benzodiazepine in the sedation of 40 patients undergoing various procedures, including endoscopy.⁴¹ While discharge times were short and analgesia was profound in the remifentanyl group, the dose to achieve adequate sedation frequently led to apneic episodes requiring intervention. It was concluded that remifentanyl use for sedation during brief procedures is not useful.

SEDATION/ANESTHESIA FOR SPECIFIC PROCEDURES

Gastrointestinal endoscopy procedures vary significantly in their complexity, duration, and degree of patient stimulation. Therefore, the anesthesiologist must tailor the sedation regimen to focus not only on individual patient requirements but also the unique variables associated with the procedure being performed.

ESOPHAGOGASTRODUODENOSCOPY

While many EGDs are performed successfully with a combination of a benzodiazepine and opioid, the majority of EGD sedations performed by anesthesiologists utilize propofol. A nationwide survey of gastroenterologists reported higher satisfaction rates with propofol compared to conventional benzodiazepine/opioid sedation.¹ The median satisfaction score for propofol was 10 on a scale where 10 was defined as best, while benzodiazepine and opioid in combination yielded a score of 8. Also, a majority of these physicians selected propofol as the agent they would choose to receive for their own endoscopy. Reasons given for favoring propofol included better sedation and analgesia, fast return to normal activity, and improved quality of examination.

While successful EGD exams can generally be performed under moderate sedation in most patients, individuals with a history of being difficult to sedate or a history of substance abuse will generally require deep sedation or general anesthesia. However, even when moderate sedation is the intended endpoint, studies have shown that deep sedation is often achieved. In one study, 60% of patients undergoing EGD reached a level of deep sedation despite a preprocedure plan for moderate sedation.⁴²

A patient's need for endotracheal intubation is another factor to consider when choosing between sedation and general

anesthesia for EGD. Many of the indications for EGD such as persistent vomiting or severe gastroesophageal reflux disease may dictate protection of the airway with an endotracheal tube. Other patients who may not tolerate the level of sedation needed for EGD include patients with obstructive sleep apnea and/or morbid obesity. Significant airway obstruction should be expected in these patients and endotracheal intubation should be strongly considered.

One unique technique that has been employed for EGD under general anesthesia in pediatric patients is use of the ProSeal laryngeal mask airway (LMA).⁴³ The ProSeal LMA features a modified cuff and a drain tube that provides gastric access. The drain tube is of a sufficient size to accept pediatric-sized gastroscopes. When compared with oxygen delivery via nasal cannula, the ProSeal group had overall higher SpO₂ values and fewer episodes of hypoxia with no discernable difference between groups in ease of endoscopy.

An adjunct to sedation for EGD that is often overlooked is topical pharyngeal anesthesia. While there are studies that have reported no additional benefit from topical anesthesia in sedated patients,⁴⁴ other studies⁴⁵ as well as a meta-analysis⁴⁶ have reported an improvement in the ease of endoscopy in patients receiving topical pharyngeal anesthesia. It should be noted that commercially available local anesthetic sprays such as Hurricane and Cetacaine sprays contain benzocaine, which has been associated with the development of methemoglobinemia.⁴⁷ Another novel method for topical anesthesia that has been described is use of a lidocaine lollipop.⁴⁸ In a study of 50 patients undergoing EGD, approximately one-third of those receiving the lidocaine lollipop did not require any further sedation throughout the procedure.

COLONOSCOPY

Like EGD, the majority of patients can be adequately sedated for colonoscopy with a combination of midazolam and opioid. One study found that when moderate sedation was planned, fewer patients progressed to deep sedation during colonoscopy than during EGD, ERCP, or EUS.⁴² This might be explained by the less stimulating nature of the colonoscopy exam when compared to the other procedures. However, most anesthesia providers who sedate patients for colonoscopy typically use propofol and aim for deep sedation or even general anesthesia. It seems likely that even in situations where the endoscopist is directing sedation, they and their patients prefer a deeper level of anesthesia. In a study of nurse-administered propofol sedation performed under the direction of a gastroenterologist, the mean bispectral index (BIS) score was found to be 59, indicating a state of general anesthesia.⁴⁹

Several sedation techniques for colonoscopy have been studied. Moerman et al. compared intravenous remifentanyl to intravenous propofol in 40 adult patients scheduled for complete colonoscopies. They found that measures of early recovery, such as spontaneous eye opening and following commands, occurred sooner in patients who received remifentanyl than in

patients who received propofol. In addition, recovery of cognitive function was quicker in the remifentanyl group. However, patient satisfaction was lower in the remifentanyl group, and respiratory depression was more common in this group as well.⁵⁰ Another study evaluating the use of remifentanyl for sedation during colonoscopy found postprocedure nausea and vomiting to be a significant problem.⁵¹ General anesthesia using an inhalational technique of sevoflurane/nitrous oxide also has been compared with total intravenous anesthesia (TIVA) using propofol/fentanyl/midazolam for colonoscopy.⁵² While emergence was quicker in the TIVA group, patients who received an inhalational anesthetic were less sedated 20 minutes after the completion of the procedure. The TIVA group also experienced psychomotor impairment lasting 30–90 minutes longer than the inhalational group.

Propofol as a sole agent for sedation during colonoscopy also has been compared to a combination of lower-dose propofol in combination with fentanyl and/or midazolam titrated to moderate sedation. Patients in the propofol-only group reached a deeper level of sedation than any of the combination groups. No differences in vital signs, adverse respiratory events, or patient satisfaction were found among the groups, although patients in the propofol-only group remembered less procedural pain. Patients who received a combination of propofol with midazolam or fentanyl were discharged more quickly, however.⁵³

Patient-controlled sedation with propofol is a relatively new technique that appears effective for sedation during colonoscopy. A prospective randomized study from France compared patient-controlled sedation with propofol administration by an anesthesiologist. Patients in the patient-controlled group self-administered 20 mg boluses of propofol as needed with a 1 minute lockout time. Patients in the anesthesiologist-controlled group received a continuous infusion of propofol that was titrated to effect. Procedural success, which was defined as reaching the cecum with the colonoscope, and technical ease of the procedure as rated by the gastroenterologist did not differ between the groups. Patient satisfaction was similar between the groups as well. Patients in the patient-controlled propofol group experienced a lighter depth of sedation and used significantly less propofol than patients in the anesthesiologist-controlled group. In addition, fewer episodes of desaturation occurred in the patient-controlled group, and the time to discharge was also shorter in this group.⁵⁴ It is possible that this evolving technology may become a preferred method of sedation for colonoscopy in the future.

ENDOSCOPIC RETROGRADE CHOLANGIOPANCREATOGRAPHY

Endoscopic retrograde cholangiopancreatography combines endoscopy and fluoroscopy (Figure 16.3) in a technique used to diagnose and treat diseases of the biliary and pancreatic ductal systems. Patients who present for ERCP are typically more



FIGURE 16.3. ERCP procedure room

severely ill than patients undergoing EGD or colonoscopy. Common presenting diagnoses include pancreatitis, bile duct or pancreatic cancer, sphincter of Oddi dysfunction, and cholangitis. The systemic illnesses in this patient population may partly account for the high risk of cardiopulmonary complications associated with ERCP. An Australian study that looked at ERCP complications related to patient age found that approximately 25% of patients 65 years or older developed new electrocardiographic changes (ischemia, arrhythmias) during or after ERCP. Elevated cardiac troponin I levels were documented in 11% of patients in this age group.⁵⁵ In comparison with colonoscopy or EGD, complex therapeutic procedures of significant duration are often undertaken during ERCP. Interventional techniques commonly employed include placement of biliary stents, biliary sphincterotomy, removal of bile duct stones, and stricture dilation. Patient immobility is paramount for successful performance of these often time-consuming and challenging procedures. Adding to the challenge for the anesthesia provider is the prone position that most gastroenterologists prefer for performing ERCP.

While many anesthesiologists prefer general anesthesia for ERCP, some do successfully provide moderate or deep sedation for this procedure. The preferred sedative drug is invariably propofol. Midazolam versus propofol sedation has been studied in the setting of ERCP.⁵⁶ Successful procedure completion was more likely in patients receiving propofol (97.5% vs. 80%), and recovery time was significantly shorter in the propofol group. Target-controlled infusion techniques have also been studied for use in ERCP sedation. Although cost-effectiveness of the system requires further investigation, successful sedation for ERCP has been reported by titrating propofol to a target concentration of 2–5 µg/ml.⁵⁷

The challenges associated with sedation for ERCP have led many anesthesiologists to prefer general anesthesia for the procedure. Data exist that support this clinical approach. A retrospective study of over 1000 ERCP procedures found the procedure failure rate with sedation to be double the failure rate of general anesthesia, usually due to inadequate

sedation.⁵⁸ Complication rates may also be lower in patients receiving general anesthesia for therapeutic ERCP. The lower complication rate with general anesthesia is hypothesized to result from less patient movement and aperistalsis of the duodenum.⁵⁹

Due to the prone position, inaccessibility of the airway to the anesthesiologist, and the presence of aspiration risk factors in many patients, endotracheal intubation is usually performed when general anesthesia is chosen for ERCP. However, the use of the LMA for ERCP has been described by investigators, even in the prone position. In a group of 20 patients, no airway complications were encountered, and there were no technical difficulties with endoscope placement or ERCP performance.⁶⁰

ENDOSCOPIC ULTRASONOGRAPHY

Endoscopic ultrasonography is used for diagnosing and staging gastrointestinal and pancreatic tumors and, like ERCP, is a more complex and stimulating procedure than EGD or colonoscopy. Frequently, needle aspiration biopsies are taken that must be examined by a pathologist before completion of the procedure. The long duration of the procedure coupled with the larger size of the ultrasound-containing endoscope results in an elevated level of patient discomfort when compared with simple EGD. As a result, adequate sedation for EUS typically requires deep sedation or general anesthesia.

Because achieving an appropriate level of sedation while avoiding hypoxemia and airway obstruction may be more challenging during EUS, many patients will not tolerate the procedure with the conventional benzodiazepine and opioid combination. Alternative strategies for sedation have been investigated. In one study, moderate doses of benzodiazepine and opioid were given before the EUS procedure began. This baseline sedation was then supplemented during the procedure with either ketamine or additional benzodiazepine and opioid. The degree of patient comfort, technical ease of the study, and recovery times were all improved in the patients that received ketamine supplementation. In addition, approximately one-third of the patients randomized to receive additional benzodiazepine/opioid had to cross over to the ketamine group in order to obtain a sedation level adequate to complete the EUS.³⁷

A propofol infusion controlled by an anesthesiologist is, of course, another popular option for EUS sedation. Other unique techniques have been explored, including target-controlled propofol infusion (see Chapter 33) and patient-controlled sedation. One group studied the effect of midazolam dosing on the amount of propofol required to successfully complete the EUS procedure. They found that pre-procedure administration of midazolam did not significantly affect the dose of propofol used, but it also did not delay the time to discharge.⁶¹ Patient-controlled sedation, with boluses of fentanyl 3.75 µg and propofol 4.25 mg without a lockout interval, has also proved successful for sedation during EUS.⁶²

NATURAL ORIFICE TRANSLUMENAL ENDOSCOPIC SURGERY

Natural orifice transluminal endoscopic surgery (NOTES) is an emerging technique within the field of minimally invasive surgery (also see Chapter 18). The aim of NOTES is to perform intra-abdominal procedures with peritoneal access via natural orifices in lieu of conventional abdominal incisions. Proposed advantages include fewer skin flora-based infections, elimination of incisional hernias, a reduction in postoperative pain, and a lower incidence of postoperative adhesions.⁶³

Multiple experiments have been carried out in animal models, evaluating the feasibility of NOTES for various operations, including cholecystectomy,⁶⁴ gastrojejunostomy,⁶⁵ tubal ligation,⁶⁶ and splenectomy.⁶⁷ The use of NOTES in humans is just beginning, although several groups have published case reports of successful transvaginal cholecystectomy.⁶⁸⁻⁷⁰ Auyang et al. have described a transgastric approach to cholecystectomy in humans utilizing a hybrid of endoscopic and laparoscopic techniques.⁷¹

Thus far, all described cases of NOTES in humans have been performed with the patient under general anesthesia. However, in a recent critical review of the surgical technique, the authors suggested a potential advantage of NOTES might be the ability to avoid general anesthesia since there is no skin incision.⁷² While avoidance of an abdominal incision would certainly lessen analgesia requirements, all published descriptions of the technique have involved creation of a pneumoperitoneum in patients who are under general anesthesia. Peritoneal insufflation is generally poorly tolerated in the lightly sedated patient and can lead to cardiopulmonary embarrassment. While laparoscopic surgery has been performed under spinal anesthesia, its success hinges on specialized techniques to ensure patient comfort. Successful laparoscopic cholecystectomy under spinal anesthesia has been described in a small number of patients using nitrous oxide to create the pneumoperitoneum, utilizing low insufflation pressures, minimizing surgical traction, and inserting trochars below the umbilicus.⁷³ Whether spinal anesthesia is a useful technique for NOTES is a subject for future study.

In the future, with technological and surgical advancements, it is quite possible that natural orifice surgery will be performed in locations outside the OR. Like conventional endoscopy, the necessary equipment is portable and the approach is minimally invasive. If techniques are developed in which pneumoperitoneum can be avoided or its side effects minimized, it may be possible to perform NOTES under sedation or regional anesthesia. For now, it seems this unique blend of endoscopy and general surgery is best performed in the OR under general anesthesia.

ENDOSCOPY FOR PEDIATRIC PATIENTS

The majority of pediatric patients will not tolerate GI endoscopy without deep sedation or general anesthesia.

Anesthesiologists are therefore more likely to participate in pediatric procedures than adult procedures and, in some centers, are responsible for all or most pediatric sedations and anesthetics. While many of the techniques and drugs used are consistent across patient age groups, the pediatric population presents unique challenges. Typically, pediatric patients require larger doses of sedative medications on a per-weight basis than adults. A group of investigators evaluating the median effective concentration of propofol required for EGD found that children aged 3–10 years required substantially higher plasma levels than adult patient groups undergoing the same procedure.⁷⁴

One of the greatest challenges faced by the anesthesiologist in the endoscopy suite is obtaining intravenous access in children. In contrast with the OR where IVs are generally started after inhalational induction of general anesthesia, it is often not practical to have an anesthesia machine available in this practice setting. Techniques to aid in placement of the IV as well as separation from the parent are invaluable. In one study, pre-procedural administration of oral midazolam (0.5 mg/kg) was found to improve the ease of IV line placement, facilitate parental separation, improve patient comfort, and result in lower overall propofol use for upper endoscopy.⁷⁵ Recovery time was substantially longer in the children who had received midazolam, but it still averaged just 26 minutes.

MANAGING COMPLICATIONS

A large prospective cohort study has been performed, examining the incidence of cardiopulmonary complications during propofol sedation for upper endoscopy and colonoscopy. Nearly 12,000 colonoscopies and 6000 EGDs in which patients received propofol sedation were examined. The overall rate of complications was 0.86% for colonoscopy and 1.01% for EGD. Serious adverse events, defined as death, perforation, or bleeding, occurred in just 18 patients receiving colonoscopy and 17 patients undergoing EGD. Of note, the complication rate was lower for both procedures when sedation was provided by anesthesia providers rather than the gastroenterologist.⁷⁶

Despite the low incidence of adverse events, the anesthesiologist should anticipate that complications will occasionally occur when administering sedation for GI endoscopy. The general principles for management of these complications is the same as for cases performed in the OR; however, the resources available to aid the provider can be limited in the endoscopy suite. While the support personnel in the OR may be comfortable assisting the anesthesiologist during episodes of patient decompensation, nursing staff in the endoscopy center may not be able to provide the same level of assistance. In addition, equipment that is readily at hand in the OR, such as that needed for advanced airway management, may not be immediately available in the endoscopy area. These limitations put special importance on adequate preparation for each case. Any special equipment that may be required should be brought to the anesthetizing location and made ready for

use before the case begins. Additionally, a plan to obtain additional assistance should be in place should a serious adverse event occur. If a patient is of sufficiently high risk, it may be advisable to perform the procedure in the OR, where serious complications can be dealt with in a more efficient manner.

POSTANESTHESIA RECOVERY

The anesthesiologist must fully appreciate the capabilities of the nursing staff responsible for monitoring patients after endoscopy. GI endoscopy units are often staffed to provide nursing care at the level necessary to recover patients who have received moderate sedation. However, it is essential that patients who have received deep sedation or general anesthesia in the endoscopy suite receive the same level of recovery care they would receive in the postanesthesia care unit of the OR. Accrediting organizations such as The Joint Commission require that equivalent postanesthesia care be delivered in all locations within the health care center. Determining whether an equivalent level of postprocedure patient care can be provided in the endoscopy center depends on whether nursing staff in the endoscopy recovery unit have received similar training as the nurses in the surgical postanesthesia care unit, and also whether the appropriate nurse–patient ratio can be maintained. If the anesthesia provider is not comfortable with the level of postprocedure care offered for a particular patient, the patient should be transferred to the surgical recovery unit.

Discharge criteria should be the same as those used for patients who have been anesthetized in the OR. Recovery nurses must understand these criteria and also must know how to reach anesthesia personnel should issues arise during the recovery period. Postanesthesia management of patients with obstructive sleep apnea may be especially challenging. Compared with normal patients, guidelines from the American Society of Anesthesiologists recommend that patients with obstructive sleep apnea should be monitored for a median of 3 hours longer before discharge.⁷⁷ If staffing issues in the endoscopy recovery area do not allow such extended monitoring, arrangements should be made for recovery in a more suitable location.

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17 | Anesthesia for Interventional Pulmonology

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There is increasing demand for providing anesthesia services for interventional pulmonology (bronchoscopic) procedures. This is a direct result of the proliferation of these procedures and the expansion of indications for performing them. Many of the traditional maximally invasive thoracic procedures, such as mediastinal staging, are now done as minimally invasive outpatient procedures.¹ Moreover, more of the new interventional procedures are performed through the flexible bronchoscope in diagnostic bronchoscopy suites outside of the operating rooms (OOOR). Even though the more invasive procedures such as those utilizing the rigid bronchoscope continue to be performed in the operating rooms, increased demand has led to the establishment of specialized OOOR interventional pulmonology centers that can accommodate these procedures. Many healthcare facilities aim to develop centers of excellence for such highly specialized care, utilizing standardized yet individualized protocols to improve safety and clinical outcomes.

The majority of patients presenting for interventional pulmonology procedures are high-risk patients. This represents a challenge for the anesthesiologist, who must simultaneously consider the severity of their lung pathology and their other comorbidities. Other complicating factors may stem from the nature of the procedure when anesthesiologists share the airway with pulmonologists, the dynamic nature of the procedure given the continuously changing airway, fraction of inspired oxygen (FiO₂) and finally, the ventilation mode to accommodate the procedure being performed. In addition, sometimes more than one procedure may be performed in the same setting on the same patient. As a result, the anesthesiologist needs to be familiar with all of the planned procedures, and needs to develop an anesthetic and airway management plan for these high-risk patients.

BRONCHOSCOPIC SURGICAL PROCEDURES

Common Traditional Procedures

Endotracheobronchial Stenting

Bronchoscopic surgical procedures are summarized in Table 17.1. In the last two decades, considerable progress has been

made in the endoscopic management of central airway obstruction resulting from causes such as benign airway stenosis or neoplasia. In particular, the use of self-expanding metallic stents (SEMs) placed bronchoscopically has provided important new clinical options.² In addition, metal and silicone stents (Fig. 17.1) are frequently used to support and maintain the tracheal lumen, restore integrity of a disrupted trachea, and support a collapsing tracheal wall (using a silicone stent) from a compressing mediastinal mass.

Endotracheobronchial Biopsy and Endotracheobronchial Laser

Biopsy of endotracheal and/or bronchial lesion is done through either the flexible or rigid bronchoscope. Nd:YAG and argon lasers are generally used to debulk an endotracheal and/or bronchial granuloma or a mass to maintain an open airway and treat airway stenosis.

Endobronchial Electrocautery

Endobronchial electrocautery is equally effective but less expensive than Nd:YAG laser therapy for intraluminal airway obstruction.^{3,4} It also leads to less airway scarring and subepithelial fibrosis compared to the Nd:YAG laser.⁵

Bronchoscopic Balloon Dilation

This procedure is customary in the treatment of stenosis of various etiologies, such as idiopathic subglottic stenosis commonly seen in female patients in their 40s. Bronchoscopic balloon dilation is also used to manage stenosis resulting from granulomatous diseases such as Wegener's granulomatosis.

Bronchoscopic Cryotherapy

This procedure entails the therapeutic application of extreme cold for local destruction of tissue. Nitrous oxide is used as a cryogen applied through a fiberoptic bronchoscope. Frozen tissue is destroyed by coagulation necrosis. In short, cryotherapy is an alternative to laser. Advantages of cryotherapy include ease of use, lower cost compared to laser therapies, reusability of

TABLE 17.1. *Bronchoscopic Surgery Procedures*

<i>Common Traditional Procedures</i>	<i>New Procedures</i>	<i>Procedures under Investigation</i>
<ul style="list-style-type: none"> • Endotracheobronchial stenting 	<ul style="list-style-type: none"> • Endobronchial ultrasound-guided transbronchial needle aspiration (EBUS-TBNA) 	<ul style="list-style-type: none"> • Bronchoscopic lung volume reduction (BLVR)
<ul style="list-style-type: none"> • Endobronchial biopsy • Endotracheobronchial laser • Bronchoscopic balloon dilation • Bronchoscopic cryotherapy • Endotracheal-broncheal electrocautery 	<ul style="list-style-type: none"> • Complete mediastinal staging using EBUS-TBNA • Electromagnetic navigational bronchoscopy (ENB) • Fiducial marker implantation 	<ul style="list-style-type: none"> • Bronchial thermoplasty for treatment of poorly controlled asthma



FIGURE 17.1. Y-shaped silicone stent. L, left (bronchus); R, right (bronchus); T, trachea.

the cryoprobe, and no risk of fire. Complications include airway perforation and bleeding.

New Procedures

Endobronchial Ultrasound-Guided Transbronchial Needle Aspiration (EBUS-TBNA) and Complete Mediastinal Staging Using EBUS-TBNA

Through EBUS-TBNA, the structure of the tracheobronchial wall and adjacent structures can be well visualized. It is an accurate, safe, and cost-effective technique that allows biopsy of mediastinal lymph nodes and peribronchial lesions.^{6,7} EBUS-TBNA has proved valuable for mediastinal lymph node staging of lung cancer.⁸

Electromagnetic Navigational Bronchoscopy

Electromagnetic navigational bronchoscopy (ENB) is designed to enable the pulmonologist to biopsy lesions within the periphery of the bronchial tree. The system components comprise the following⁹:

1. A sensor probe able to navigate the bronchial tree
2. An electromagnetic location board
3. A bronchoscope with an extended working channel
4. Computer software that converts computed tomography (CT) scans into multiplanar images with 3D virtual lung reconstruction. This setup allows navigational guidance within the lungs to endobronchially invisible targets and subsequent biopsy, almost in the same fashion as stereotactic brain biopsy.

Fiducial Marker Implantation

Stereotactic radiosurgery (CyberKnife: Accuray Incorporated; Sunnyvale, CA) is a treatment option for a lung tumor.

For precise tumor ablation, fiducial markers are placed in or near the target tumor. For bronchoscopically invisible peripheral lung lesions, ENB may offer an attractive alternative to CT-guided placement of these fiducials.¹⁰

Procedures under Investigation

Two procedures are worth mentioning. *Bronchoscopic lung volume reduction (BLVR)* is being investigated for treatment of emphysema to replace open lung volume reduction surgery, given the very invasive nature and associated morbidity and mortality of the latter. *Bronchial thermoplasty* is another bronchoscopic procedure under development. During this procedure, controlled heat is applied endobronchially to reduce the mass of the airway smooth muscle as a treatment for poorly controlled asthma.¹¹

ANESTHETIC CARE

Preoperative Evaluation

The extent of preoperative evaluation depends on several important considerations. Important questions to ask are: is the procedure elective or emergent? How stable or critical is the airway? In elective cases, preoperative assessment is usually conducted in the customary fashion with special attention to the following:

- Airway evaluation, symptoms of compromise: dysphagia, hoarseness, orthopnea, stridor, the use of accessory muscles of respiration
- Review of the pulmonologist's notes on the size and location of the lesion or tumor, and the intended procedure(s).
- Review of computerized tomographic scan of the neck and chest to rule out airway abnormalities and mediastinal masses.

- Prior chemotherapy and any effects on vital organs (especially the heart and lungs)
- Commonly associated conditions, such as heavy tobacco smoking and alcohol use
- Common comorbidities: coronary artery disease and chronic obstructive/restrictive pulmonary disease, chronic alcoholism, malnutrition, and aspiration pneumonitis

Premedication

Premedication with sedatives and anxiolytics should be considered only for a very anxious patient, because the respiratory status of patients has already been compromised, and many of the typically used medications are known to have respiratory depressant effects. Nevertheless, when it is considered necessary to use them, small titrated doses should be given. Once medicated, patients should not be left alone without appropriate monitoring. As an added safety precaution, supplemental oxygen should be provided before sedation.

Monitored Anesthesia Care (MAC)

This commonly used technique, especially in the OOR settings, can be used for selected patients undergoing simpler procedures. The majority of uncomplicated and routine diagnostic flexible bronchoscopic procedures can be performed under light sedation. However, ventilation support may be necessary if the lung is compromised, or when a patient becomes unable to tolerate the respiratory depressant effects of many of the commonly used sedatives. On the whole, because of their understanding of the lung pathology in question and their knowledge of the patient's respiratory status, pulmonologists can make accurate judgments regarding the type of sedation for the patient. Options might include mild or moderate sedation provided by the sedation nurse and supervised by the proceduralist, or (MAC)/general anesthesia provided by an anesthesiologist. Midazolam, fentanyl, morphine, remifentanyl, alfentanil, ketamine, and propofol are among the medications successfully used as part of sedation and total intravenous anesthesia techniques. More recently dexmedetomidine and fospropofol have been added to the list of acceptable choices.¹²⁻¹⁴

General Anesthesia

A total intravenous anesthetic technique (TIVA) is preferred over an inhalational anesthetic technique for the following reasons:

- It ensures continuous delivery of anesthesia compared to an inhalation anesthetic-based technique when ventilation leaks occur around the rigid bronchoscope;¹⁵ while the flexible bronchoscope is being inserted into, and removed from the airway; and is more practical when instruments such as balloons, forceps, and cautery and techniques such as intermittent apnea or jet ventilation are used.

- It prevents pollution of the operating room by inhalational anesthetic agents.
- It avoids the risk of sedating operating room personnel, including the anesthesia team, pulmonology team, and the operating room nursing and support staff (advantages of TIVA are summarized in Table 17.2.).

TIVA can be initiated as a pure propofol infusion (administered at 50 - 200 µg/kg per minute) or as combination of propofol and an opioid such as remifentanyl (administered at 0.1-0.3 µg/kg per minute). Finally, it should be noted that while administering TIVA, the practitioner may consider using EEG brain function monitor (Bispectral Index or Sedline) to prevent intraoperative recall and to titrate intravenous anesthetic agent to appropriate anesthetic depth.¹⁶

The Use of Muscle Relaxation

First, muscle relaxation facilitates supraglottic airway (SGA)/endotracheal tube (ETT) insertion. In addition, relaxing the jaw muscles makes insertion of the rigid laryngoscope (for suspension laryngoscopy) and rigid bronchoscope much easier and safer. It also improves overall lung compliance by eliminating the chest wall component, which would be very helpful during jet ventilation. Muscle paralysis can be advantageous because unexpected patient movement can result in unintended airway injury. For example, during laser therapy, a motionless patient dramatically decreases the risk of unwanted misdirection of the laser beam; sudden movement by the patient could result in damage to healthy tissues and possible major vessel or esophageal injury. In cases where an SGA is used, the use of muscle relaxation also helps minimize trauma to the vocal cords caused by the frequent insertion and removal of the bronchoscope against contracted cords (the advantages of muscle relaxants are listed in Table 17.3.).

Fluid Management in Bronchoscopic Surgery

It is wise to restrict all administered fluids to the minimum needed, since many of the patients present with a limited lung reserve. Pulmonary congestion may aggravate their lung condition. This is especially true if they have concomitant cardiac disease, such as left-sided or right-sided heart failure, which may be a complication of their long-standing lung pathophysiology (e.g. cor pulmonale).

TABLE 17.2. *Advantages of Total Intravenous Anesthetic Technique (TIVA) in Bronchoscopic Surgery*

-
- Ensures continuous delivery of anesthesia
 - Prevents pollution of the operating room by inhalational agents
 - Avoids risk of sedating operating room personnel
-

TABLE 17.3. *Advantages of Muscle Relaxants in Bronchoscopic Surgery*

<ul style="list-style-type: none"> • Facilitates SGA/ETT and rigid bronchoscope insertion • Improves overall lung compliance • Provides a motionless patient • Helps minimize trauma to the vocal cords
ETT, endotracheal tube; SGA, supraglottic airway.

The Use of Steroids in Bronchoscopic Surgery

Many anesthesiologists and surgeons use corticosteroids, in particular dexamethasone, as a prophylactic measure to decrease airway edema after airway surgery. Common scenarios when steroids may help reduce postoperative vocal cord swelling include: cases where the flexible fiberoptic bronchoscope (alone or through an SGA and in the absence of ETT) has been inserted into, and removed from the airway several times, bronchoscope continually rubbing against the vocal cords, or if a rigid bronchoscope has been used for a prolonged duration. Steroids also are used in cases where extensive tracheobronchial tissue trauma is caused by a prolonged procedure. However, the use of steroids is defended on the basis only of their putative clinical advantage, since evidence of their real advantage is controversial at best. Evidence supporting the use of steroids includes their beneficial effects prior to certain maxillofacial procedures due to their proven benefit in reducing postoperative edema and inflammation.¹⁷⁻¹⁹ However, Hughes et al. have shown that steroids are ineffective in reducing airway edema following carotid endarterectomy.²⁰ Additionally, steroids are beneficial as a preventive measure for postoperative nausea and vomiting.²¹ Finally, many bronchoscopic surgery patients with underlying lung conditions (e.g., Wegener's granulomatosis) that require chronic steroid therapy are treated by many clinicians with 100 mg of hydrocortisone (the so-called stress dose steroids) to avoid adrenocortical insufficiency in the setting of chronically suppressed suprarenal gland by the exogenous steroid. However, the effectiveness of this treatment has not been demonstrated conclusively.²²

Anti-nausea and Aspiration Prophylaxis

Pulmonary aspiration can be detrimental to patients with limited pulmonary reserve. Additionally, since ETT is used only in a limited number of cases, the majority of the procedures are done with techniques that might not protect against pulmonary aspiration—the risk is higher when a rigid bronchoscope, SGA, or no airway are used. The use of maximum anti-nausea prophylaxis, especially in patients with risk factors for pulmonary complications is therefore justified. In such cases, the use of propofol as part of TIVA technique is helpful since propofol has anti-emetic properties. The avoidance of inhalation anesthetics and of nitrous oxide also may be justified. Effective post-operative nausea and vomiting prophylaxis drugs include steroids (e.g. 4–8 mg of dexamethasone), dopamine receptor antagonists (e.g. 10–20

mg of metoclopramide) and H₂ antagonists (2–4 mg of ondansetron).²⁰

Management of the FiO₂

Administering 100% FiO₂ in such procedures is very common. However, during thermal treatment with Nd:YAG lasers or EBES (endobronchial electric surgery), it is usually necessary to maintain it at the lowest tolerable level, that is, below 40%. Periods of extended apnea and complete airway obstruction can be expected during more challenging cases. Complete airway occlusion frequently occurs during the critical phase of removing the stent or stent fragments or the inflated balloon dilators used for tracheobronchial dilation. Therefore, it is always advisable to return to ventilation with 100% oxygen before extraction of the stent, prior to exchange of airways, and prior to extubation.

Finally, during thermal treatment, if the patient cannot tolerate lower oxygen levels it may become necessary to defer treatment temporarily and ventilate with higher oxygen concentrations.

AIRWAY CHOICE

Without Artificial Airways

This is a popular technique, especially when relatively short procedures are performed in a remote bronchoscopy suite where an anesthesia machine and capnography are unavailable. An intravenous sedation technique is more appealing for these procedures, with the goal of maintaining spontaneous ventilation. Great emphasis should be placed on airway topicalization to tolerate the bronchoscope without the need for deeper planes of sedation and to avoid the associated risks.

Endotracheal Tube

Intubation with a large-diameter (e.g., size ≥ 8.0) ETT facilitates ventilation around the relatively large-diameter flexible bronchoscope. Many pulmonologists prefer to have the ETT cut short following intubation and to secure the tube with tape. This is because a shorter tube can facilitate navigation of the flexible fiberoptic bronchoscope (Fig. 17.2). Intubation of patients with a tracheal stent, whether a SEMS stent or a silastic type requires caution, because it can dislodge the stent distally or cause other complications. A short, large-bore ETT could be used via an existing tracheotomy with flexible bronchoscopic instruments.

Rigid Bronchoscope

A rigid bronchoscope (see Fig. 17.3) is preferred for procedures such as insertion and removal of silicone stents due to their size and noncompressible nature, removal of large broncholiths and granulation tissue, coring out of a large tumor invading the tracheobronchial tree, and supporting airway patency if a large mediastinal mass is compressing the airway.



FIGURE 17.2. A large 8.5 mm ID endotracheal tube cut short with the bronchoscope through it. Ventilation around the bronchoscope is made possible through attaching the circuit to a swivel adapter.

When the rigid bronchoscope is used, ventilation can be accomplished through either attaching the anesthetic circuit to the bronchoscope side port or through jet ventilation, where the jetting device is attached through a special adaptor to the bronchoscope side port. Leaks around the rigid bronchoscope are common, but they can be easily remedied by maximizing the fresh gas flow and packing the mouth with saline-soaked gauze. Special attention should be given to removing all the gauze to avoid subsequent airway obstruction from retained gauze pieces when the bronchoscope is removed.

Supraglottic Airway

In cases where the tracheal lesion is high up in the trachea, a supraglottic airway device (eg. LMA) can be effective,^{23,24} since the device does not enter the glottis. The SGA provides a conduit for the flexible bronchoscope to access the subglottic lesion, and at the same time allows ventilation of the patient. However, since it is a less “definitive” airway compared to the ETT, the SGA device does not guarantee reliable protection against aspiration. The techniques just described require clear communication between the anesthesiologist and the pulmonologist. Use of a fiberoptic swivel connector adaptor will allow continuous ventilation, thereby avoiding circuit disconnect during flexible bronchoscopy.

The Use of Airway Exchange Catheters in Bronchoscopic Surgery

Exchange of airway is often needed during bronchoscopic surgery because of the dynamic nature of the procedures, and because of situations in which the airway is judged to be difficult to intubate. Accordingly, it is advisable to start with awake intubation and with a relatively small-sized ETT, such as the Parker Flex-Tip tracheal tube. Compared to the

standard tube, the use of the Parker tube has reduced the need to reposition the tube during insertion into the trachea from 89% to 29% ($p < 0.0001$).²⁵ After the Parker tube is in place, an airway exchange catheter can be used to replace it with a larger tube to facilitate the flexible bronchoscopic procedure. If a rigid bronchoscope is required, the exchange catheter can be used for access to the airway until the laryngeal inlet is visualized through the rigid bronchoscope and the scope is secured in position. The same principle can be applied again after being done with the rigid bronchoscope: the exchange catheter can be introduced through it and used to insert an ETT after removing the rigid bronchoscope. The exchange catheter is also effective for intubation through an LMA.²⁶

POSTOPERATIVE CARE

Most of the procedures described earlier are performed as same-day, outpatient procedures. However, patients with significant comorbidities or advanced disease undergoing a complicated resection or lasering of endotracheobronchial lesions may benefit from overnight admission. Still, this compares favorably with invasive thoracic surgery, which often requires postoperative intensive care unit admission and a prolonged hospital stay.

MANAGEMENT OF SPECIAL AIRWAY CASES

Management of Anterior Mediastinal Mass

The presence of an anterior mediastinal mass (AMM) can predispose patients to severe respiratory and cardiovascular complications during anesthesia. These may include airway narrowing or obstruction, compression of the cardiac chambers,



FIGURE 17.3. Positive pressure ventilation through connecting the anesthesia circuit to the side port of a rigid bronchoscope. Note the wet gauze packing around the rigid bronchoscope barrel to minimize leak around the scope.

and compression of the pulmonary artery.²⁷⁻³³ Extreme caution is required in managing these patients.

Airway obstruction is a serious complication of general anesthesia in patients with an AMM. Spontaneous ventilation has been highly recommended in the anesthetic management of AMM patients, because it eliminates the use of muscle relaxants and maintains negative intrapleural pressure.³⁴

Several conservative anesthetic plans have been proposed for managing AMM.³⁵ Under one plan, the patient should be intubated awake after being topicalized and mildly sedated while in the least symptomatic position (possibly through use of the flexible fiberoptic scope). An inhalational agent-based technique that maintains spontaneous respiration is another effective course of action.

Another option is to use dexmedetomidine, a selective α_2 agonist with sedative, analgesic, amnesic,³⁶ and antisialagogue properties.³⁷ Dexmedetomidine helps maintain spontaneous respiration with minimal respiratory depression. Its maintenance of spontaneous ventilation in the management of AMM has been described.³⁸ Patients under dexmedetomidine sedation are generally easy to arouse,³⁹ making it a useful drug for awake fiberoptic-assisted intubation.¹² However, these advantages may not hold with higher doses (off label).

Cases that include the management of patients with larger AMM (causing >50% reduction in airway diameter as seen on a CT scan) should not be treated outside of the operating room. Some authorities recommend that cardiopulmonary bypass be available on standby and that femoral vessel cannulation should be achieved prior to induction.^{28,35}

COMPLICATIONS

Potential Complications of Bronchoscopic Procedures

Potential complications are numerous and range from hypercarbia and minor levels of hypoxemia to major bleeding, tracheal rupture, and loss of airway integrity.

Stent removal provides an example of a potentially risky interventional procedure. Possible complications include retention of stent pieces, mucosal tears with bleeding, re-obstruction, the need for postoperative mechanical ventilation, pneumothorax, and damage to the pulmonary artery.⁴⁰ When the stent is fractured during removal, unwanted fragments may remain permanently embedded in the tissue. In one report, critical airway obstruction occurred during removal of a tracheal stent using a rigid bronchoscope under general anesthesia, and cardiopulmonary bypass had to be instituted urgently. The stent was eventually removed by directly opening the trachea.⁴¹

The jet ventilation technique can lead to barotrauma and may result in a pneumothorax, necessitating chest tube insertion. Laser airway fire, although rare, is also a potential complication.

Suggested steps to take in case of an airway fire are as follows:

1. Discontinue lasering and turn off O_2 (and N_2O if it was mistakenly used).

2. Remove the burning ETT and drop it in a bucket of water.

3. Flush area with water or normal saline.

4. Re-intubate immediately and resume ventilation with 100% O_2 .

5. When the patient's condition has stabilized, assess damage to the airway with a ventilating rigid bronchoscope. Remove any debris or foreign bodies.

6. Consider the use of intravenous steroids (however, their efficacy has not been proven).

7. Consider administering antibiotics.

8. Implement supportive therapy, including ventilation, and extubate when clinically indicated.

9. Consider tracheotomy, if necessary.

Tracheal Rupture

Tracheal rupture or loss of tracheal integrity can complicate any of the aforementioned interventional pulmonology procedures. However, these complications occur more frequently with balloon dilation or complicated stent removal. Reported risk factors for tracheal rupture include advanced age, chronic obstructive pulmonary disease, weakened tracheal walls usually secondary to chronic airway inflammation, previous procedures, infection, and prior steroid therapy.⁴²⁻⁴⁵

The signs and symptoms of tracheal rupture are nonspecific, but a combination of the associated symptoms and/or signs in the clinical setting should lead to a high degree of suspicion. Dyspnea and a dry cough are sometimes the only signs evident in an awake patient. Cyanosis and tachycardia may also be evident. Other signs include hemoptysis, persistent air leak, subcutaneous emphysema, pneumomediastinum, and pneumothorax.⁴⁶⁻⁴⁸

Bronchoscopy is the gold standard for the diagnosis of tracheal rupture. It is also critical in differentiating between small tears (<1 cm), which may be treated conservatively, and more severe injuries requiring surgical management. Routine chest radiographs and bronchoscopy are usually sufficient for diagnosis in 90% of cases.

The management of a tracheal tear can be observational (conservative) or surgical, depending on the extent of the injury, the presenting signs and symptoms, and the general condition of the patient. In general, small, shallow tears that do not lead to severe compromise in ventilation and oxygenation can be treated conservatively.^{49,50} If the patient is dependent upon positive pressure-assisted ventilation, however, surgical treatment is mandatory. Regardless of the choice of management, the status of the trachea should be monitored with tracheoscopy.

Ventilatory management consists of adequate oxygenation and ventilation of the patient and prevention of worsening subcutaneous emphysema, pneumomediastinum, or pneumothorax. This is best accomplished by positioning the ETT so that the cuff is distal to the level of the injury, and also by keeping the airway pressures as low as possible. A higher FiO_2 and respiratory rate may be required. Selective or bilateral bronchial intubation can be performed in tears located above

or near the carina. It is important to note that standard direct intubation can be potentially hazardous, because a false passage can be easily created. Fiberoptic-guided intubation may be safer.

Other possible options in management include high-frequency oscillating ventilation and hyperbaric oxygen therapy in patients who are difficult to oxygenate or ventilate.^{51,52} In rare situations, cardiopulmonary bypass or percutaneous cardiopulmonary support systems have been used.^{53,54} Other management goals include treating pneumothoraces with chest tubes, controlling pain, and supporting the patient's hemodynamic status.

SUMMARY

Interventional pulmonology is a fast-growing field. These procedures are at times very complex, and the patient population often has many co-morbidities. Many of the interventional pulmonology procedures are performed outside of the operating room. Anesthesiologists need to stay abreast of the advances in this field, and be prepared to deal with the anesthetic challenges that may arise. The key to favorable outcomes lies in understanding of the underlying lung pathology, open two-way communication between the anesthesiologist and pulmonologist, understanding the nature of the procedure, and above all, extreme vigilance and preparedness.

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Anesthetic Implications of Natural Orifice Transluminal Endoscopic Surgery (NOTES) and Single-Incision Laparoscopic Surgery (SILS)

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Natural orifice transluminal endoscopic surgery (NOTES) is currently investigated as an experimental alternative to diagnose and treat abdominal pathology combining endoscopic and laparoscopic techniques. Using a transluminal approach, the abdominal cavity is accessed with flexible endoscopes through an incision in the stomach, colon, or vagina. By obviating abdominal incisions, this approach may be less invasive than standard surgical techniques. This novel technique is currently performed at a few academic research institutions, but these less invasive operations potentially can be performed in an office-based setting in the future.

There are actually a variety of procedures characterized as “NOTES” in the news and medical literature. “Pure NOTES” implies the performance of a surgical procedure through a natural orifice without making any abdominal incisions. At this developmental stage, most studies are still investigational animal research projects. Human case reports are usually “Hybrid-NOTES” procedures with additional laparoscopic ports for visualization, retraction, and technical assistance as, for example, the application of laparoscopic clips for hemostasis or ligation. Some NOTES procedures involve the use of rigid laparoscopic instruments, and others involve flexible endoscopic instruments. The latter was the initial concept as developed by the Johns Hopkins group in 1997.¹

Even though NOTES claims to be new and innovative, rudimentary techniques existed in culdoscopy—the exam of the female pelvic viscera by a rigid endoscope introduced into the pelvic cavity through the posterior vaginal fornix.^{2,3} Before the introduction of NOTES, these transvaginal operations have been performed safely and shown to decrease postoperative pain, improve recovery, and cause fewer complications than conventional open or laparoscopic procedures.⁴ Other reports of transvaginal organ resection include gastric tumors, gall bladder, and rectal tumors during laparoscopic surgery.⁵⁻⁷

The most significant benefit of NOTES appreciated by patients is improved cosmesis by avoiding abdominal scars. The less invasive character of the approach may lead to a faster recovery with less perioperative pain. By avoiding

abdominal incision, there is no risk of abdominal wall infection or herniation. Due to the less invasive character of the procedure, there is a decreased requirement for intraoperative and postoperative opioids, which may decrease or even avoid the risk of postoperative ileus. Some sites adjacent to the organ of entry may become more accessible especially if they are difficult to reach by laparoscopy (e.g., posterior side of the liver). The development of new procedures using flexible endoscopes promotes the development of new surgical equipment, which may prove superior to the current standard of care.

SINGLE-INCISION LAPAROSCOPIC SURGERY (SILS) OR SINGLE-PORT ACCESS (SPA) SURGERY

Single-incision laparoscopic surgery is a minimally invasive approach carried out as an extension of traditional laparoscopic surgery. In SILS, a single cutaneous incision is created, within which a SPA device with multiple ports or several single ports adjacent to each other may be placed to laparoscopically approach the abdominal cavity. Commonly, the periumbilical location is the location of choice for the operating surgeon. One major potential benefit of SILS is improved cosmesis. Improved pain, however, has not been a realized potential benefit, likely due to extensive surgical manipulation of the fascial wall beneath the skin incision. Due to slightly increased size of the incision in comparison to multiple ports at various locations with standard laparoscopy, the risk of abdominal wall infection or hernia is probably not reduced. In comparison to NOTES, standard laparoscopic instruments or slightly modified instruments with angled handles or a curved shape can be used to avoid an interference of the surgeon’s hands while manipulating the instruments. Some endoscopic cameras (EndoEye, Olympus America Inc.) provide a flexible tip that allows visualization of structures around bends. Retraction of large organs, such as, the liver, for cholecystectomy may

provide a challenge if attempted through a single port. Some surgeons use additional, less than 5 mm in size needle ports to supplement retraction capabilities independent from the trajectory of the multiport in the umbilicus.

ANESTHETIC CONSIDERATIONS OF NOTES

Preliminary data suggest that, in the porcine model, NOTES peritoneoscopy is associated with higher peak inspiratory pressures and marked increase in median intraabdominal pressure with wide variation compared to laparoscopic peritoneoscopy. This increase in intraabdominal pressure leads to a decrease in cardiac output based on decreased cardiac return, or preload. Thus, increases in peak inspiratory pressure correlated with an increase in intraabdominal pressure. If the pneumoperitoneum is maintained with on-demand insufflation using a standard endoscopic insufflator, higher intrabdominal pressures are detected than with controlled insufflation through a Veress needle using carbon dioxide. More data about hemodynamic changes during NOTES still need to be generated. In addition, a formal comparison of nociception during NOTES in comparison to laparoscopy is currently warranted to provide evidence about the less invasive character of this new approach. Studies comparing perioperative complications of NOTES versus laparoscopy are currently underway. The current standard for NOTES procedures performed in humans is to use general endotracheal anesthesia. However, a few cases of NOTES have been performed under moderate sedation.

Patients may require less sedative medications and opioids perioperatively due to the minimally invasive approach and avoidance of abdominal incisions. This may further increase the potential of performing NOTES procedures under intravenous sedation and monitored anesthesia care rather than general anesthesia. With further improvement of the surgical technique and the avoidance of high peak pressures during abdominal insufflation, patients will be able to tolerate these procedures with less sedation.

ANESTHETIC CONSIDERATIONS OF SILS

The combination of SILS with a bilateral transverse abdominal plane block with ultrasound guidance provides the advantage of a reduced use of perioperative opioids or even none at all. There are reports of single-site surgeries for placement of an adjustable gastric band and gynecological oncology applications that required no opioids postoperatively.^{8,9} We recently performed a SILS cholecystectomy combined with a bilateral transversus abdominis plane (TAP) block that allowed us to avoid any perioperative opioids and general anesthesia. The TAP block is a useful adjunct regional anesthetic technique that may result in significantly decreased postoperative pain and thus decreased amounts of postoperative opioid use as shown in prospective, randomized trials involving cesarean delivery, total abdominal hysterectomy, and open large-bowel

resection.¹⁰ The TAP block also reduced postoperative pain in observational studies in open retropubic prostatectomy and laparoscopic colorectal surgery.^{11,12}

Anatomically, the abdominal wall consists of three lateral muscle layers, from internal to external: transversus abdominis, internal oblique, and external oblique. The anterior abdominal wall consists of the three previous layers, in addition to the more superficial rectus abdominis and fascial sheaths. The afferent nerves that communicate pain from the anterior abdominal wall are located in the potential space deep to the internal oblique muscles and superficial of the transversus abdominis muscles. It is this space that is referred to as *transversus abdominis plane*. The nerves supplying the anterior abdominal wall that course through this space may be blocked with local anesthetics. The addition of the TAP block, which blocks the afferent nerves affected by the anterior body wall manipulation in a SILS cholecystectomy, is a logical choice for adjunct pain relief. We also combined ketamine with preoperative ketorolac for analgesia. The response to the intubation was blunted using a combination of propofol, ketamine, and lidocaine. Ketorolac was given for visceral pain associated with the procedure. The reduction or avoidance of perioperative opioids provides advantages in patients sensitive to consumption of opioid medications, including the morbidly obese, those with pulmonary compromise, or those with previous poor tolerance for opioids.

COMPLICATIONS

One of the challenges of providing anesthesia for NOTES procedures would be the limited knowledge or experience with unexpected complications. A pure NOTES approach involves the use of flexible endoscopic devices that are generally not designed for this particular purpose. Due to the fast development of this disruptive technology and early clinical application of prototypes or use of devices other than for their intended purpose, the development of advanced equipment specifically for NOTES is lagging behind. Some devices used for intraabdominal surgery are designed for the endoluminal use of interventional gastrointestinal endoscopy. In the setting of vascular injury during a nonhybrid NOTES procedure, the ability to achieve hemostasis is limited by lack of access and functionality of flexible endoscopic devices. This may result in an unexpected blood loss and a potential conversion to laparotomy if hemostasis cannot be achieved endoscopically. Even in NOTES centers with research experience, surgeons still operate at the steep part of the learning curve. The management of unexpected complications may challenge even experienced surgeons. A limited visualization of the abdominal cavity with flexible endoscopes could lead to minor bleeding which may remain unrecognized hidden behind other structures. The transluminal access involves potential injuries of adjacent organs, particularly in a nonhybrid procedure with lack of visualization of the access procedure. While NOTES is currently being studied extensively in animal

models, there is still insufficient evidence of the impact of the impact of its intraoperative cardiopulmonary effects.

With the current standard of endoscopic devices used for NOTES, there is limited ability to treat a major vascular injury. In the setting of a significant intrabdominal hemorrhage, transabdominal laparoscopic ports may need to be inserted or a laparotomy performed. Due to the lack of sufficient expertise with this emerging surgical technique, anesthesiologists have to be prepared for a major blood loss even with minor procedures such as a transvaginal cholecystectomy or appendectomy. Due to anatomical differences, research experience in the animal lab cannot compensate for experience with human cases. NOSCART strongly discourages surgeons interested in NOTES to advance to human application too quickly. The establishment of transluminal access is different from current laparoscopic procedures. With the access of the abdominal cavity, adjacent organ structures may be injured. There may be a time delay until sufficient visualization of the peritoneal cavity is accomplished, and there may be a lack of visualization of the entire abdominal cavity, leading to significant hemorrhage being detected late or not at all. Proper surgical ligation of major vessels may take longer than expected in comparison to standard laparoscopic or open procedures. A similar vigilance and meticulousness is required by anesthesiologists to carefully select patients for NOTES, to observe for any possible complications, and to be prepared for complications like venous air embolism, pneumothorax, or massive hemorrhage even during standard surgical procedures.

The most propagated concern about NOTES appears to be the safety of closure of the transluminal access point. The closure of a transvaginal access port may be less critical since the bacterial flora of the vagina is rather benign and may unlikely lead to a significant infection of the abdomen. However, with transgastric or transcolonic access the efficiency of closure is of utmost importance due to the increased potential of an intrabdominal infection in the setting of closure insufficiency. When providing perioperative care for patients undergoing NOTES procedures, significant abdominal discomfort, tenderness, or clinical signs of infection may point toward a complication in relation to the transluminal closure.

If flexible endoscopy is chosen for a NOTES approach, the increased length of the endoscopic instruments is associated with an increased risk of infection because the instruments may touch unsterile areas of the operating room table or even the floor. This may be unrecognized, especially since this is a new technique and the operating team may be too focused on the procedure and pay less attention to sterility. Here the anesthesiologist needs to be aware of these potential sources of infection and inform the surgeons accordingly.

COST

The cost of NOTES procedures is certainly an issue that may have an impact on the development and acceptance of this

new technology. A NOTES cholecystectomy is currently approximately 2–3 times as expensive as a standard laparoscopic procedure. Coverage by insurance is limited by the lack of proper International Classification of Disease (ICD) coding. Some hospitals bill NOTES procedures as a regular laparoscopic intervention, while others have been denied payment altogether. Once NOTES becomes more accepted, new ICD codes have to be developed. With the development of new equipment and procedures, and an increased experience of surgeons, the cost of the procedure may decrease. In particular, overall cost can be decreased by a potentially shorter hospital stay. It will be challenging to provide the same safety profile with NOTES as laparoscopic appendectomy or cholecystectomy. However, certain procedures may be associated with decreased complications, in particular if performed in patients with poor access to the abdominal cavity (e.g., obesity). There is also the potential that certain procedures that require an overnight stay may be performed as outpatient procedures. Due to the minimally invasive character of NOTES, patients experience less pain postoperatively. Some procedures may be performed with minimal use of perioperative opioids if NOTES is performed under regional anesthesia with monitored anesthesia care. In addition, elderly patients or patients with multiple comorbidities will benefit from a less invasive surgical approach and can potentially avoid general anesthesia. The enthusiasm of gastroenterologists and minimally invasive surgeons about NOTES keeps pushing the development of this technology and the progress of research.

OUTCOME DATA

The American Society for Gastrointestinal Endoscopy (ASGE) and the Society for American Gastrointestinal Endoscopic Surgeons (SAGES) founded the Natural Orifice Consortium for Assessment and Research (NOSCART). NOSCART requires physicians performing NOTES on humans to document their outcomes in an international databank. The performance of a large number of patients undergoing NOTES is currently limited to only a few centers worldwide. As of 2009, it is estimated that approximately 300 human NOTES procedures have been performed so far. Most of these were hybrid procedures with laparoscopic visualization and/or assistance.

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New Challenges for Anesthesiologists Outside of the Operating Room: The Cardiac Catheterization and Electrophysiology Laboratories

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The character of invasive cardiology procedures has changed dramatically over the past 5–10 years. With technological advancement, diagnostic and therapeutic procedures have become broader in scope and complexity; patient acuity has dramatically escalated as well. In parallel, the involvement of anesthesiologists has grown. In this chapter, we present an overview of the laboratory environment(s), the evolution and future pathways of current practice(s), cases performed in each venue, and current anesthetic approaches.

Invasive cardiology procedures performed in the cardiac catheterization laboratory (CCL), the electrophysiology laboratory (EPL), and the transesophageal echocardiography laboratory have become the purview of anesthesiologists. Common CCL procedures include the following: diagnostic cardiac catheterizations, percutaneous coronary interventions, peripheral vascular diagnostic and therapeutic procedures, implantation of percutaneous left ventricular assist devices, placement of septal occlusion devices, and percutaneous valve repair or replacement procedures. Common EPL procedures consist of EP studies, atrial and ventricular radiofrequency (RF) ablation procedures, implantation and removal of pacing and cardioverter defibrillator devices, and electrical cardioversion. TEE procedures include trans-esophageal echocardiography (TEE) and combined TEE/direct current cardioversions (DCCV). All of these procedures may require the involvement of anesthesiologists if the patient has significant comorbidities or if the procedure requires that the patient be absolutely still and/or asleep. Even without the added concern of patient comorbidities, modern procedures are often lengthy, requiring technical precision and focus on the part of the proceduralist. In such situations, preservation of hemodynamic stability and maintenance of a sedated or asleep state is often best left

to anesthesiologists. In this new and changing arena, collaboration and planning between cardiologists and anesthesiologists maximizes patient safety and increases the probability of procedural success. A thorough understanding of the procedure to be performed is required in order for anesthesiologists to define and delineate the extent of their involvement, and is a clear prerequisite for the formulation of a safe and effective anesthetic plan. A common knowledge base and mutual respect for each contributing discipline form the basis for integration of cardiology and anesthesia services in pursuit of optimized patient care.

THE LABORATORY ENVIRONMENT: MAKING ROOM FOR ANESTHESIOLOGISTS

The laboratory environment differs significantly from that of the operating room. It is imperative that anesthesiologists become familiar with this new venue by understanding the objectives and flow of procedures as well as the structure and function of equipment and the responsibilities of personnel. Innovative flexibility on the part of the anesthesiologist is frequently necessary with respect to equipment availability/positioning and the tempo of anesthesiology–cardiology interaction.

All labs include a separate control station and procedure room. The control station, shielded from radiation, is the vantage point from which a technician usually records the progress of the procedure. The technician communicates with the cardiologist from outside of the procedure room and controls recording of data, patient monitoring, video recording and

editing, and digital record keeping. Robotic equipment is usually stationed outside of the procedure room as well, and catheter manipulations are sometimes made by the proceduralist from outside of the procedure room if a robotic device is used.

Within the procedure room itself, cardiologists, anesthesiologists, nurses, and other (radiology and cardiovascular [CV]) technicians care for the patient during the procedure. The procedure room includes fluoroscopy equipment, the procedure table, screens for viewing the procedure, sterile tables for the cardiologist, closets or portable storage units for various catheters and wires for the procedures, and blood analysis machines. The anesthesiologist should become familiar with the contents of each procedure room, which varies from institution to institution. Gas outlets and suction, monitors for vital signs, cardioverter/defibrillator, emergency medications, and airway equipment are critical and may not be optimally or even obviously placed. The anesthesiologist may have to become familiar with equipment not typically found in the operating room. Consistent locations for a ventilator, anesthesia machine, anesthesia cart, and fiberoptic cart should also be identified. Other frequently utilized equipment includes ventricular assist devices, intra-aortic balloon pumps, device programmers, and echocardiography machines.

Catheterization labs and EP labs are designed for cardiologists, not for anesthesiologists. Space becomes an issue in complex cases, particularly when additional equipment is utilized. The fluoroscopy table and fluoroscopy equipment are controlled by radiology technicians under the direction of cardiologists. These move during the procedure to facilitate imaging. Extensions for intravenous lines, extra oxygen tubing, and long breathing circuits are often needed to allow for movement of the table and to accommodate fluoroscopy equipment.

Basic monitoring equipment for sedation, regional, or general anesthesia may not be present in the CCL and EPL. Capnography monitoring in all procedure rooms is as important for safe patient care outside of the operating room as it is in the operating room, perhaps even more so. Assisting with a sedation problem during a procedure can be more difficult if end-tidal CO₂ monitoring is not available. Similarly, the local availability of extra airway equipment and an emergency airway cart becomes essential when the anesthesia workroom is not nearby. An anesthesia cart stocked with IVs, medications, airway equipment, and medication essentials is important in the CCL and EPL. All personnel in the laboratory should know the location and names of emergency equipment since the anesthesiologist will be occupied with the patient if called emergently to a procedure area. Collaboration and preprocedure planning is truly essential.

ANESTHESIA CONSULTATION: WHEN SHOULD ANESTHESIOLOGISTS BE INVOLVED

Each institution has established guidelines for anesthesia consultation in the CCL and EPL, but criteria vary widely. Emergencies can be minimized by preprocedure planning and

review of patient sedation needs. When patients present with significant comorbidities and/or when the procedure promises to be complicated or unusual, the covering anesthesiologist should be involved. Sometimes it is necessary to decide between sedation and/or general anesthesia, and often the determination must be made by both the cardiologist and the anesthesiologist together. Consultation based on patient presentation and/or procedure complexity is often initiated by nurses or physician assistants (PAs) involved in the case. Continuous communication is important so that all team members are aware of pertinent issues. Case management decisions and planning should include all team members to the extent possible.

Patient airway characteristics that should trigger an anesthesia consultation include morbid obesity, obstructive sleep apnea, inability to lie flat, and known or suspected difficult airways (Mallampati Class III or IV). Non-anesthesiology personnel should be taught how to perform basic airway histories and exams on order to establish the need for consultation. Other pertinent patient comorbidities include chronic obstructive pulmonary disease, low oxygen saturation, current congestive heart failure, hemodynamic instability, psychiatric disorders, chronic pain syndromes, neurological disorders, inability to handle oral secretions, and the presence of acute ongoing syndromes. In addition, patients taking medications that could complicate the administration or alter the effectiveness of sedative agents should be seen by an anesthesiologist.

Sometimes the nature of the procedure itself prompts a provider to seek an anesthesia consultation. If the potential need for immediate surgical backup is increased such as with unprotected left-main coronary artery stenting or investigational percutaneous valve procedures, the anesthesiologist may be asked to see the patient either to provide support during the case or to be available in case of emergency. If the nature of the case is likely to precipitate instability (i.e., valvuloplasties in very elderly and frail patients), a consultation is also warranted. Such procedures are typically long and technically sophisticated. The undivided attention of the cardiologist is required, and there is benefit in having an anesthesiologist in the room whose attention is focused solely on airway and hemodynamic control. Complex arrhythmia ablation procedures, complicated lead extractions requiring laser equipment, and biventricular pacemaker procedures should also invite the attention of anesthesiologists because the procedures are potentially long and complex and the patients are typically challenging. Of course, any procedure performed under general anesthesia requires a preprocedure anesthesia workup.

Criteria for anesthesia consultation will lead to more efficient and safer patient care, but the criteria will fluctuate as drugs, personnel, and technology change. Better preprocedure planning, including interdisciplinary discussion to establish route of catheterization (radial versus femoral), planned modification of patient positioning to accommodate body habitus and avoidance of sedation-induced airway obstruction, are critical so that intraprocedural complications are avoided. In this way, non-anesthesia personnel administering sedative

medication can increase their vigilance about important details, cardiologists are free to focus on the fine points of the procedure at hand, and anesthesiologists are alerted to the potential complications they may be called upon to manage during the case.

PATIENT ASSESSMENT FOR CARDIAC PROCEDURES OUTSIDE OF THE OPERATING ROOM

For some patients, a comprehensive preprocedure evaluation by an anesthesiologist is essential. A complete history not only includes a standard preanesthetic assessment but also must encompass a comprehensive review of all previous cardiac interventions: diagnostic caths, stent placement (type, location, and age), known left- and right-sided cardiac pressures, surgical interventions, arrhythmia interventions and ablations, echocardiograms (ventricular function and dimensions, valve disease), chest X-rays, and a comprehensive medication list along with recent changes to the medication regimen particularly with respect to anticoagulation.

Many patients present for procedures after failed interventions, during or immediately after myocardial infarctions, during acute exacerbations of heart failure, or with uncontrolled arrhythmias. These patients represent a population not normally cared for electively in the operating room, since current American College of Cardiology (ACC)/American Heart Association (AHA) guidelines for preoperative assessment¹ recommend cancellation of elective surgery under these conditions. In cardiac procedure rooms, as in the operating room, anesthesiologists must be keenly aware of the overall current medical condition of their patients. In some cases due to the urgency of the case, the anesthesiologists may be the only care providers aware of recent changes in health status. The focus of the cardiologist may be on the cardiac and technical aspects of the intervention at hand. Frequently the patient is referred from an outside source.

Establishing the true urgency of the procedure is important both for optimal outcome and in order to identify potential intra and postprocedural complications and management considerations. Communication among nurses, radiology technicians, anesthesiologists, interventionalists, and electrophysiologists is critical. Different perspectives and lack of common understanding may generate conflict. What may seem essential to an anesthesiologist may seem of secondary importance to a cardiologist, and vice versa. Maintenance of patient flow can assume undue importance if the urgency of a case is not articulated. Patient optimization prior to procedures is important if it is possible to achieve. Diuresis, adjustment of medication, resolution of acute infection, and improvement of respiratory function may permit the patient to lie flat during the procedure, thereby increasing the probability of a successful result. Radial rather than femoral artery catheterization may be a better option in some patients, since this permits the patient to sit up to some extent during the procedure. When patients present emergently, however, options are limited and direct involvement of an anesthesiologist for sedation or general anesthesia becomes necessary.

Under these circumstances, clear and direct communication between anesthesiology and cardiology attendings is critical.

Emergent airway management in an already sedated patient can be challenging, particularly in the CCL and EPL environment. The fluoroscopy table is more limiting for anesthesiologists than an operating room table. The head of the bed cannot be elevated and the cardiologist has the table controls, usually at the foot of the bed. Fluoroscopy equipment, particularly in rooms with biplane imaging capability, usually surrounds the patient's head. In addition, the patient may be hemodynamically unstable, further complicating airway management. Finally, personnel in the CCL and EPL do not have training in advanced airway management and are often not helpful or even unintentionally obstructive in an emergency.

Preprocedure and ongoing airway assessment is therefore critical in this environment. Not only should ease of endotracheal intubation be assessed, but the ability to mask ventilate should be evaluated. Mask ventilation often bridges a moment of oversedation during a procedure. Langeron et al. identified five independent criteria associated with difficult mask ventilation (age >55, BMI >26, beard, lack of teeth, and history of snoring); the presence of two of these indicates possible difficult mask ventilation.² A history of difficult intubation or possible difficult intubation does not preclude sedation, but it should be a warning that rescue from oversedation might be problematic. Under such circumstances, all personnel involved in the procedure should be alerted. Training in mask ventilation should be ubiquitous so that the patient is covered if the anesthesiologist must come from another location to attend to the patient. The location of airway supplies should be standardized and known to all personnel. Early communication of and prompt response to sedation problems during the procedure is imperative. Remember that undersedation can be as dangerous as oversedation since it can lead to tachycardia, hypertension, and excessive patient movement.

THE SEDATION CONTINUUM... WHERE DO ANESTHESIOLOGISTS BELONG?

Many procedures in the CCL and EPL are performed under mild to moderate sedation administered by trained nonanesthesiologists, usually nurses who are supervised by nonanesthesia physicians. Local anesthetic infiltration at the site of catheter placement by the cardiologist alleviates pain while the proceduralist gains access. Nonanesthesia personnel administering mild to moderate sedation should be trained in the pharmacology of commonly used agents and in the use of monitoring equipment. Early recognition and management of abnormal respiratory patterns and hemodynamic problems that evolve during mild, moderate, and deep sedation³ is also important. Personnel administering sedative agents should be able to safely manage the next deeper level of sedation. Caregivers must understand the potentially synergistic drug interactions of benzodiazepines, opioids, and other commonly administered sedatives such as diphenhydramine (given to patients who have intravenous contrast reactions), especially in patients with complicated airways or diminished respiratory

capacity. Anesthesiologists should take an active role in developing and maintaining sedation standards for nonanesthesia personnel throughout the hospital³.

Patients in the CCL and EPL are often sedated with fentanyl and midazolam. Minimal sedation with liberal use of local anesthetic is usually recommended for patients with complicated airways, obstructive symptoms, or respiratory or hemodynamic compromise. For these patients, anxiety and fear can be treated with verbal comfort, reassurance, and a small amount of midazolam. Avoidance of fentanyl eliminates the synergistic respiratory depressant effect and is usually well tolerated since most pain is alleviated once local anesthesia has been administered. Zofran, decadron, and haldol can be used as antiemetics.

Anesthesiologists have a broad spectrum of medications available to them. Many are more conducive to rapid deepening of sedation than midazolam and fentanyl, and they have shorter redistribution times. Management of sedation needs must be based on a firm understanding of the procedure and a thorough grasp of the patient's comorbidities. It is critical to know when the patient is likely to be stimulated so that deeper sedation can be administered. Tachypnea and tachycardia resulting from inadequate sedation can be just as dangerous as airway obstruction and/or snoring from oversedation. Both situations can make interventions more difficult for the cardiologist and less safe for patients. In circumstances where brief unconsciousness is necessary during a procedure, the assistance of an anesthesiologist should be sought (i.e., ICD testing after implantation or cardioversion during ablation).

In some cases dexmedetomidine (α_2 -agonist) may be ideal for sedation because there is less respiratory depression associated with its administration.⁴ In EPL patients dexmedetomidine may not be appropriate because it causes sympatholysis, which can be a counterproductive when trying to induce arrhythmias for either diagnosis or treatment (ablation).

If the complexity of the procedure and/or comorbidities of the patient indicate that nurse-administered sedation is not appropriate, then an anesthesiologist should take over the case so that deep sedation or general anesthesia can be administered. Persistent oversedation with repeated reversal using narcan and flumazenil is not recommended. In most instances, it is safer to start a procedure with general anesthesia than to convert during the procedure.

MONITORING

Patient monitoring in the CCL and EPL is often designed with the cardiologist in mind. The fluoroscopy screen and patient vital signs are easy for the cardiologist to see, but they may be 90 degrees from the anesthesiologist if he or she is at the head of the bed. Establishing the best location from which to view the necessary monitors may involve changing the current room setup. Being able to see the fluoroscopy screen is helpful in monitoring the progress of the procedure and is helpful in anticipating changes in hemodynamics or comfort level. The anesthesiologist may have to ask the cardiologist frequently for progress reports if the fluoroscopy screen is not visible from the head of the bed.

Since some monitoring functions such as cycling of blood pressure cuffs and adjustment of pulse oximetry volume are typically controlled by CV technicians outside of the actual procedure room, the anesthesiologist may find that utilizing his or her equipment is preferable. During prolonged cases or with compromised patients (or both), invasive arterial monitoring with a display visible to the anesthesiologist may be preferable. It is worth remembering that blood pressure cuffs may not function during fast or erratic heart rhythms. It may be difficult for the anesthesiologist to see pressure waveforms if they are displayed only on the cardiologists screen. Therefore, it may be worth the effort to attach a Y-adapter at the transducer in order to display the arterial waveform at the anesthesia machine or other equipment close to the anesthesiologist. Some CCLs and EPLs may not have end-tidal CO₂ monitoring readily available. End-tidal CO₂ monitoring is recommended, especially for patients who might unintentionally become deeply sedated or whose respiratory status is difficult to ascertain.³ The American Society of Anesthesiologists (ASA) has established monitoring guidelines for sedation by anesthesia and nonanesthesia personnel in non-operating room locations.^{3,5}

Many centers rely on transesophageal echocardiography (TEE) to guide procedures and monitor the patient during various CCL and EPL procedures. Cardiac anesthesiology presence is therefore preferred, although some institutions utilize cardiology TEE staff for this purpose. A complete TEE exam encompassing standard views and assessment of cardiac function allows the anesthesiologist to assist the cardiologist in evaluating the progress of the case, the hemodynamic status of the patient, and any potential complications. If hemodynamic instability occurs, TEE provides instant assessment of contractility, volume status, and valve function. In some labs the TEE image is incorporated into the screen visible to the cardiologist; if this is not the case, it is helpful to position the TEE screen so that it is visible to the cardiologist performing the procedure as well as the anesthesiologist performing the TEE. Often, fluoroscopy and TEE together are critical to guide the progress of an intervention.

MEDICATIONS

In addition to the standard medications used for sedation and general anesthesia, the anesthesiologist must be aware of medications used in the CCL and EPL, including their pharmacokinetics and pharmacodynamics. Medications include heparin, glycoprotein IIb/IIIa platelet receptor inhibitors, clopidogrel, direct thrombin inhibitors such as bivalirudin, and vasoactive and inotropic medications. In addition, many patients in the EPL are treated with a variety of antiarrhythmic agent classes. Common medications include sodium channel blockers (class 1: quinidine, lidocaine, flecainide), beta-blockers (class 2: metoprolol, sotalol), potassium channels blockers (class 3: amiodarone, sotalol, ibutilide, dofetilide), and calcium channel blockers (class 4: verapamil, diltiazem).

Prior to the procedure, it must be made clear how medications will be delivered to the patient and who will administer them. The cardiologist usually directs the nurse in the room to administer drugs such as heparin, vasoactive, and inotropic medications. In addition, the cardiologist may directly bolus medications such as nitroglycerine or calcium channel blockers directly into cardiac catheters which can have a profound effect on the patient's hemodynamics. Communication must be clear so that cardiologists and anesthesiologists are both aware of when drugs are administered so that subsequent hemodynamic effects can be anticipated and double dosing can be avoided.

A clear understanding of the procedure to be performed is important in order to be able to anticipate the anesthetic needs of the patient. Many of the procedures performed in the CCL and EPL are individually tailored for patients, so it is frequently necessary for the anesthesiologist to ask the cardiologist what is going on. Unlike in the operating room, it is often difficult to ascertain the progress of an intervention. It is important not only that each practitioner communicate his or her thoughts and actions but also that each ascertains that the other is aware of any intervention. The following section describes the history and process of common interventions, along with some of the relevant anesthetic considerations. Considerable attention must be given to room setup, availability and choice of anesthesia equipment, and preprocedure patient evaluation, as previously indicated.

PERCUTANEOUS CORONARY INTERVENTIONS

In recent years percutaneous coronary interventional procedures for patients with both stable coronary artery disease and acute coronary syndromes have proliferated.⁶ In 2007 a total of 525,654 PCI stent (79,769 non-drug-eluting and 445,885 drug-eluting) procedures were performed in the United States.⁶ Presently, the spectrum of percutaneous coronary interventions (PCIs) include coronary angioplasty mostly performed immediately prior to coronary stenting, with use of both bare metal stents and drug-eluting stents; atherectomy procedures with use of a diamond-tipped burr catheter applied at high rotational speeds to "pulverize" atherosclerotic plaque; and intracoronary thrombectomy procedures for removal of intracoronary thrombus in patients with acute ischemic syndromes (unstable angina, non-ST elevation myocardial infarction, or more commonly with ST elevation myocardial infarction).⁷ In the stable coronary artery disease setting, PCI procedures are commonly performed on patients with 70% or greater intracoronary luminal atherosclerotic obstruction and demonstrated myocardial ischemia. Although PCI has not been shown to decrease the risk of myocardial infarction or prolong life in stable non-acute ischemic syndrome, its major benefit is to reduce or relieve symptoms of ischemic heart disease and increase aerobic capacity.⁸ The COURAGE Trial demonstrated that no significant difference in total mortality, nonfatal myocardial infarction, or

other major cardiovascular events existed between randomized patients treated with aggressive medical therapy or aggressive medical therapy along with PCI angioplasty with bare metal stenting.⁹ However, in patients presenting with acute coronary syndromes, PCI has been shown to decrease mortality and decrease recurrent myocardial infarction when compared to medical treatment without invasive intervention.¹⁰⁻¹²

Recent studies demonstrate similar benefit of PCI for left main coronary artery disease in selected patients.¹³⁻¹⁵ The SYNTAX trial demonstrated that there was no significant difference at 1 year in the composite endpoint of death, myocardial infarction, stroke, or repeat revascularization between the subgroup with left main coronary artery disease that underwent coronary artery bypass surgery versus those who underwent PCI with stenting.¹⁶ The most recent 2009 guideline update for PCI has now made left main coronary artery stenting a class IIB indication (usefulness/efficacy less well established by evidence/opinion) as an alternative to coronary bypass graft therapy in patients who may be at increased surgical risk and who have anatomic left main coronary obstruction that is associated with low risk of a PCI complication.⁷ An analysis of the American college of Cardiology-National Cardiovascular Data Registry (ACC-NCDR) demonstrates an increase in the use of stenting for unprotected (>50% stenosis without prior coronary artery bypass graft surgery [CABG]) left main coronary artery disease in both elective and urgent/emergent clinical settings along with a concomitant decrease of CABG.¹⁷ A recent meta-analysis of 16 observational studies involving 1278 patients undergoing drug-eluting stent PCI for left main coronary artery disease demonstrates a 2.3% in-hospital mortality rate and a 5.5% mortality rate at a median of 10 months following the procedure.¹⁸ Although target-vessel revascularization was significantly higher in those patients who received stents (hazard ratio, 4.76; 95% confidence interval, 0.75 to 1.62), the Korean-based MAIN-COMPARE study demonstrated no difference in either death or a composite outcome of death, Q-wave myocardial infarction, and/or stroke for those patients who underwent either PCI (with bare metal or drug-eluting stents) or coronary artery bypass graft surgery in matched cohorts of patients with unprotected left main coronary artery disease followed on average for 3 years.^{13,19} However, this study showed that patients who received drug-eluting stents had a better outcome with a trend toward lower rates of death and the composite endpoint of death, Q-wave myocardial infarction, and/or stroke compared to those patients who underwent CABG.

Percutaneous coronary interventions are commonly performed using mild to moderate sedation under the direction of the cardiologist. Anesthesiologists are usually involved when patients present with respiratory insufficiency or hemodynamic compromise.

When sedation-related complications or acute patient decompensation occurs, anesthesiologists are called emergently. Close communication with the cardiologist is imperative because management decisions usually need to be made expeditiously. Information such as recent medications given, intravenous access, invasive monitoring, and stage of the procedure

must be obtained. Access to the patient's head can be difficult, as mentioned previously. If an airway needs to be established, priority must be given to the anesthesiologist to temporarily move the table and fluoroscopy equipment. Placement of an endotracheal tube is preferred to a laryngeal mask airway (LMA). In general, LMAs are not recommended in the CCL and EPL because the constant movement of the fluoroscopy equipment and table can dislodge the LMA. In addition, patients can become acutely unstable and having an endotracheal tube eliminates the need to further manage an airway in a crisis.

PERCUTANEOUS VENTRICULAR ASSIST DEVICES

Percutaneous left ventricular assist devices (p-LVADs) are placed in the CCL to support the failing heart in various clinical settings: that is, cardiogenic shock associated with myocardial infarction or hemodynamic compromise with severe left ventricular dysfunction from other etiologies. These p-LVADs have the capability to support patients in cardiogenic shock until either a recovery occurs or more definitive therapy is administered in the acute setting.²⁰ These devices are also utilized to support patients who are undergoing high-risk PCI procedures.²⁰ The TandemHeart (Cardiac Assist, Inc., Pittsburg, PA) and the Impella Recover LP 2.5 and 5.0 (Abiomed Inc., Danvers, MA) are two commercially available percutaneous ventricular assist devices.²⁰⁻²⁵

The Tandem Heart is comprised of a transeptal cannula, arterial cannulae, and an externally located centrifugal blood pump. This device is percutaneously placed via the femoral vein and transeptally placed in the left atrium to create a left atrial to (contralateral) left femoral artery bypass system. The pump can deliver flow rates of up to 4.0 l/min at a maximum speed of 7500 rpm.²⁰ Use of the TandemHeart device has been reported to be associated with a 30-day survival rate of 61% in 18 patients (11 in cardiogenic shock and 7 undergoing high-risk PCI) in one center. The device helped patients in cardiogenic shock improve their cardiac index from 1.57 ± 0.31 l/min/m² to 2.60 ± 0.34 l/min/m².²⁰ The mean duration of percutaneous LVAD support was 88 ± 74.3 hours (range, 4–264 hours).²⁰

A similar percutaneous-based left ventricular assist device is the Impella Recover LP 2.5 and 5.0 pump devices.²¹ The Impella Recover LP 2.5 and 5.0 pump systems both utilize a retrogradely inserted cannula via the femoral artery into the left ventricle across the aortic valve.²² Their ease of implantation, avoidance of the need for a transeptal puncture, and smaller catheter size (13 French vs. 17 French) are advantages over the Tandem Heart. In addition, there is no extracorporeal blood because the microaxial pump is integrated directly into the catheter system. Circulatory support of either 2.5 l/min or 5.0 l/min can be achieved with the Impella devices. Patient selection must be carefully considered.²²

Percutaneous ventricular assist devices (TandemHeart, Cardiac Assist, Inc., Pittsburg, PA, and Impella Recover LP 2.5 and 5.0, Abiomed Inc, Danvers, MA) are placed in patients

who are having high-risk PCI (unprotected left main), high-risk ablation procedures, or who are hemodynamically compromised (cardiogenic shock).^{20,23,24} The anesthesiologist is usually consulted for these procedures because the patient is usually already unstable and/or the procedure can have both airway and hemodynamic complications. Depending on the procedure and state of the patient, either sedation or general anesthesia can be used to care for the patient. Communication between anesthesiologist and cardiologist should determine the type of anesthetic most appropriate for the case.

The TandemHeart and Impella LP 5.0 produce cardiac outputs that can completely replace left ventricular function. During this time, pulse oximetry and noninvasive blood pressure cuffs may not work properly because blood flow may not be pulsatile. The Impella LP 2.5 uses a smaller cannula that achieves a maximum cardiac output of 2.5 l/min. The patient must have some intrinsic cardiac function to maintain hemodynamic stability.

Invasive monitoring is available because arterial cannulation is used during the procedure. Large-bore intravenous access is desirable because significant blood loss is possible during the procedure.²⁵ Blood loss is more likely with the TandemHeart or Impella LP 5.0 because the cannulas used are larger. Surgical backup may be necessary during these procedures. The anesthesiologist should be in touch with the operating room and confirm that backup is available.

PERCUTANEOUS CLOSURE OF SEPTAL DEFECTS

The placement of intracardiac atrial septal occluder devices requires an anesthesiologist if TEE is used to guide placement of the device; the alternative is for the cardiologist to use intracardiac or intravascular echo. In 2001 the U.S. Food and Drug Administration (FDA) approved the AMPLATZER Septal Occluder (AGA Medical Corporation, Golden Valley, MN) as a treatment for a secundum atrial septal defect and for patients who have undergone a fenestrated Fontan procedure requiring closure of the fenestration.²⁶ In 2005 the FDA approved the Gore Helex septal occluder (W.L. Gore and Associates, Flagstaff, AZ) for the percutaneous, transcatheter closure of ostium secundum atrial septal defects. The Helex implant (W.L. Gore and Associates, Flagstaff, AZ); the Premere PFO Closure System (St. Jude Medical, Inc., Maple Grove, MN); the Solysafe Septal Occluder (Swissimplant AG, Solothurn, Switzerland); the IntraSept Occluder (CARDIA, Inc., Burnsville, MN); the Occlutech Device (Occlutech, Jena, Germany); the SeptR Occluder (Secant Medical, Perkasi, PA); the BioSTAR Septal Occluder, the first partially bioabsorbable septal repair implant (NMT Medical, Boston, MA); the SuperStitch Device (Sutura Inc., Fountain Valley, CA); and the PFX System (Cierra, Inc., Redwood City, CA) are other devices that are currently available.²⁷ A unique occluder device, the PFX system uses vacuum suction to hold the septum primum and secundum in place and RF energy to directly close the patent foramen ovale (PFO).²⁷ There presently has not been any prospective randomized controlled

trial of percutaneous closure of PFOs in patients who have suffered from a cryptogenic stroke despite widespread use. Therefore, the FDA has not approved the use of percutaneous occluder devices for the prevention of recurrent cryptogenic stroke.²⁸ Nonetheless, we will describe the AMPLATZER and the CardioSEAL devices because they are routinely utilized in clinical practice.

The AMPLATZER Septal Occluder provides a permanently implanted percutaneous-based delivery system comprised of a two-sided “clam shell” appearing occluder.²⁹ This “clam shell” is comprised of two flat discs with a middle or “waist.” Nitinol wire mesh, a wire made from an alloy of nickel and titanium, along with polyester fabric inserts, are the materials that comprise the disc. These fabric inserts provide a foundation for growth of tissue over the occluder after placement on either side of a PFO or an atrial septal defect (ASD).²⁹ Advantages of the AMPLATZER Septal Occluder include the following:

1. Smaller overall size with the delivery through smaller catheters
2. Round retention discs that extend radially beyond the defect, allowing firmer contact and enhancing endothelialization, therefore reducing the risk of residual shunting
3. Easy repositioning with a self-centering mechanism³⁰

The CardioSEAL device is composed of two self-expanding Dacron patch-covered umbrellas that attach to either side of the intra-atrial septum. The umbrellas are formed by four central radiating metal arms attached to each other in the center. In order to minimize arm fractures and protrusion of the arm through the atrial septal defect, the device was re-engineered with a self-centering mechanism comprised of nitinol springs. These springs connect the two umbrellas and a flexible core wire with a pin-pivoting connection. The name of the device is the STARflex, and it has significantly reduced the rate of arm fractures.^{31,32}

Patients with recurrent cryptogenic stroke due to presumed paradoxical embolism through a patent foramen ovale and who have failed conventional drug therapy have undergone atrial septal occlusion, although these devices have not yet been approved for this indication.³³ Muscular and perimembranous ventricular septal defects (either congenital or acquired) have also been successively closed 96% of the time with a 2% major complication rate with these devices.³⁴ Success rates for closure of PFOs and ASDs have ranged from 79% to 100% after several years.²⁵

Complications of percutaneous closure devices include but are not limited to the following: intraprocedure air embolism; device embolization; device malpositioning; device thrombosis and embolization (cerebral embolization may occur from either air a piece of the device itself or thrombus) during or following the procedure; and device related arrhythmias (usually atrial but include sudden death); and cardiac perforation with or without cardiac tamponade.^{25,35-39} These complications must be immediately recognized, evaluated, and treated to either prevent permanent sequelae or minimize their impact.³⁷ Transesophageal echocardiography (TEE) or intracardiac echocardiography (ICE) help guide the placement of

these devices at the time of implantation. Since the procedure requires that the patient remains still and quiet, the use of TEE requires endotracheal intubation and general anesthesia. Although intracardiac ultrasound does not require endotracheal intubation or general anesthesia, implantation of septal occluder devices still demands the presence of a cardiac anesthesiologist. This team approach allows the operator to focus his or her attention on proper device placement and remain vigilant for any complication that may arise while patients receive optimal anesthetic care.

Procedures such as these are used to close PFOs, ASDs, and ventricular septal defects (VSDs). Patient history is important to determine the reason to close the defect. Closure of PFOs tends to be simpler than closure of ASDs. In patients with ASDs, it is important to determine whether right ventricular function and pulmonary arterial pressures are normal because the right side of the heart has been volume overloaded due to the typical left to right shunt through the ASD. In patients with VSDs, the anesthesiologist needs to determine whether the VSD is congenital or acquired (postmyocardial infarction) and the direction of flow through the defect. Typically VSDs have left-to-right flow. Patients with postmyocardial infarction VSDs can be hemodynamically unstable and may be more likely to have complications (hypotension, arrhythmias) during closure of the defect.^{40,41} Complications with any device placement in the CCL include air-embolism, device embolization, malposition, thrombosis and embolization (pulmonary or systemic), arrhythmias (AV nodal block), hypotension, valve dysfunction, and cardiac perforation.^{25,39,42}

Echocardiography is used during the procedure to help guide placement and confirm a successful result. If TEE is used, then general anesthesia will be necessary for the procedure. Intracardiac echocardiography (ICE) can also be used to guide the procedure. If ICE is used, the procedure can be performed under sedation.⁴³ The determination of sedation versus general anesthesia should be based on the complexity of the closure and patient medical history.

If arterial monitoring is needed and the cardiologist is not planning femoral arterial access, a radial arterial line should be placed by the anesthesiologist. Two IVs should be available so that one can be used for boluses and the other for infusions. The cardiologist can place a femoral venous line for infusions if necessary.

PERIPHERAL ARTERIAL DISEASE

The prevalence of peripheral arterial disease (PAD) increases with age and occurs more commonly in African Americans.⁴⁴ At the present time it is estimated that peripheral arterial disease afflicts approximately 8 million Americans.⁴⁴ Atherosclerotic occlusion of the peripheral is the main etiologic factor.⁴⁵ Men have a slightly higher prevalence than women.⁴⁶ Intermittent claudication and rest pain are the principal symptoms. Claudicare is the Latin derivative of *claudication* and means “to limp.”⁴⁷ Claudication symptoms are due to insufficient arterial blood flow and leg ischemia. Patients suffering from

intermittent claudication have symptoms of pain, aching, and a sense of fatigue or other discomfort that is experienced in the affected muscle group during exercise, especially walking, and relieved at rest.⁴⁷ Symptoms are most often experienced in the muscle bed supplied by the most proximal stenosis.⁴⁷ Buttock, hip, or thigh claudication is related to obstruction of the aorta or iliac flow. Calf claudication commonly is a result of either femoral or popliteal arterial stenosis, and either tibial or peroneal disease causes ankle or pedal claudication.⁴⁷

According to ACC/AHA guidelines, percutaneous revascularization in patients with intermittent claudication should be considered when any one of the following circumstances is encountered:

1. Claudication symptoms significantly disable the patient, resulting in an inability to perform normal work or other activities that are important.

2. The patient is able to benefit from an improvement in claudication (i.e., exercise is not limited by another cause, such as angina, heart failure, chronic obstructive pulmonary disease, or orthopedic problems).

3. Exercise rehabilitation and pharmacologic therapy have not been successful in providing the patient with an adequate response.

4. A very favorable risk–benefit ratio to performing the procedure exists with a high likelihood of initial and long-term success.

5. The characteristics of the lesion permit appropriate intervention at low risk with a high likelihood of initial and long-term success; and/or the patient has limb-threatening ischemia, as manifested by rest pain, ischemic ulcers, or gangrene.⁴⁶⁻⁴⁹

Epidural anesthesia may attenuate stress responses and reduce the production of acute-phase reactants, leading to reduction in hypercoagulation-related complications in lower-extremity stent procedures.⁵⁰ Equipment for general anesthesia must be available if regional anesthesia is to be administered. As most of these patients are on antithrombotic medications (e.g., clopidogrel, aspirin, warfarin, or heparin) given during the procedure, a major concern is the risk for an epidural or a spinal hematoma.^{51,52} However, the anesthesiologist may be critical to the interventional cardiologist during a peripheral vascular intervention because many of these patients are unable to lie still during the procedure because of resting claudication symptoms. In addition, painful transient ischemia may occur as a result of the procedure itself. The resulting patient movement may further increase the risk of complication.

Percutaneous Valve Repair and Replacement

Newer percutaneous techniques for the treatment of mitral regurgitation and percutaneous aortic valve replacement have recently been developed and are presently under investigation and in clinical trials.⁵³⁻⁵⁵

Percutaneous Mitral Valve Repair

At the present time cardiac surgical mitral valve repair is the procedure of choice for the treatment of symptomatic mitral regurgitation or mitral regurgitation with “impaired” left ventricular ejection fraction (<60%). However, current techniques under investigation for percutaneous mitral valve repair include coronary sinus annuloplasty, direct annuloplasty, leaflet repair, and chamber + annular remodeling.⁵⁶

The annular circumference of the mitral annulus can be decreased with placement of a device in the coronary sinus since the sinus overlies the annulus.⁵⁶ One device utilizes connecting spring to bridge anchors or stents percutaneously placed in the coronary sinus ostium and the distal coronary sinus (Monarc device, Edwards Lifesciences Inc., Orange, CA). As the spring shortens, tension develops and the coronary sinus is pulled, diminishing the annular diameter. Another percutaneous coronary device system, the Carillon Mitral Contour System (Cardiac Dimensions, Kirkland, WA), uses a Nitinol wire-shaping ribbon between the proximal and distal anchors.⁵⁷⁻⁵⁹ These devices are presently in clinical trials. In about half of patients, however, the coronary sinus crosses over branches of the circumflex coronary artery, and in many patients the coronary sinus does not directly parallel the mitral annulus.⁶⁰ Therefore, circumflex coronary artery compression can occur at the time of implantation and cinching the coronary sinus may not change annular diameter. In the case of the Monarc device, circumflex coronary artery compression may occur later as the biodegradable material in the spring spaces absorbs and the spring element shortens over a period of weeks to months.⁵⁶ Coronary sinus erosion and thrombosis are other potential complications. Therefore, the safety and the efficacy of the coronary sinus approach in the treatment of mitral regurgitation are yet to be determined.

In surgical contexts, Alfieri previously demonstrated that suturing of the free mitral valve leaflet edges of the midpart of the line of mitral coaptation creates a double orifice mitral valve.^{61,62} This technique also has had mixed clinical results^{63,64} as a way of reducing mitral regurgitation. However, in selected patients isolated edge-to-edge mitral valve repair may be durable with 5-year 90% freedom from reoperation and mitral regurgitation >2+.⁶⁵

A percutaneously delivered device under investigation (MitraClip) duplicates the Alfieri edge-to-edge repair (Evalve, San Francisco, CA). Following a trans-atrial-septal puncture, the clip is positioned in the center of the mitral valve orifice. The mitral valve leaflets are grasped by opening the clip, passing it into the left ventricular cavity, and drawing it back to come in contact with the mitral valve leaflets. The clip is closed to create a double-orifice mitral valve.^{66,67} A Phase I clinical trial demonstrated 2-year freedom from death, mitral valve surgery, or recurrent mitral regurgitation > 2+ in up to 80% of patients receiving successful clip deployment.⁶⁸ This Phase I trial success of the Evalve clip procedure has led to a randomized trial comparing this procedure to mitral valve surgery in selected patients, the EVEREST II trial.⁵⁶ General anesthesia, fluoroscopy, and transesophageal echocardiography to

help guide placement of the device are part of the E-valve procedure.²⁵

PERCUTANEOUS AORTIC VALVE REPLACEMENT

Anderson and Pavcnik performed the initial animal work in the development of percutaneous aortic valve replacement, and Cribier developed the first percutaneous heart valve for humans.^{69,70} Percutaneous aortic valve replacement trials are currently open only for patients with severe aortic stenosis, New York Heart Association Class IV symptoms related to their aortic stenosis, and comorbidities excluding them from cardiac surgery due to excessive risk.⁷¹ However, ongoing randomized controlled clinical trials are in progress comparing surgical aortic valve replacement to percutaneous aortic valve replacement in patients who are candidates for cardiac surgery using newer generation percutaneous aortic prosthetic valves.⁷² Depending on the trial results and future technological advances, some experts in this field believe that percutaneous aortic valve replacement may be a viable option for a patient in need of a prosthetic aortic valve so as to avoid the concomitant complications inherent in open heart surgery.⁷²

The Cribier-Edwards valve (Cribier-Edwards aortic valve, Edwards Lifesciences, Irvine, CA) is comprised of three bovine pericardial leaflets sutured to a stainless steel balloon expandable stent. This valve is crimped on an aortic valvuloplasty balloon that is expandable to 23 mm or 26 mm (NuMed Inc., Hopkinton, NY). An antegrade approach using a transatrial septal puncture delivers this system through a 24 French (8 mm) sheath. The percutaneous valve is then positioned across the native aortic valve and delivered with rapid inflation and deflation of a balloon. High rate pacing temporarily minimizes antegrade aortic flow.⁷¹ In a recently reported series of 35 patients undergoing this procedure, 27 patients underwent a successful implantation with improvement of aortic valve area and left ventricular function.⁷³ Moderately severe aortic insufficiency developed in five patients and no patients developed a device related death in 9 to 26 months of follow-up.⁷³

Technological advances are rapidly occurring in this domain. A self-expanding percutaneous aortic valve consisting of a bioprosthetic pericardial tissue valve sutured into a Nitinol metal stent is in development (CoreValve; Paris, France).⁷¹ Preliminary results indicate that one advantage of a self-expanding stent-valve system is lack of significant aortic regurgitation.⁷¹ The AorTx (Redwood City, CA), another percutaneously delivered aortic valve, can be retrieved after deployment. Technological advancement will improve delivery systems so that valves are easier and safer to deploy.⁷¹

Edwards Lifesciences Corp. announced European approval for commercial release of the Edwards Sapien transcatheter aortic valve technology with the Retroflex transfemoral delivery system on September 5, 2007.⁷⁴ The profile of this bovine pericardial tissue valve constructed with a cobalt chromium alloy stent reduces the profile of the system by four to five French as compared to the other systems described earlier. This system allows easier access into and within the patient's

vasculature, potentially reducing the risk of procedural complication.⁷⁵ This valve is presently being studied in the PARTNER TRIAL: Placement of AoRTic TranNscathetER Valve Trial in high-risk symptomatic patients with severe aortic stenosis.⁷⁵ This valve may also be placed in the aortic position via a transapical approach with the Ascendra delivery system, which is also being studied in the PARTNER Trial.⁷⁵

The initial clinical experience for transapical transcatheter aortic valve implantation was first reported in 2006.⁷⁶ An anterolateral intercostal incision is used to expose the left ventricular apex. Direct needle puncture of the left ventricular apex allows introduction of a hemostatic sheath into the left ventricle. The prosthetic valve is placed into the left ventricular cavity after being crimped onto a valvuloplasty balloon and passed over a wire. Proper positioning is confirmed by fluoroscopy, aortography, and echocardiography. Rapid ventricular pacing is utilized to decrease cardiac output while the balloon is inflated and the prosthesis is deployed within the annulus. The initial experience was reported on seven patients. There were no procedural deaths. However, one death occurred within 87 ± 56 days.⁷⁶ More recently other reports in the literature have demonstrated safety with good early results in high-risk patients.^{77,78} Although all of these procedures are investigational, they represent the changing paradigm of interventional cardiology procedures; procedures are more complex with increased patient acuity. Medical and surgical approaches to complex cardiac patient care are now sharing common ground. Anesthesiologists must be prepared for this new and changing patient population.

All percutaneous mitral valve repairs are performed under general anesthesia with fluoroscopic and TEE guidance. Patients typically have moderate to severe mitral regurgitation. The type of device and approach should be communicated prior to the procedure.^{56,79}

During percutaneous valve replacements/repairs, the procedure room is very crowded. Planning for equipment deployment can be difficult for anesthesiologists. It is well worth taking time to look the room over before the case. Sometimes two anesthesiologists are needed, since TEE guidance is often critical. Two peripheral IVs should be placed for infusions and boluses. Endotracheal intubation is required if TEE is used and arterial monitoring is important because noninvasive blood pressure cuffs will not work when the patient goes into a fast rhythm. Communication during the procedure is vital to successful placement of the device, as the case can be long and multiple attempts may be needed to ensure proper device placement with an acceptable result.

Percutaneous aortic valve replacement involves patients that are extremely ill. Patients have severe aortic stenosis, New York Heart Association Class IV symptoms, and comorbidities excluding them from cardiac surgery due to excessive risk.⁷¹ Fluoroscopy and TEE are used to guide device placement. Patients frequently become hemodynamically unstable during the case and can develop myocardial ischemia and significant arrhythmias. Most patients receive general endotracheal anesthesia and invasive monitoring. Central IV access is preferable for infusion of necessary medications.

EVOLUTION IN THE MAKING: THE PEDIATRIC CARDIAC CATHETERIZATION LABORATORY

A description of anesthetic care in the pediatric cardiac catheterization laboratory in 1954⁸¹ instructs the anesthetist and anesthesiologist to consider the following:

- The type of patients that will undergo this procedure
- The details of the procedure itself and how to provide ideal conditions
- The potential complications of the procedure
- The challenges produced by the environment (remote access to patient, exposure to radiation, etc).

Over half a century later, while these tenets still hold true, the increasing complexity of the patient population and the transition from diagnostic to transcatheter or combined surgical and transcatheter (hybrid) interventions have drastically changed the landscape of the pediatric cardiac catheterization laboratory.^{82,83}

The Patients

First, consider the profile of the patients that will be selected for cardiac catheterization: with advances in echocardiography, magnetic resonance imaging/angiography, and computed tomography angiography, diagnosis of congenital heart disease and presurgical evaluation are accomplished noninvasively in the majority of patients. Patients are small and have a complex anatomy. They often present for preoperative stabilization or transcatheter interventions to correct postoperative defects.⁸⁴ For example, the neonate with parallel circulation and inadequate mixing of systemic and pulmonary venous returns may present to the catheterization laboratory for balloon atrial septostomy in cardiogenic shock associated with profound hypoxemia and lactic acidosis.⁸⁵ Hybrid palliation is often used to stabilize the tenuous parallel circulation of the critically ill neonate with hypoplastic left heart syndrome. Table 19.1 demonstrates the complexity of this particular patient population who may present to the catheterization suite for a combined surgical and transcatheter intervention.⁸⁶

The patient with a failing Fontan circulation may present moribund for diagnostic catheterization in anticipation of possible Fontan revision or transcatheter fenestration of their Fontan pathway. Ventricular dysfunction, arrhythmias, hepatic and renal insufficiency, marginal cerebral perfusion pressure, thromboembolic complications, and poor vascular access are frequent sequelae of the failing cavopulmonary circulation. Positive pressure ventilation, often a supportive modality in the patient with biventricular circulation, may cause acute deterioration of hemodynamics in these patients.

Pediatric patients ranging from neonates to adolescents present with hypertrophic, dilated, or restrictive cardiomyopathies for diagnostic evaluation for transplant and endomyocardial biopsy. Careful titration of anesthetics and sedatives is paramount in these patients with limited hemodynamic reserve.

TABLE 19.1. *Characteristics of Neonates with Hypoplastic Left Heart Syndrome (HLHS) for Hybrid versus Norwood Palliation*

Variable	Hybrid (n = 14)	Norwood (n = 19)	p Value
Age (days)	4.3 ± 3.4	3.5 ± 1.6	0.96
Weight (kg)	2.6 ± 0.6	2.7 ± 0.04	0.77
ACS	19.3 ± 3.1	18.3 ± 2.6	0.46
Asc Ao (mm)	3.2 ± 1.7	2.7 ± 1.0	0.13
Lowest pH	7.14 ± 0.2	7.29 ± 0.05	0.040
Ao atresia	6 (43%)	12 (63%)	0.15
Additional cardiac factors	3 (21.4%)	13 (68.4%)	0.009
Organ dysfunction	9 (64%)	5 (26%)	0.03
Genetic/chromosomal	3 (21.4%)	4 (21.8%)	0.78
LBW (<2.5 kg)	5 (35.7%)	6 (31.5%)	0.54
Prematurity (<36 weeks)	4 (28.5%)	4 (21%)	0.46

ACS, Aristotle comprehensive score; Asc, ascending; Ao, aorta; LBW, low birth weight.

Source: Information taken from the U.S. Department of Health and Human Services, Agency for Healthcare Research and Quality. Healthcare Cost and Utilization Project (HCUP). <http://hcupnet.ahrq.gov>.

The Procedure

Second, the clinician providing sedation or general anesthesia should be familiar with the objectives and technical aspects of the catheter procedure. This is often easy to obtain by reviewing the medical history of the patient and interviewing the family, but a preprocedural discussion with the interventional cardiologist will often determine whether the case can be accomplished best with sedation, a natural airway, a general anesthetic, and so forth. Although complications are infrequent, a candid discussion about the worst-case scenario will allow the anesthetist or the clinician responsible for sedation to be better prepared.

Diagnostic catheterizations typically involve three processes: obtaining multiple blood samples for saturation data used in the Fick equation; pressure measurements to evaluate ventricular function, gradients across stenotic valves and vessels, and as variables in calculating pulmonary and systemic vascular resistance; and angiography of the cardiac chambers, pulmonary architecture, and outflow tracts. Alveolar oxygen content and arterial pH markedly affect pulmonary vascular resistance, and maintaining a consistent FiO₂ (often 21%) and normal pH is paramount to obtaining accurate and reliable data. Achieving this with a natural airway and spontaneous ventilation can be challenging. Even in the older, cooperative child, a skilled anesthesia provider may opt for a general anesthetic, endotracheal intubation, and controlled ventilation. The cardiologist may prefer that respirations are “held” during critical hemodynamic data so that various ventilation modalities and their influence on venous return and ventricular wall tension are trivial.

Challenging vascular access is not uncommon in children presenting to the catheterization laboratory. Multiple factors contribute to this, such as prolonged intensive care unit stays, long-term indwelling central venous and arterial lines, and thromboembolic complications associated with congenital heart disease. Thrombosis of femoral veins and arteries may make routine femoral access impossible. Transhepatic access to the hepatic venous system and inferior vena cava may be used in these cases and is remarkably safe in skilled hands.⁸⁷⁻⁹⁰

Nitric oxide is often used as a provocative agent to determine whether elevated pulmonary vascular resistance is reversible. The anesthesia/sedation provider should be familiar with the delivery system, pharmacology, and pharmacokinetics of this agent in the pediatric cardiac catheterization lab.

Transcatheter interventions in the pediatric population typically require general anesthesia. The interventionalist must

have a motionless patient, and the anesthetist must be prepared for hemodynamic instability and hemoptysis. With the increasing use of intracardiac (ICE) versus transesophageal echocardiography, transcatheter closure of patent foramen ovale can be accomplished using general anesthesia with a natural or laryngeal mask airway in the older cooperative child (femoral venous sheaths for the ICU probe are still fairly large).^{91,92}

The types of catheter interventions commonly performed in the pediatric catheterization laboratory can be grouped as shown in Table 19.2.

Hybrid procedures combine surgical and transcatheter interventions in a single maneuver or in short succession of maneuvers to overcome the limitations of each modality. For example, the percutaneous approach in low birth weight infants can be challenging and risk vascular damage and hemodynamic instability. These infants may also be at an

TABLE 19.2. *Indications for Transcatheter Interventional Procedures*

<i>Intervention</i>	<i>Indication</i>
Opening of atrial communications	Transposition of the great arteries with inadequate venous return mixing Tricuspid atresia with restrictive ASD Pulmonary atresia with intact ventricular septum
Occlusion of septal defects	Secundum ASD with adequate septal rims Patent foramen ovale* Muscular VSD Fenestration closure in Fontan patients
Balloon dilation of cardiac valves	Pulmonary valve stenosis Aortic valve stenosis (congenital)
Balloon angioplasty	Coarctation of the aorta (native and recoarctation) Branch pulmonary artery stenosis Systemic vein stenosis
Endovascular stents	Pulmonary artery stenosis Superior or inferior vena caval stenosis Systemic venous obstruction at the superior or inferior baffle limb after atrial repair of transposition Stenotic right ventricle-to-pulmonary artery conduit* Aortic coarctation* PDA in infants with ductal dependent circulations*
Coil occlusion	Aortopulmonary collaterals with dual supply Small patent ductus arteriosus Surgical aortopulmonary shunts Intrapulmonary arteriovenous fistulas Anomalous venovenous or venoatrial connections— Post bidirectional Glenn or Fontan patients Coronary arteriovenous fistulas*

*Condition for which the procedure may be indicated.

ASD, atrial septal defect; VSD, ventricular septal defect.

Source: Allen HD, Beekman RH 3rd, Garson A Jr, et al. Pediatric therapeutic cardiac catheterization: a statement for healthcare professionals from the Council on Cardiovascular Disease in the Young, American Heart Association. *Circulation*. 1998;97(6):609-625.

increased risk with prolonged cardiopulmonary bypass times. Therefore, combining both the transcatheter and surgical venue may avoid complications. For instance, muscular VSDs can be very difficult for surgeons to adequately visualize and repair without a left ventriculotomy. In the small infant, deploying a septal occlusive device requires a relatively large introducer sheath and the transcatheter procedure is often complicated by valvar insufficiency, blood loss requiring transfusion, and arrhythmias. Sternotomy and periventricular insertion of an introducer into the right ventricular wall followed by deployment of a septal occluder under fluoroscopic guidance has been described.^{94,95} Both cardiopulmonary bypass and insertion of large catheters in small vessels is avoided.

An alternative strategy for neonatal palliation of the infant with hypoplastic left heart syndrome is well described and avoids the complex arch reconstruction in the first 1–2 weeks of life^{82,86,96,97} (Fig. 19.1). An alternative hybrid “bailout” for palliation of a failed biventricular repair of critical congenital aortic stenosis has recently been described and adds another layer to the complexity of the patients in the pediatric cardiac catheterization laboratory.⁹⁸

Hybrid procedures present the greatest challenges to the anesthesia provider, who is often the individual most familiar with the requirements of both the surgical and interventional teams. This is a truly collaborative effort that can easily become chaotic when competing interests (space, sterile

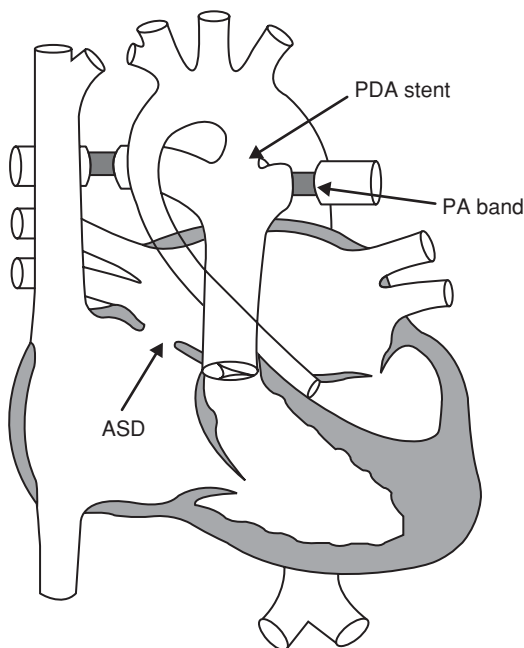


FIGURE 19.1. Illustration demonstrates the key features of hybrid palliation for hypoplastic left heart syndrome (HLHS). Note the bilateral pulmonary artery bands (PA bands) are surgically placed. The ductus arteriosus (PDA) patency is maintained by a transcatheter ductal stent, and the atrial septal defect (ASD) is made nonrestrictive by either a septostomy or a transcatheter stent. (From Langeron O, Masso E, Huraux C, et al. Prediction of difficult mask ventilation. *Anesthesiology*. 2000;92:1229.)

setups, visibility, etc.) collide. The anesthetist’s ability to help coordinate and align these two medical services can mean the difference between success and failure. Detailed planning and constant communication among the surgical, interventional, and anesthesiology services is paramount.

Anesthetizing critically ill patients for catheter procedures becomes daunting when median sternotomies and cardiac procedures are done in an environment designed for fluoroscopic procedures. Today, more and more medical facilities are designing and building “hybrid” suites that have the capacity to accommodate the electrical and physical requirements of these procedures.

The Complications

In a prospective study of over 4000 pediatric cardiac catheterizations at a single institution from 1987 to 1993, investigators found a mortality rate of 0.14% among diagnostic, interventional, and electrophysiologic studies performed in the pediatric cardiac catheterization laboratory.⁹⁹ (See Table 19.3.) Complications occurred in 8.8% of procedures. Independent risk factors for major complications (death, life-threatening instability, need for surgical intervention) were interventional procedures and age less than 6 months. In a similar study examining complication rates from 1993 to 2007, investigators found the incidence of adverse events to be 9.3%. Interventional catheterizations had an adverse event rate of 11.7%. Infants (<1 year of age) had a complication rate of 13.9%.¹⁰⁰

A frequent complication in the pediatric cardiac catheterization laboratory is bleeding and hematoma formation at the catheter sites.⁹⁹ The anesthetic must provide a smooth emergence, devoid of coughing and delirium while still maintaining airway patency and adequate ventilation. This calm state must continue in the early recovery period so that the infant, toddler, or uncooperative child can remain in the supine position for anywhere from 30 minutes to 2 hours (depending on introducer sheath size and activated clotting time) to avoid bleeding at puncture sites.

Arterial injury and potential limb ischemia can occur, particularly in transcatheter procedures that require large arterial sheaths such as balloon angioplasty of congenital aortic stenosis or aortic coarctation. Heparin therapy, thrombolytic therapy, and/or surgical intervention may be required to prevent significant morbidity.^{99,101}

Thermal injuries from forced air-warming systems can occur and have been described in the lower extremity where arterial and venous sheaths were placed [personal communication]. Patients with low cardiac output states may be at particular risk. Precautions include avoiding the highest temperature setting and preventing direct contact of the warming blanket with the patient’s skin.^{102,103}

Device embolization is always a possibility in interventional procedures. Embolization to the systemic circulation is generally an indication for emergent surgical retrieval. Embolization of devices or ruptured balloons into the pulmonary circulation can often be retrieved by transcatheter approaches. Arrhythmias, valvar obstruction or insufficiency,

TABLE 19.3. *Mortality Data in the Pediatric Cardiac Catheterization Laboratory*

	Age	Cardiac Lesion	Notes	Procedure	Event Leading to Death	Location
1	1 day	Pulmonary atresia with intact ventricular septum	On PGE ₁	Diagnostic	Perforation of the left atrium	Catheterization lab
2	3 days	Pulmonary atresia with intact ventricular septum	On PGE ₁	Pulmonary valve dilation	Ductal thrombosis	OR
3	14 days	Double outlet right ventricle with transposition of the great arteries		Balloon atrial septostomy	Cardiac perforation	Catheterization lab
4	4 years	Complete AV canal with right ventricular hypoplasia	POD #4 Fontan	Branch PA stent	Cardiac tamponade	ICU
5	5 years	Double inlet LV with transposed great arteries	POD #1 Fontan	Atrial defect dilation	Desaturation and bradycardia	Catheterization lab
6	4 months	Pulmonary atresia with intact ventricular septum	Cyanotic	Diagnostic	Desaturation and bradycardia	Catheterization lab
7	3 days	Aortic valve stenosis and aortic coarctation		Diagnostic	Bleeding from perforation of paraductal area	OR

AV, atrioventricular; ICU, intensive care unit; LV, left ventricle; OR, operating room; PGE₁, prostaglandin E₁.

Source: Reprinted from Vitiello R, McCrindle BW, Nykanen D, Freedom DM, Benson LN. Complications associated with pediatric cardiac catheterization. *J Am Coll Cardiol.* 1998;32(5):1433-1440, with permission from Elsevier.

or vascular obstruction/ischemia may require escalating pharmacologic or mechanical support until the device can be removed.

Pulmonary hemorrhage ranging from trivial to life-threatening can occur in patients who undergo balloon angioplasty of pulmonary arteries, a common intervention in the pediatric cardiac catheterization laboratory. Angioplasty is unlikely to be successful unless there is disruption of the intima extending into the media.¹⁰⁴ Cutting balloons are often employed to achieve this intimal tear. Extension of the vascular disruption past the media and adventitia may result in massive hemoptysis and cardiovascular instability. Cuffed endotracheal tubes are a must and will allow the anesthetist to escalate ventilator parameters and add positive end-expiratory pressure.

Perforation of thin atrial walls, calcified conduits, and hypertensive pulmonary arteries can occur during diagnostic or interventional catheterizations. Cardiac tamponade and massive hemoptysis require the skills of both the interventional and anesthesia teams. The cardiologist can place a covered stent at vessel rupture sites and emergently place a drainage catheter in the pericardial space. The anesthetist must be prepared to start inotropic support, transfuse blood products, and provide care while transitioning onto mechanical support in the catheterization lab.¹⁰⁵ Surgical intervention may be urgently required and may occur in the catheterization suite or involve transfer to an operating room.¹⁰⁶ Unlike the adult catheterization laboratories that may be in free-standing facilities or hospitals without cardiac surgical services, cardiac surgical support is mandatory for any institution performing diagnostic or therapeutic pediatric cardiac catheterizations.¹⁰⁷

The clinician providing anesthetic care of children in the pediatric catheterization laboratory must have a working

knowledge of the wide spectrum of congenital heart defects, their pre- and postrepair physiology, the various transcatheter procedures and their concomitant risks, and the challenges of resuscitation in an environment that may be remote from the operating room. The anesthetist must remain engaged in the procedure, alert to any signs of potential cardiovascular compromise. As in all non-operating room areas where sedation and general anesthesia are performed, the clinician's ability to effectively communicate with other services is requisite to providing safe and effective care.

THE ELECTROPHYSIOLOGY LAB

Overview of Electrophysiology Interventions

Since the 1960s, modern clinical electrophysiology has undergone a transformative evolution from simple diagnostic procedures to major, life-saving, therapeutic interventions. As technology has advanced and the demand has significantly increased, there has been exponential growth in the number of electrophysiology procedures. Additionally, the complexity and length of these procedures has also dramatically increased.

The performance of these procedures now frequently mandates administration of moderate sedation or general anesthesia. Consultation with a cardiac anesthesiologist may be necessary since many patients frequently have comorbidities such as advanced heart failure and multisystem disease. Optimal conscious sedation/general anesthesia requires the anesthesiologist to understand electrophysiology procedures to maximize potential for desired outcomes and to avoid complications. This section will review the most commonly performed electrophysiology procedures.

ELECTROPHYSIOLOGY STUDIES

Diagnostic electrophysiology studies (EPS) are presently commonly performed in conjunction with therapeutic procedures to evaluate and treat specific arrhythmias. Currently EPS is performed to determine the electrophysiologic etiology of specific symptoms or events such as syncope or palpitations.⁸⁰ Intracardiac recordings are made from catheters that are commonly placed via femoral venous access into the high right atrium (HRA), His bundle, coronary sinus (CS), and right ventricular apex (RVA) or right ventricular outflow tract (RVOT). Ventricular or supraventricular tachycardias are induced by programmed stimulation performed from the HRA, RVA, or RVOT. The etiology of bradyarrhythmias may also be assessed from intracardiac recordings. For these studies, sedation with benzodiazepines and short-acting analgesic medication such as Fentanyl is usually sufficient. Drugs that may affect inducibility of certain arrhythmias should be avoided. These include sympathetic and parasympathetic modulating agents because they commonly influence the function of the atrioventricular node and sinus node and thus may influence the outcome of the study.

CATHETER ABLATION

Catheter ablation is commonly used to treat supraventricular tachyarrhythmias such as atrioventricular nodal re-entry tachycardia; Wolf-Parkinson-White syndrome-related tachycardias, atrial flutter, atrial fibrillation, and ventricular arrhythmias in selected patients. Recent ACC/AHA Atrial Fibrillation Guidelines state that in patients with little or no left atrial enlargement, catheter ablation is a “reasonable alternative to pharmacologic therapy” to help prevent recurrence of atrial fibrillation. These guidelines have categorized catheter ablation for atrial fibrillation as II-A, level of evidence C.¹⁰⁸

Although other energies such as focused ultrasound, laser, microwave, and cryotherapy have been employed in cardiac ablation procedures, RF is the energy most commonly utilized.¹⁰⁹ However, regardless of the energy source delivered to specific targets, the patient may experience pain and may require deep sedation or general anesthesia.

Radiofrequency catheter ablation has been used as a treatment for arrhythmias that are refractory to pharmacologic therapy as well as a first-line treatment for other arrhythmias.⁸⁰ The following arrhythmias have been treated with RF ablation: atrioventricular reentrant tachycardia, supraventricular arrhythmias associated with the Wolf-Parkinson-White syndrome, atrial ventricular reentrant tachycardia, atrial tachycardia, atrial flutter, idiopathic ventricular tachycardia, bundle branch re-entrant ventricular tachycardia, right ventricular outflow tachycardia, atrial fibrillation with an uncontrollable rapid ventricular response (RF ablation of the atrial ventricular node and placement of a permanent pacemaker), and atrial fibrillation. Radiofrequency is also used as adjunctive therapy

for recurrent ventricular tachycardia due to coronary artery disease or arrhythmogenic right ventricular dysplasia.¹⁰⁹ During the ablation procedure, catheters are placed in different cardiac chambers, and programmed stimulation is performed from different sites to induce tachyarrhythmias. In addition, different medications such as isoproterenol, epinephrine, dopamine, aminophylline, atropine, adenosine, beta-blockers, ibutilide, verapamil, and procainamide are used to induce as well as terminate tachyarrhythmias.⁸⁰

Complex mapping techniques are utilized to identify the source of the arrhythmia so as to specify the exact intracardiac location to which the RF energy must be applied. Mapping techniques include activation mapping; pace mapping; entrainment mapping; anatomic fluoroscopy-based, three-dimensional (3D) electroanatomical mapping; 3D non-contact mapping; and intracardiac echo-guided anatomical mapping. Because of the precision needed to identify and apply the RF energy to the intra-cardiac site of an arrhythmia, the patient must lie still during the procedure. Therefore, deep sedation or general anesthesia is necessary to ensure patient comfort and to optimize mapping. Thus, the role of the anesthesiologist becomes crucial during the procedure in order to maintain the patient’s airway and ensure hemodynamic stability with minimal movement of the patient’s body. A multidisciplinary team approach, including both anesthesiologists and electrophysiologists, is necessary to efficiently facilitate ablation procedures while optimizing patient safety.

Radiofrequency ablation procedures are becoming more tedious and more time consuming. Patients with atrial fibrillation often require a procedure time of at least 4–6 hours, followed by a prolonged observation time after ablation with repeat electrophysiology testing to ensure success of the procedure.⁸⁰

Patients can be young and essentially healthy or have extensive comorbidities. Coughing, snoring, and partial airway obstruction can be problematic during intracardiac mapping because they precipitate a swinging motion of the intra-atrial septum and make transseptal catheter placement difficult. Deep sedation is sometimes necessary to keep the patient comfortable during ablations, and ventilatory control with general anesthesia may be needed for obese patients, those with sleep apnea, or those with potential pulmonary problems. Drugs that affect the sympathetic nervous system should be avoided, if possible, during mapping of ectopic foci and tracts. Local anesthetics that are of moderate or long duration should be avoided during intubation. In patients with ventricular dysfunction, inotropic and vasoactive agents may be necessary in order to both sedate and maintain hemodynamic stability during arrhythmia induction.²⁵ Communication with the cardiologist is necessary in these situations to maintain patient safety and still allow the mapping process to proceed. Frequently, electrical cardioversion is necessary during the case, which may require at least transient general anesthesia for the patient to tolerate the delivered shock. Usually 20–40 mg of propofol is all that is needed to accomplish temporary deep sedation.

ELECTROPHYSIOLOGIC DEVICES

Devices for the control and/or eradication of arrhythmias have diminished in size and increased in sophistication over the past 10 years. As a result, more patients qualify for device implants, and the number of procedures for implantation and upgrade of devices has increased enormously. The two most common types of devices are implantable cardioverter-defibrillators and pacemakers.

Implantable Cardioverter Defibrillators

Implantable cardioverter defibrillators (ICDs) have been demonstrated to be efficacious and safe in a number of large, prospective multicenter randomized trials in patients with coronary and noncoronary heart diseases. Benefits accrue in mainly in patients with depressed left ventricular ejection fractions of 35% or less.¹¹⁰ Indications for ICD implantation as listed in the 2008 ACC, AHA, and the Heart Rhythm Society (HRS) Guidelines (seven Class I indications) has clearly been shown to prolong life and decrease the risk of sudden cardiac death for both primary and secondary ventricular tachycardia and/or ventricular fibrillation.¹¹⁰ With the advent of smaller biphasic, transvenous ICDs and the experience gained over the years, it is now feasible for electrophysiologists to implant ICDs safely in the pectoral under general anesthesia in the operating room. However, currently only local anesthesia combined with conscious sedation is utilized. The role of anesthesiologist is crucial during defibrillation threshold (DFT) testing where general anesthesia is required. This is especially true in patients who generally have significant comorbidities and significant left ventricular dysfunction.

Many electrophysiologists consider defibrillation threshold testing to be the most critical part of the ICD implantation procedure. Serious complications may occur during DFT, although the risk is usually low. Complications may include transient ischemic attack, stroke, cardiopulmonary arrest due to refractory ventricular fibrillation (VF), pulseless electrical activity, cardiogenic shock, embolic events, and death.^{110,111} DFT testing is commonly omitted due to the potential life-threatening risks of the procedure in unstable patients or patients with untreated coronary artery disease.

Biventricular Pacing and Defibrillation Lead Placement

Cardiac resynchronization therapy with and without defibrillation systems are prescribed for both primary and secondary prevention of sudden cardiac death in patients with heart failure associated with both an ischemic and nonischemic etiology. In 2008 the ACC/AHA/HRS guidelines gave cardiac resynchronization therapy with or without an ICD a Class I indication for those with a left ventricular ejection fraction less than or equal to 35% with a QRS duration greater than or equal to 120 milliseconds and drug-refractory New York Heart Association functional Class III or ambulatory Class IV heart failure who are receiving optimal medical therapy.¹¹⁰⁻¹¹²

Because of advanced heart failure these patients may be unable to lie flat on the electrophysiology table despite optimal medical therapy. Therefore, close monitoring of the patient's vital signs and oxygenation is extremely important. The skill of an anesthesiologist is needed to successfully administer conscious sedation and avoid cardiac decompensation during these long procedures. The procedure is frequently complex and lengthy due to positioning the left ventricular lead via the coronary sinus and great cardiac vein in the setting of distorted ventricular anatomy resulting from cardiac dilatation and advanced heart failure. In addition, valvular regurgitation may potentially further complicate lead positioning. Finally, lead dislodgement may occur immediately after lead placement, further prolonging these procedures.

Since implantation of biventricular pacing/ICD systems may precipitate development of refractory heart failure, the need for airway protection is critical, and the ability to intubate the patient is crucial to the success of the procedure and survival of the patient. Pneumothorax and coronary sinus perforation related to lead placement are also possible. Coronary sinus perforation can immediately be recognized by contrast extravasation. Perforation of the coronary sinus or cardiac perforation related to ventricular or atrial lead placement may lead to the development of cardiac tamponade. This necessitates immediate intraprocedure pericardiocentesis.

ANESTHETIC ISSUES: IMPLANTABLE CARDIOVERTER DEFIBRILLATORS AND BIVENTRICULAR PACEMAKERS

Many patients who qualify for these devices have multiple comorbidities, including a history of ventricular tachycardia/fibrillation, ejection fraction <30%, and coronary artery disease (these are indications for ICD placement).^{110,113} Other indications include arrhythmogenic right ventricular dysplasia, long QT syndrome, and hypertrophic cardiomyopathy.¹¹⁰

Most of these devices are placed with mild to moderate sedation and standard monitors. Testing the device requires deep sedation or general anesthesia. ICD placement and testing can be accomplished without an arterial line. External cardioverter/defibrillator pads are placed on the patient at the beginning of the procedure. When testing ICDs, they are used to induce ventricular fibrillation and to serve as backup if the implanted device fails.

Typically an implanted ICD is tested twice at the end of the procedure. Repeated testing is usually well tolerated without deterioration of ventricular function even in patients with ejection fractions <35%.^{114,115} In patients with evidence of untreated coronary disease, recent stent placement, or evidence of atrial or ventricular thrombus, testing is sometimes omitted. Significant coronary artery disease is a concern when testing with prolonged hypotension as a possible complication. It is important to remember that ICD testing is always an elective procedure should the patient demonstrate deterioration during implantation.²⁵

Some patients needing ICDs are also having biventricular pacemakers placed for cardiac resynchronization therapy.

Any patient scheduled for a biventricular pacemaker has extensive cardiac morbidity, including low ejection fractions, valvular heart disease, pulmonary hypertension, and right ventricular dysfunction. Patients may not be able to lie flat comfortably and can easily become hemodynamically unstable with sedation. Oversedation can lead to hypercapnia, which is problematic in patients with pulmonary hypertension and/or right ventricular dysfunction. The anesthesiologist must be ready to convert to general anesthesia at any time during the case. Coronary sinus lead placement for biventricular pacing can be difficult, making the procedure much longer than dual-chamber pacemaker and ICD placements. Complications from these procedures include possible cardiac injury (perforation/tamponade), myocardial infarction, stroke, and pneumothorax from the subclavian venous access.

RADIATION

Anesthesiologists need lead in procedure rooms where radiation is utilized. Unfortunately, it is all too common that they come to the CCL or EPL and have to dig through the available lead aprons usually worn by others because anesthesiologists are not considered part of the team. Yet many of the cases described involve significant radiation exposure during the procedure.

All radiation exposure should be “as low as reasonably achievable” during the procedure.¹¹⁶ Reductions in radiation time, distance from the source of radiation, and barriers to radiation are the three mechanisms to reduce exposure. Radiation time is under the control of the cardiologist performing the procedure. Many of the new and more complex procedures (device placement, percutaneous valves, biventricular pacemakers, ablations) require prolonged exposure to radiation.

Distance from the source of radiation and barriers to radiation are under the control of the anesthesiologist. The radiation beam attenuates based on the inverse square law ($1/d^2$).¹¹⁶ The strength of the beam decreases exponentially the farther away the anesthesiologist is from the radiation source. Barriers such as lead aprons and thyroid collars should be worn at all times. Even with proper leaded apparel, 18% of active bone marrow is still exposed to the effects of radiation.¹¹⁷ Lead shields should be used for additional protection. It is highly recommended to wear leaded eyeglasses to reduce the risk of cataracts. Every anesthesiologist spending time in the CCL or EPL should wear a dosimeter to track cumulative radiation exposure. A study by Katz in 2005 demonstrated that radiation exposure to an anesthesia department doubled after the introduction of an EPL.¹¹⁷

CONCLUSION

The anesthesiologist's patient safety record in the operating room is well documented. As procedures become more complex and the acuity of patients increase, safe and efficient care for the growing patient population in the CCL and EPL

is now a concern for all anesthesiologists and cardiologists. Anesthesiologists are uniquely trained to care for this complicated patient population, allowing the cardiologist to focus on successfully completing the interventional procedure. Anesthesiologists, in collaboration with cardiologists, must establish guidelines for their involvement in patient care and procedure planning in the CCL and EPL. We are in many ways victims of our own success. Increased numbers of more complicated patients, an ever-expanding arsenal of technologically sophisticated tools, and an aging population make it likely that the demand for CCL and EPL services will continue to grow. Collaboration between cardiologists and anesthesiologists is increasingly necessary. Reframing the boundaries between disciplines is the likely pathway to success. The goal is to improve patient safety and procedural efficiency while advancing the frontiers of medical care in an expanding and exciting new venue.

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20 | Anesthesia for In Vitro Fertilization

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In vitro fertilization (IVF) is a broad term used to describe the process of obtaining an egg and uniting it with sperm in a laboratory setting, and subsequently placing the fertilized egg into the uterus in hopes of achieving a live birth. In terms of anesthesiology, IVF primarily means oocyte retrieval. Historically the oocytes were retrieved laparoscopically. With the introduction of the vaginal ultrasound, the method of retrieval changed to a less invasive and costly procedure. Transvaginal ultrasound-guided oocyte aspiration changed the requirements of anesthesia. In this chapter, the anesthesia for oocyte retrieval and related IVF procedures are described.

INFERTILITY IN THE UNITED STATES

Infertility is defined as a couple of reproducing age who is unable to conceive for a given period of time, usually 1 year. With IVF, the infertile couple has a greater chance of a child.

CAUSES OF INFERTILITY

The causes of infertility include (fallopian) tubal factor, ovulatory dysfunction, diminished ovarian reserve, endometriosis, uterine factor, male factor (very low sperm count or abnormal sperm motility), other factor (not treatable by current available methods), and unknown factors. Women's infertility problems account for approximately for one-third of the infertility cases as does the male factor. The remaining one-third of cases are caused by a mixture of female and male problems or by unknown factors.¹

ASSISTED REPRODUCTIVE TECHNOLOGIES

Assisted reproductive technologies (ARTs) refer to all the techniques involving the direct extraction of eggs from the ovaries.² ART is the technique by which IVF is made possible. Advances in endocrine assays, controlled ovarian stimulation, hormonal manipulation, cryopreservation, ultrasonography, and procedures on eggs, sperm, and embryos have transformed IVF. The ART physician is a specially trained gynecologist in

reproductive medicine endocrinology. IVF usually refers to the process of oocyte retrieval and fertilization in the laboratory with the subsequent embryo transfer to the uterus. Intrauterine insemination (IUI) is the placement of prepared sperm into the endometrial cavity via a small catheter. Intracytoplasmic sperm injection (ICSI) is an ART procedure where a single sperm is injected into the retrieved ova. IVF also refers to other ART techniques such as gamete intrafallopian transfer (GIFT) and zygote intrafallopian transfer (ZIFT). The GIFT procedure involves the transfer of retrieved oocytes and washed sperm into the fallopian tube by laparoscopy. ZIFT laparoscopically transfers embryos into the fallopian tube. Since the introduction of the transvaginal ultrasound probe for oocyte retrieval, these technologies are rarely used. IVF-embryo transfer (IVF-ET) is a widely used term for transvaginal ultrasound guided oocyte aspiration and the subsequent transcervical embryo transfer.

THE IVF CYCLE

The IVF cycle consists of several ART steps over the period of approximately 2 weeks. The cycle is considered a series of treatments, rather than a procedure. The IVF cycle starts when a woman begins taking hormonal drugs to stimulate oocyte production, or starts ovarian monitoring with the intention of having embryos transferred. A successful IVF cycle starts either naturally, or with medication followed by the production of eggs. This is followed by egg retrieval. If fertilization is successful, then the next step is embryo transfer. If the embryo implants within the uterus, then pregnancy is achieved. This is followed by the delivery of one or more live births. The absence of egg production, excessive ovarian hyperstimulation, or other medical reasons may require the discontinuation of the cycle.

CONTROLLED OVARIAN HYPERSTIMULATION

Controlled ovarian hyperstimulation (COH) is an ART hormonal process through which the ovaries are purposely stimulated to develop more than one dominant follicle. This is

considered the start of an IVF cycle. Having multiple dominant follicles with eggs will increase the number of eggs retrieved and the likelihood of pregnancy from transferred embryos. The goal of COH is to promote the development of a relatively synchronous cohort of ovarian follicles so that the timing of egg retrieval can be made. A typical COH protocol uses a combination of a gonadotropin-releasing hormone agonist (GnRH-a), human menopausal gonadotropin (hMG), and human chorionic gonadotropin (hCG). Ovarian suppression and follicular variation are achieved with GnRH-a. The ovaries are monitored by serial ultrasound examinations and for low estrogen levels. Ovarian stimulation is begun with hMG. Serial follicular diameter and estrogen levels guide the timing of the administration of hCG. Oocyte retrieval is usually approximately 36 hours after the start of hCG. COH also achieves the development of the proper endometrial environment for the subsequent embryos to be transferred.³ The hormonal protocols vary from clinic to clinic, endocrinologist to endocrinologist, patient to patient, as well as individual patient hormonal response. COH is always carefully monitored with serial ultrasound examination to evaluate the follicle size and progression of hormonal blood levels.

OVARIAN HYPERSTIMULATION SYNDROME AND IVF SURGICAL RISKS

The ART of controlled ovarian hyperstimulation is not without adverse effects. Ovarian hyperstimulation syndrome (OHSS) is an iatrogenic consequence of COH. It is a serious and potentially life-threatening physiologic complication. Symptoms begin with abdominal bloating and progress to nausea, vomiting, and diarrhea. Lethargy and loss of appetite follow. Shortness of breath and decreased urine output may indicate accumulating ascites and increasing morbidity. The patient with moderate or severe OHSS may have signs of rapid weight gain, oliguria, hemoconcentration, leukocytosis, hypovolemia, electrolyte imbalance, ascites, pleural and pericardial effusions, adult respiratory syndrome, hypercoagulability and thromboembolic events, and multiorgan failure. OHSS should be self-limiting and regression takes place as long as prompt and appropriate supportive care is provided. Exogenous and endogenous human chorionic gonadotropin will worsen OHSS.⁴

Surgical risks for IVF transvaginal ultrasound-guided oocyte retrieval may include bleeding, infection, and injury to pelvic or abdominal organs. These surgical complications may require hospitalization and/or subsequent surgery. Oskowitz et al.⁵ reported on a series of 6776 procedures performed in a free-standing surgical facility dedicated to ART. They recorded the number of patients that required hospital admission during the first 24 hours after surgery. Of the 4199 vaginal oocyte retrieval procedures, seven were admitted. Two patients were of serious morbidity, defined as those that required major intervention such as a repeat surgery. Nausea and vomiting, syncope, hemoperitoneum, and ovarian hematoma were included in the admitting diagnoses.

ANESTHESIA FOR TRANSVAGINAL OOCYTE RETRIEVAL

Ultrasound-guided oocyte retrieval can be performed under a paracervical block, intravenous sedation, general, spinal, and epidural anesthesia. All have advantages and disadvantages. The literature concerning the effective anesthesia on the success of IVF should be interpreted with caution. Specific anesthetic drugs and techniques must be evaluated for their compatibility. Animal data may not reflect the human experience.⁶

UNITED KINGDOM AND UNITED STATES IVF ANESTHESIA PRACTICE EVALUATIONS

According to Elkington's postal questionnaire of ART centers in the United Kingdom, there are significant variations in personnel present during the procedure, the use of drugs, degree of monitoring, and the availability of emergency drugs.⁷ Eighty-four percent of the ART centers used intravenous sedation and 16% used general anesthesia for transvaginal oocyte retrieval.

Results from a Ditkoff et al.⁸ telephone survey in the United States of 278 ART programs revealed that 91 private (68%) and 41 academic (56%) programs used personnel from the department of anesthesiology. A large number of ART programs used their own trained personnel to provide sedation. Ninety-five percent of the transvaginal oocyte retrieval and transcervical embryo transfer were performed under conscious sedation. For the remaining 5%, general, regional, or local anesthesia was used. The majority of the IVF personnel typically used meperidine and midazolam. Ninety percent of the anesthesiology personnel used midazolam and/or propofol with fentanyl.

IVF PATIENT DEMOGRAPHICS

Although the majority of IVF patients are healthy adult women, overweight and morbidly obese patients are sometimes encountered. Other medical conditions common in this population include asthma and hypertension. Psychosocial disorders such as anxiety, depression, and stress secondary to the infertility status may be present. The women typically range in age from the late 20s to mid-40s.

THE IVF FACILITIES

According to Yasmin and colleagues⁹ postal questionnaire, 69% of the responding IVF centers perform oocyte retrieval outside of the general operating room environment. A typical IVF procedure room may be located within a university-based or free-standing fertility clinic. The embryology and andrology laboratories are usually adjacent to the procedure room for immediate processing of the oocytes and sperm. The IVF

anesthesiologist is required to be familiar with the IVF procedures, the fertility center's choice of sedation/analgesia and anesthesia, the individual surgeon's needs, and the needs of the IVF patient.

ANESTHESIA GOALS FOR IVF

The anesthetic goals for IVF oocyte retrieval and related procedures are effective pain relief and sedation, together with minimal postoperative nausea and vomiting. These goals should be executed in a safe manner. IVF goals also include the ease of administering intravenous medications and patient monitoring. The medications should be short acting and easily reversible. These drugs should minimally affect the oocytes, embryos, and endocrine or immune system. It is important to keep in mind that procedures are costly, and economic factors should be considered.¹⁰

ANESTHESIA CONSIDERATIONS

The anesthetic considerations for the IVF patient in the preprocedural period are foremost patient anxiety management. This unique population of patients may have stress, anxiety, and depression due to their infertile status. They may arrive with varying degrees of anxiety from the expectant wait of the oocyte or sperm retrieval. Empathy from all those involved in their care such as the IVF nursing staff, the procedure room staff, the embryologist, the reproductive medicine physician, and anesthesiologist is invaluable.

Preprocedural anesthesia concerns are minor due to the general health of the IVF patient. On occasion, airway issues can arise from patients who have a history of loud snoring, sleep apnea, or obesity. Any patient with a history of asthma or hypertension is usually medically compliant and well controlled. A history of postoperative nausea and vomiting (PONV), or motion sickness, should be elicited and reduction of baseline risks planned for and initiated. Pain management should be discussed with the patient.

Once in the procedure room, any airway issues should be communicated to the surgeon because the sedation level or anesthetic may be different than usual. Care and vigilance should be taken during the placement and care of the patient in the dorsal lithotomy position. Positioning while awake and not sedated ensures proper padding and positioning comfort of the patient. Adequate anesthesia and sedation should ensure an immobile patient to help avoid injury to pelvic vessels or organs.

ANESTHESIA RISKS

Apnea is a risk when administering intravenous (IV) agents, especially when combining two or more. Recognition and immediate treatment is therefore essential. Reducing the IV agents and providing a greater stimulus (chin lift or a painful jaw thrust) may help overcome the apnea. In a case of airway

obstruction, an oral or nasal airway insertion may be necessary. Bag/mask ventilation may become necessary if the patient experiences apnea. Opioid or benzodiazepine reversal should not be routinely used. Instead, the desired anesthetic level is achieved by careful titration of the IV agents to proper effect.

Patients at risk for aspiration should be identified. Aspiration needs to be recognized quickly, and suction should be readily available. Laryngospasm is a risk in the anesthetized and obtunded patient. Successful laryngospasm management includes early recognition followed by positive pressure ventilation and either the deepening of the anesthetic level, possible intubation, or waking up the patient. Hypotension from an anesthetic agent such as propofol is treated with generous fluid hydration. Vasopressors are rarely needed. Postoperative nausea and vomiting can be seen in this patient population and appropriate prophylaxis strategies should be employed.

THE IVF PROCEDURES

The most common procedure that requires anesthesia during an IVF cycle is the egg or oocyte retrieval. On occasion, an embryo transfer procedure will be scheduled with anesthesia. The dilation and curettage procedure is infrequently encountered. Additionally, the urologist incorporates MESA and TESE procedures into the IVF anesthesia schedule.

Oocyte Retrieval

The reproductive medicine surgeon selectively retrieves eggs from the individual ovarian follicles, which have been stimulated via controlled ovarian stimulation. Since the patient has been given hormonal drugs to induce the ovaries, there is a small window of time in which the eggs can be retrieved. Since oocyte retrieval is a specially scheduled and timed procedure, the anesthesia service should be available to accommodate these patients 7 days a week. The surgeon may request a dose of antibiotics for the patient with a history of tubal disease to prevent a pelvic infection.

The patient is positioned in the dorsal lithotomy. Once the patient is sterilely prepped, draped, and rendered immobile, the surgeon places a transvaginal ultrasound probe equipped with a long needle to aspirate the ovarian follicles. The aspirating needle is usually of a 16 or 17 gauge, which is then guided through the posterior vaginal wall to the ovary where each follicle is aspirated. Follicular fluid is aspirated into a test tube with culture medium. These test tubes are given to the embryologist, who then examines and counts the eggs. The oocyte retrieval is then continued on the contralateral ovary. The duration of this procedure is usually 5–10 minutes.

Embryo Transfer

Embryo transfer is an ultra-short IVF procedure. The process consists of transferring embryos from the laboratory to the patient's uterus. The patient is placed in the dorsal lithotomy

position with stirrups. The vagina is sterilely prepped. A small semi-rigid catheter containing the embryos is placed into the uterine cavity via the cervix. When the uterine anatomy is difficult or abnormal, an abdominal ultrasound may aid in this process. The catheter is then returned to the embryology lab to ensure the embryos are no longer in the catheter. Patients with difficult, or abnormal, cervical or uterine anatomy and those who are extremely anxious patients may require anesthesia.

Dilation and Curettage

The IVF patient is at a higher risk for increased miscarriage or abortion. The dilation and curettage (D&C) procedure in the outside-of-operating room (OOOR) environment such as IVF should be done only on select patients. A healthy patient of normal weight, normal coagulation, who is not excessively bleeding and is less than 12 weeks pregnant is ideal for D&C in the OOOR setting. Obese patients, those with a full stomach and patients with second trimester pregnancies should be reserved for the operating room.

The patient is in dorsal lithotomy with stirrups. The vagina is sterilely prepped and draped. The surgeon examines the uterus with the vaginal ultrasound to reconfirm the miscarriage. A vaginal speculum is inserted and the cervix is grasped with a clamp. The cervical canal is then dilated with progressively larger dilators. Utmost care is taken not to perforate the uterine cavity. The endometrial lining and products of conception are removed with the curette and the suction aspirate.

Sperm Retrieval Techniques

Microscopic epididymal sperm aspiration (MESA), percutaneous epididymal sperm aspiration (PESA), and testicular sperm extraction (TESE) are a few of the different sperm retrieval procedures that take place at an infertility center. These methods refer to certain cases of male infertility. These procedures are done by the urologist and are tailored to the individual couple's needs. The sperm that is obtained is then used in conjunction with intracytoplasmic sperm injection. MESA uses microsurgical techniques to obtain sperm from the epididymis. The TESE technique removes a small sample of testis tissue for extraction of sperm by the andrology lab. PESA uses a needle to draw sperm from the epididymis.

The male patient is in the supine position. The scrotum is sterilely prepped and draped. Local anesthesia is used. If the procedure is an open one, the urologist will use the operating microscope. The sperm retrieval usually lasts approximately 1 hour. The urologist may request anesthesia.

CRITERIA FOR SELECTION OF ANESTHETIC TYPE

The selection for anesthesia type will depend on the IVF center and surgeon's preference. This is seen by the variation in personnel and drugs used. The anesthesia provider should have input, especially in select patients who may have a

difficult airway, are obese, or have a history of PONV. Patient preference may not have a significant effect because most IVF centers usually have firmly established protocols.

ANESTHESIA FOR EGG RETRIEVAL: MODERATE SEDATION

Intravenous moderate sedation for transvaginal ultrasound-guided oocyte retrieval is reportedly the most used anesthetic type.⁸ This is usually accomplished by the IVF center's dedicated anesthesia group or its own personnel who are especially trained in administering moderate sedation. The personnel may include nursing staff and/or medical doctors who are trained and experienced in IVF procedures.

According to the American Society of Anesthesiologists (ASA), moderate ("conscious") sedation is defined as follows:

*A drug-induced depression of consciousness during which patients respond purposefully to verbal commands, either alone or accompanied by light tactile stimulation. No interventions are required to maintain a patent airway, and spontaneous ventilation is adequate. Cardiovascular function is usually maintained.*¹¹

Keeping in mind the goals of moderate sedation, the oocyte retrieval can be safely accomplished. The patient's chart is reviewed, including the nursing staff's preoperative assessment. This includes the medical and surgical history and the patient's medications and allergies. The height, weight, and baseline vital signs are noted.

The patient interview includes the NPO status, medical and anesthesia history, as well history of PONV or motion sickness. After the physical examination, the discussion of the sedation plan and the expectations of the periprocedure period are explained to the patient. This explanation helps alleviate some of the anxiety associated with the procedure.

The discussion should include the information that the patient will be sleepy yet responsive to tactile touch or voice for the evaluation of pain or discomfort. Reassure the patient that comfort and pain control are the goals of conscious sedation. The sedation consent is obtained. The IVF procedure team readiness is checked so that the patient can be brought into the procedure room. This is necessary because the embryology laboratory also participates in this procedure by accepting the collected eggs and reports the egg count intraprocedurally. Once in the procedure room, the nursing staff will identify the patient, and the embryologist will follow a similar patient identification process.

The patient is positioned supine on the operating room table. The routine monitors and an intravenous catheter are placed. Oxygen is usually provided via a nasal cannula. As soon as the intravenous is in place, the patient is repositioned to the dorsal lithotomy position with perineum positioned at the edge of the operating room table just like during a vaginal examination.

Once the patient reports no discomfort in this position the sedation is started. The opioid is usually the first agent given because the goal of sedation is pain management during the

oocyte retrieval. The opioid most frequently used is fentanyl. The usual dose of fentanyl is in the range of 50 to 100 micrograms, intravenously.⁷ Once fentanyl titration is begun, then the anxiolytic is administered. The most common agent is a benzodiazepine, such as midazolam or diazepam. This agent is also titrated to the desired effect: the patient is relaxed and sleepy yet responsive to light tactile touch and voice.

Once the desired sedation level is achieved, the surgeon places the vaginal ultrasound into the vagina. Both ovaries are examined and the physician reports a gross estimate of eggs to be retrieved. The usual conversation is as follows: “she has a lot of eggs (young patient), she has a few eggs (older patient), or there is only one ovary.” This report helps gauge the length of time expected for retrieving eggs. The placement of the probe can be very stimulating when the ovaries are difficult to visualize and maximal pressure is applied into the posterior vaginal wall. The next stimulus is the puncture through the vaginal wall into the ovary and follicles. A 16- or 17-gauge needle is used alongside of the vaginal probe. Each follicle that is visualized is aspirated until there are no follicles left in the ovary. This procedure is then repeated on the contralateral ovary. Once the retrieval is complete, the probe is used to evaluate the ovaries for possible bleeding, or surrounding vessel and tissue injury. Finally, the probe is withdrawn. A vaginal speculum is then placed to evaluate for bleeding or vaginal wall injury. Pressure is typically held at the vaginal wall puncture sites for a minute. Usually no additional medication is needed at this point because the inspection of the vagina may not be uncomfortable or painful. If the surgeon needs to place a suture, or hold extensive vaginal pressure, additional narcotics may be needed as well as further verbal reassurance. Once there is no bleeding, the patient is brought to a more awake state. The patient is then transferred to a gurney and transported to the adjacent postprocedure room.

GENERAL ANESTHESIA

Anesthesiologists use general anesthesia (most commonly total intravenous anesthesia) extensively during IVF procedures. The most commonly used drug for general anesthesia is propofol as reported by Ditkoff.⁸ This type of anesthesia may need airway support, but it rarely requires endotracheal intubation. The support of the airway is generally assisted with minimally invasive maneuvers such as a chin lift or jaw thrust. On occasion, a nasopharyngeal airway may be needed in the patient who snores, has a small chin, or is obese. The goals of this type of anesthetic are an immobile, or nearly immobile, patient, who is unconscious. Associated risks such as apnea, aspiration, laryngospasm, or hypotension need to be considered. Therefore, the especially trained anesthesiologist is required, and expert airway management is essential. In this anesthetic, plans for emergency management of the airway include having equipment available in the procedure room. A laryngoscope, various sizes of blades and endotracheal tubes, and a self-inflating type of bag-mask should be present.

After careful review of the IVF patient chart and the check of NPO status, the interview focuses on medical and

anesthesia issues, and a focused airway examination is performed. A past history of PONV, pain management treatment, and any vasovagal events are noted.

The goals of the anesthetic are discussed, and a brief description of the procedure and postprocedure anesthesia plan is outlined. This overview is very much appreciated by the IVF patient and may alleviate some of the preprocedural anxiety. The oocyte retrieval anesthesia consent is obtained. Once the procedure team, which includes the embryologist, is ready to proceed, the patient is brought into the procedure room. The patient identifications are obtained by the IVF nursing staff and the embryologist. The patient is placed supine on the operating room table. The routine monitors that are placed include a continuous electrocardiogram, pulse oximetry, noninvasive blood pressure, and CO₂ analysis. An intravenous catheter is placed. The patient is repositioned into the dorsal lithotomy with the perineum at the edge of the table. Pressure points and any discomfort are checked and relieved. Oxygen is administered by a nasal cannula. Once the patient position is complete, the anesthetic is begun with the narcotic. Fentanyl is titrated along with the hypnotic agent propofol by boluses or continuous infusion. The usual required doses of fentanyl range from 75 to 150 micrograms with the most common total being 100 micrograms. A small dose of lidocaine is usually administered along with the start of the propofol when the intravenous catheter is in place. Lidocaine is not required when the intravenous catheter is located at the antecubital area in a large vein.

The surgeon is allowed to start once the patient has been rendered unconscious and immobile. There are two potentially stimulating portions of the IVF-oocyte retrieval. The first stimulus is the placement of the vaginal probe deep into the vagina to examine the ovaries and its follicles. The second stimulus is the puncture of the vaginal wall and ovarian follicle with the 16- or 17-gauge aspirating needle. This procedure is repeated until all the follicles have been aspirated and then continued on the contralateral ovary. Once the aspiration is completed, the ovaries and surrounding tissue and vessels are examined by ultrasound for bleeding or injury. The probe is removed and replaced with a vaginal speculum for inspection of the posterior vaginal wall for bleeding or injury. On occasion, a bleeding puncture site may need a suture or maximal tamponade with pressure. If this is the case, the patient is kept asleep until the vaginal wall examination is completed.

The patient is awakened at the end of the procedure and asked to move to the awaiting gurney. The patient is transported to the adjacent recovery room. The dedicated recovery room nursing staff is given report and monitors the patient until discharge is completed.

INTRAVENOUS GENERAL ANESTHESIA FOR EMBRYO TRANSFER

At times, the IVF patient will request anesthesia for the transcervical embryo transfer. The main reason is to alleviate the procedural anxiety and discomfort of the vaginal speculum and cervical stimulation. Usually the IVF center will administer an oral benzodiazepine for those with mild to moderate

anxiety because the patient is kept “awake” for this very short, yet anxiety-provoking event. The reproductive medicine physician will request anesthesia for the patient with a difficult cervical or uterine anatomy. Having the patient under for a brief period of deep anesthesia will facilitate the maneuvering of the small plastic catheter containing the embryos into the uterus. The embryo transfer is facilitated by the simultaneous use of the abdominal ultrasound by an assistant to visualize the uterine cavity. This ultra-short procedure is not very stimulating or painful; therefore, the use of short-acting agents is encouraged.

The patient chart is reviewed and the history and physical exam are obtained. The goal of the anesthetic is discussed with the patient. Patient safety, comfort, and anxiolysis are emphasized. Describing the anesthetic/IVF procedure helps ease some of the pre-procedure anxiety.

In the procedure room, the patient identification is verified by the nurse and again by the embryologist. The patient is positioned supine on the operating table. The routine monitors and an intravenous catheter are placed. Then the patient is repositioned into the dorsal lithotomy position. Pressure points are padded and checked. The anesthesia is started during the vaginal wash, which also includes the placement of a vaginal speculum by the procedure technician. Deep sedation/general anesthesia can be accomplished with a combination of fentanyl and propofol. Approximately 50 micrograms of fentanyl is titrated along with 75 to 150 milligrams of propofol. Care is taken to keep the patient breathing spontaneously, deep, and immobile for the embryo transfer.

ANESTHESIA FOR DILATION AND CURETTAGE

From time to time the IVF anesthesiologist will be scheduled to administer an intravenous. Deep sedation or general anesthesia for a missed abortion. This is not unusual because the IVF patient has a higher risk for a missed abortion. The ideal patient for a D&C in the OOR environment is a healthy patient of normal weight. This should not include the morbidly obese individual or a patient with a coagulation abnormality or difficult airway. Additionally, the patient should not be past 12 weeks gestational age or considered to be a “full stomach”. These more challenging patients should be scheduled in an operating room facility equipped to handle these situations. They may need general anesthesia with an endotracheal tube, a regional anesthetic and or blood products available. Few reproductive medicine surgeons may elect to do the D&C without the anesthesiologist’s presence. In these instances, the surgeon may provide moderate intravenous sedation together with a paracervical block.

The patient’s chart is reviewed with emphasis on the reason for the D&C and the approximate gestational age. The laboratory work is reviewed for the hematocrit, platelet, and blood type. When an Rh-negative woman carries an Rh-positive pregnancy, Rhogam is given to prevent the woman’s immune system from reacting to Rh-positive blood of any subsequent pregnancy.

The goals of the anesthetic are reviewed with the patient. Safety and comfort are emphasized. Empathy and reassurance helps with the preprocedural anxiety.

The anesthesia setup should include an emergency intubation kit and vasoactive drugs. Major surgical risks include uterine bleeding and perforation. A dose of antibiotic will be requested by the reproductive medicine surgeon. The most stimulating part of the D&C is the serial dilation of the cervical os and canal.

In the procedure room, the nursing staff verifies the patient identification. The patient is positioned supine onto the operating room table. The routine monitors are placed. A minimum of 20-gauge IV catheter is placed. The patient is then repositioned in the dorsal lithotomy with perineum at the lateral edge of the table. Pressure points are checked for any discomfort. Oxygen is administered via a nasal cannula. A small dose of midazolam is given for anxiolysis and amnesia. A few minutes later fentanyl is titrated in doses of 25 micrograms. The usual required doses of fentanyl range from 50 to 100 micrograms, with the most common total being a 100 microgram dose. Propofol is usually administered in a bolus (250–500 mcg/kg) followed by an infusion (25–75 mcg/kg/min) to induce hypnosis yet keep the patient spontaneously breathing with minimal airway assistance. The duration of the D&C procedure is usually short, lasting from 10–20 minutes.

IVF POSTANESTHESIA CARE UNIT CONSIDERATIONS

The postanesthesia care unit (PACU) or recovery room stay of the IVF patient care has a few, yet very important considerations. In the designated recovery area, the patient care is transferred to the assigned recovery room nurse. The patient care transfer begins with proper patient identification, followed by a description of the procedure, the anesthetics used, drug allergies, and antiemetics, antibiotics, and fluids administered. Anesthesia or surgery-related complications encountered are communicated. Pertinent IVF patient details such as history of PONV, extreme preprocedural anxiety, large amounts of anesthetics required intraoperatively, retrieval of no eggs, and few eggs or many eggs should be communicated. This information will help patient management. A young patient or egg donor with many eggs retrieved will most probably require additional analgesic care in the PACU.

Upon arrival to the PACU, attention is focused on the oxygenation, ventilation, and circulation by monitoring the pulse oximetry, breathing frequency, airway patency, systemic blood pressure, and heart rate. Supplemental oxygen and suction should be readily available. The vital signs are recorded at the very least every 15 minutes while in the recovery room. Initially in the PACU, care may be directed toward the need for airway support for a sleepy patient. This is treated by patient stimulation and a chin lift. Initial hypotension is usually secondary to the propofol anesthesia and is self-limiting. Continuing the IV fluids and awakening the patient usually resolve the hypotension. Moderate to severe pain on admission should be immediately treated with intravenous fentanyl; discharge may be otherwise delayed secondary to increasing pain or PONV.

IVF patients usually stay in the PACU from 90 to 120 minutes.⁸ Typical causes for a delay in the discharge from the

recovery room are abdominal cramping or pain, PONV, a vasovagal event, or delay in urination.

The approach to the treatment and relief of abdominal or pelvic pain in the IVF patient is to first identify what type of pain the patient is experiencing and where it is located. Usually it is on one side and is cramping in nature. It is also important for the anesthesiologist to quantify the amount of pain experienced in order to follow the treatment success. Moderate to severe pain is treated with opioids, while mild pain is treated with nonopioids such as acetaminophen. Reassurance also helps. Any unrelenting pain should be evaluated by the reproductive medicine surgeon. The evaluation involves talking to the patient, a physical examination, and possibly a pelvic ultrasound. A full bladder also may be responsible for ongoing abdominal pain. If this is the case, the patient is encouraged to urinate; otherwise the patient may undergo straight catheterization of the bladder.

PONV considerations actually start during the preprocedure period. The recognition that the IVF population is at risk is the first step.¹² Furthermore, the identification of the high-risk PONV individual is extremely important for patient safety, satisfaction, and efficiency. By identifying the individual in need of prophylactic antiemetic therapy, patient care and satisfaction can significantly improve. According to Apfel,¹³ the four primary risk factors for PONV are female gender, nonsmoking status, a history of PONV, and opioid use. The typical IVF patient has at least three of the four risk factors. A history of PONV and motion sickness can be specifically determined during the patient interview. Asking about prior anesthesia complications is not sufficient to identify these patients. Though the IVF procedures are short, it is imperative to identify the individuals so PONV risk reduction strategies can be initiated. These include reduction in preprocedural anxiety, aggressive intravenous hydration, supplemental oxygen, and total intravenous anesthesia with propofol. PONV antiemetic prophylaxis coupled with these strategies is known as a multimodal approach.¹²

PONV risk reduction begins with a calming and reassuring interview and plan. Intravenous hydration is started intraprocedurally and continued in the PACU. Oxygen is administered during the procedure, and prophylactic antiemetics are given to select patients such as those with a history of PONV and motion sickness. Additionally, a patient with many aspirated follicles and an increased opioid requirement will benefit from prophylactic antiemetics.

When PONV occurs in the PACU and the patient has not received prophylaxis, a 5-hydroxytryptamine (serotonin) receptor 3 (5-HT₃) antagonist such as ondansetron should be administered. Aggressive intravenous fluid administration should be verified as ongoing and a vasovagal event eliminated. In the event that PONV prophylaxis with a 5-HT₃ antagonist is found to be inadequate, an additional dose of a 5-HT₃ antagonist should not be used as a rescue agent because it does not give additional benefit when used within the first 6 hours after surgery.¹⁴ Compazine, droperidol, dexamethasone, or metoclopramide has been used for PONV rescue.

On occasion, a patient may experience lightheadedness and nausea as a result of becoming bradycardic and hypoten-

sive. This vasovagal event should be immediately identified and treated. Placing the patient in the supine position and administering a bolus of crystalloid fluid should suffice. Symptoms usually resolve quickly. If bradycardia accompanied by hypotension persists, a dose of atropine should be administered. Cramping pain may be responsible for the vasovagal event and should be treated.

Rarely, brisk vaginal bleeding is observed in the PACU. If this is the case, the reproductive medicine surgeon should evaluate the patient. This may involve a trip back to the procedure room for a thorough vaginal examination. Persistent hypotension is rarely seen but should be evaluated as well by the reproductive medicine surgeon.

The IVF nursing staff documents the patient PACU course. Once the PACU criteria for discharge are met, the patient and the adult escort are given written discharge instructions. A postprocedure follow-up call is made the following morning by the nursing staff.

CONCLUSION

The oocyte retrieval is a very important part of the IVF cycle. Transvaginal oocyte retrieval is increasingly being performed outside of the operating room. Moderate "conscious" sedation is most commonly used for egg retrieval in the United States and the United Kingdom, although the trend is towards greater involvement of an anesthesia professional and more cases performed under deep sedation and general anesthesia. There is variability in personnel and medications used. A significant number of IVF centers are providing their own sedation team. The best sedation and anesthetic practices have yet to be proven.

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21 | Anesthesia for Urologic Procedures

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Thirty years ago, removal of a kidney stone meant a large incision, possible need for blood transfusion, potentially a week-long hospitalization, and risk of significant morbidity.⁴ With improvement in surgical technique and available technology, surgeries performed in offices tripled from 400,000 to 1.2 million per year from 1984 to 1990.^{6,7} Maximizing cost and time efficiency, improving patient outcome, and minimizing recovery and hospitalization time became a focus of many anesthetic practices throughout the United States.

Because more procedures are being performed in outpatient and outside of the OR (OOOR) settings, it is important for the anesthesiologist to not only provide an optimal anesthetic for these patients but also ensure patient and personnel safety. This chapter will discuss anesthesia for common urologic outpatient/OOOR procedures, including cystourethroscopy, ureteroscopy, transurethral procedures except TURP, laser use, percutaneous renal procedures, and extracorporeal shock wave lithotripsy.

PREOPERATIVE CONSIDERATIONS

Urologic procedures comprise 10%–20% of most anesthetic practices and include patients of all ages. Particularly high-risk individuals (i.e., known difficult airway, severe aortic stenosis, morbid obesity) may not be candidates for outpatient surgery or offsite anesthesia and should have their procedures performed in a more controlled environment. Patients of any age undergoing urologic procedures should be evaluated preoperatively for renal insufficiency.

Some specific patient populations frequently present for outpatient and/or OOOR urologic procedures and require special anesthetic considerations and will be discussed here. Elderly patients must be evaluated for coexisting diseases, including coronary artery disease, pacemaker or AICD history, peripheral vascular disease, cerebrovascular disease, congestive heart failure, and chronic obstructive pulmonary disease. The risk of acute renal dysfunction is amplified by certain patient characteristics often associated with advancing age (see Table 21.1), specifically after shock wave lithotripsy. These conditions should be evaluated, documented, and optimized if possible.

Paraplegics and quadriplegics have a high rate of recurrent nephrolithiasis and instrumentation^{8,9} and require special consideration. Preoperatively, the anesthesia team must have a high suspicion for autonomic hyperreflexia, spastic contractures, and chronic infections, including pressure sores,

recurrent urinary tract infections, and pneumonia. If muscle relaxants are to be used, resistance to nondepolarizing muscle relaxants may be present secondary to denervated muscle containing an increased number of extrajunctional acetylcholine receptors. Patients with denervated muscle are at higher risk for hyperkalemia and subsequent risk of cardiac arrest when succinylcholine is used. In addition, renal insufficiency may worsen after succinylcholine use due to increased myoglobin release from atrophied muscle.

Pediatric patients may also present for outpatient/OOOR urologic procedures. Effective and safe use of percutaneous lithotripsy and nephrolithotomy, holmium laser, and even shock wave lithotripsy have each been demonstrated in the pediatric and infant populations.¹⁰ Cystoscopy is often performed in children with vesicoureteral reflux and patients with congenital kidney malformations; these patients may have associated syndromes or genetic defects.^{11,12} A history of associated congenital anomalies should be pursued, even though the external features may be subtle; this is particularly true for cardiac and craniofacial abnormalities because the potential for cardiac complications or a difficult airway is not adept to the OOOR environment. If a complicated medical history or suspected difficult airway is anticipated, the anesthesiologist should rethink the benefit/risk ratio of performing the procedure in the outpatient/OOOR milieu.

Therapies started by the urology team for most nonobstructed patients prior to the procedure include a high fluid intake (2–3 liters), as well as pain medications and antibiotics. Certain patients should receive intravenous prophylactic antibiotics^{13,14} before endourologic procedures (Table 21.2) or may already be receiving scheduled antibiotics. Percutaneous nephrolithotomy (PCNL) is considered clean-contaminated, and prophylactic antibiotics are recommended in all patients.¹⁵ Typically cephalosporins are given for PCNL to cover *S. epidermidis*. Patients requiring SBE prophylaxis typically receive gram-positive and gram-negative coverage, most often with gentamycin and ampicillin.¹⁶

PREOPERATIVE PAIN CONTROL

Renal colic is a phenomenon caused by increased ureteral peristalsis in the setting of a partial obstruction. It is characterized by intense flank pain with radiation to the groin. Prostaglandins are often released to aid in stone passage, along with bradykinins which sensitize nociceptors to stimuli.

TABLE 21.1. *Risk Factors for Acute Renal Side Effects after Shock Wave Lithotripsy*

Age
Obesity
Coagulopathies
Thrombocytopenia
Diabetes mellitus
Coronary artery disease
Peripheral vascular disease
Preexisting hypertension

Source: This table was published in *Campbell-Walsh urology*. 9th ed., Vol. 2. Copyright Elsevier 2007.

These induce pain and visceral responses such as nausea and vomiting.¹⁷ Parenteral opioids, particularly meperidine, have been the mainstay of treatment. Morphine has been traditionally avoided because of its propensity to increase smooth muscle tone and peristaltic activity of the ureter, whereas meperidine has been the agent of choice secondary to its mild, atropine-like antispasmodic effect. However, recent studies have shown no difference in analgesic efficacy between the two agents.¹⁸ Nonsteroidal anti-inflammatory agents such as ketorolac have been shown to be equal in efficacy to narcotics in these patients.^{19,20} There have been studies to support the use of anticholinergics to reduce pain with renal colic.²¹ Studies have been mixed regarding the efficacy of calcium channel blockers.²²

EMERGENCY EQUIPMENT

When called to administer anesthesia in the lithotripsy suite, office, or other offsite location, it is prudent to have all emergency equipment available, including a crash cart, emergency medications, and airway equipment. Airway equipment

TABLE 21.2. *Diagnoses That Warrant Prophylactic Intravenous Preoperative Antibiotics*

<i>Proximal or impacted stone</i>
<i>Preoperative stent, catheter, nephrostomy tube</i>
<i>High-risk comorbidities</i>
<i>Immunosuppression</i>
<i>Diabetes</i>
<i>Presence of urinary stasis</i>
<i>HIV</i>
<i>Malignancy</i>
<i>Malnourishment</i>

Source: This table was published in *Campbell-Walsh urology*. 9th ed., Vol. 2. Copyright Elsevier 2007.

should include appropriately sized laryngeal mask airways, oral airways, laryngoscopes, endotracheal tubes, and suction as well as an oxygen supply and manual ventilation equipment. Should complications arise, the anesthesia provider should realize that many outpatient surgery centers and OOR environments may lack certain facilities such as a laboratory, blood bank, and inpatient care. In addition, the outpatient/OOR staff may need more direction regarding complicated patient care, especially in a crisis situation.

PATIENT POSITIONING

The most common position for patients undergoing outpatient/OOR urologic procedures is supine; however, lithotomy position is also commonly encountered. In lithotomy position, however, there are physiologic changes and dangers to the patient that the anesthesiologist needs to consider. While positioning the patient, two persons should move the legs simultaneously, securing the ankles into position with a strap. Ensure that the lateral or medial thigh does not rest on the strap, because this may result in injury to the common peroneal or saphenous nerve,^{23,24} respectively. If the thigh is excessively flexed at the groin, obturator and femoral nerve injury may result. There is a risk of compartment syndrome of the lower extremity if prolonged time is spent in lithotomy position.^{23,25} It is important to pay careful attention to the patient's fingers because they are in danger of being crushed between the lower and center sections of the mechanical operating room table. Physiologic alterations with lithotomy position include decreased functional residual capacity (FRC), resulting in atelectasis and hypoxia. Increased venous return and preload and increase in mean arterial pressure can be anticipated in lithotomy as well; these effects dissipate once the legs are lowered.

For percutaneous nephrolithotomy, nephrostomy, nephroscopy, and lithotripsy procedures, the patient may be in prone or flank position. Ensure that pressure points are padded, extremities are not hyperextended, and adequate eye care is given, because injury to these structures is not only harmful to the patient but will delay patient discharge from the recovery room. Other physiologic changes and specific risks pertaining to supine, prone, and flank positions can be reviewed in other sources.²⁴

UROLITHIASIS

The most common indication for a majority of these procedures is urolithiasis. The incidence is estimated to be 10%–15% of all people during their lifetime^{26,27}; men are three times more likely to be afflicted than women.^{28–30} Although any age can be afflicted, urolithiasis is most likely to occur in the fourth to sixth decade.^{27,28,31} Pediatric incidence is approximately one-tenth that of adult incidence, but it is thought to be increasing in prevalence.³² Decision for type of surgical intervention is dependent on stone composition, size, and location.

Anesthetic requirements may be influenced by stone composition. Because stones composed of cystine, calcium oxalate, brushite, and uric acid are hard, they are more likely to require retreatment, and higher levels of shock wave energy during lithotripsy. Higher levels of energy may cause more pain, leading to increased anesthetic requirements in these individuals. Stone composition, occurrences, and associated conditions can be reviewed in Table 21.3.

UROENDOSCOPIC PROCEDURES

The most commonly performed outpatient/OOOR urologic procedure is cystoscopy. Common indications, surgical time, blood loss, morbidity, and mortality for this procedure are listed in Table 21.4.

Often transurethral procedures may be performed via cystoscope or ureteroscope. A resectoscope may be used for some transurethral procedures. A resectoscope is a cystoscope that has both cutting and cauterizing functions and is capable of resecting tumor. Commonly encountered procedures include bladder biopsy, retrograde pyelograms, extraction or laser lithotripsy of renal stones, as well as stent placement for stricture or tumor. We will not discuss transurethral resection of the prostate (TURP) in this section. If additional transurethral procedures are planned, procedure time and morbidity increases significantly (see Table 21.4). Specifically, bladder perforation is a serious complication of this procedure and the anesthesiologist should be aware of its presentation. Bladder perforation in the awake patient will present as shoulder pain. Under general anesthesia, bladder perforation may initially present as hypertension and tachycardia. Hypotension has also been a described phenomenon in bladder perforation.

ANESTHESIA FOR ENDOUROLOGIC PROCEDURES

Local anesthesia alone is the typical agent used for simple cystoscopy and ureteroscopy, particularly in office settings. However, a few recent studies have shown no benefit in using lidocaine gel over simple lubricant.³⁶⁻⁴⁰ If the patient requires additional sedation, preferred agents include midazolam,

TABLE 21.3. *Composition of Renal Stones and Anesthetic Implications*

Type	Occurrence	Notes
Calcium oxalate	60%	Associated with primary hyperparathyroidism, hypercalciuria, sarcoidosis, cancer, resistant to fragmentation
Calcium phosphate (hydroxyapatite)	20%	Associated with chronic UTI and alkalemic urine
Uric acid	7%	Associated with acidic urine, gout, radiolucent
Cystine	1%–3%	Associated with cystinuria, higher risk for renal loss with procedures; resistant to fragmentation
Struvite	7%	Associated with UTI due to urea splitting bacteria; may release endotoxin if fragmented ^{34,35}
Brushite	2%	Resistant to fragmentation

Note: Other rare causes of stones include 2,8 dihydroxyadenine, silica, triamterene.

UTI, urinary tract infection.

Source: From Pearle MS, Pak YC. Renal calculi: a practical approach to medical evaluation and management. In: Andreucci VE, Fine LG, eds. *International yearbook of nephrology*. New York, NY: Oxford University Press; 1996: 69.

nitrous oxide,⁴¹ propofol, and short-acting opioids. If interventions such as tumor resection are planned in addition to uroendoscopy, often local with light sedation will be inadequate. If so, general anesthesia is performed, often with short-acting agents and a laryngeal airway mask (LMA). Children typically require general anesthesia for all urologic procedures depending on age and developmental level, and mask technique or LMA is generally satisfactory. Please note that it is important, particularly in children, to maintain a relatively deep plane of anesthesia prior to insertion of the cystoscope because urethral stimulation may precipitate laryngospasm (Breuer-Lockhart reflex).⁴²

Although rarely necessary, regional anesthesia and neuraxial techniques may be chosen for this procedure. Most recent

TABLE 21.4. *Indications, Surgical Time, Blood Loss, Morbidity, and Mortality for Cystoscopy and Transurethral Procedures (Except TURP)*

	Indications	Surgical Time	Blood Loss	Morbidity	Mortality
Without transurethral intervention	Hematuria, hemmorrhagic or interstitial cystitis, recurrent UTI, renal calculi, hydronephrosis, BPH, cancer, stricture	15–30 min	Minimal	5% infection <5% ureteral perforation	<1%
With transurethral intervention	Same	1 hour	100 cc	10% bleeding, 5% infection, 2% bladder perforation	<1%

BPH, benign prostatic hyperplasia; TURP, transurethral resection of the prostate; UTI, urinary tract infection.

Source: From Harcharan S, Freiha FS, Deem SA, Pearl RG. Diagnostic transurethral (endoscopic) procedures. In: Jaffe RA, Samuels SI, eds. *Anesthesiologist’s manual of surgical procedures*. 3rd ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2004: 696–699.

studies have shown that neuraxial techniques prolong recovery time and delay time to discharge when compared to intravenous sedation or general anesthesia.^{43,44} However, these may still be used if a patient is a poor candidate for sedation or general anesthesia, transurethral procedures are to be performed, or patient intolerance prevents adequate analgesia with local. A transrectal periprostatic block alone has recently been shown to be inadequate analgesia as a lone anesthetic for transurethral manipulations.⁴⁵ For neuraxial anesthesia, a T10 sensory level is necessary to provide analgesia for bladder manipulations (cystoscopy), while a T8 level is required to provide analgesia to the ureters (ureteroscopy). Please note that if a neuraxial technique is chosen, the obturator reflex is not abolished; this reflex is characterized by external rotation and adduction of the thigh after stimulation of the obturator nerve by electrocautery through the bladder wall.

PERCUTANEOUS RENAL PROCEDURES

Percutaneous nephrolithotomy, nephrostomy, or nephroscopy may be infrequently performed in the OOR setting. These patients are often admitted for at least 24 hours postoperatively. Typically PCNL or percutaneous nephrostomy is performed for relief of renal obstruction, particularly when it involves the renal pelvis or calyx. Surgical time, blood loss, morbidity, and mortality for this procedure are listed in Table 21.5. Urologists may use electrocautery, shock wave or laser lithotripsy, and ultrasound or fluoroscopy for guidance. A stab wound incision is made and a nephrostomy tube may be placed. Typically, a high volume of irrigant, usually 0.9% saline is used to disperse heat, remove stone fragments, and prevent obstruction. If a nephrostomy tube or bladder catheter is placed, the patient may require flushing of the Foley catheter or nephrostomy tubes postoperatively to prevent obstruction and clear blood clots.

Complications other than those listed in Table 21.5 may include trauma to the spleen, kidney, liver, or colon, so one must be aware of the potential for acute blood loss. If access above the 12th rib or a cephalad kidney is necessary, pleural injury is possible. If irrigant is absorbed intravenously, a TURP-like syndrome, including fluid overload and electrolyte abnormalities, may be observed.^{46,47} Fluid may be extravasated into the pleural space leading to pleural effusion and hydro-pneumothorax, or into the retroperitoneal or intraperitoneal spaces. Monitoring fluid intake in comparison to output is particularly important, and the anesthesiologist should have a high index of suspicion for these complications once the discrepancy is greater than 500 ml.

Anesthetic choice for PCNL is often general anesthesia with an endotracheal tube, particularly if prolonged time in the prone position or need for paralysis is anticipated. Local anesthesia, an intercostal block, or a paravertebral block may be used as an adjunct for pain control. Neuraxial techniques are a viable option, but again, they may delay discharge and will require a relatively high sensory level, approximately

TABLE 21.5. *Indications, Surgical Time, Blood Loss, Morbidity, and Mortality Associated with Percutaneous Nephrolithotomy*

<i>Indications</i>	<i>Surgical Time</i>	<i>Blood Loss</i>	<i>Morbidity</i>	<i>Mortality</i>
Renal obstruction	2–3 hours	500 cc	10% bleeding, 5% infection, 2% bladder perforation, 2% retained stones	<1%

Source: From Harcharan S, Freiha FS, Deem SA, Pearl RG. Diagnostic transurethral (endoscopic) procedures. In: Jaffe RA, Samuels SI, eds. *Anesthesiologist's manual of surgical procedures*. 3rd ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2004: 697–698.

T6. Of note, regional and neuraxial anesthesia may not attenuate the vasovagal reaction associated with distention of the renal pelvis.

LASER USE IN UROLOGY

Light amplification by stimulated emission of radiation (LASER or, more commonly, laser) use is also frequently encountered in urologic surgery. Specifically, it is used in treating the following conditions: renal calculi, condyloma acuminatum of external genitalia and urethra, ureteral strictures or bladder neck contractures, interstitial cystitis, benign prostatic hyperplasia (BPH), superficial carcinomas of the penis, bladder, ureter, and renal pelvis. There are several advantages to laser therapy, including minimal blood loss, decreased postoperative pain, and tissue denaturation. Several common types of laser and their indications can be found in Table 21.6. The anesthesiologist's role during laser surgery is to ensure that all personnel and the patient are safe to proceed with laser use.

Between January 1989 and June 1990 there were 21 injuries reported to the U.S. Food and Drug Administration (FDA): 2 were minor, 12 were serious, and 7 were fatal.⁴⁸ The hazards associated with laser use can be divided into four major categories:

1. Atmospheric contamination
2. Perforation of vessel or structure⁴⁹
3. Embolism (associated with hysteroscopic surgeries)⁵⁰
4. Inappropriate energy transfer

With regard to inappropriate energy transfer, there have been case reports of lasers igniting fires and causing thermal injury to patients, personnel, surgical drapes, and endotracheal tubes.^{51,52} Risk of airway fire exists in any procedure room where oxygen is in use. Appropriate caution in avoiding direct laser contact and minimizing oxygen concentrations when possible is of paramount importance.

TABLE 21.6. *Commonly Used Lasers in Urologic Surgery: Advantages and Special Notes*

<i>Laser Type</i>	<i>Advantages</i>	<i>Notes</i>
CO ₂	Useful in cutaneous lesions; minimal tissue penetration	Unable to penetrate water
Argon	Used for coagulation of bleeding	Poorly absorbed by water, absorbed by hemoglobin and melanin
Holmium:YAG (pulsed dye)	Photothermal mechanism, works via vaporization of water, good cutting effect with poor hemostasis; used often to fragment calculi	Safe, effective. Capable of cutting through metal, e.g., endoscopes, guide wires
Nd-YAG (Neodymium-yttrium-aluminum-garnet)	Little heat generation, good deep tissue penetration, and protein denaturation	Beam is carried over bare wire through rigid ureteroscope; risk of ureteral perforation; GA preferred to stop patient movement
KTP-532 (Potassium-titanium-phosphate)	Frequency doubled Nd-YAG; better at cutting with less deep tissue penetration	Can be used in water or urine without loss of effectiveness

Source: Data taken from Fitzpatrick JM. Minimally invasive and endoscopic management of benign prostatic hyperplasia. In: Wein AJ, Kavoussi LR, Novick AC, Partin AW, Peters CA, eds. *Campbell-Walsh urology*. 9th ed. Philadelphia, PA: WB Saunders; 2007: http://www.mdconsult.com/das/book/body/222579540-3/1068602670/1445/91.html#4-u1.0-B978-0-7216-0798-6..50090-x_5979. Accessed 10/14/2010.

Direct and reflected laser beams can cause eye injury. CO₂ lasers cause corneal ulcerations and pass no energy to the fundus,⁵⁴ while argon, Nd-YAG, and KTP-532 pass through the anterior chamber of the eye and damage the retina.⁵⁵ Therefore the anesthesia team should ensure that all operating room personnel and the patient wear wavelength-specific goggles prior to laser activation. All windows in the operating room should be covered and specific warning signs should be posted. The patient's eyes should be taped closed and then padded with opaque, saline-soaked knit or metal shield^{56,57} and wavelength-specific goggles applied. Lasers can also cause inadvertent thermal injury to the skin; put in standby mode when not in operation.

If the CO₂ laser is being used to excise condyloma acuminatum, laser masks should be used to prevent small particles from being inhaled. Ordinary surgical masks efficiently filter particles only to 3.0 μm, while laser particulate was found to be an average size of <0.8 μm.⁵⁸ Atmospheric contamination associated with laser particulate has been shown to cause interstitial pneumonia, bronchiolitis, reduced mucociliary clearance, inflammation, and emphysema in animal models.^{59,60} The laser plume has also been shown to be mutagenic, teratogenic, and a vector for viral infection,⁶¹⁻⁶⁴ and it is most safely managed with a smoke evacuation system.

EXTRACORPOREAL SHOCK WAVE LITHOTRIPSY

Removal of renal calculi prior to the 1980s involved an invasive, lengthy surgery with significant morbidities. The introduction of extracorporeal shock wave lithotripsy (ESWL) via the Dornier HM-3 in Munich, Germany, in 1984 revolutionized the treatment of ureteral calculi. As lithotripter technology advanced, ESWL was transformed into an outpatient/ASA procedure. Eighty to eighty-five percent of patients harboring "simple" renal calculi can be treated satisfactorily with shock wave lithotripsy (SWL).⁶⁵⁻⁶⁷

Lithotripter Structure and Function Principles

In ESWL, repetitive high-energy shocks or sound waves are generated and focused on the calculus, which fragments as tensile and shear forces develop inside the stone and cavitations are formed outside the surface. There are four components to a shock wave lithotripter (see Fig. 21.1):

1. *Energy source*, most commonly an electrohydraulic, or "spark plug" type, also electromagnetic and piezoelectric types
2. *Focusing device*, either ellipsoid or reflecting mirrors
3. *Acoustic coupler or coupling medium*, usually water or conducting gel, links the energy source to the patient
4. *Stone localization system*, usually ultrasound or fluoroscopy

During stone fragmentation, a "spark plug" capacitor is discharged within the shock wave generator, generating a loud noise and intense heat, which vaporizes surrounding water. A gaseous water bubble is created and subsequently collapses, generating a shock wave. Shock waves are perpetuated to the stone by the coupling medium (deionized water, warmed to 36°C–37°C), and focused on the stone by a hyperbolic reflector mirror. The focus point (F2) is the point of maximum energy and beyond this point energy is dissipated.^{65,68,69} F2 can be matched to the stone location via fluoroscopy and avoid damage to surrounding tissues. It is important, if possible, to avoid movement of the stone. Therefore, respiratory variations and patient movement should be minimized.

Very little energy loss or tissue damage occurs as the shock waves move from the coupling medium, usually water cushion or conducting gel, to the patient, because the acoustic impedance is similar. As the shock wave enters the stone's surface, a change in acoustic impedance occurs, releasing compressive energy on the stone approximately several atmospheres in magnitude. As the wave exits on the opposite side of the stone, a change in acoustic impedance is again

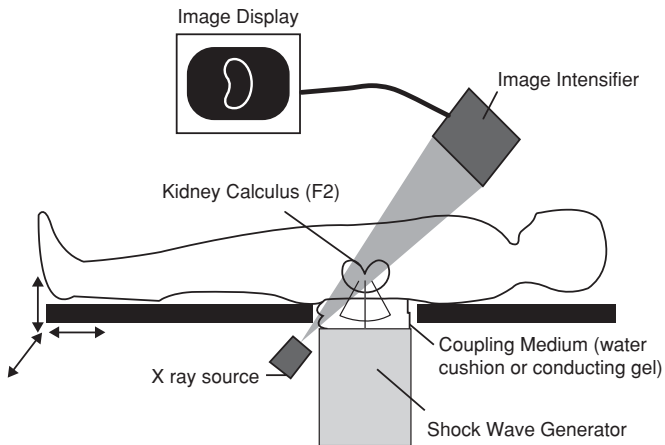


FIGURE 21.1. Components of a shock wave lithotripter, shown as second- or third-generation lithotripter. In first-generation lithotripters, the patient was strapped to a gantry chair and immersed to the clavicles in a metal tub filled with warmed water (coupling medium). (Courtesy of Ronald G. Frank, MD. <http://www.urologistnewjersey.com>)

encountered, and energy is released in a blast. Repetition of this process causes the stone to disintegrate; typically 1000–2000 shocks are required. The limits to avoid tissue injury are 3000 shocks at maximum voltage of 24,000; if stone is in ureter, the limit is 2400 shocks at 30,000 V.

Contraindications to Extracorporeal Shock Wave Lithotripsy

Contraindications to ESWL include pregnancy, bleeding disorders, urinary obstruction below the stone, and untreated infection. Relative contraindications, more relevant to first-generation lithotripters, include calcified abdominal aortic aneurism, which may rupture or embolize distally; gas/tissue interfaces such as pneumothorax or dilated bowel loops; orthopedic prosthetic devices; or pacemaker/AICD in the path of the shock waves. If the pacemaker/AICD is in the path of the shock waves, it is recommended to check with the manufacturer if the device should be reprogrammed or if use of a magnet is recommended.

Safe Use of Shock Wave Lithotripsy

Shock wave lithotripsy has been used safely in the pediatric population, including infants.¹⁰ Higher water concentration in pediatric tissue compared with adults is thought to increase resistance to tissue damage.^{70,71} Special precautions with shock wave lithotripsy in infants include using lower energy levels on the lithotripter and the use of foam tape to protect their lungs from contusion.⁷²

Using ESWL safely includes limiting exposure to ionizing radiation by providing staff with lead shields, radiation badges, and keeping physical distance from fluoroscopy equipment.

Total radiation exposure per ESWL is approximately the same as a barium enema.⁷³ Secondly, if using immersion lithotripsy, headphones or earphones should be utilized by lithotripsy suite personnel and the patient.^{74–76} With the most current lithotripters, the use of hearing protection by staff and the patient is optional by Occupational Safety and Health Administration (OSHA) standards (exposure >90 dB for 8 hours daily).⁷⁶

Complications

There are several problems specific to the first-generation lithotripters. These devices were located on a separate lithotripsy unit, separate from the operating suite and available resuscitation equipment. If additional interventions such as stent or cystoscopy needed to be performed, the patient had to be removed from the water bath and placed onto another operating table. With regard to the device itself, the calculus and patient must be moved to align the shock wave generator with the target F2 focus, which varies with the patient's respirations. There are several hemodynamic and physiologic changes associated with immersion water bath (see Table 21.7). Vasodilatation associated with the warm water bath was exacerbated by epidural or spinal anesthesia, often requiring a fluid preload of 1000–2000 ml. Additionally, immersion requires waterproof monitors and occlusive dressings over epidural and intravenous sites.

Unfortunately, cardiac arrhythmias are encountered up to 80% of the time with first-generation lithotripters.⁷⁷ This is primarily thought to be due to two mechanisms: irritation of the myocardium by the shock wave; or the 10–20 kV discharge prior to each shock could evoke premature electrical stimulation of the atria, most frequently resulting in supraventricular tachycardia.^{78,79} This can be reduced by coupling shock wave delivery to the electrocardiogram (ECG) so that shocks are delivered 20 milliseconds after the R wave, corresponding to the ventricular refractory period. However, once coupled, the length of the procedure is directly correlated to the heart rate. This became an issue if regional anesthesia was undertaken and a sympathectomy with a resultant bradycardia occurred. Some practitioners used atropine or isoproterenol to alleviate the bradycardia, but these drugs can significantly increase cardiac workload and oxygen demand.

Second- and Third-Generation Lithotripters

Some of the difficulties encountered with the first-generation lithotripters were avoided in the development of the second- and third-generation lithotripters. The water bath was replaced with a water cushion or conductive gel,^{80,81} thereby avoiding problems specific to immersion. Furthermore, newer models incorporated a cardiac simulator and reduced energy delivered to improve treatment times and reduce rate of arrhythmia to approximately 20%.⁸² However, even with the lowest energy lithotripters, arrhythmias have been encountered.⁸³ If observed, the internal simulator can be deactivated and

TABLE 21.7. *Physiologic Changes with Immersion Extracorporeal Shock Wave Lithotripsy*

Pulmonary

Decreased FRC, VC, TV*

Increased intrathoracic blood volume 30%–60%

Increased RR*, work of breathing, promotes atelectasis

Cardiac

Increased preload secondary to compression of submerged veins

Increased central venous, right atrial, and pulmonary artery pressures

Increase in systemic MAP & CO*

If LV failure, may see decreased MAP & CO*

Temperature

Cold water: vasoconstriction, shivering, hypothermia

Warm water: Vasodilatation, decreased blood pressure, hyperthermia

Sitting position: Decreased RAP* and PCWP,* decreased CO*

FRC, functional residual capacity; VC, vital capacity; TV, tidal volume; RR, respiratory rate; LV, left ventricle; MAP, mean arterial pressure; PCWP, pulmonary capillary wedge pressure; RAP, right atrial pressure.

Source: From Malhotra V, Sudheendra V, Diwan S. Anesthesia and the renal and genitourinary systems. In: Miller R, ed. *Miller's anesthesia*. 6th ed. Philadelphia, PA: Churchill Livingstone; 2005: 2105–2134.

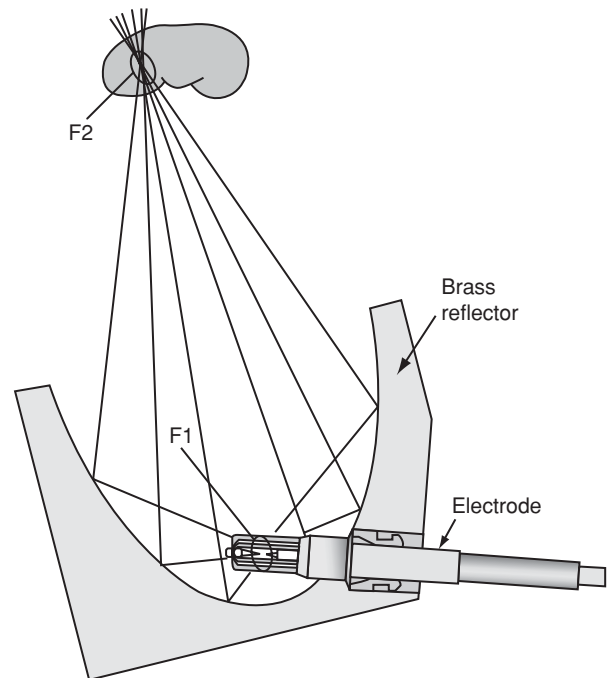


FIGURE 21.2. Schematic for an electrohydraulic generator. (This figure was published in *Campbell-Walsh urology*. 9th ed, Vol. 2. Copyright Elsevier 2007.)

ECG triggered mode can be utilized.⁸⁴ Stone localization is still frequently performed with fluoroscopy; however, ultrasound may also be used with these devices.

Because pain at the entry site was linked to the increased voltage and energy density,^{85,86} an effort was made to decrease the energy necessary to produce adequate stone fragmentation. However, with decreased energy density and voltage, the total number of shocks delivered was increased to compensate. Shock wave generators are still commonly electrohydraulic (see Fig. 21.2) as in the Dornier HM3, but currently lower energy lithotripters with more focused beams are used. Other lithotripters use electromagnetic or piezoelectric sources in efforts to decrease energy needs. Electromagnetic generators vibrate a metallic plate over an electromagnet, generating shock waves in a water-filled “shock tube” (see Fig. 21.3). The advantage of electromagnetic lithotripters is that they provide more controllable and reproducible shock waves than electrohydraulic sources; however, the energy is introduced over a larger skin area, which may cause decreased pain.³ Because a small focal region with increased energy density is being utilized, patients are at an increased risk for subcapsular hematoma.⁸⁷

Piezoelectric generators apply electrical current to a crystal, whose external dimensions change when electric current is applied. Once applied to many crystals in a spherical dish, this results in shock waves (see Fig. 21.4). Piezoelectric lithotripters are the lowest energy lithotripters, have focusing accuracy, low energy at the skin, and the least amount of pain, allowing for an “anesthetic-free” treatment.⁸⁰

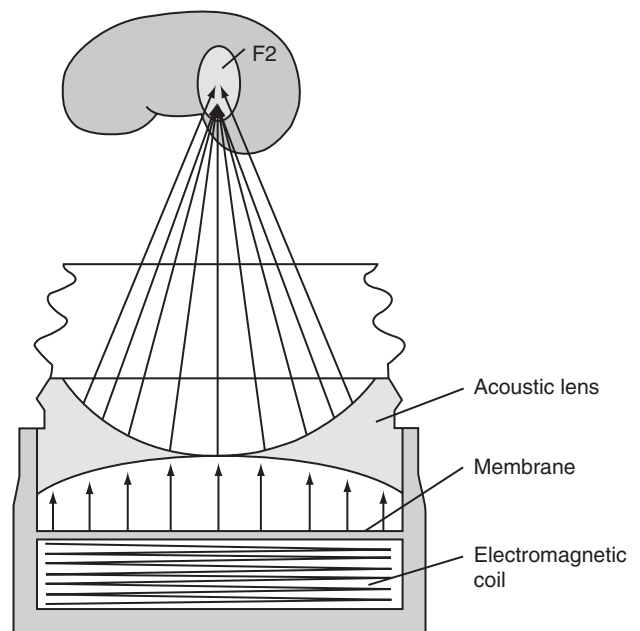


FIGURE 21.3. Schematic for electromagnetic generator with acoustic lens focusing mechanism (not shown: parabolic reflector). (This figure was published in *Campbell-Walsh urology*. 9th ed, Vol. 2. Copyright Elsevier 2007.)

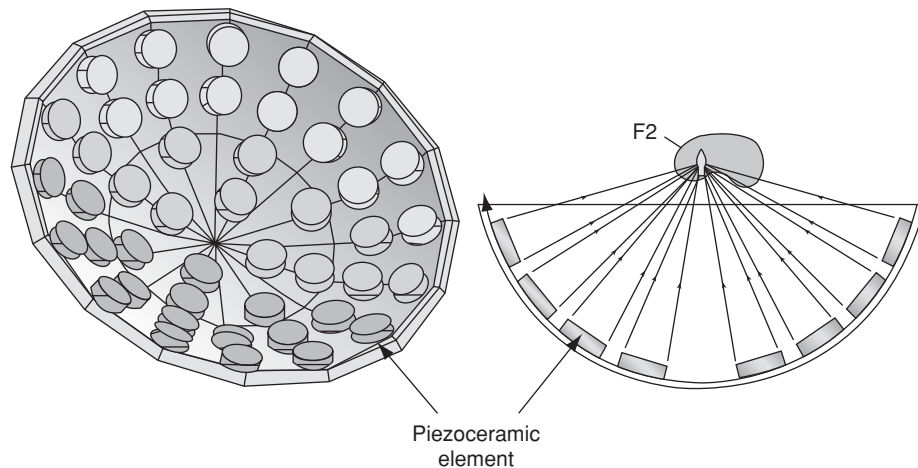


FIGURE 21.4. Schematic view of a piezoelectric shockwave generator. Numerous polarized polycrystalline ceramic elements are positioned on the inside of a spherical dish. (This figure was published in *Campbell-Walsh urology*, 9th ed, Vol. 2. Copyright Elsevier 2007.)

Laser lithotripters are also used instead of SWL, particularly in stones that are low in the ureter or if SWL has failed or cannot be used.

Anesthesia for Extracorporeal Shock Wave Lithotripsy

Pain associated with ESWL is cutaneous, somatic, and visceral in nature.^{84,88} Patients may experience shock wave and cavitation mediated irritation of the renal capsule, lumbar muscles, rib periosteum, vertebrae, and skin; upper calyx stones may be more painful than middle and lower caliceal stones.⁸⁹⁻⁹¹ The use of subdermal infiltration with local anesthesia or use of EMLA cream has been described to mediate the cutaneous pain.

Local anesthesia with sedation is the preferred method for nonimmersion SWL.⁹² Even the low-energy, “anesthesia-free” lithotripters still require supplemental analgesia.^{84,88} Local anesthesia does reduce total anesthetic requirements, but it is inadequate for analgesia as SWL energy is increased.^{90,93-95}

Shock wave lithotripsy is stimulating and painful during shock wave delivery; however, postoperatively patients are fairly comfortable. The use of short-acting opioids, nonsteroidal anti-inflammatory drugs (NSAIDs), and tramadol is recommended. Intravenous opioids are well known to cause hypoventilation, apnea, and nausea^{88,96-98} and therefore may prolong recovery time. Alternatively, analgesia with diclofenac and tramadol has been shown in several studies to have a lower side effect profile.⁹⁹

General anesthesia may be the modality of choice if a secure airway is necessary. One must consider whether OOR setting is appropriate for this patient requiring a secure airway. Alternatively, this patient might be better suited for a more controlled environment where additional help is available. The risk/benefit ratio of the alternate site environment should be continuously reassessed. Recovery from general anesthesia has been shown to be faster than from regional.⁴⁴ Shorter acting agents are preferred, and nitrous oxide has been shown to

provide effective analgesia in SWL.¹⁰⁰ General anesthesia allows tidal volume control and improves control over stone movements that may vary with respiration during regional anesthesia.⁹⁶ If stone movement with respiration is anticipated, despite minimizing tidal volumes, this may cause difficulty with stone targeting. In such a scenario, it may be necessary to move this procedure in advance to a center where high-frequency jet ventilation (HFJV) is available. HFJV has been described as superior over conventional ventilation in controlling stone movement and improving ease of stone targeting.¹⁰¹⁻¹⁰⁴

Occasionally, regional or neuraxial techniques will be chosen if the patient is unable to tolerate sedation or general anesthesia. If regional anesthesia is chosen, intercostal nerve blocks and paravertebral blocks have been described with adequate analgesic results.^{105,106} If neuraxial anesthesia is chosen, achieving a sensory level to T8 will provide analgesia for renal structures and ureters; however, if immersion lithotripsy is being used, T6 sensory levels bilaterally should be achieved. If epidural anesthesia is chosen, note the onset time for analgesia will take approximately 10–20 minutes. Injection with air should be avoided; this provides a theoretical air fluid interface or change in impedance that may lead to damage to surrounding structures.¹⁰⁷ The use of foam tape should be avoided because this can dissipate shock waves.

In the past, a spinal with lidocaine was preferred, and it is still used at some institutions. If chosen, a lower dose of lidocaine may improve return of motor function and decrease time to discharge.⁴³ However, lidocaine, is now being avoided at most institutions for spinal anesthesia, because there has been a higher risk of transient neurologic syndrome, particularly associated with lithotomy position.¹⁰⁸ Many combinations of lidocaine, multiple other local anesthetics,¹⁰⁹⁻¹¹¹ and various opioids have been studied to delineate a combination with the fewest side effects and fastest time to recovery. Of note, sufentanil is comparable to lidocaine with regard to analgesia. Patients receiving sufentanil have a lower incidence of hypotension¹¹² and earlier discharge¹¹³ than patients

receiving lidocaine, and sufentanil has a beneficial effect in conjunction with bupivacaine and other agents.^{112,114}

SUMMARY AND CONCLUSIONS

In summary, outpatient/OOOR urologic procedures are commonly performed, and a variety of patients may be encountered. Some patients may have special needs that must be evaluated with considerable scrutiny. It is paramount that the anesthesiologist, in consultation with the surgical team, decides whether the patient is suited to an OOOR setting, or if the procedure must be performed in the operating room. The anesthesiologist's role is not only to perform a safe, timely, and effective anesthetic, but to be aware of and to unsafe patient scenarios potentially recognize patient, staff, and equipment safety issues that are deleterious when encountered in this challenging environment.

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22 | Anesthesia for Procedures in the Emergency Department

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The practice of emergency medicine has changed significantly over the past several decades, having evolved into a separate and distinct specialty with a unique knowledge base and training program. As the specialty has evolved, so have the types of patients being cared for in the emergency department (ED), as well as the range of therapies and procedures being performed. For many of these patients, the acute management of pain and anxiety will be an essential component of their ED care and fundamental to the performance of many diagnostic and therapeutic interventions. Possessing an arsenal of anesthesia techniques is invaluable to the practice of emergency medicine. This chapter reviews anesthesia techniques that have special relevance in the ED setting.

SPECIAL CONSIDERATIONS

Practice in the ED poses special challenges to anesthesia providers. Unlike the typically controlled environment of the operating room where most patients have been maximally optimized and are usually scheduled for a given procedure, by definition, most ED patients present unexpectedly, often have undefined past medical and surgical histories, and may be critically ill or unstable, requiring emergent care. In these situations, there is no option to “cancel a case” and anesthesia providers may be forced to proceed with limited information, time, and a different set of resources than they are accustomed to.

LOCAL ANESTHESIA

Local Infiltration

Often used for lacerations, superficial injuries, and procedures, local infiltration is a fast and effective way to provide anesthesia. While 1% lidocaine is generally adequate for local infiltration, the vasoconstrictor effect of epinephrine-containing solutions can be useful to increase the duration of anesthetic effect and aid hemostasis in actively bleeding areas. Epinephrine-containing anesthetic solutions should be avoided in areas of compromised or end circulation, “fingers, toes, nose, and hose (penis)” to avoid potential ischemia.

To anesthetize open wounds, the needle should enter from within the wound and anesthesia should be injected parallel to the wound edge, avoiding intact skin that is more painful to inject through. Unless the wound is grossly contaminated, anesthesia should be injected into most lacerations prior to wound irrigation because irrigating an wound that is not anesthetized can be painful.

While most physicians feel comfortable with administering local anesthetics, several simple considerations can reduce pain on injection and improve effectiveness:

Use a small needle

- **Needle size:** Using the smallest bore needle possible for the job is helpful in reducing the pain of skin puncture; for most procedures a 25- or 27-gauge needle will usually suffice.
- **Needle length:** Using a 1 or 1½ inch needle and injecting under the skin parallel to the skin surface from a single needle puncture site reduces the pain of multiple skin punctures.

Inject slowly

- Much of the pain of injection is proportional to the speed with which the anesthetic is injected, as the anesthetic dissects between tissues planes; injecting more slowly can significantly reduce discomfort.
- Injection while simultaneously withdrawing the needle may decrease pain of injection as well.

Use a buffered solution

- The pH of most amide anesthetics (e.g., lidocaine, bupivacaine) is acidic, increasing their pain on injection. Using a buffered solution by mixing one part sodium bicarbonate (8.4%, 1mmol/l) solution to nine parts anesthetic has been demonstrated to significantly reduce the pain of injection.^{1,2}

Minimize patient anxiety

- Talking to the patient throughout the procedure and keeping him or her informed of the steps in the procedure will reduce patient anxiety and can help to prevent unexpected movements, which could result in either patient or caregiver injury.
- Obstructing the view of the needle while withdrawing the anesthetic solution from the vial or while approaching the patient can prevent unnecessary anxiety from seeing the needle, particularly among pediatric patients.

- Utilize distraction for pediatric patients by having a family member or another provider talk to the child, or use toys or a television to divert the child's attention from the procedure.

Use a topical anesthetic

- Especially among pediatric patients, applying a topical anesthetic to the injection site can be helpful by reducing or eliminating the pain of the initial needle puncture. Cream anesthetics such as lidocaine-prilocaine (EMLA) can be applied over unbroken skin, and liquid anesthetic such as lidocaine-epinephrine-tetracaine (LET) can be applied directly to an open wound either by a soaked cotton swab or through repeated dabs by a parent or family member. Many pediatric EDs have triage personnel apply topical anesthetic to injuries likely requiring irrigation or suturing as standard practice.

Allow time for the anesthetic to work

- Because most local anesthetics take several minutes to achieve full effect, inject early and use the time that the anesthesia is taking effect to prepare your instruments or attend to other tasks, rather than starting the procedure before the anesthesia is fully effective.

Field Block

A field block is a useful technique for providing anesthesia around small areas of tissue where direct injection would be ineffective or inappropriate. Examples include abscesses where the associated tissue inflammation and acidic pH of the abscess reduce anesthetic effectiveness, or grossly contaminated wounds requiring irrigation where injection directly through the wound would be expected to increase the risk of infection by introducing foreign materials deeper into the tissue.

The field block is performed by encircling the operative field with a ring of local anesthetic. It is best performed with a long needle, preferably 1.5" in size, whereby a skin puncture is made near one corner of the desired area, and the needle is advanced tangentially to the wound, injecting anesthetic as the needle is advanced. The next puncture is then made through already anesthetized skin, and the needle is advanced tangentially to the wound. This simple process is repeated until a ring of anesthetic has been created around the desired area, effectively anesthetizing it (Fig. 22.1).

Hematoma Block

A hematoma block, where anesthetic is injected directly into a fracture site, is a commonly used technique for providing anesthesia during fracture reduction.³ First the fracture site is clearly identified by physical examination, the needle is then advanced through the soft tissue and walked along the bone until the fracture site is entered. The operator then aspirates blood by pulling back on the syringe, confirming that the needle has entered the hematoma at the fracture site, and the anesthetic is injected. The clinician must be confident that there are no major blood vessels in the vicinity of the injection

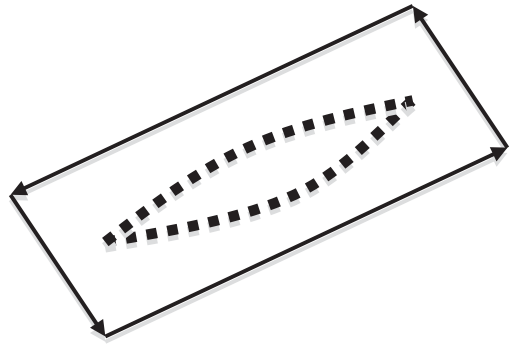


FIGURE 22.1. The field block.

site to avoid inadvertent intravascular injection. Injecting 5–15 cc of 1% lidocaine or 5–10 cc of 2% lidocaine directly into the fracture site can provide effective analgesia for fracture reduction.⁴

Dental Block (Supraperiosteal Infiltration)

A commonly used procedure for providing quick, nonopioid relief of dental pain occurring from infection, dental caries, or trauma, the supraperiosteal infiltration or dental block is quick and easy to perform. The affected tooth is first identified, and the cheek is grasped and pulled away to expose the mucobuccal fold. When the fold is identified, the area is dried with gauze and 20% benzocaine or 5% lidocaine ointment is applied directly or on a piece of soaked gauze to provide topical anesthesia. The needle is then introduced at the mucobuccal fold directly above the affected tooth, with the bevel facing the bone, aspirated to rule out intravascular placement, and 1–2 cc of anesthetic are injected. While a regular 1% lidocaine solution can be used, lidocaine plus epinephrine or bupivacaine can be used to increase the duration of anesthetic effect.

REGIONAL ANESTHESIA

Regional anesthesia is a technique of injecting an anesthetic agent near a nerve in order to achieve anesthesia to the entire distribution of the nerve distal to the site of injection. This is a highly useful technique to achieve analgesia to large areas of the body, where local infiltration of anesthetic is not feasible because of anatomy or because the adequate anesthetic effect would require toxic doses of anesthetic. There are many anatomical distributions amenable to regional anesthesia, including the extremities, face, mouth, and penis, but describing them is beyond the scope of this chapter. As one example, digital blocks are discussed later in this chapter, because of the frequency with which they are used and the ease with which they are performed in an ED setting.

Digital Block

A commonly used technique for anesthetizing the fingers and toes is the digital block. The technique works by anesthetizing some or all of the four digital nerves as they course near the base of the proximal phalanx (Fig. 22.2), thereby providing anesthesia to the remainder of the digit distal to the injection site. There are some techniques for performing the digital block, some of which are discussed next.

The dorsal approach is probably the most commonly used technique for performing the digital block, where the hand is held flat, palm down on the table. The skin over the finger webs on either side of the digit is prepared with alcohol or povidone-iodine, and a needle puncture is made just proximal to the finger web, on either side of the finger. After the needle is advanced and contacts the bone of proximal phalanx, it is withdrawn 1 mm, aspirated to rule out intravascular injection, and 1–2 cc of anesthetic is injected. The technique is repeated on the opposite side of the finger if both sides of the finger require anesthesia (Fig. 22.3). The area in which the anesthesia has been injected should then be massaged firmly for 30 seconds to aid diffusion of the anesthetic.

The volar or metacarpal head approach is useful when anesthesia is required only for the fingertip or volar aspect of the finger. The approach differs in that only a single injection is made to the volar surface of the hand over the metacarpal head. The hand is held supinated, palm up, and the metacarpal head is palpated. The skin is prepped, and the needle enters the skin directly over the metacarpal head and is advanced slowly toward the bone. When the bone is contacted, the needle is withdrawn 3–4 mm and angled successively to the right and left of the metacarpal head while injecting anesthetic in order to infiltrate the area around the volar digital nerves (Fig. 22.4). A total of 4–5 cc of anesthetic is required to achieve adequate anesthetic effect. As in the dorsal approach, the area should be massaged firmly after injection to aid diffusion of the anesthetic.



FIGURE 22.3. The Digital Block (Dorsal Approach) This figure was published in McGee D. Local and Topical Anesthesia. In: Clinical Procedures in Emergency Medicine, 5th Edition. Roberts JR, Hedges, et al (Eds). Elsevier 2009.

INTRAARTICULAR ANESTHESIA

Intraarticular anesthesia is, as the name suggests, injection of an anesthetic agent directly into a joint for pain relief or to facilitate the performance of a painful procedure or maneuver. While requiring more technical skill and preparation than other methods of anesthesia and analgesia, it offers numerous advantages, including better local pain control, decreased systemic effects, and decreasing or eliminating the need for narcotic analgesia. Intraarticular anesthesia may be useful for many joints, including the shoulder, elbow, knee, and ankle.

Shoulder

The shoulder has the greatest range of motion of any joint in the body, but mobility comes at the price of instability, and shoulder dislocations are the most common large joint

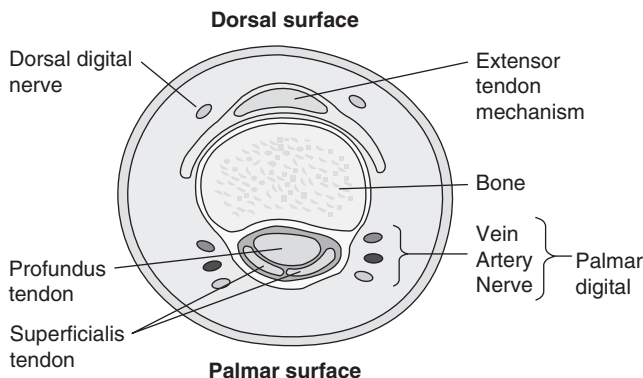


FIGURE 22.2. Cross sectional anatomy of the phalanx. This figure was published in McGee D. Local and Topical Anesthesia. In: Clinical Procedures in Emergency Medicine, 5th Edition. Roberts JR, Hedges, et al (Eds). Elsevier 2009.



FIGURE 22.4. The Digital Block (Volar Approach). This figure was published in McGee D. Local and Topical Anesthesia. In: Clinical Procedures in Emergency Medicine, 5th Edition. Roberts JR, Hedges, et al (Eds). Elsevier 2009.

dislocations seen in EDs. Reduction of shoulder dislocations can require significant force and can be quite painful, and adequate analgesia is an essential component of procedural success and patient satisfaction. Many shoulder dislocation reductions utilize intravenous procedural sedation to achieve adequate pain control; however, there is a large body of literature supporting the use of intraarticular anesthesia for dislocation reduction, demonstrating equivalent procedural success with benefits in terms of both procedural and post-procedural pain control, diminished side effects and complication rates, fewer nursing resources, reduced cost, decreased ED length of stay, and patient satisfaction⁵⁻⁸

Other Joints

While there is little research currently examining the efficacy and feasibility of intraarticular analgesia for other joints in the ED setting, applications for other joints may develop in time.

PROCEDURAL SEDATION AND ANALGESIA

Definition

Procedural sedation and analgesia (PSA), formerly known as “conscious sedation” or “IV conscious sedation,” is a technique of administering sedatives, analgesics, and/or dissociative agents to induce a state that allows the patient to tolerate unpleasant procedures while maintaining cardiorespiratory function.⁹ Mastering this technique is essential to the performance of many procedures that would otherwise be impossible in the ED setting, including long-bone fracture and large-joint dislocation reductions, electrical cardioversion, and pediatric and complex minor surgical procedures.

There are several levels of procedural sedation, defined by the degree to which consciousness, respiratory, and cardiovascular functions are suppressed (also see Chapter 4). The first level is minimal sedation or anxiolysis, in which patients are in a state of drug-induced relaxation but respond normally to verbal commands, and respiratory and cardiovascular function is unaffected. Moderate sedation refers to a drug-induced depressed level of consciousness where patients are still able to respond purposefully to verbal commands, and where respiratory and cardiovascular function is usually preserved. Deep sedation is a drug-induced depressed level of consciousness from which patients cannot be easily aroused but will respond purposefully after noxious or repeated stimuli. In this state, patients may need support in maintaining airway patency and may require mild respiratory support to maintain adequate ventilation. This contrasts with general anesthesia in which patients experience total loss of consciousness as a consequence of drug administration, are not arousable, and may have significant impairments to both respiratory and cardiovascular function. One final sedation state that must be noted is dissociative sedation, in which patients are in a trance-like state, maintaining respiratory and cardiovascular function, but experience deep analgesia and amnesia. The goal of most

procedural sedations performed in the ED on adult patients is to reach a state of moderate or deep sedation in order to facilitate performance of a diagnostic or therapeutic maneuver. A dissociative state is more often achieved in children because of the proven efficacy and favorable side effect profile of ketamine in pediatric procedural sedation.

Procedural sedation and analgesia is commonplace in both adult and pediatric EDs around the country, and the American College of Emergency Physicians (ACEP) supports its practice by emergency physicians.¹⁰ Accordingly, ACEP has developed its own clinical policy regarding PSA in the ED.¹¹ Practice guidelines for sedation and analgesia for nonanesthesiologists have also been approved by the American Society of Anesthesiologists.¹²

Indications and Contraindications

There are many indications for PSA in the ED, including fracture and dislocation reduction, abscess incision and drainage, tube thoracostomy, lumbar puncture, imaging, electrical cardioversion, and a host of procedures in pediatric, agitated, or mentally challenged patients. While there are no absolute contraindications to PSA, relative contraindications can include hemodynamic instability, predictors of difficult airway, critical illness, patients with severe cardiac or pulmonary disease, patients with a history of drug reactions or interactions with PSA agents. Recent oral intake is not a contraindication to PSA, but it should be taken into account when planning the timing and depth of PSA.

Preprocedure Assessment

General Assessment

Procedural sedation is an advanced anesthesia technique in which the patient may experience total loss of consciousness, diminished protective airway reflexes, and serious complications such as apnea or hypotension;¹³ therefore, it is essential that a thorough assessment of the patient be made prior to initiating the procedure. This should include an AMPLE history (i.e., allergies, medications, past medical history, last oral intake, events leading to the present situation). Allergies to medications or related medications to those planned for use in the procedure, or the concurrent use of medications with known drug interactions may necessitate different medications than originally planned. Past medical history of asthma or lung disease, sleep apnea, heart disease, trauma, or drug use/abuse may necessitate significant modifications to the procedural sedation method, agents used, or dosing, or may result in abandoning PSA entirely and opting for definitive airway control in an operating room setting. Because there is a theoretical increased risk of aspiration during PSA, published guidelines recommend last oral intake of solids ideally should be 6 hours before the procedure, and for liquids at least 2 hours before the procedure to reduce the risk of aspiration.¹² However, preprocedure fasting has not been shown to decrease aspiration risk,¹⁴ and recent oral intake is not a

contraindication to PSA.¹¹ Still, it may be prudent to avoid procedural sedation for nonemergent procedures in patients who have recently eaten a large meal. Finally, the events leading to the patient's presentation must be known, as drug intoxication, head injury, recent ingestion, or other historical factors may make procedural sedation challenging or inappropriate in that particular patient.

Physical Exam and Airway Assessment

A physical exam of relevant systems and a formal airway assessment must also be completed in all patients undergoing procedural sedation. At a minimum, the physical exam should include vital signs, mental status, as well as examination of the cardiovascular and respiratory systems. Airway assessment should include an evaluation of the likelihood of difficulty with spontaneous respiration during PSA, as well as the difficulty of bag-mask ventilation and intubation (Table 22.1).¹²

TABLE 22.1. *Airway Assessment Procedures for Sedation and Analgesia*

Positive pressure ventilation, with or without tracheal intubation, may be necessary if respiratory compromise develops during sedation–analgesia. This may be more difficult in patients with atypical airway anatomy. In addition, some airway abnormalities may increase the likelihood of airway obstruction during spontaneous ventilation. Some factors that may be associated with difficulty in airway management are as follows:

History

- Previous problems with anesthesia or sedation
- Stridor, snoring, or sleep apnea
- Advanced rheumatoid arthritis
- Chromosomal abnormality (e.g., trisomy 21)

Physical examination

Habitus

- Significant obesity (especially involving the neck and facial structures)

Head and neck

- Short neck, limited neck extension, decreased hyoid–mental distance (<3 cm in an adult), neck mass, cervical spine disease or trauma, tracheal deviation, dysmorphic facial features (e.g., Pierre-Robin syndrome)

Mouth

- Small opening (<3 cm in an adult); edentulous; protruding incisors; loose or capped teeth; dental appliances; high, arched palate; macroglossia; tonsillar hypertrophy; nonvisible uvula

Jaw

- Micrognathia, retrognathia, trismus, significant malocclusion

Source: Reprinted with permission from American Society of Anesthesiologists Task Force on Sedation and Analgesia by Non-Anesthesiologists. Practice guidelines for sedation and analgesia by non-anesthesiologists. Anesthesia. 2002;96(4):1004–1017.

Finally, an accurate patient weight should be obtained in order to appropriately dose the PSA agents.

Informed Consent

Finally, when it has been determined that the patient is a good candidate for procedural sedation, the physician performing the procedure must obtain an informed consent from the patient or health care proxy after explaining in detail the rationale for the procedure, the risks and benefits, and providing time to answer questions the patient or family members may have.

Medications

Many medications have been used with varying degrees of success in EDs for PSA, with midazolam combined with fentanyl one of the most commonly used regimens. Ketamine, propofol, and etomidate are also useful. The dose, pharmacologic profile, and side effects differ among the drugs considerably, making some agents particularly advantageous in some situations and contraindicated in others (Table 22.2).¹⁵ However, the formularies of many hospitals are restrictive and do not permit the use of certain medications outside of the operating room or in the hands of nonanesthesiologists.¹⁶ As such, the widespread adoption of new medications with potentially better efficacy and side effect profiles has been delayed in many instances.

The clinician must take into account many factors when choosing a PSA strategy, including the patient's age, past medical history and comorbidities, the type and duration of procedure being performed, adjunctive pain control therapies, and elements of the patient's presentation that could complicate PSA. As such, it is essential to have a detailed understanding of the commonly used PSA agents, their advantages, disadvantages, and contraindications.

Sedatives and Analgesics

Midazolam

Midazolam belongs to the benzodiazepine class of drugs and is well known for its anxiolytic, sedative, and anticonvulsant properties. Because it acts rapidly, has a short half-life, and has amnestic properties, it is the most commonly used benzodiazepine for PSA. The most common adverse effect of midazolam is hypotension when rapidly administered and, especially when used in combination with an opioid such as fentanyl, respiratory depression. The benzodiazepine antagonist flumazenil can be useful for reversing respiratory depression associated with midazolam administration, but it can provoke seizures in long-term benzodiazepine users, so it should be used cautiously. While midazolam is used for PSA in many EDs, newer drugs with shorter durations of action and better side effect profiles are becoming more widely available and may soon supplant midazolam as a first-line agent for PSA in adults.

TABLE 22.2. Medications Commonly Used in Procedural Sedation

Medication	Route	Initial IV Dose	Usual Total Dose	Time of Onset	Duration of Action	Advantages	Serious Adverse Effects	Comments
Sedative-hypnotic agents								
Midazolam (benzodiazepine)	IV	1–2 mg	0.02–0.1 mg/kg	1–2 min	30 min	Rapid onset	Respiratory depression	Respiratory depression more severe in elderly patients, those with COPD, and when coadministered with other respiratory depressants Reduce dosage in patients with COPD or older than 60 years of age
	IM		0.05–0.15 mg/kg	10–15 min	60–120 min	Short duration		
	PO		0.5–0.75 mg/kg	15–30 min	60–90 min	Easily titrated		
	PR		0.5–0.75 mg/kg	10–30 min	60–90 min	Low incidence of pain on injection and phlebitis Multiple routes		
Propofol (alkylphenol)	IV	0.5 mg/kg	1.0 mg/kg	<1 min	8–10 min	Rapid onset	Respiratory depression Hypotension Injection pain	Procedures lasting longer than 8–10 min will require repeat boluses or infusion To prevent injection pain, administer IV lidocaine, 0.5mg/kg with a rubber tourniquet in place 30–120 seconds before injection
	INF		25–125 mcg/kg/min			Short duration; antiemetic		
Etomidate (imidazole derivative)	IV	0.1 mg/kg	0.1–0.2 mg/kg	<1 min	5–8 min	Rapid onset	Respiratory depression Myoclonus Injection pain Vomiting	Adrenal suppression non-clinically relevant with one-time administration
	PO		50 mg	10–20 min	30–60 min	Short duration		
	PR		4.5 mg/kg			Minimal cardiovascular effects Cerebral protective		

Dissociative agents

Ketamine	IV	1 mg/kg	1–2 mg/kg	1 min	15 min	Rapid onset	Hypertension	Causes hypersalivation
(phencyclidine derivative)	IM		4–5 mg/kg	5 min	15–30 min	Short duration	Tachycardia	Contraindicated in: infants <3mos, active pulmonary infection, cardiovascular disease, TBI, CNS mass lesions/increased ICP, increased intraocular pressure/globe injury
	PO		5–10 mg/kg	30–45 min	2–4 hr	No respiratory depression	Increased ICP	
	PR		5–10 mg/kg	5–10 min	15–30 min	Multiple routes Predictable given IM	Emergence phenomena	

Analgesics

Fentanyl (opiate)	IV	0.5–1.0 mcg/kg	2–3 µg/kg	1–2 min	20–30 min	Rapid onset, short duration, titratable Minimal cardiovascular effects	Respiratory depression Muscle rigidity	Respiratory depression more pronounced when administered with other respiratory depressants Does not cause histamine release
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Reversal agents

Naloxone (opiate antagonist)	IV	0.1–0.4 mg	0.1–2.0 mg	<1 min	15–30 min	Rapid-acting reversal	Opiate withdrawal	Short duration; monitor for re sedation
Flumazenil (benzodiazepine antagonist)	IV	0.2 mg	1.0 mg	1–2 min	45 min	Rapid-acting reversal	Benzodiazepine withdrawal	Short duration; monitor for re sedation Use cautiously in patients with a history of benzodiazepine or ethanol use; can precipitate withdrawal and seizures

IV, intravenous; IM, intramuscular; PO, oral; PR, rectal; INF, infusion; CNS, central nervous system; COPD, chronic obstructive pulmonary disease; ICP, intracranial pressure; TBI, traumatic brain injury.

Source: Marx JA, Hockberger RS, Walls RM. Rosen's emergency medicine: concepts and clinical practice. 6th ed. New York, NY: Elsevier; 2006.

Propofol

Propofol is a nonbenzodiazepine, nonbarbiturate drug that has long been favored in the operating room for induction of general anesthesia because of its extremely fast onset and short duration of action. Hospitals have been slow to adopt the use of propofol in the ED, however, because of concerns over difficulty titrating the medication outside the operating room and the risk of respiratory depression, aspiration, and oversedation. These concerns persist despite considerable evidence supporting the use of propofol in the ED setting,¹⁷⁻²⁰ and many emergency physicians do not have access to this drug for use in procedural sedation because of these administrative and political barriers.^{16,21} Nonetheless, as evidence of the efficacy and safety of propofol in PSA continues to accrue, we expect wider acceptance and availability of the drug in EDs in the future.

Etomidate

Etomidate is nonbarbiturate sedative-hypnotic that has gained widespread adoption in EDs because of its demonstrated efficacy and safety in induction for rapid sequence intubation. It has many theoretical advantages for use in PSA because of its rapid onset, short duration of action, and well-documented preservation of hemodynamic stability, and there is a growing body of literature suggesting that etomidate can be used safely for PSA in the ED.^{20,22-26} Side effects, such as vomiting and myoclonus which can occur in 20%–45% of people undergoing PSA with etomidate (and can consist of full-body tonic-clonic activity), may limit its widespread adoption as a first-line agent for PSA.^{27,28}

Fentanyl

A highly lipid-soluble synthetic opioid, fentanyl is a rapidly acting and highly potent analgesic that has been used extensively for PSA when combined with a sedative. Fentanyl causes less respiratory depression and histamine release than other opioids, leading to a very favorable side effect profile. Because of its rapid onset, short duration of action, and demonstrated respiratory and hemodynamic stability, it is currently the analgesic of choice for PSA in the ED. Its respiratory depressant effects are synergistic with benzodiazepines such as midazolam, and hypotension can occur in the presence of ethanol, so caution must be demonstrated when using fentanyl in patients who already have either of the above agents on board. Rapid administration of high-dose fentanyl has been associated with chest wall and glottic rigidity requiring intubation, so care must be taken to administer boluses of the drug slowly, over 3 to 5 minutes. It is important to note that in analgesic doses, fentanyl alone has little if any sedative properties; because of this, it is commonly used in combination with a sedative-hypnotic agent such as midazolam.

Ketamine

Ketamine, a phencyclidine derivative and dissociative anesthetic, is a first-line agent for pediatric PSA.²⁹ It is used less

frequently among adults in the ED, however, largely for concerns over “emergence phenomena,” which can include hallucinations and intense dysphoric experiences.³⁰ Administration of a benzodiazepine such as midazolam can attenuate these side effects. Ketamine, which results in release of endogenous catecholamines, is well known for its maintenance of hemodynamic stability and bronchodilatory effects, making it an ideal agent in patients with borderline hypotension or pulmonary disease. The catecholamine release can induce tachycardia, hypertension, and increased intracranial pressure. Although these effects have given clinicians pause when treating patients with hypertension or head injuries, it should be noted that these theoretical risks have not been borne out in terms of adverse patient outcomes. Hypersalivation is another known side effect of ketamine administration, and it can be mitigated by pretreatment with glycopyrrolate or atropine.

Other Agents

Other medications have been successfully used in ED PSA, including methohexital and nitrous oxide. Methohexital is a short-acting barbiturate that has been used in general anesthesia for many years, and more recently it was applied to ED PSA with good results.^{31,32} Because of side effects including hypotension and respiratory depression, the drug has fallen out of favor with the advent of newer agents. Nitrous oxide is a colorless gas long used in general anesthesia and has both sedative and analgesic properties. Because it is a known teratogen and requires a well-ventilated room with a dedicated scavenging system to prevent inhalation by health care providers, it was never broadly adopted for ED PSA in the United States, although is widely accepted in other countries.

Reversal Agents

While rarely required in carefully performed PSA, clinicians should be aware of the reversal agents available in their EDs should the need arise and these agents should be readily available when performing PSA.

Naloxone

Naloxone is an opioid antagonist readily available in most EDs. It is usually administered intravenously, but it can also be given subcutaneously, intramuscularly, or via an endotracheal tube. It has a rapid onset of action and can reverse opiate-induced sedation and respiratory depression within a minute or less. However, the drug's short half-life means that patients receiving long-acting opioids can become re-sedated as the naloxone effect diminishes. This is not usually an issue in PSA because relatively small amounts of short-acting opiates (such as fentanyl) are usually used. Nonetheless, patients receiving naloxone should be observed for at least 1 hour following administration of the drug to be sure re-sedation does not occur. Naloxone may precipitate acute opioid withdrawal in patients with a history of chronic opiate use.

Flumazenil

Flumazenil is a competitive antagonist of the benzodiazepine GABA receptors in the central nervous system. The drug is rapidly acting, reversing benzodiazepine effects within 1–2 minutes, but like naloxone, it has a short duration of action and patients can become resedated following a single administration. As such, patients should be observed for at least 1 hour following flumazenil administration. Flumazenil can also precipitate acute benzodiazepine withdrawal and seizures, particularly in long-term benzodiazepine users. Flumazenil should be used cautiously and at the lowest possible doses whenever required.

Preprocedure Preparation

Equipment

It is essential that all necessary PSA and reversal medications, monitoring equipment, health care providers, and rescue airway equipment are prepared prior to administration of medication. An oxygen supply and basic facemask should be available prior to and throughout the procedural sedation to preoxygenate the patient prior to sedation and maintain oxygen saturations throughout the procedure, especially during periods of depressed respiratory drive. Basic airway equipment should include, at a minimum, a bag-mask, suction, and nasopharyngeal or oropharyngeal airway. Other equipment that should be located nearby and easily accessible should include rescue airway devices such as laryngeal mask airways (LMAs), a working laryngoscope with multiple sizes of laryngoscope blades and endotracheal tubes, and any other equipment necessary to facilitate a successful intubation or rescue airway should cardiorespiratory failure occur.

Basic monitoring equipment must include a pulse oximeter and blood pressure cuff, as some of the most common side effects of procedural sedation are respiratory depression and hypotension, and it is therefore essential that both oxygen saturation and blood pressure can be monitored throughout the induction, procedure, and recovery phases. If available, capnography can also be considered.

Personnel

Several guidelines recommend that a minimum of two health care providers should be involved in any procedural sedation. The first provider should be wholly dedicated to monitoring the patient, documenting vital signs and administering medications, and the second should be the physician performing the procedure for which the procedural sedation is being administered. This ensures that the patient is closely monitored for depth of sedation and signs of respiratory depression, and does not become neglected while the operator is focused on performing the procedure.

Drug Administration

When appropriate agents have been selected for the indication, drug administration should proceed in a weight-based

and stepwise fashion to ensure effectiveness and patient safety. The physician performing the PSA should feel comfortable in his or her knowledge of the drug's weight-based dosing, contraindications, adverse effects, and reversal agents (if any).

Aside from ketamine, most commonly used PSA agents do not have significant analgesic properties; consequently, most PSA strategies involve a combination of fentanyl and a sedative-hypnotic agent. Because effective analgesia is a cornerstone of PSA, and respiratory depression and excessive sedation are adverse effects primarily associated with the administration of sedative-hypnotic agents, it is recommended that the analgesic agent be administered first in any PSA. Therefore, when using fentanyl and sedative-hypnotic agents, fentanyl should be administered first, observed for effect, and then the sedative-hypnotic agents should be titrated slowly and incrementally until the desired level of sedation is reached.

It is important to remember that constant painful stimuli during procedures such as fracture or dislocation reduction can result in a higher level of consciousness than would be expected in the absence of painful stimuli, and thus one must be careful not to overtitrate medications. It is not uncommon for a patient who is actively screaming in pain while undergoing fracture reduction to become completely unconscious and apneic within seconds of removal of the painful stimulus.

Monitoring

Patient monitoring should begin with vital signs including blood pressure, oxygen saturation, and heart rate and rhythm at the onset of the case prior to the administration of medications. Patient monitoring should continue at regular intervals throughout the PSA and into recovery period to detect possible respiratory depression, hypotension, or other adverse effects.

While not yet a standard of care in the ED, capnography has been shown to be beneficial in early detection of respiratory depression, and it should be considered, if available. End tidal CO₂ (ETCO₂) >50mm Hg, absent ETCO₂ waveform, or an absolute change in ETCO₂ >10mm Hg recorded on capnography during PSA has been shown to correlate with respiratory depression not detected by pulse oximetry.³³ While research is ongoing, all indications are that capnography will assume a greater role in PSA in the future and will soon emerge as standard of care in the ED as it is in the intensive care unit and the operating room.^{34,35}

The bispectral index, an electroencephalography (EEG)-based tool well established for measuring depth of sedation in the operating room during general anesthesia, also has been applied to PSA in the ED³⁶⁻³⁸ and has shown some benefit in preventing respiratory depression.³⁹ However, there is insufficient evidence at this point to recommend its routine use in PSA.

Postprocedure Care

Patients should be monitored in an adequately staffed and monitored area of the ED following completion of the procedural

sedation until the patient has regained normal mental status, is no longer at risk of cardiorespiratory depression, and has normal vital signs.¹² On discharge, patients should be given written instructions detailing postprocedure diet, medications, level of activity, and be alerted to seek medical attention for concerning signs and symptoms.

CONCLUSION

Practice in the ED provides many unique opportunities and challenges to the anesthesia provider. As the number and complexity of patients presenting to EDs continues to increase, anesthesia providers must be aware of their growing scope of practice, as well as the tools and techniques available to them outside of the operating room.

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23 | Office-Based Anesthesia

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Over the past several decades surgery has become less invasive. This change has led to a shift from the inpatient hospital-based paradigm of surgery to an ambulatory surgery model. It was estimated that even by 1998, 60%–70% of all surgical procedures were done on an ambulatory basis.¹ Further improvements in anesthetic drugs have enabled this shift. Newer anesthetic agents are generally associated with quicker onsets, shorter durations of action, and fewer hemodynamic side effects.^{2,3} These combined advances in both surgery and anesthesia have allowed surgical procedures to be performed not only in hospitals or freestanding ambulatory surgery centers (ASCs) but also even in private offices. It is now estimated that approximately 16% of all ambulatory surgery or approximately 12 million procedures are performed in private offices annually.⁴

There are many advantages to office-based procedures for both patients and practitioners. The patient is afforded more privacy with a more personal experience, as well as decreased facility fee if paying out of pocket and less risk of exposure to nosocomial infections. The practitioner will generally have improved ease in scheduling of cases, the convenience of being able to perform surgery within the same office as preoperative and postoperative care, and in some cases will receive an enhanced professional fee.⁵

An office practice cannot provide the same level of care as a tertiary care medical center or even a small community hospital. For this reason, not all surgical procedures or patient populations are appropriate for this venue. For example, procedures associated with large fluid shifts, blood loss, excessive postoperative pain, or respiratory compromise should continue to be performed in the hospital setting. Likewise, patients with significant comorbidities, potentially difficult airways, or those at risk for aspiration should not be considered suitable candidates for an office-based procedure. The American Society of Anesthesiologists (ASA) has published specific recommendations regarding what types of surgery and patient populations should be excluded from this venue.⁶

SAFETY IN THE OFFICE

Anesthetic care performed in a private office must be as safe as that performed within a hospital or freestanding ASC. In this regard, the ASA has taken the position that office-based practitioners must adhere to the same perioperative guidelines as the more traditional hospital-based caregivers.⁷

Almost since its inception, the safety record for office-based surgery and anesthesia has been reported and debated. It was not long ago considered the “Wild West” of medicine.⁸ Reports of injuries and deaths were seen in the lay press and covered by national news organizations.⁹ Vila recently reported that there is as much as a 10% increase in morbidity and mortality associated with surgery performed in this remote location.¹⁰ There have, however, been several conflicting published studies highlighting the fact that office-based surgery and anesthesia are safe.¹¹⁻¹² The reason for this discrepancy is multifactorial. A major problem with any study investigating adverse patient outcomes starts with the accuracy of data collection. Most analysis of office-based morbidity and mortality relies on self-reporting of these outcomes by the private offices. Moreover, even in states where adverse event reporting is mandated and enforced, the anesthesia care delivery model for the individual surgical offices will vary. For example, in one office, the anesthetic may be performed by a board-certified anesthesiologist, while in another by a nurse anesthetist being supervised by the surgeon, and in yet another by a dental anesthetist who may be simultaneously doing the procedure. The training and qualifications of the caregiver may in fact have more of an effect on safety than the location of the operating room suite. Because of advances in anesthetic agents, perioperative monitoring, and provider training, modern-day anesthesia has an impressive safety record. The risk of injury during an anesthetic is quite small. Thus, the calculation of any true anesthetic-related morbidity or mortality rate will require sample sizes much larger than those presently reported.

The ASA along with other medical societies such as the American Society of Plastic Surgeons (ASPS) have been active patient safety advocates. Both have released guidelines and recommendations for office-based practitioners. The ASPS has mandated that as of 1996, all of its members must only operate in accredited office facilities.

OFFICE ACCREDITATION

One way of attempting to standardize quality of patient care within and among private offices is office accreditation. Hospitals have long had governmental oversight into the way they are run and managed. Hospitals have strict rules and regulations regarding all aspects of care, ranging from infection control, fire safety, administration, patient records,

staffing, and so on. The Joint Commission (TJC) has been the organization responsible for hospital accreditation. Participation with TJC is required for most private and governmental insurance reimbursements. There can be no doubt that this has helped lead to the tremendous safety record in hospitals within the United States.

As office-based surgery has expanded as a viable venue for patient care, there has been much attention placed on the creation of a similar type of regulatory agency or accreditation bodies to oversee and standardize patient care. Three such organizations have emerged. Currently the organizations that can accredit an office to perform surgery are TJC, American Association of Ambulatory Surgical Facilities (AAAASF), and Accreditation Association for Ambulatory Health Care (AAAHC). All three agencies, although unique, have similar requirements for office accreditation. This chapter will begin by looking at some of the important aspects required for accreditation.

As states began to regulate office-based surgery and anesthesia, with many requiring accreditation, it became important to categorize these surgical offices as to the type of anesthesia and surgery being performed. Surgical offices are presently classified as Level I, II, or III (Table 23.1). As mentioned, these levels are based upon the types of surgery performed as well as the depth of anesthesia. This classification system varies a bit from state to state, but the fundamentals remain constant. For the most part, the office-based anesthesiologist will have more involvement with Level III facilities, and the regulations are generally more stringent as the level of the office increases.

TABLE 23.1. *Levels of Surgical Offices and Surgery*

Level I (Class A) office surgery includes minor procedures performed under topical or local anesthesia not involving drug-induced alteration of consciousness other than minimal preoperative antianxiety medications.
Level II (Class B) office surgery includes any procedure that requires administration of minimal or moderate sedation/analgesia making postoperative monitoring necessary. The surgical procedures are limited to those in which there is only a small risk of surgical and anesthetic complications and hospitalization as a result of these complications is unlikely. (Many states limit this type of facility to ASA physical status [ASA PS] 1 or 2 patients, and some ASA PS 3 patients if the patients' physical status would not be affected by the procedure.)
Level III (Class C) office surgery is a procedure that requires or reasonably should require the use of deep sedation/analgesia, general anesthesia, or major conduction blockade. The known complications of the surgical procedure may be serious or life threatening. (Many states limit this type facility to ASA PS 1, 2, or 3.)

**Each state has its own definitions, but they are similar in nature to this document.

ASA, American Society of Anesthesiologists.

Source: Mississippi State Board of Medical Licensure.

GOVERNANCE AND ADMINISTRATION

The office should be a legally constituted entity with a medical director and governing body. This governing body should be responsible for creating the mission statement of the organization, establishing and enforcing all policies and procedures, and assuring that all applicable local laws and regulations are adhered to. It is also responsible for determining patients' rights within the facility and the credentialing and privileging process of caregivers.

The governing body must work in conjunction with the administrative arm of the organization to assure that quality health care is administered in a uniform fashion in accordance with the mission statement. There must be policies in place for hiring and training of all new employees. The administrative responsibilities include care of private patient information and records in accordance with state, local, and federal laws; patient satisfaction data collection; and employee occupational safety.

There must be a printed and/or electronic policy and procedures manual readily available. This manual must address staff conduct and responsibilities during all medical emergencies, including fire, bomb threat, malignant hyperthermia (when triggering agents are stocked), emergency admissions, and hospital transfers. To assist office workers in familiarizing themselves with individual responsibilities during such emergencies, drills must be conducted regularly throughout the year. There must be identified sentinel events that would trigger a chart review. Policies must be in place that specify how all drugs, controlled and noncontrolled, will be purchased, stored, dispensed, and disposed of.

QUALITY IMPROVEMENT AND OUTCOME MONITORING

Every surgical office should have a continuous quality improvement program built into its policies and procedures.⁶ The program should constantly assess and document outcomes and should include corrective actions. The quality improvement committee should meet on a regular basis and include members of the surgical team, nursing staff, and anesthesia providers.

The ASA taskforce on office-based anesthesia has published a list of outcome indicators that should be examined at each office site.¹³ Examples of sentinel events that should trigger a chart review would include events such as cardiopulmonary arrest, reintubation, return to the operating room, intractable nausea and vomiting, nerve injury, prolonged PACU stay, equipment malfunction, medication error, infection, or uncontrolled pain.

PHYSICIAN QUALIFICATIONS

All practicing physicians must hold an active state medical license and registration, and a current drug enforcement authority (DEA) certificate. They should have the education and training commensurate with their responsibilities within

the office and have current curriculum vitae (CV) on file. Board certification or board eligibility within the American Board of Medical Specialties (ABMS) or its equivalent is preferable. All training and qualifications must be verified independently by the office administration. The National Practitioner Database and the American Medical Society are helpful resources for primary source verification. Physicians should carry the amount of malpractice mandated by state and local law, and the presence or absence of such insurance must be communicated to patients.

All practitioners must be properly credentialed and privileged by the organization. Although it may be helpful to ensure that a practitioner has privileges to perform the intended procedures in a community hospital, it is not usually a requirement. However, the physician should have admitting privileges in a local hospital. There should be a process in place to provide peer review, performance improvement, and to ensure continued medical education (CME).

All physicians should hold an active certificate in basic cardiac life support (BLS). There should be at least one physician with advanced cardiac life support (ACLS) certification (or pediatric advanced life support [PALS] certification in the case of pediatric patients) present in the office until the last patient is physically discharged from the facility.

THE OFFICE FACILITY

Much information can be garnered during a brief walk-through of a surgical office. The anesthesia provider must have an idea of what to look for when evaluating a potential new office practice site (Table 23.2). The office should be clean, well lit, and properly ventilated, with well-marked emergency and fire exits. Doors and hallways should have been designed in such a way that would allow for the safe egress of a sedated patient on a stretcher during an emergency evacuation. Arm rails in hallways should have been designed to not inadvertently “catch” on clothing. There must be proper firefighting equipment available and inspected regularly. The operating suite must be large enough to not only perform the intended procedure but also to allow room at the head of the bed for the anesthesia provider to secure the patient’s airway if need be. There must also be adequate room on both sides of the stretcher to allow health care workers patient access should there be the need for cardiopulmonary resuscitation. There must be a “crash” cart with a defibrillator, equipped with backup battery power, and appropriate emergency drugs, which are checked and documented on a regular basis. This cart should have age- and size-appropriate defibrillator paddles and emergency airway equipment.

If volatile anesthetics or succinylcholine are being used or stocked, it is necessary to have on hand the supplies and equipment needed to perform the initial treatment of malignant hyperthermia (MH). These supplies are best organized in a designated MH cart. The cart must include at least dantrolene with its dilutant (sterile water), bicarbonate, glucose, calcium, and insulin. There must be ice available as well as

TABLE 23.2. *Office Checklist*

1.	Size of surgical suite and recovery area
2.	Hallway width and turns to maneuver a stretcher with an anesthetized patient
3.	Lighting
4.	Ventilation
5.	Monitors in surgical suite with battery backup
6.	Monitors in recovery area with battery backup
7.	Adequate oxygen supply with backup
8.	Source of suction
9.	Defibrillator, “crashcart”
10.	Double-lock narcotic cabinet
11.	Backup generator
12.	Fire-fighting equipment
13.	Policy and procedure manual
	a. Emergency transfer plan
	b. Office governance and administration
	c. Infection control
	d. Disaster planning
14.	Accreditation status
	a. Proceduralist’s
	i. Curriculum vitae
	ii. License and registration
	iii. Drug Enforcement Administration certificate
	iv. Postgraduate training record
	v. Continuing Medical Education, peer review, Performance Improvement, admitting privileges
	b. Basic Life Support/Advanced Cardiac Life Support/Pediatric Advanced Life Support certificates of clinical staff
	c. Fire marshal report

cooled intravenous fluids. A complete up-to-date listing of all necessary supplies and equipment for the initial treatment of MH can be found at <http://www.mhaus.org>. There must be a transfer agreement with a local hospital in place for this medical emergency, and the office-staff should have an MH drill at least annually.

The office must have reliable sources of both supplemental oxygen and suction. There must be a means of delivering the oxygen to the sedated patient both passively (i.e., nasal cannula or face mask) and actively, via positive pressure ventilation (i.e., manual self-inflating resuscitation device or anesthesia machine). If an anesthesia machine is present, it need not, and often will not, be a state-of-the-art machine. However, it must not be obsolete and the ASA has published guidelines on anesthesia machine obsolescence that must be adhered followed.¹⁴ The machine must be routinely maintained and serviced in accordance with the manufacturer’s specification and have battery backup.

Physiologic patient monitors, to be used throughout the perioperative period, also must be present. They must be serviced in accordance with the manufacturer’s recommendation and have a battery backup. At a minimum, there must be a continuous electrocardiogram (ECG) monitor, as well as monitors to measure noninvasive blood pressure, oxygen saturation, and exhaled carbon dioxide (CO₂). A device to

measure patient temperature also must be available. The anesthesia provider must adhere to the ASA monitoring standards perioperative.^{15,16}

Medical gases must be transported and stored in accordance with state and local regulations, and waste gases must be adequately scavenged in accordance with Occupational Safety and Health Administration (OSHA) regulations. Controlled substances must be purchased, stored, and dispensed in accordance with federal, state, and local law.

There must be an adequately staffed area for patient recovery. This is usually a separate room outside the operating suite. If space is an issue, it is acceptable to recover the patient in the operating room. Like the operating room, the recovery area must be of adequate size to allow for resuscitation of the patient should the need arise. The patient must be monitored postoperatively in accordance with the ASA guidelines.¹⁷ Although this seems intuitive, a review of the closed claims data revealed it is not uniformly done. In this study, Domino reported that 100% of respiratory events leading to patient morbidity in the postanesthesia care unit after an office-based anesthetic would have been prevented by the use of an oxygen saturation monitor.¹⁸

SUPPLIES AND EQUIPMENT

There are complex federal and state laws that deal with monopolies, antitrust issues, self-referrals, and “kick-backs.” It would be unusual for a health care provider to be conversant with all of the nuances of these laws. It would be even more uncommon for a health care provider to be adept enough to arrange a business agreement that does not inadvertently violate them. It is a tenet of the U.S. legal system that ignorance of the law is not an excuse. Therefore, before providing anesthesia services it would be advisable for the office-based practitioner to engage outside legal counsel to draft the requisite agreement(s). This contract should cover insurance participation, global fees, fee-for-service arrangements, liability, and termination of services. Additionally, it should clearly delineate responsibility for the purchasing and storage of drugs and supplies associated with the anesthetic care. This is of particular importance with Medicare as well as privately insured patients, for whom either an enhanced surgical fee or a facility fee is paid to the office. These additional fees pay for the associated costs of many, if not all, of the drugs and supplies utilized on the patient. Therefore, the party collecting these fees should be required to purchase the associated drugs and supplies.

THE FLORIDA OFFICE-BASED EXPERIENCE

The trend within this country is one of increasing governmental oversight of the office-based practitioner. The history of this medical field within the state of Florida teaches many lessons. The Florida Medical Board has long been an outspoken advocate for patient safety as it relates to office-based surgery and anesthesia. Between March and July of 2000, there were nine adverse outcomes associated with office-based surgery reported to their office. Of these injuries, five were patient

deaths. On August 10, 2000, the Florida Medical Board placed an emergency 90-day moratorium on all Level III surgeries within surgical offices.¹⁹ During this moratorium, the board looked at all aspects of office-based surgery safety. At the expiration of the moratorium, the board allowed resumption of office-based Level III surgery, but with several stipulations. Surgeons were no longer permitted to perform liposuction in combination with abdominoplasty or any other surgical procedure. The new law required that offices performing Level II and III procedures submit surgical logs to the department of health and implement a risk management program. It also forbade ASA physical status (PS) 3 and greater patients to undergo a Level III office-based procedure, and it required that all patients 40 years of age and older and/or patients of an ASA PS 2 or greater have a complete medical workup prior to undergoing Level III surgery. Finally, the law mandated compliance with the ASA guidelines for perioperative monitoring.¹⁹

As more states adopt regulations overseeing office-based surgery and anesthesia, many have implemented requirements similar to those of Florida. It is imperative that any office-based practitioner consult with the state and local health departments in his or her area to assure that all laws are adhered to. Failure to do so can result in civil or even criminal prosecution.

OFFICE-BASED SURGERY AND PLASTIC SURGERY

Many medical and surgical disciplines regularly utilize private offices to perform surgery and invasive procedures. These specialties include plastic surgery, urology, otolaryngology, gynecology, dentistry, general surgery, and gastroenterology. Plastic surgeons have long been in the forefront of office-based surgery, and their society, the ASPS, regularly publishes statistics on cosmetic surgery frequency and outcomes. According to recent ASPS statistics, in 2007, 11.8 million cosmetic procedures were performed. This represents a 59% increase from 2000. Of these procedures, 59% were performed in private offices throughout the United States.²⁰ The top five procedures according to this publication were liposuction, breast augmentation, eyelid surgery, abdominoplasty, and breast reduction.

Both plastic surgeons and dermatologists routinely perform liposuction, currently the most common office-based cosmetic procedure.²¹ The procedure is initiated by inserting hollow rods into small incisions in the skin and suctioning subcutaneous fat into an aspiration canister. Superwet and tumescent techniques were introduced into the practice of liposuction in the mid 1980s. These techniques involve utilizing large volumes (1–4 ml) of infiltrate solution (0.9% normal saline with 1;1,000,000 epinephrine and 0.025%–0.1% lidocaine) for each 1 ml of fat to be removed. Blood loss of approximately 1% of the aspirate should be anticipated.²² With this technique of liposuction, the peak serum levels of lidocaine will occur 12–14 hours after injection and decline over the next 6–14 hours.^{23,24} Although the maximum dose of lidocaine is usually limited to approximately 7 mg/kg, dosages of 3.5–5.5 mg/kg are considered safe by the authors because this

technique results in a single compartment clearance of lidocaine similar to that of a sustained release medication.^{24,25}

One of the important lessons from the Florida moratorium is that liposuction should not be considered a procedure without risk. In 2000, Grazer published a report that revealed an overall mortality rate of 19.1 per 100,000 after liposuction.²⁶ A common cause of death was pulmonary embolism (28.5%). Other reported causes included fat embolism, abdominal viscus perforation, infection, hemorrhage, and anesthesia-related causes. Several risk factors associated with morbidity and mortality were also documented (Table 23.3).

Perioperative anesthetic care of the patient undergoing liposuction should include careful attention to fluid management. The patient's preexisting fluid deficit, as well as physiologic maintenance, intra-operative loss, and third spacing should guide fluid replacement. In addition to pain control, during the postoperative period, fluid and electrolyte balance should continue to be given special attention. It is recommended that office-based liposuction be limited to 5 liters of total aspirant (supernatant fat and fluid).²⁷ Large-volume liposuction (greater than 3 liters) should not be done in conjunction with other procedures in an office. In 2002, Iverson in conjunction with ASPS published specific considerations for practitioners performing office-based liposuction^{22,28} (Table 23.4).

DEEP VEIN THROMBOSIS

The development of deep vein thrombosis (DVT) and ultimately pulmonary embolism (PE) is a common cause of death after liposuction and other cosmetic procedures. It accounts for a significant number of deaths among office-based surgical patients in general.²⁹⁻³⁰ Reinish reported 0.39% rate of DVT formation in patients who underwent rhytidectomy (37/9493).³¹ Of these patients 15 out of 37 (40.5%) went on to develop a PE. It was also reported that although general anesthesia accounted for only 43% of the anesthetics used in this patient population, this anesthetic technique accounted for 83.7% of the embolic events. Grazer reported a 1.2% inci-

TABLE 23.3. *Considerations and Recommendations Regarding Office-Based Liposuction*

1. Plastic surgeons should follow current ASA guidelines for sedation and analgesia.
2. General anesthesia can safely be used in the office setting.
3. General anesthesia has advantages for more complex liposuction procedures, including precise dosing, airway management, and controlling patient movement.
4. Epidural and spinal anesthesia are discouraged because of their association with vasodilatation, hypotension, and fluid overload.
5. Moderate sedation/analgesia augments the patient's comfort and is an effective adjunct to local infiltration.

ASA, American Association of Anesthesiologists.

Source: Reprinted with permission from Iverson RE, Lynch DJ, American Society of Plastic Surgeons Committee on Safety. Practice advisory on liposuction. *Plast Reconstr Surg.* 2004;113:1478-1490.

TABLE 23.4. *Risk Factors Associated with Liposuction*

1. Use of multiliter wetting solution infiltrate
2. Mega-volume (greater than 5 liters) aspiration causing massive third spacing
3. Multiple concurrent procedures
4. Anesthetic sedative effects causing hypoventilation
5. Permissive discharge policies (discharge criteria not based upon peer reviewed and accepted discharge parameters)

Source: Reprinted with permission from Grazer FM deJong RH. Fatal outcome from liposuction: census survey of cosmetic surgeons. *Plast Reconstr Surg.* 2000;105:436.

dence of DVT formation among abdominoplasty patients and a 0.8% incidence of developing a PE.³²

The development of DVT is related to both the procedure³³ and the underlying medical conditions of the patient. Patient-related risk factors appear in Table 23.5.³⁴⁻³⁵ It has been established that the risk of developing DVT can be decreased by the use of either mechanical or pharmacologic methods.^{36,37} Mechanical compression can be accomplished via intermittent pneumatic compression of the leg, or through a graduated elastic compression of the leg. Contraindications to this type of mechanical DVT prevention would include skin lesions or peripheral artery occlusive disease. Pharmacologic interventions include three types of anticoagulants: heparins (both unfractionated and low-molecular-weight), Vitamin K antagonists, and the newer oral antithrombotic agents (anti-IIa, anti-Xa). The ASPS recommends stratifying patients according to their risk of development of DVT and guiding therapy based upon this stratification³⁸⁻³⁹ (Table 23.6).

FIRE SAFETY

The office-based anesthesia provider must be knowledgeable regarding the issue of operating room fires. The ASA has recently published an advisory on the prevention and management of such an emergency.⁴⁰

Fire requires three components known as the "fire triad": an oxidizer (oxygen and nitrous oxide), an ignition source (electrocautery, laser, drill, etc.), and fuel (sponges, drapes, endotracheal tubes, solutions containing alcohol or other volatile compounds, etc.). The modern operating room contains all three in great supply.

The first step in fire prevention is education. All members of the surgical and anesthesia team must be educated on how fires are started, maintained, and prevented. There must be regularly scheduled fire drills that include all employees, even those with nonclinical duties. These drills should highlight the responsibilities of each staff member.

Fire prevention is of the utmost importance. The ASA recommends that if flammable materials are used to prep the skin they should be allowed to completely dry prior to draping the surgical field. The field should then be draped in a manner that does not allow for oxygen to accumulate. This is

TABLE 23.5. *Risk Factors Associated with the Development of Deep Vein Thrombosis*

important because these accumulated pockets of oxygen may flow into the surgical field where there is a source of ignition such as electrocautery. There must be communication between the surgeon and anesthesiologist when an oxygen-rich environment is being created near a surgical site. This is particularly relevant during procedures with monitored anesthesia care (MAC)—utilizing deeper sedation in and around the face. This scenario is common during facial plastic surgery. The surgeon and anesthesiologist must decide upon the depth of sedation required throughout different points of the procedure, and the need for supplemental oxygen must be determined. The inspiratory oxygen flow rate should be kept at a minimum, as guided by the oxygen saturation, and nitrous oxide should be avoided. The surgeon must be made aware of the inspiratory oxygen concentration, and the anesthesiologist must keep the oxygen concentration as low as clinically

possible. Medical air insufflations or suctioning can be used to reduce oxygen accumulation. When using an ignition source in an oxygen-rich environment, the ASA recommends reducing the oxygen flow as low as possible without creating hypoxia, and waiting several minutes to allow the oxygen to dissipate.⁴⁴

The management of a fire will require recognizing the early signs, stopping the procedure and ignition source, extinguishing the fire, and delivering care to the patient. It may even be necessary to evacuate the building. In any case, it is imperative that all these steps be reviewed regularly and drills performed.

CONCLUSIONS

Surgery and anesthesia performed within an office is a viable alternative to care within a hospital or freestanding ambulatory surgery center. This unique venue offers a multitude of benefits to both the patient and practitioner. However, like all new innovations it is not without its own possible risks.

Safety concerns are legitimate. The relative lack of governmental oversight in many areas of the country shifts the responsibility of assuring patient and location safety to the physicians and related health care workers. The ASA has long been a politically active advocate of patient safety within the hospital. They along with other medical societies such as the ASPS have continued to be outspoken advocates for safety within this new venue for providing surgical and anesthetic care. It would be recommended that any anesthesia providers or even surgeons/proceduralists planning to shift their medical practice to include this remote area review the recommendations and guidelines of these societies available at <http://www.ASAHQ.org> and <http://www.ASPS.org>. Additionally, since state and local regulations are in a constant state of flux, it is recommended that all practitioners regularly check local state medical boards for any new regulations and or statutes.

As with health care delivered in a traditional hospital or freestanding ASC, patient safety must always be a priority.

TABLE 23.6. *Stratification of Risk and Treatment for the Development of Deep Vein Thrombosis*

	<i>Patient Risk Factors</i>	<i>Treatment</i>
Low risk (one factor)	No risk factors Uncomplicated surgery Short duration of surgery	Comfortable position Knees flexed 5 degrees Avoid constriction and external pressure
Moderate risk (two factors)	Any age, uncomplicated surgery, other risk factors Age 40–60 with no other risk factors Major surgery, age less than 40, no other risk factors Oral contraceptive use	Proper positioning Intermittent pneumatic compression of calf or ankle (before sedation and continued postoperatively) Frequent alterations of the operating room table
High risk (three factors)	Age greater than 60 with other risk factors and uncomplicated surgery Major surgery and older than 40, or additional risk factors	Treatment identical to moderate risk patients Pre-op hematology consultation to consider pharmacologic intervention

This entails assuring that all safety mechanisms, often with areas of redundancy, are in place, before the first patient is anesthetized. As other chapters in this text have pointed out, any depth of sedation can be safely performed in many remote locations, including the private office. However, it is imperative that the operative and perioperative location is properly staffed, equipped, and stocked. Staffing must take into account not only the qualifications of the surgeon or proceduralist but the training and qualifications of the anesthesia provider(s), nursing staff, and office staff.

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24 Pediatric Anesthesia Outside of the Operating Room

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The anesthesiologist is increasingly being called on to provide pediatric anesthesia care for children in settings outside the operating room (OR). Providing anesthesia in these off-site venues challenges us to gain a familiarity with the procedures, tailor an anesthesia plan to the procedure and location, as well as to plan for the management of life-threatening situations. This chapter will review the different off-site locations and discuss the unique aspects of patient management associated with each area. Typical locations are outlined in Table 24.1.

A TOUR OF THE DIFFERENT OFF-SITE LOCATIONS AND PROCEDURES

The Gastroenterology Suite

Endoscopic Procedures

Gastrointestinal endoscopy is the most common procedure performed by pediatric gastroenterologists.¹ Children may tolerate this procedure with various levels of sedation (moderate or deep), monitored anesthetic care (MAC), or general anesthesia. Aside from a general anesthetic, other intravenous agents have been explored as an alternative to an inhalational anesthetic. Propofol is the most commonly used intravenous agent employed for adult endoscopies. It is gaining popularity for the pediatric population. Controversy exists between the anesthesia and nonanesthesia community regarding whose

scope of practice should encompass propofol. Propofol, considered by the American Society of Anesthesiologists to be an anesthetic agent that should be delivered by anesthesiologists, is considered by the American Society of Gastroenterologists to be an acceptable deep sedative for gastroenterologist administration.²⁻⁷ Regardless of who administers propofol, its success for providing acceptable conditions for lower endoscopy with an unsecured airway has been described.⁸ Alternative agents, which include narcotics, benzodiazepines, and more recently, dexmedetomidine, have been described as an acceptable alternative to propofol.^{5,7-11} Spontaneous ventilation without intubation is a reasonable choice in those patients who are not prone or at risk of aspiration or gastroesophageal reflux.¹²⁻¹⁴ Upper endoscopies are prone to respiratory complications, which include apnea, laryngospasm, bronchospasm, and airway obstruction. These complications may persuade some anesthesiologists to secure the airway with an endotracheal tube. Particular consideration should be given to smaller children and infants who undergo these esophagogastroduodenoscopies. Insufflation of air during the upper endoscopy can lead to distension of the stomach, small intestine, and sometimes even large intestine. Abdominal distension may impair diaphragmatic excursion and lead to hypoventilation, hypercarbia, and possibly oxygen desaturation. Recognizing these risks, some experts suggest that infants less than 6 months of age should undergo general anesthesia with endotracheal intubation.^{13,15}

The Epilepsy Service

Electroencephalograms

Performing electroencephalograms (EEGs) in infants and children can be challenging. These children often present with intractable seizures, aberrant behavior, and sleep disturbances. These children are often neurologically and developmentally challenged and pose a challenge. Even the process of applying the electrodes to the scalp can be difficult, and not infrequently patient movement makes these studies difficult to interpret. In general, general anesthesia, narcotics, and propofol disrupt the EEG.¹⁶⁻²¹ Chloral hydrate has been the mainstay agent administered to children who require sedation for

TABLE 24.1. *Typical off-site anesthetizing locations*

Gastroenterology Suite
Epilepsy Service
Radiology Suite
CT
MRI
Nuclear Medicine
Interventional Radiology
Radiation Oncology
Emergency Department
Cardiac Catheterization Laboratory

EEG.²² In clinical use for almost a century, chloral hydrate is generally safe and effective with the disadvantage of its long half-life of up to 24 hours. Dexmedetomidine was approved by the U.S. Food and Drug Administration (FDA) in October 2008 for adult procedural sedation. It has applications in children and may be a valuable sedative for EEG with minimal effects on the recordings.²³ Studies in rat models indicate that dexmedetomidine simulates the natural sleep pathway.²⁴ If dexmedetomidine has similar effects on sleep in the pediatric population, its use as a sedative for EEG studies will be supported.

Department of Radiology

Computed Tomography Scan

Computed tomography (CT) imaging uses ionizing radiation to differentiate between high-density (calcium, iron, bone, contrast-enhanced vascular and cerebrospinal fluid [CSF] spaces) and low-density (oxygen, nitrogen, carbon in air, fat, cerebrospinal fluid, muscle, white matter, gray matter, and water-containing lesions) structures. The majority of actual scanning sequences are short and can range from 10 to 80 seconds. With distraction techniques and scheduling these examinations around nap time, many children are able to complete a CT scan without adjuvant sedation or anesthesia. When an anesthesia is required, it is commonly for those children who are medically compromised, complicated, or fragile. Computed tomography scans for evaluation of craniofacial anomalies or choanal atresia may be particularly challenging because of the head manipulation that is required: extreme head extension, sometimes with the head suspended below the neck. This positioning enables better visualization of the sinuses, ears, inner auditory canal, and temporomandibular bones. Three-dimensional airway and cardiac studies have evolved and pose unique anesthetic requirements. The airway studies require breath holding during image acquisition on both inspiration and expiration to visualize potential areas of airway collapse.²⁵ To minimize motion artifact and ensure immobility upon inspiratory pause and full expiration, anesthesiologists usually intubate these children for the study. Cardiac studies pose an added challenge because the anesthesiologist is asked to administer adenosine during the study to briefly pause heart function so that image quality is maximized.²⁶⁻²⁸ Neck imaging with CT or magnetic resonance imaging (MRI) may be requested to evaluate neck stability in those patients with Down syndrome and possible atlantoaxial instability. In these patients with Down syndrome, the reported risk of subluxation is between 12% and 32%.²⁹ Cervical spine films should not be referred to as an indication of neck stability nor to indicate whether there is a risk for dislocation.³⁰ Rather, the clinical exam and history is the best determinant to distinguish those necks that are stable from those that are at risk. Those children who exhibit neurological signs or symptoms such as abnormal gait, increased clumsiness, fatigue with ambulation, or a new preference for sitting games are at risk. In these patients, anesthetic management should be guided only after direct consultation and evaluation by orthopedics

or neurosurgery. Angiography and venography using CT imaging is an evolving and useful imaging technique. These patients require motionless conditions, often breath holding to minimize motion artifact, and are administered contrast to map the vasculature. The timing of the image acquisition is critical, and imaging must be obtained during contrast injection. Any patient movement during this time will render the imaging study uninterpretable. In these cases, reinjection of contrast for image reacquisition is not possible because the children will have already received their maximum allowable amount of iodine contrast for that 24 hour period.

In infants and children, CT studies of the abdomen and pelvis may require the administration of oral contrast. The gastrograffin contrast is required to be present in the areas for which imaging is requested, thus rendering these children with contrast in their upper gastrointestinal system at the time of an anesthetic induction. Diluted to a concentration of 1.5%, many anesthesiologists and radiologists consider gastrograffin to be a clear liquid. The volume that is administered orally can vary. Newborns less than 1 month of age receive 60 to 90 ml, infants between 1 month and 1 year of age may receive up to 240 ml, and children between the ages of 1 and 5 years receive between 240 to 360 ml. Gastrograffin typically requires no more than a 2 hour window after ingestion until actual CT imaging. The scan must be completed while the gastrograffin is still in the gastrointestinal tract. There is no published data citing an increased aspiration risk in this population. Rather, a large review of children who received oral contrast prior to receiving pentobarbital or chloral hydrate sedation indicates that there is no significant risk of aspiration.³¹ Full-strength (3%) gastrograffin is hyperosmolar and hypertonic and should be diluted to an isomolar and isotonic 1.5% concentration of neutral pH prior to oral or nasogastric tube administration. There is one case report of 1.5% gastrograffin aspiration in a child³² with no adverse sequelae; therefore, the risk of using a 1.5% concentration of neutral of gastrograffin seems low.³³ In our institution, we do not consider these patients as "full stomachs" and would manage them as we would any child who presents nil per os (NPO).

Magnetic Resonance Imaging

Magnetic resonance imaging is employed for the evaluation of neoplasms, trauma, skeletal abnormalities, vascular anatomy,³⁴ developmental delay, behavioral disorders, seizures, failure to thrive, apnea/cyanosis, hypotonia, and mitochondrial/metabolic disorders. Magnetic resonance angiography (MRA) and magnetic resonance venography (MRV) are especially helpful to evaluate vascular flow, generally does not require the administration of intravenous contrast, and can sometimes replace invasive catheterization studies for follow-up or initial evaluations of vascular malformations, interventional treatment, or radiotherapy.³⁵

Gadolinium diethylenetriaminepentaacetic acid (DTPA) is a low osmolar ionic contrast medium used for MRI, with a slower clearance in neonates and young infants than adults, yielding longer windows for imaging.^{36,37} Free gadolinium is

quite toxic and is therefore chelated to another structure that restricts the ion and decreases its toxicity. Transient elevations in serum bilirubin (3-4% of patients) have been reported and a transient elevation in iron for Magnevist and Omniscan (15%–30% of patients) tends to reverse spontaneously within 24–48 hours.³⁸ Anaphylactoid reactions occur on the order of 1:100,000 to 1:500,000 and are more rare (<1:100,000 doses) in children.

Functional MRI (fMRI) is an evolving technology that measures the hemodynamic or even metabolic response related to neural activity. It is useful for localizing sites of brain activation, as well as for brain mapping.³⁹ Some fMRI studies require cognitive facility and require interaction with a responsive patient.⁴⁰ All-digital audiovisual stimulation technology (Resonance Technology, Inc, Los Angeles, CA) employs MRI-safe goggles that are worn by the child and useful for fMRI. Even with these audiovisual stimulating goggles, there may be the added challenge if a 3 Tesla magnet is used rather than a 1.5 Tesla: the noise of the 3 Tesla can interfere with the acoustic stimulation generated for purposes of obtaining the fMRI.^{41,42} It is recommended that earplugs or MRI-compatible headphones be offered to all pediatric patients. They are required for all patients imaged in the 3 Tesla magnet. Functional MRI studies are challenging in children who are unable to respond appropriately whether because of age or cognitive compromise. The advent and introduction of the MRI-safe video goggles, introduced in 1993, has revolutionized our ability to perform fMRI studies as well as provide distraction to the child and avoid sedation in some.

Even motivated children and adolescents may suffer from claustrophobia and have difficulty cooperating when down the confined bore of the magnet. In adults, anxiety reactions⁴³ can occur in 4% to 30%.⁴⁴ The MRI-safe video goggles are equipped with headphones and enable patients to watch favorite videos or listen to music while in the MRI scanner. These goggles can offer children an alternative to sedation or anesthesia and are particularly useful in those patients between the age of 5 to 7 years who are motivated but require distraction. Alternatively, some patients although motivated may not be able to complete a MRI scan without adjuvant sedation or anesthesia. For example, patients with extreme skeletal abnormalities such as advanced scoliosis or flexion contractures, although motivated, may be unable to lie motionless or supine on the solid, uncushioned MRI table for the extended duration of a spine MRI. These patients may require general anesthesia for positioning and comfort or may need adjunctive pain medication.

With newer sedatives, it is possible that immobility in some children may be achieved without a general anesthetic. Propofol may be used to maintain spontaneous ventilation without airway intervention. The risk of respiratory complications, albeit small, must be anticipated with propofol. Dexmedetomidine, although not FDA approved for usage in children, presents another alternative. An alpha-2 agonist dexmedetomidine may present hemodynamic variability but generally preserves the respiratory drive and airway. Dexmedetomidine has been successful at high doses in

maintaining spontaneous ventilation and adequate sedation for MR imaging.^{45,46}

Those children who are not appropriate for sedation will require general anesthesia. Over the past decade, the ability to provide anesthesia in the MRI suite has evolved, paralleling the development of MRI-compatible and safe anesthesia machines, equipment, and monitors. Historically, anesthetic management of children in the MRI suite has been highly dependent and somewhat limited by the availability of MRI-compatible monitors and anesthesia gas machines.⁴⁷⁻⁴⁹ In 2007, the American College of Radiology established guidelines to minimize the risk of MRI related mishaps, but it did not address the anesthesiologist's needs.⁵⁰ These guidelines were written in response to fatalities which had occurred when loose, nonferrous oxygen cylinders became projectiles when brought inadvertently into the MRI suite.⁵¹ In 2008 the ASA assembled a Task Force composed of anesthesiologists and a radiologist with MRI expertise to create a Practice Advisory on Anesthetic Care for Magnetic Resonance Imaging.⁵² This document establishes important recommendations for safe practice as well as consistency of anesthesia care in the MRI environment. The purpose of this Advisory was to promote safety in the MR environment, avoid MR-associated mishaps, optimize patient care and decrease adverse events associated with MR anesthesia, identify and discuss physiologic monitors and anesthesia equipment available in the MR suite, and identify health-related concerns with exposure to the MR environment. Important to this Advisory was the need for MRI-safe/conditional physiological monitors which adhere to ASA standards as well as the preference for MR-safe/conditional anesthesia machines. The practice of using non-MRI-safe anesthesia machines outside of the MRI suite (zone III) with elongated ventilator tubing threaded through a wave guide in the scanner wall was cited as posing an added risk of adverse events as compared to the use of the MRI-safe anesthesia machines within the suite.

Safety in the MRI environment is maximized when the anesthesiologist is fully educated to MR safety and hazards of the environment and has a heightened awareness for the potential risk of ferrous objects inadvertently exposed to the MR environment. Clipboards, pens, watches, scissors, clamps, credit cards, eyeglasses, paper clips, and even stethoscopes are just some of the objects that can become projectiles.⁵¹ Physiologic monitoring can also be distorted in the MR suite, regardless of modifications to the equipment. Conventional electrocardiogram (ECG) monitoring, similar to that used in the operating room, may not be used in the MR suite. The ECG leads would cause patient burns. Rather, the traditional ECG cables must be replaced with fiberoptic ECG to minimize the risk of burns. Even with fiberoptic cables, it is important to recognize that the connections between the ECG pads and the telemetry box are still hardwired, and careful attention must be paid to prevent frays, overlap, exposed wires, and knots in the cables.⁵³ To prevent patient injury, no exposed wires or conductors should touch the patient's skin. Similar to the ECG leads, pulse oximeters are also fiberoptic. Particularly when inpatients are transported to the MRI suite,

the anesthesiologist must uncover the patient and do a thorough search for conventional leads, probes, or adhesives (ECG, pulse oximeter probes), which could result in second- and third-degree burns if not removed.^{53,54}

When MRI-safe/conditional anesthesia machines are available in the MRI suite, anesthesiologists may elect to perform the anesthetic induction and subsequent management in the MRI suite itself. As in the operating room, some anesthesiologists may offer parent-present inductions in these situations. However, the biologic effect of MRI should be considered when offering parent-present induction, although to date there are no conclusive reports implicating chromosomal aberrations in humans to the MR environment. Amphibians exposed to a high Tesla magnet field have been shown to be free of any defects in embryologic development.⁵⁵ Most hospital MRI machines are 1.5 Tesla. Despite these studies, many institutions still prohibit pregnant patients or family members from accompanying the child into the MRI suite. Unless fetal imaging is required or the MRI is necessary for emergent medical care, MRI during the first and second trimester is discouraged by the American College of Radiology.²⁸

Nuclear Medicine

Single photon emission computed tomography (SPECT) scans and positron emission tomography (PET) scans are commonly utilized nuclear medicine imaging studies in children. SPECT scans use produce three-dimensional brain images and involve the use of radiolabeled technetium-99 (half-life, 6 hours).⁵⁶ The technetium radionuclide is trapped intracellularly, in proportion to regional blood flow. When injected immediately following a seizure, the technetium can identify areas of increased blood flow, potentially identifying areas of recent seizure activity. Ideally, the imaging should be performed within 1–6 hours of the seizure. PET scans use positron emission tomography and radionuclide tracers of metabolic activity, such as oxygen or glucose metabolism.^{57,58} Unlike SPECT scans, PET scans should be performed during the seizure itself. Because of the short half-life of the glucose tracer (110 minutes), the scan is best completed during the seizure or within 1 hour thereafter. These children do not commonly require general anesthesia, particularly since many are postictal and naturally sedated in this state. However, those that are unable to undergo the imaging alone can frequently receive moderate to deep sedation to induce motionless conditions. These children may be resistant to some anesthetics and barbiturates, particularly since they may be already on a multitude of antiepileptic medications. Dexmedetomidine or propofol may offer reasonable intravenous sedation, monitored anesthesia care or intravenous anesthesia for these children.

Radiation Oncology

Pediatric radiation oncologists use ionizing photons to destroy lymphomas, acute leukemias, Wilm's tumor, retinoblastomas, and tumors of the central nervous system. Repeat sessions are typical, requiring reliable motionlessness to precisely aim the

beam at malignant cells while sparing healthy cells. Radiation oncology requires anesthesia involvement for procedures ranging from daily radiology therapy to stereotactic radiosurgery. Radiation therapy—whether it occurs once, daily, or as a fractionated or hyperfractionated (multiple sessions per day) session—is challenging for the anesthesiologist. The procedures, albeit brief, require absolute immobility. The anesthesiologist and all other personnel remain outside the suite during the therapy. Remote video monitoring along with remote monitoring of physiological vital signs is essential. Most of these patients present with a central line for easy access. A small core group of anesthesiologists is appreciated by family and patients enabling the child to develop a nonthreatening, consistent, positive relationship with the anesthesiologist.

Stereotactic radiosurgery (Gamma knife) is a major advance in the treatment of selected intracranial arteriovenous malformations and tumors in children and usually requires coordination between the departments of radiology, radiation therapy, neurosurgery, and anesthesiology.⁵⁹ Typically, the stereotactic procedure begins in either CT or MRI, during which a stereotactic head frame is applied. Although most adults tolerate this with local anesthesia or sedation, pediatric patients (including most adolescents) typically require a general anesthetic.

Following the MRI or CT scan, these images are reviewed and calculations for dose and the three-dimensional coordinates for the focused single large fraction radiation beam may take several hours. During this time, the younger patient usually remains intubated and sedated to avoid untoward airway incidents while the heavy, cumbersome head frame is still in place. The most common perioperative problem for this procedure is nausea and vomiting, probably due to radiation sensitivity of the chemoreceptor trigger zone. The actual radiosurgery occurs in the radiosurgery suite, following which the patient is typically extubated following removal of the head frame.⁵⁹

Total body irradiation (TBI) is generally performed twice a day over a 6-week period. As these patients progress with their TBI treatment, vomiting, respiratory illness, poor nutrition, and hypovolemia are all possible. Although anesthesiologists are wary of the risks of aspiration, both sedation and general endotracheal anesthesia have been found to be equally safe.^{60,61} Anesthesiologists should be reluctant and resistant to cancel a child's TBI session, as consistent repeat treatment is necessary for a favorable chance of positive outcome.

Interventional Radiology

The emerging technologic advances in the field of interventional radiology have expanded the breadth, complexity, and duration of the procedures in the pediatric population. Interventional radiology encompasses both nonvascular and vascular intervention.⁶² The majority of interventional procedures are nonvascular and include biopsies, insertion and/or repositioning of drainage catheters, and insertion of catheters for central intravenous access. These procedures may often be managed with monitored anesthesia care or even deep

sedation. For the pediatric patient, even short and brief procedures may require a general anesthetic to ensure safe and motionless conditions. Airway management is dictated by the imaging needs: endotracheal intubation when the radiologist requires controlled ventilation, breath holding during angiography sequences, and hypercarbia to promote vasodilatation. Regional anesthesia, rarely administered outside the pediatric operating room, nevertheless remains a valid choice in some circumstances. Intercostal nerve blocks may be very useful for lung or rib biopsies, chest tubes, biliary or subphrenic drainage procedures, and insertion of biliary stents.

The vascular interventions can range from straightforward angiography to complex procedures. Embolization and sclerotherapy are important and often complex interventional vascular procedures used in the management of vascular malformations, aneurysms, fistulas, hemorrhage, and to accomplish renal ablation. Percutaneous transluminal angioplasty and fibrinolytic therapy are gaining popularity even in small babies. Vascular malformations are congenital aberrant connections between vessel, lymphatic, arterial, or venous connections. Vascular malformations may be high-flow or low-flow lesions. Particularly with large lesions, high-output cardiac failure and congestive heart failure with the potential for pulmonary edema should be anticipated. Stainless steel coils, absorbable gelatin pledgets and powder, polyvinyl alcohol foam, glues, thread, and ethanol may be used for sclerotherapy or embolization. Absolute ethanol is unique and has special safety considerations of which the anesthesiologist should be aware. Ethanol promotes sclerosis, first producing a coagulum of blood and subsequent endothelial necrosis.⁶³ Sclerotherapy or embolization with absolute (99.9%) ethanol increases the risk of developing a postprocedure coagulopathy.⁶⁴ Ethanol also denatures blood proteins and can result in hematuria for which generous fluid replacement can avoid potential renal failure. During procedures that involve lower extremity lesions and tourniquets, hemoglobinuria should be anticipated as soon as the tourniquet is released. Generous hydration and furosemide (0.5 to 1.0 mg/kg) facilitate the resolution of gross hematuria. At our institution, in the event of persistent hemoglobinuria, in the recovery room, the radiologists request that sodium bicarbonate (75 mEq/l in 5% dextrose and water) be administered at two-times maintenance rate to alkalinize the urine and minimize precipitation of hemoglobin in the renal tubules.⁶⁵

Administration of ethanol has the potential for cardiovascular collapse. Most reported cases of cardiovascular collapse involved lower extremity malformations.⁶⁶

Ethanol can produce a state of intoxication. The ethanol used for embolization and sclerotherapy is 95% to 98% pure. Patients who receive >0.75 ml/kg can be clinically intoxicated and display extremes of behavior.⁶³ Hypothermia is a risk in interventional radiology because these suites are kept cool to maintain the equipment. Heating lamps and force air heaters may be used when safe and appropriate.

Cerebral angiograms, although often short and straightforward, typically require endotracheal intubation in the pediatric population to provide hypercarbia and breath-holding conditions. Hypercarbia to endtidal $\text{CO}_2 \geq 50\text{mm Hg}$ will

promote vasodilation to allow better access and visualization of AQ2 cerebral vasculature. Orogastric, nasogastric tubes, esophageal stethoscopes, and esophageal temperature probes should be avoided for cerebral angiography because they create artifacts on the angiographic images.

It is important that the anesthesiologist understand the indications for the cerebral angiography. For example, any child requiring a study for the potential or confirmed diagnosis of moya moya have anesthetic techniques that minimize the risk of transient ischemic attacks and stroke during the procedure.^{67,68} Angiographic imaging of the abdomen or pelvis may be enhanced through the use of glucagon. Glucagon is efficacious for digital subtraction angiography, visceral angiography, and selective arterial injection in the viscera. Glucagon, when needed, is administered in divided doses of 0.25 mg to a maximum of 1.0 mg intravenously. Risks include glucagon-induced hyperglycemia, vomiting (particularly when given rapidly), gastric hypotonia, anaphylaxis with rapid administration, and physiologic signs (tachycardia and hypertension) that mimic pheochromocytoma.⁶⁹⁻⁷¹ Antiemetics may be considered prophylactically, although the efficacy of prophylactic treatment has not been proven.

Ketamine is a useful agent in the interventional suites. It is one of the oldest intravenous agents still in use, introduced into clinical anesthesia in 1958 and released for clinical use in the United States in 1970. Although associated with untoward effects in adults, ketamine-induced nightmares, hallucinations, delusions, and agitation are rare in children.^{72,73} Intravenous or intramuscular ketamine is valuable for painful procedures in the radiology and gastroenterology suite, often avoiding the need for securing the airway. In some situations, ketamine can be a successful alternative to general inhalational anesthesia and has been used even for those procedures that require immobility.^{74,75}

PREPARING FOR EMERGENCIES IN AREAS DISTANT TO THE OPERATING ROOM

Cardiopulmonary Resuscitation

Each extramural anesthetizing location is unique with regard to logistics, planning, and equipment necessary to conduct airway or cardiopulmonary resuscitation. Redundancy of monitoring devices and equipment is important in all off-site areas. Areas with restricted access, MRI in particular, should have designated adjacent locations equipped with wall oxygen, suction, and full monitoring and resuscitation capability. A self-inflating silicone bag (no ferromagnetic working parts) or nonferrous Jackson Rees circuit should always be kept inside the MRI suite to initiate resuscitation while transporting the child outside the MRI suite. Codes should never be conducted in the MRI scanner for multiple safety reasons. First, there is a risk of morbidity or mortality from ferrous objects. As support personnel rush inside to assist, unremoved ferrous materials will become projectiles and create an even more hazardous situation. Quenching a magnet should not be an alternative, because it requires a minimum of 3 minutes to

eliminate the magnetic field. To date, there are no MRI-compatible defibrillators and those that have been brought in have demonstrated lack of adequate function.⁷⁶ To reiterate, in an emergency, the patient should be removed from the scanner to an area outside of the magnetic field that is equipped with a wall oxygen source for a self-inflating bag and access to appropriate monitors.

Difficult Airway Management

The unrecognized difficult airway is particularly challenging in any area that is remote to the operating room. If a child with a known difficult airway requires endotracheal intubation, a conservative approach is to perform the anesthetic induction in the operating room. Airway management in the operating room environment provides the comfort and security of having backup expertise and equipment in the event of a difficult airway. Following intubation, the child may then be transported to the off-site location. It is important, however, to have alternative airway devices in all off-site locations. Laryngeal mask airways in particular should be available at all these locations, because their placement can successfully manage children with craniofacial anomalies associated with difficult airways.⁷⁷⁻⁷⁹

SUMMARY

The demand for anesthesia and sedation services for the pediatric patient in sites distant to the operating room, both within the hospital and in freestanding ambulatory centers, are increasing. Over half of most off-site pediatric anesthetics are performed in the Department of Radiology. As technology advances, the anesthesiologist must also maintain an understanding of the procedures in order to tailor the anesthetic appropriately. Unlike with adults, the outcomes of monitored anesthesia care versus general anesthetics in the pediatric population have never been examined.⁸⁰ There are no data to support one technique over another. Deep sedation with agents that preserve ventilation, such as ketamine and dexmedetomidine, may be reasonable alternatives for procedures that are minimally invasive.^{45,81,82} As more experience with the procedures, risks, and newer sedation alternatives is gathered, the anesthesiologist will be better able to care for the pediatric patient in settings distant to the operating room.

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25 | Anesthesia for Procedures in the Intensive Care Unit and the Neonatal Intensive Care Unit

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Anesthesiologists who are assigned to provide anesthesia for operations in the intensive care unit (ICU) must adapt principles of safe and effective anesthesia practice to this novel outside-of-the-operating-room environment. Among the reasons to perform surgical procedures at the bedside in the ICU is the avoidance of transporting an unstable, critically ill patient from the ICU to the operating room.¹ Therefore, patients who need anesthesia care to undergo surgical procedures in the ICU can present a major challenge. The types of procedures performed in the ICU are listed in Table 25.1.

THE ENVIRONMENT

Although an ICU does not qualify as an austere anesthetizing location, it presents significant challenges to the anesthesiologist.

TABLE 25.1. *Surgical Procedures Performed at the Bedside in the Intensive Care Unit*

I. Under Local Anesthesia
Chest tubes
Thoracentesis
Diagnostic peritoneal lavage
Diagnostic ultrasound; pericardiocentesis
II. Under General Anesthesia
A. Common procedures
Percutaneous tracheostomy
Percutaneous endoscopic gastrostomy (PEG)
Esophagogastroduodenoscopy (EGD)
Transesophageal echocardiogram (TEE)
B. Uncommon procedures
Thoracotomy
Laparotomy
Amputation

Unless surgical nurses accompany the surgeons, the anesthesiologist will have to work with nurses who are unfamiliar with the pace of the operation and the needs of the anesthesiologist. It is important to gather needed equipment and supplies prior to commencing anesthetic care for the surgical procedure. If the anesthesiologist has the necessary equipment and supplies conveniently at hand, he or she will be able to remain near the patient and concentrate on those necessary anesthetic tasks instead of being frustrated by lack of cooperation from naïve assistants. Table 25.2 lists anesthetic equipment typically needed in an ICU.

Although the monitoring standards for critically ill patients in the ICU are similar to the monitoring standards for anesthetized patients in the operating room, subtle differences exist between monitoring systems in the two areas.² Anesthesiologists should familiarize themselves with the bedside monitoring system in the ICU prior to initiating anesthesia. It is especially important that the anesthesiologist understand how to change the monitor display in order to follow the needed frequency of measurements for monitoring the anesthetized patient.

TABLE 25.2. *Anesthetic Equipment for the Intensive Care Unit*

Airway:	Laryngoscope
	Endotracheal tube
	Stylet
	Self-inflating ventilation bag. (For patient intubated prior to procedure only needed in case of emergency extubation.)
Hemodynamic:	Intravenous fluid
	Pumps as needed
Pharmaceuticals:	Hypnotics—propofol/midazolam
	Analgesics—fentanyl
	Muscle relaxants
	Antibiotics
	Miscellaneous diuretics

Space allocation in the typical ICU room frequently cramps the anesthesiologist in an awkward position. This space limitation may also interfere with maintenance of sterile fields necessary for surgery.³ The anesthesiologist should take a few minutes to plan for position of personnel and equipment.

Fluid management of the ICU patient usually is less hurried than fluid management for an anesthetized patient with ongoing surgical fluid losses. For example, many critically ill patients have only a few small-gauge peripheral IVs or small-bore ports in relatively high-resistance central venous catheters. Therefore, if rapid intravenous volume replacement is anticipated for the bedside surgical procedure, the anesthesiologist should place appropriate vascular access. If blood replacement is anticipated, the anesthesiologist must verify availability of appropriate blood products before becoming ensnared with continually managing the ICU patient undergoing a surgical procedure.

MONITORING REQUIREMENTS

Table 25.3 lists monitors required during ICU anesthesia. Managing general anesthesia in the critical care unit requires the same standards of monitoring used in the operating room. Cardiopulmonary monitoring includes continuous pulse oximetry for oxygen saturation and heart rate; continuous electrocardiography for heart rate and rhythm; noninvasive blood pressure to monitor cardiac performance and intravascular volume status; continuous capnography to monitor endotracheal tube position, respiratory rate, and metabolic function, and body temperature monitoring to assess metabolic state.

Invasive hemodynamic monitors provide useful information about cardiovascular performance and are frequently indwelling in unstable ICU patients who require bedside procedures. Arterial catheters provide a route to monitor beat-to-beat arterial pressure as well as ready access for blood sampling to assess glycemic control, gas exchange, and acid base status. Central venous pressure and/or pulmonary artery pressure monitoring provides information about a patient's blood volume and myocardial performance. Either systolic pressure variation or pulse oximeter plethysmographic volume variation with respiration suggests hypovolemia correctable by volume infusion.

Cardiac output is an important metabolic variable that can be monitored in the critically ill patient. Pulse wave contour analysis via an intra-arterial catheter provides measurements of cardiac stroke volume and cardiac output. Either intermittent or continuous thermodilution via a pulmonary artery catheter also can be used to measure cardiac output. A pulmonary artery catheter has the added advantage of providing a route to sample mixed venous blood gases that are used to monitor a critically ill patient's metabolic demand for oxygen and the cardiopulmonary system's ability to supply that demand.

Other techniques to monitor adequacy of myocardial response are transesophageal echocardiography (TEE) and transesophageal ultrasound on the descending aorta. However, these techniques are only useful for relatively short time periods.

Table 25.4 outlines advanced monitoring procedures for critical care anesthesia patients.

CHOICE OF ANESTHETIC DRUGS

Anesthesia vaporizers are rarely fitted to critical care ventilators; therefore, the anesthesiologist must rely on total intravenous anesthesia (TIVA) in the ICU.⁴ Besides the lack of vaporizers in the ICU, ability to scavenge waste anesthetic gases is compromised in this setting. Therefore, TIVA has significant environmental advantages in the ICU. Another advantage of TIVA in the ICU is the fact that most of the patients are managed with sedation and analgesia similar to the analgesics and hypnotics used with TIVA.

Opioids continue to be basic components of critical care unit sedation. Fentanyl infusions are commonly used for critical care sedation and analgesia. The anesthesiologist can titrate the fentanyl infusion to blunt physiologic responses to surgical procedures. Patients that are receiving fentanyl infusions as part of their ICU sedation may need a bolus to supplement their infusion prior to commencing the surgical procedure. Other useful opioids include hydromorphone, sufentanil, and morphine, although these are not routinely used for ICU patients.

Hypnosis is frequently provided by a propofol infusion that is also commonly used to sedate ventilator-dependent ICU patients. However, extended use of propofol can be problematic in the ICU because of the propofol infusion syndrome. Infusions of propofol at greater than 50 $\mu\text{g}/\text{kg}$ per minute for longer than 24 hours puts the patient at risk of developing metabolic acidosis and muscle necrosis secondary to a defect of mitochondrial fatty acid metabolism. However, propofol continues to be safe and efficacious for short-term use in ICU patients undergoing surgical procedures. Patients who have already developed propofol infusion syndrome should be managed with alternative hypnotics.

Other hypnotics include lorazepam, midazolam, and etomidate. Midazolam has a pharmacokinetic profile that works very well for hypnosis in critically ill patients undergoing surgical procedures. It can be titrated either by bolus administration or by continuous intravenous infusion. Although recovery is somewhat slower than with propofol, quick recovery from surgical anesthesia is rarely a priority in ICU patients. Furthermore, hemodynamic stability is somewhat improved by using midazolam instead of propofol. Lorazepam, a long half-life drug, is difficult to titrate to the varying intensity of pain stimulation characteristic of surgical procedures. Etomidate has a short half-life, but repeated administration (as in an infusion) is associated with significant adrenal cortical suppression and an acute Addisonian crisis.⁵

The specific alpha-2 adrenergic agonist, dexmedetomidine, is a useful addition to balanced multidrug TIVA for ICU patients undergoing surgical procedures.⁶ Stimulation of central alpha-2 receptors causes sedation and mild analgesia without depressing brainstem respiratory centers. The main side effects arise from modulation of the sympathetic nervous

TABLE 25.3. *Monitoring Requirements for Anesthesia in the Intensive Care Unit*

Respiration:	Capnography
	Pulse oximetry
	Minute ventilation
Circulation:	ECG
	Pulse oximeter
Metabolic:	BP noninvasive
	Core temperature

BP, blood pressure; ECG, electrocardiogram.

system—bradycardia and hypotension during high-dose infusions. Patients may also display a hypertensive response to rapid bolus administration which should be avoided. However, a modest infusion rate of dexmedetomidine will reduce the requirements of hypnotics and analgesics required for surgical anesthesia.

Neuromuscular blocking drugs are frequently needed for anesthesia for patients who require bedside surgical procedures. Succinylcholine may be useful for intubation of patients who are not ventilator dependent and have a native airway. However, it should be avoided in patients who have significant body surface area burned, upper or lower motor neuron paralysis including spinal cord injury, or significant crush injury with rhabdomyolysis who are at risk for extreme hyperkalemia and cardiac arrest from succinylcholine.⁷ There seems to be little pharmacologic reason to choose one nondepolarizing neuromuscular blocking drug over another. Vecuronium, pancuronium, cis-atracurium, and rocuronium all have devotees among critical care anesthesiologists. The presence of impaired hepatic drug clearance and/or renal failure may favor cis-atracurium, which spontaneously degrades in the plasma, thus providing a route of elimination. Vecuronium and rocuronium are associated with cardiovascular stability, which may make them the drug of choice in hemodynamically labile patients.

SURGICAL PROCEDURES IN THE CRITICAL CARE UNIT

Tracheostomy

Although formal open tracheostomies can be performed on a patient in an ICU bed, percutaneous dilated tracheostomy (PDT) is especially adapted for the critical care unit. The anesthesiologist will place a bronchoscope near the top of the endotracheal tube to view the endotracheal mucus during transtracheal needle puncture at the first or second tracheal rings. The needle puncture is followed by passing a flexible guidewire through the needle, which is exchanged for tracheal dilator over the wire, similar to the Seldinger technique used for vascular cannulation. Prior to the surgeon inserting the needle into the trachea, the anesthesiologist must partially withdraw the endotracheal tube and bronchoscope so that the tip of the endotracheal tube is not spared by the needle. The anesthesiologist's observations through the bronchoscope

TABLE 25.4. *Advanced Monitoring Procedures for Anesthesia in the Intensive Care Unit*

Arterial catheter
Central venous catheter
Pulmonary artery catheter
Cardiac output monitoring

ensure that the needle does not traverse the posterior membranous trachea before the guidewire is inserted. Further observations via the bronchoscope document the correct positioning of the wire distally in the center of the tracheal lumen. After the dilator prepares a track for the tracheostomy, an appropriate sized tracheostomy tube is rapidly advanced through the stoma and the ventilator circuit is attached to the tracheostomy tube to reestablish mechanical ventilation.

The procedure is ideally monitored via a video tower attached to the bronchoscope so that all members of the surgical and anesthesia team can observe. The bronchoscope rapidly identifies needle malposition so that the guidewire, dilator, and tube will not be forced into a false passage. Anesthesia needs to be calibrated to prevent the patient from coughing during the procedure.

Gastrostomy

Similar to the PDT, a percutaneous endoscopic gastrostomy (PEG) combines a percutaneous needle entry into an internal hollow organ, a guidewire exchange of the needle for a tube, and endoscope guidance.

In this procedure, an endoscope placed in the gastric antrum identifies the proper position of a needle pushed through the left upper quadrant of the abdomen into the stomach. A long flexible guidewire advanced through the needle into the gastric lumen is snared by the endoscope and pulled out through the patient's mouth. The gastrostomy tube is attached to the wire and pulled by its distal end through the esophagus and out through the abdominal wall where a flange on the end of the tube holds it in the gastric lumen.

The anesthesiologist must ensure adequate gas exchange throughout the procedure as well as analgesia for the stimulation of passing the endoscope into the esophagus, and the needle stick through the anterior abdominal wall. The anesthesiologist must be especially vigilant that the endoscope does not dislodge the endotracheal tube during these manipulations.

Major Surgical Procedures

Occasionally, unstable ICU patients require emergency thoracotomies or laparotomies to be performed in the ICU because of lack of operating room time or inability to transport the patient to the operating room. These procedures require a full operating room crew with a circulating nurse, a scrub nurse, surgeon, and assistants, and an anesthesiologist. Because these patients are often bleeding, it is imperative to have adequate venous access before draping the patient for the procedure.

Many surgical ICUs have built-in lighting that can illuminate a surgical procedure; however, in many ICUs portable lighting must be brought in to illuminate the surgical field. Adequate suction for the surgical field also has to be assured prior to starting the surgical procedure. Electrosurgical cautery units are also among the necessary equipment brought to the ICU before commencing major surgery.

The anesthesiologist needs to ensure easy access to an adequate supply of necessary anesthetic drugs. As discussed earlier, TIVA with muscle relaxation is the technique of choice for anesthesia in critical care units. Fortunately, most ICU patients that are appropriate for major bedside surgery are receiving some form of TIVA for sedation and analgesia. The anesthesiologist then needs to adjust the level of TIVA drugs to achieve surgical anesthesia.

Other Procedures

Many of the surgical procedures performed in an ICU, such as thoracostomy tubes to relieve pneumothorax or hemothorax, or placement of an intraventricular catheter to measure/relieve intracranial pressure, can be performed with local anesthesia and sedation. These procedures rarely require an anesthesiologist to manage the patient.

NEONATAL INTENSIVE CARE

The neonatal period, encompassing the first 30 days of extrauterine life, is filled with many anatomic, physiologic, and pharmacologic changes to maintain hemodynamics, which are necessary for infant survival. Varying pathologic states, anesthesia, and/or surgery can alter the necessary developmental changes and even threaten neonatal survival. The anesthesiologist and surgeon must understand normal neonatal development and the pathophysiology of these neonatal disease processes to develop a logical, effective anesthetic and surgical plan.

In the past decade tremendous advances have been made in the field of neonatology, particularly managing severe prematurity, respiratory failure, sepsis, and congenital heart disease, thus improving neonatal morbidity and mortality. Therefore, as anesthesiologists, we are caring for more and more premature infants with critical issues, many of which require some form of surgical intervention. With critically ill neonates, it may be safer to move the operating room to the infant, rather than transporting the infant to the operating room. This change in surgical locale takes tremendous planning and anticipation of problems by the surgeon, anesthesiologist, operating room nurses, and neonatal intensive care staff.

Performing surgery and anesthesia in the neonatal intensive care unit (NICU) provides several logistical challenges. Space for equipment and patient access is very limited. This space must be shared with the surgeon, scrub nurse, ventilator, and any other medical equipment. A direct route to the neonate must be identified prior to the start of surgery in the case of an emergency requiring intravenous drugs or an

inadvertent disconnection of a vital monitor or respiratory equipment. Most NICUs have several patients and related personnel sharing one large community-style room. Infection control is a concern because of the nature of the room, including the exposure from multiple patient areas. Thus, a sterile radius must be set up before the start of the procedure. Finally, the NICU nursing staff has very different roles than the operating room staff, and the NICU nurse's role during the procedure must be clarified before the start of the case for all to work well as one cohesive team.

Neonatal Thermoregulation

The neonatal body habitus favors heat loss. The large surface area of the head relative to the body of a newborn enhances radiant heat loss. Covering the head can significantly reduce heat loss.^{6,7} Neonates have a very thin layer of subcutaneous fat, increasing thermal convective heat loss. Evaporative heat loss is increased due to the reduced keratin content of neonatal skin. Neonates do not shiver or sweat effectively to maintain body temperature and rely primarily on brown fat metabolism to maintain body heat. Brown fat cells begin to develop between 26 and 30 weeks of gestation and thus may not be present in severely premature infants.⁸ Normally in the operating room environment, one would use radiant warming lights, convective air warming blankets, or raise the ambient temperature in the operating room, although in the NICU these modalities may not be as easily obtainable. Radiant warming lights will not be effective when the infant is under the drapes, a convective warming blanket may be too forceful for a low birth weight neonate, and the temperature of the entire NICU cannot be adjusted as easily as a single operating room. Thus, thermoregulation during surgery in the NICU may be difficult, but careful attention to temperature regulation is imperative to decrease the neonatal stress response and adverse affects associated with hypothermia.

Drug Choice

Anesthetic management in the NICU is not the same as that in the operating room. Because an anesthesia machine is not usually present, volatile agent-based anesthesia is seldom used for the same reasons it is not used for adults and older children. The basis of most anesthetics given in the NICU is high-dose fentanyl for analgesia and amnesia with muscle relaxation. Fentanyl is used frequently because of its ability to provide rapid analgesia,⁹ maintain cardiovascular stability, block the endocrine response,^{10,11} and prevent pain-induced increases in pulmonary vascular resistance.¹² Drawbacks of fentanyl include vagal bradycardia, chest wall rigidity,¹³ opioid tolerance after prolonged therapy,¹⁴ and higher respiratory rates and peak inspiratory pressures for ventilated patients.¹⁵

Oral sucrose has been used for effective analgesia in term and preterm infants.¹⁶ The efficacy of sucrose for procedural pain has been dealt with in many systematic reviews,¹⁷ but its efficacy for ongoing pain or postoperative pain remains questionable. Analgesic effects are present with doses as low as

0.1 ml of 24% sucrose, and other sweet tasting liquids, such as glucose or breast milk, are just as effective. The administration of sucrose via a pacifier, which stimulates nonnutritive sucking, may increase its effectiveness, but very preterm infants are more likely to show immediate adverse effects,¹⁸ such as gagging or choking.¹⁹

SURGICAL PROCEDURES IN THE NEONATAL INTENSIVE CARE UNIT

Traditional policies would dictate that any neonate requiring surgery would be transported from the NICU to the operating room. Typically, the NICU is not in close proximity to the operating room, thus requiring a fragile, often critically ill newborn be transported a significant distance. Transports can be extremely cumbersome for maintaining the necessary intravenous lines, respiratory support, and monitoring equipment. If any of these interventions are disrupted for even a moment in a neonate, the results can be disastrous. Lastly, the neonate may be exposed to unnecessary physiologic stress during transport, most notably hypothermia. Thus, there is an enormous amount of risk in transporting a critically ill neonate to the operating room.

Despite the risks associated with transporting the neonate to the operating room, not every neonate is a candidate for surgery in the NICU. There are infection control risks, improper lighting, significant distance for forgotten equipment, and so on. Indications for surgery outside the operating room are based on the specific diagnosis and the underlying medical condition of the neonate. Neonates with a medical diagnosis of a patent ductus arteriosus are routinely repaired in the NICU. Additionally, if a neonate is requiring maximum ventilatory and pharmacologic support, that is, his or her medical condition is critically tenuous, the neonate is not a candidate for safe transport and should remain in the NICU until medical status improves. These two guidelines are useful in determining proper patient selection for surgical procedures in the NICU.

Patent Ductus Arteriosus

The ductus arteriosus is a connection between the left pulmonary artery and the descending thoracic aorta (Fig. 25.1). This connection allows blood to bypass the fetal lungs in utero. The ductus arteriosus typically closes shortly after birth, from the increased arterial oxygen exposure. If the ductus arteriosus does not close, one can develop increased pulmonary circulation from left to right shunting across ductus, leading to possible congestive heart failure, hemodynamic instability, and/or respiratory failure. First-line therapy for a patent ductus arteriosus (PDA) is medical management with indomethacin. If medical management fails or is contraindicated, as in cases of renal dysfunction or bleeding abnormalities, surgical correction is warranted. The surgical approach typically utilizes a left lateral thoracotomy, but thoracoscopic approaches have been described.²⁰⁻²¹ The neonate is placed in the right lateral

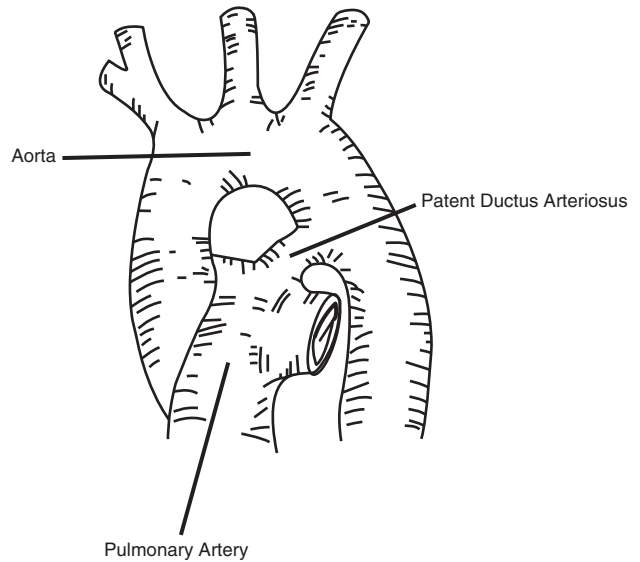


FIGURE 25.1. Ductus arteriosus.

decubitus position, with specific attention to positioning of fragile extremities and location of vascular access and emergency equipment prior to draping the patient.

General anesthesia requires an endotracheal tube that is maintained with a total intravenous anesthetic (TIVA). This is necessary because anesthesia machines are too cumbersome to transport and require significant space in an already limited environment, and they require scavenging of waste anesthetic gases. Typical intravenous agents include midazolam, fentanyl, ketamine, and pancuronium. Fentanyl is typically chosen for its cardiovascular stability. The dose of fentanyl varies according to hemodynamic stability of the patient and the possibility of early extubation. Typical dosages range from 5 to 15 $\mu\text{g}/\text{kg}$. One must closely monitor gas exchange, hemodynamic parameters, temperature regulation, drug metabolism, and oxygen exposure throughout the case. Blood loss is typically minimal, but blood products and albumin must be available in case of an emergency. Survival rates from PDA ligations are excellent with the overall survival dependent on the comorbid medical conditions of the neonate.²²

Emergency Laparotomy for Necrotizing Enterocolitis

The most common surgical emergency in the premature neonate is necrotizing enterocolitis (NEC). The cause is unclear, but events that produce hypoxemia and hypotension have been implicated as triggers, resulting in ischemic damage to the intestine and can progress to full-thickness necrosis and/or perforation.

Early clinical signs of NEC may be apnea, bradycardia, and feeding intolerance, progressing to signs of abdominal distention and bloody stools. The diagnosis can be confirmed with an abdominal radiograph showing small pockets of gas in the bowel wall, pneumatosis intestinalis. Necrotizing enterocolitis

can rapidly progress to sepsis, with hemodynamic instability, respiratory failure, and coagulopathy.

Medical management should be initiated promptly at the first warning sign of NEC. Medical management consists of bowel rest with parenteral nutrition, fluid management to counteract the third space fluid losses, and antibiotic therapy. Serial radiographs are used to follow the progression of the disease. If there are any signs of peritoneal air or perforation of the gastrointestinal tract, surgical intervention is certainly indicated. However, extensive necrosis or perforation can occur without evidence of free air on the radiograph. As a result, other signs that indicate bowel necrosis must be considered, including unremitting clinical deterioration, the presence of an abdominal mass, ascites, or intestinal obstruction.²³ The surgical correction of NEC typically utilizes a transverse abdominal incision. Proper positioning of the patient is paramount, with specific attention to access of vascular lines and the endotracheal tube.

For emergency laparotomy, general anesthesia is indicated, because the sepsis associated with NEC causes some degree of coagulopathy contraindicating neuroaxial anesthesia. Anesthetic technique in the NICU is typically TIVA. Fentanyl and a muscle relaxant are routinely used, but benzodiazepine and ketamine can add additional amnestic and analgesic properties depending on the hemodynamic stability of the patient. Neonatal fluid requirements may be excessive secondary to fluid loss into the bowel wall causing massive third spacing of fluid. Thus, adequate vascular access needs to be established prior to surgical incision. Blood loss is usually minimal, but blood products and 5% albumin should be available prior to the start of the operation. Heart rate and blood pressure fluctuations are indicators of the patient's dynamic fluid balance, and any necessary fluid resuscitation can be accomplished using a balance of crystalloid, albumin, and/or blood products.

The surgical procedure involves the removal of perforated or necrotic segments of intestine with a resulting diverting intestinal stoma. There have been cases of primary anastomosis if the patient is stable and there is a small amount of affected bowel.²⁴ If a significant portion of the intestine is affected, the resection can be extensive, predisposing the infant to short gut syndrome.

Advances in neonatal intensive care, earlier diagnosis, and aggressive treatment have improved the outcome of infants with NEC.²⁵ As a result, approximately 70%–80% of infants who have NEC survive. The mortality rate is higher in infants, (as high as 50%), with more severe disease usually requiring surgical intervention.²⁶

Retinopathy of Prematurity

Retinopathy of prematurity (ROP) is a proliferative vitreoretinopathy of preterm infants. The precise pathways that regulate apoptosis and retinal vascularization in ocular development remain uncertain. Low birth weight and gestational age are significant risk factors for the development of ROP. Other risk factors include respiratory distress, bradycardia, patent ductus arteriosus, sepsis, transfusion, multiple births, white race, jaundice, and intraventricular hemorrhage (IVH). Premature infants born prior to 32 weeks gestation or less

than 1500 grams are at risk of developing ROP. These at-risk neonates should have a complete ocular examination starting at 4 to 6 weeks after delivery and at biweekly intervals thereafter until retinal vascular maturation. If threshold ROP is identified, laser treatment with peripheral retinal ablation should be instituted within 72 hours of diagnosis.²⁷

The choice of general anesthesia versus local anesthesia with intravenous sedation remains largely based on the surgeon's preference and the infant's medical condition. The advantage of general anesthesia with an endotracheal tube is the ability to paralyze the infant, which makes the procedure technically easier for the surgeon. The infant also may be more heavily sedated without the concern of apnea and hypoxia. Inhaled volatile anesthetic is an ideal agent for infants because of its lack of major hemodynamic effects and its quick wash-out. Disadvantages of general anesthesia include increased laryngeal trauma, bronchospasm, prolonged recovery time necessitating careful observation for at least 24 hours, and possible pulmonary complications in many infants with bronchopulmonary dysplasia.

General anesthesia can be administered through a laryngeal mask airway (LMA). A major disadvantage is the bulk of the apparatus is located in the center of the patient's face and may hinder the ophthalmologist's visualization of the peripheral retina, making the procedure technically difficult for the ophthalmologist.²⁸ An oral RAE endotracheal tube can provide a secure airway and provide room for the ophthalmologist to examine the eyes.

Topical anesthesia with monitored intravenous sedation is another option. The infant is bundled and the head restrained by a technical assistant, topical local anesthetic is applied to the eye, and the infant is sedated using fentanyl and midazolam. In most cases, complete treatment can be applied with minimal patient movement or hemodynamic instability. Heart rate decelerations and apnea with oxygen desaturations are frequent complications of sedation. The apnea and bradycardia often resolve with cessation of eye manipulation, but the vital signs may not recover spontaneously, thus requiring stimulation and bag mask ventilation. Often, the apneas and bradycardias may continue into the postoperative period, requiring additional monitoring and interventions.²⁹

The procedure may be completed at the bedside in the NICU or in the operating room depending upon the hospital facilities and neonate's current medical condition. To complete the procedure in the NICU, an environment is needed where the lights can be dimmed to facilitate the ocular exam. Additionally, appropriate eye protection must be provided to all health care providers in proximity to the laser. Thus, a private room is the most appropriate place to perform the laser therapy. If this type of environment is not available in the NICU, it may be better to perform the procedure in the operating room.

SUMMARY

Unstable critically ill patients frequently need surgical interventions for either diagnostic or therapeutic purposes. These procedures can be performed at the bedside for neonates,

older children, and adults, based on the principle of moving the operating room to the patient in order to provide a safe environment for the unstable patient.

Total intravenous anesthesia is the anesthetic technique of choice, and patients should be monitored to the same standards as patients undergoing anesthesia in the operating room. The anesthesiologist must familiarize himself or herself with the bedside monitors in the ICU, gather drugs and supplies into a convenient place prior to starting the anesthetic, and ensure access to an adequate supply of intravenous fluids.

When one is prepared for providing anesthesia in the ICU, it is a satisfying and rewarding experience.

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26 | Electroconvulsive Therapy

LISA ROSS, MD

Electroconvulsive therapy (ECT) is used in the United States for the treatment of major depression and a limited number of other psychiatric disorders. Patients require general anesthesia and airway management for this procedure, which is most often performed on psychiatric wards or in outpatient facilities. Because many of these patients are elderly and often have accompanying comorbidities, the sudden stimulus to the cardiovascular and cerebrovascular systems during this brief procedure creates the potential for significant cardiac and neurological complications. Despite this, ECT remains a very safe and well-tolerated procedure for inpatients as well as outpatients, as long as proper preoperative evaluation is performed and there is adherence to safe anesthesia practice guidelines.

EPIDEMIOLOGY

At any given time 5.4%–6.6% of the U.S. population above 12 years of age meets the *DSM-IV* criteria for major depressive disorder (MDD).^{1,2} It is a leading cause of disability, carries an increased mortality risk (primarily due to suicide), and in 2000 cost the United States \$83 billion—two-thirds of which was related to decreased productivity in and absence from the job site.^{3,4} Ohayon et al. published a study in 2006 where 6694 individuals in New York state and California were randomly interviewed by phone and asked questions pertaining to sleep habits and symptoms of depression. Their findings, similar to those published in the National Comorbidity Survey (NCS) revealed depression to be more prevalent in women, the unemployed, the less educated, those divorced or separated, and significantly higher in those who were obese. The incidence was overall lower in the non-white population.^{1,2} And although depression is found to be less common in the elderly population, these patients undergo ECT therapy more frequently because it is tolerated better than the side effects of most antidepressants and because these individuals are seen and diagnosed by physicians who are addressing other medical problems.⁵

In the 1990s there was increased focus on the diagnosis and treatment of depression; in fact the number of patients diagnosed and prescribed medication doubled between 1987 and 1997.⁵ Even with such a high prevalence of depression in the general population, the Centers for Disease Control and Prevention (CDC)/National Center for Health Statistics

(NCHS) study found that only 29% of those with the condition actually sought help from a mental health professional. Explanations for this include the continued stigma attached to mental illness, failure to recognize the condition, and medical expenses for therapy and medication.¹ Antidepressant medications, psychotherapy, and ECT are methods of treating this disease, with ECT being the one of the most successful and safest modalities to date.

HISTORY

Electroconvulsive therapy was first performed in Italy by Cerletti and Bini in 1937⁶ and then introduced into the United States in the early 1940s. Initially it was used to treat several types of psychiatric disorders and to subdue unruly inpatients on psychiatric wards, regardless of their diagnosis. At that time ECT was performed by the “unmodified” technique in which patients were conscious and muscle relaxants were not used; the incidence of musculoskeletal complications was as high as 40%. Because this treatment was considered abusive, in the 1970s its popularity declined not only due to an anti-ECT movement but also due to the advancement in pharmacotherapy, development of better neuroleptics, and the institution of judicial and regulatory restrictions.⁷

Currently antidepressants are the first line of therapy for those diagnosed with major depression. The first of these drugs were the monoamine oxidase inhibitors (MAOIs) followed by the tricyclic antidepressants (TCAs) and then most recently the new generation selective serotonin reuptake inhibitors (SSRIs) and the serotonin-norepinephrine reuptake inhibitors (SNRIs). The success rate in the treatment of depression using antidepressants alone is between 65% and 70%; however, none of these medications is without side effects. The TCAs have anticholinergic and cardiac effects, that make them difficult to tolerate, especially within the elderly population. The MAOIs often cause orthostatic hypotension, require a tyramine-free diet, and are associated with hypertensive crises and malignant neuroleptic syndrome. The SSRIs have undesirable sexual side effects, often requiring additional medication to offset these effects.⁸ And antidepressants can take anywhere from 2 weeks to 2 months to demonstrate their efficacy.

Once guidelines for ECT were defined by the American Psychiatric Association (APA) and the procedure was

administered safely, the practice regained popularity and it was discovered to be very successful and well tolerated. A meta-analytical review published in 2004 found ECT alone to be statistically favorable when compared to simulated ECT, placebo, antidepressants in general, and TCAs and MAOIs specifically.⁹ And Gagne et al. found that the continuation of ECT and long-term antidepressant therapy helped prevent the relapse of depression when compared to patients who discontinued ECT and were maintained on antidepressants alone.¹⁰ It is estimated that 100,000 patients receive ECT each year in the United States and 1,000,000 worldwide. Even though there have not been studies comparing ECT to the SSRIs or SNRIs to date, no trials with these medications have proven to be better than ECT in the treatment of depression.¹¹

INDICATIONS FOR ELECTROCONVULSIVE THERAPY

Indications for ECT are clearly outlined by the APA and are as follows: major depression (unipolar or bipolar) with lack of response to medications, intolerance to medication due to side effects or coexisting conditions, a need for a rapid response in conditions such as catatonia, psychosis, suicidal ideations, or clinically significant dehydration or malnutrition. Schizophreniform and schizoaffective manic disorders are also treated with ECT (see Table 26.1).¹¹ Electroconvulsive therapy has also been indicated in patients who previously demonstrated a positive response to ECT. A course of ECT is comprised of 2–3 treatments per week with a usual course of 6–12 treatments over a 3–4 week period of time.¹¹

PREPROCEDURE EVALUATION

The role of the anesthesiologist in the evaluation and treatment of the patient for ECT is the same as that for any patient who will undergo general anesthesia. The anesthesiologist interviews the patient, performs an appropriate physical

TABLE 26.1. *Indications for Electroconvulsive Therapy*

Major depression (unipolar or bipolar)

Lack of response to medications

Intolerance to medications due to side effects or coexisting conditions

Need for rapid response due to conditions such as catatonia, psychosis, suicidal ideations, or significant dehydration or malnutrition

Mania

Schizophreniform disorder

Schizoaffective disorder

Source: Richard D. Weiner *The practice of electroconvulsive therapy: recommendations for treatment, training and privileging*. 2nd ed. Washington, DC: American Psychiatric Association; 2001.

examination, concentrating on airway assessment, and reviews the medical history and pertinent laboratory data.¹² Any patient at increased risk for ECT should be identified and the appropriate consultations performed beforehand. Electrocardiograms (EKGs) are recommended in patients over the age of 50 because this group is most at risk for major cardiac complications.

MECHANISM OF ACTION

There are many theories about the mechanism by which ECT works. One hypothesis is that the seizure itself leads to a flood of neurotransmitters (specifically dopamine and serotonin) into the brain. These neurotransmitters are known to play a role in depression and schizophrenia.¹³ Another hypothesis suggests that the seizure activity affects the rate of glucose metabolism and cerebral blood flow to specific regions of the brain.¹⁴ Still others suggest that treatment changes the way in which brain cells communicate at the synaptic level and may even promote the generation of new brain cells.¹⁵ The understanding as to why ECT creates a positive outcome is far from clear and research is ongoing.

CARDIOVASCULAR RESPONSES

There are significant hemodynamic changes that occur during ECT. Initially there is a predictable decrease in heart rate and sometimes brief asystole resulting from the parasympathetic outflow. Following this is an increase in both the systolic and diastolic blood pressures by as much as 25mmHg and on average a 52% increase in heart rate due to sympathetic outflow. Most of these changes resolve within the first 20 minutes following treatment, but in those who remain hypertensive and/or tachycardic, beta-blockers, calcium channel blockers, hydralazine, and sodium nitroprusside have been used successfully to return the blood pressure to normal values.¹² Increased myocardial consumption of oxygen is expected due to the increase in heart rate, and inconsequential EKG changes similar to those seen surrounding an intracranial event have been seen and sometimes misdiagnosed as acute subendocardial infarctions.¹⁶

CEREBRAL RESPONSES

During the induced seizure, cerebral metabolic activity increases, which in turn increases the cerebral blood flow 100%–400% above baseline, leading to an acute rise in cerebral oxygen consumption and resultant increased intracranial pressure. In the presence of an intracranial space occupying lesion, there is concern regarding an increase in intracerebral edema. For patients with a cerebral aneurysm, hydralazine, sodium nitroprusside, and beta-blockers have been used to control swings in blood pressure.^{12,17}

NEUROENDOCRINE RESPONSES

Epinephrine, norepinephrine, adrenocorticotropin hormone, arginine vasopressin, and cortisol levels all increase following ECT to varying degrees and peak at different times. The catecholamines that are released from the adrenal medulla and sympathetic nerve endings cause the hypertensive response. Blood samples have shown norepinephrine levels to increase 3-fold and epinephrine levels to increase 15-fold. Norepinephrine levels remain elevated longer than the epinephrine levels.¹⁸ Corticotropin is immediately released from the pituitary during the seizure itself.¹⁹ Attempts have been made to attenuate these neuroendocrine and cardiovascular responses by pretreatment with fentanyl, labetalol, and esmolol. It was found that fentanyl and esmolol significantly decreased the norepinephrine peak that followed the seizure, but only esmolol decreased the epinephrine secretion. Fentanyl was found to decrease the levels of ACTH following therapy.¹⁸

MONITORING

Standard monitors include EKG, a manual or automatic blood pressure device, and a pulse oximeter throughout the procedure and into the recovery stage. Additionally the American Society of Anesthesiologists (ASA) in its *Standards for Basic Monitoring* states that the adequacy of ventilation must be evaluated in all patients receiving general anesthesia. Because patients receiving ECT are usually ventilated by mask, qualitative clinical signs such as chest excursions are acceptable. However, in cases where an endotracheal tube or laryngeal device is inserted, proof of adequate ventilation must be measured quantitatively with a continuous end-tidal carbon dioxide monitor.²⁰ Table 26.2 lists the required and recommended equipment and medications that should be available when performing ECT. In the event of a complication that would require intubation and transport to another location for continued care, included in the list are a long-acting sedative and an intermediate-acting muscle relaxant.

Use of a laryngeal airway for ECT has been suggested because it reduces hypercarbia when compared to mask ventilation and provides a viable alternative when mask fit is difficult.²¹ However, because ASA monitoring standards require quantitative CO₂ monitoring when using an endotracheal tube or laryngeal airway device, its use is limited outside of the operating room.²⁰

SETTING

Electroconvulsive therapy is usually administered to inpatients in psychiatric wards and occasionally to outpatients who receive maintenance therapy less frequently. Inpatients are fasted overnight and the procedures usually take place in the morning to prevent nil per os (NPO) violations in patients who are impaired or have difficulty with memory.¹¹ There is usually a separate procedure or treatment room on the inpatient ward designated for the administration of ECT. The room

TABLE 26.2. *Recommended Equipment and Medication for Electroconvulsive Therapy*

Required equipment

Ambu bag with oxygen supply
 Device that administers positive pressure ventilation via mask
 (this can be the ambu bag)
 Intravenous access either by hep-lock or infusing intravenous bag
 Continuous electrocardiogram
 Pulse oximeter
 Automatic or manual blood pressure cuff
 Continuous suction
 Laryngoscope
 Oral airway
 Endotracheal tube
 Bite block
 Resources to maintain the airway for prolonged period of time if necessary

Required medications

Induction agent
 Muscle relaxant
 Anticonvulsant
 Sympathomimetic (atropine or glycopyrrolate)

Suggested equipment

Laryngeal mask airway/King airway
 Nerve stimulator

Suggested medications

Beta-blocker
 Long-acting sedative appropriate for intramuscular injection
 Intermediate-acting muscle relaxant

is equipped with stretcher, oxygen source, continuous suction, positive pressure ventilation device, standard ASA monitors, medications, and an electroencephalography (EEG) stimulus machine which often has an incorporated EEG monitor. Electroconvulsive therapy is performed only by psychiatrists.

As recently as 2007, ECT practice was not officially regulated in the United States. Electroconvulsive therapy is not a required subject in medical schools in the United States, but is a required skill in accredited psychiatric residency training programs. Privileging for ECT practice at institutions is a local option, no national certification standards are established, no ECT-specific continuing training experiences are required of ECT practitioners,²² nor is ECT clinical training a required rotation in anesthesia residency programs.¹¹

ADMINISTRATION OF THERAPY

For ECT to be performed safely, the patient must be rendered unconscious and have the appropriate degree of muscle relaxation. In the past when the “unmodified” technique was

employed, there was a significant incidence of vertebral and long bone fractures. The role of unconsciousness is two-fold: to prevent the feeling of suffocation after the administration of the muscle relaxant before the stimulus is applied, as well as to prevent recall of the procedure in patients who do not have a seizure and therefore are not amnesic to the preceding events. A generalized seizure is necessary for the ECT to exert its antidepressant effects.²³

After monitors have been applied, baseline vital signs are obtained and intravenous access is established. An induction agent is administered followed by a short- to intermediate-acting muscle relaxant after unconsciousness is confirmed. The patient is ventilated or hyperventilated with 100% oxygen usually administered by mask until muscle relaxation is confirmed and then a bite block is inserted to prevent damage to the teeth. Several techniques have been employed to track the point of maximal muscle relaxation. A nerve stimulator can be used to follow the train-of-four ratio, one can use the cessation of fasciculations as a sign of relaxation (more difficult to determine in the elderly patient) or decrease of the knee, ankle, or plantar withdrawal reflexes.

The goal is to induce a generalized motor seizure that lasts at least 25 seconds and a central EEG seizure that lasts at least 40 seconds at a stimulus dose of approximately 50–100 joules of energy with approximate voltage of 150–200V.²⁴ The therapeutic seizure involves the entire brain, from the point of contact on the scalp, deep into the brain, and then spreading to both cortices. It is delivered either unilaterally on the non-dominant hemisphere or bilaterally. Contrary to previous beliefs, the success of the therapy is not directly related to the length of the seizure; however, seizures lasting less than 25 seconds are considered subtherapeutic. Electroconvulsive therapy is administered either by a brief pulse stimulus or sine wave. Although the efficacy has been found to be equivalent, administering sine wave stimulus causes more cognitive dysfunction.¹¹ Thymatron DGx (Somatics, Inc., Lake Bluff, IL) is a commonly used machine that administers the stimulus and records the EEG. If a seizure of desirable length is not elicited, the stimulus can be increased for the subsequent treatment or, once confirming the patient is still anesthetized and relaxed, an additional stimulus can be applied immediately. In the past, caffeine had been used to increase seizure length,²⁵ but with more recent review of the issue, evidence of its efficacy is lacking, and most psychiatrists have abandoned this practice. When using the “cuff” technique, a blood pressure cuff is inflated above the systolic blood pressure just prior to the administration of the intravenous medications. This way the limb is isolated from the effects of muscle relaxation and the beginning and end of the motor seizure is more evident. Recording of the EEG is more reliable and is usually longer than the motor seizure. Blood pressure, oxygen saturation, and EKG are recorded at regular intervals.

Once it is established that the seizure is complete, the patient is again ventilated by mask until spontaneous respirations resume. Only after the patient is hemodynamically stable, has patent airway, and does not appear unusually restless or disoriented is the intravenous access discontinued. The patient is recovered by a registered nurse either in the same room or

in a separate postanesthesia care unit (PACU). The PACU is equipped as mandated by ASA guidelines. Although there might be some postprocedure confusion, the patient should be able to answer basic questions correctly before discharge from the PACU.

SIDE EFFECTS

Side effects include loss of retrograde memory (recall of events before treatment) and/or anterograde memory (inability to retain new memories), cognitive dysfunction, headache, nausea, and vomiting. The incidence and severity of memory loss is dependent upon the location of the scalp electrodes (unilateral versus bilateral) the type of stimulus administered, and the age of the patient. Fasciculations that occur from the administration of succinylcholine often lead to myalgias.¹¹

PREMEDICATION AND MEDICATION INTERACTIONS

The initial parasympathetic discharge can cause severe bradycardia and even asystole. Glycopyrrolate is often administered intramuscularly in a dose of 0.2–0.4 mg as a premedication at least 3 minutes before the scheduled procedure or the same dose can be given intravenously just prior to injecting the induction agent. Its antisialogogue properties are also advantageous because the parasympathetic outflow causes increased salivation.¹¹ Some criticize the routine use of an anticholinergic before treatment because it may lead to an increased heart rate which could lead to myocardial ischemia in those with cardiac disease. Glycopyrrolate causes less heart rate increase than atropine and is therefore preferable.

Medications that should be held prior to ECT include the anticonvulsants and benzodiazepines because they increase the seizure well lithium is held because it is associated with increased confusion post-ECT. It was previously recommended that MAOIs be discontinued 2 weeks before the first treatment due to concerns about wide fluctuations in blood pressure, especially if vasopressors are needed during therapy. More recently patients have been maintained on MAOIs without adverse reactions. One should continue dosing of antidepressants and antipsychotic because they decrease the seizure threshold. Cardiac and antihypertensive medications should be continued as well.²⁶

INDUCTION AGENTS

The ideal induction agent should maintain hemodynamic stability, have a short half-life, be economical, cause few side effects, and maintain or lower the seizure threshold. Unfortunately, almost all general anesthetics impart some antiepileptic activity. Currently the barbiturate methohexital is used most frequently and is the medication to which all others are compared. Sodium pentothal, ketamine, etomidate, propofol, and the inhalational agent sevoflurane have all been

used with varying results. Table 26.3 shows the different induction agents and recommended doses. Sodium pentothal was the first medication used because it was the only intravenous induction agent available. When methohexital, a newer barbiturate, was developed, it became more popular because it had slightly less anticonvulsant activity than its predecessor.²³

Propofol, which is used frequently, is associated with reduced cardiovascular response due to its direct myocardial depression and vasodilator properties.²³ Although the seizures were found to be shorter and the threshold increased, the efficacy was similar to the barbiturates. It has been suggested that propofol is the medication of choice in patients who experience prolonged seizures with methohexital or in patients who suffer with postprocedure nausea and vomiting.²⁷ Propofol has demonstrated an earlier return to cognitive function when compared to methohexital while allowing comparable seizure quality.²⁸

In a double-blind comparison of etomidate, propofol, and sodium pentothal in patients without previous cardiovascular disease, Rosa et al. found that the three had similar cardiovascular effects with respect to blood pressure and heart rate.²⁹ Grati et al. had similar findings when they compared propofol and etomidate.³⁰ The conclusion was that all three can be used safely in patients without preexisting myocardial disease because the hemodynamics are similar.^{29,30}

Narcotics are known to blunt autonomic responses to noxious stimuli and they lack anticonvulsant activity. Remifentanyl has been studied alone and in combination with methohexital and propofol to compare hemodynamic effects, seizure length, and cognitive function. In a study of 110 ECT treatments, Irefin et al. showed that when remifentanyl is added to a hypnotic dose of methohexital, the hemodynamic effects of the sympathetic discharge were reduced significantly when compared to methohexital alone.³¹ Current evidence shows that remifentanyl alone or in combination with another agent might even lower the seizure threshold, thus allowing for

lower absolute stimulus doses, imparting longer seizures, leading to comparable recovery times, and when given in appropriately large doses, blunting the hemodynamic response. It is the medication recommended in patients who when treated with methohexital remain refractory despite maximum stimulus.^{23,32} Unlike methohexital, there is no increase in seizure threshold from treatment to treatment with remifentanyl.³³ To date there have not been extensive prospective studies on the efficacy and cognitive side effects when using this narcotic regimen.²³

In recent years there has been interest in neuroprotection, which is equated with improved cognitive function post-ECT. Ketamine has been known for its cognitive sparing properties and is a "proconvulsant," but because it causes transitory psychotic episodes it is an undesirable choice for ECT.²³ Ketamine, which had been used in the past and then fell out of favor, has made a resurgence both in the area of pain management and anesthesia in general. In its current clinical usage ketamine is administered as an intravenous racemic mixture; however, the development of the (S) isomer, which has fewer psychomimetic effects and is more potent,^{23,34,35} has led to renewed interest in this drug on many fronts. Research on ketamine and its neuroprotective quality in preliminary studies demonstrated shorter reorientation times after treatment, when compared to methohexital.³³

Sevoflurane in concentrations of 5%–8% has been evaluated as an induction agent for ECT. This method is particularly useful in patients who are agitated or uncooperative, making intravenous access a challenge. Sevoflurane has been compared to sodium pentothal, methohexital, etomidate, and propofol with varying and conflicting results. Rasmussen et al. compared hemodynamic changes, seizure length, and postictal recovery between sodium pentothal and sevoflurane. They found that although the hemodynamics were similar, the postictal orientation 20 minutes after therapy was superior with sevoflurane. Furthermore, even though patients who received sevoflurane had shorter motor and EEG recorded seizures when compared to pentothal, the length still remained within the therapeutic range of seizures seen with the more commonly used medication methohexital.^{23,36,37} In another study where the hemodynamics of sevoflurane and sodium pentothal were compared, the rate pressure product increased for both, but it was attenuated the most with 2MAC sevoflurane.³⁸ The overall conclusions support sevoflurane as a comparable alternative to sodium pentothal. Propofol and sevoflurane have been compared with findings inconsistent with respect to seizure length.^{39,40} But with respect to hemodynamics, two studies found that the pulse and heart rate increased more with sevoflurane than with propofol, emphasizing cautious use in patients with ischemic heart disease.^{39,41}

TABLE 26.3. *Induction Agents and Recommended Doses*

<i>Induction Agent</i>	<i>Dosage</i>
Methohexital	0.5–1.0 mg/kg
Propofol	1.0–1.5 mg/kg
Pentothal	2–3 mg/kg
Etomidate	0.15–0.30 mg/kg
Ketamine	2–3 mg/kg
Remifentanyl + methohexital or propofol	1 µg/kg + methohexital 0.5–0.75 mg/kg or propofol 0.5–1 mg/kg
Fentanyl	1.5 µg/kg + methohexital 0.5–0.75 mg/kg or propofol 0.5–1 mg/kg
Alfentanil	10–25 µg/kg + methohexital 0.5–0.75 mg/kg or propofol 0.5–1 mg/kg
Remifentanyl alone	4–8 µg/kg

MUSCLE RELAXATION

During ECT the appropriate degree of muscle relaxation is required to minimize the motor component of the seizure. Like the induction agent, a short-acting medication that

imparts hemodynamic stability and has few side effects is ideal. Because of its desirable properties, succinylcholine in a dose of 0.5–1.0 mg/kg intravenously is the most frequently used muscle relaxant. For those patients in whom succinylcholine is contraindicated, an intermediate-acting muscle relaxant administered in doses that can easily be reversed is used. However, it is imperative that consciousness is not regained prior to complete reversal.

To assure maximum muscle relaxation, a nerve stimulator is the most reliable instrument available. Less sophisticated clinical signs include the cessation of muscle fasciculations and/or the ablation of deep tendon reflexes.

CONTRAINDICATIONS

The most recent APA guidelines of 2001 state that there are no absolute contraindications to ECT. The guidelines had previously included increased intracranial pressure as a contraindication; however, most recently it is among those conditions that only present an increased risk of complications (see Table 26.4). It can be performed safely with tight control of blood pressure and the appropriate monitoring and anesthetic management. Electroconvulsive therapy has been administered safely in patients with Parkinson's disease, seizure disorders, and pacemakers, and it is the treatment of choice for depressed or psychotic patients who are in their first trimester of pregnancy. Other conditions that place patients at increased risk for ECT, include recent myocardial infarction recent cerebrovascular accident, ASA 4 classification, unstable or severe cardiovascular disease (severe valvular or uncompensated congestive heart failure), cerebral aneurysm and or AV malformation.¹¹

SPECIAL CONDITIONS

Pregnancy

Electroconvulsive therapy is safe for both the pregnant patient and the fetus. In most cases it is the treatment of choice, especially during the first trimester when organogenesis occurs.

TABLE 26.4. *Conditions That Pose Increased Risk during Electroconvulsive Therapy*

Recent cerebrovascular accident
Increase intracranial pressure
Valvular heart disease
Uncompensated congestive heart failure
Pheochromocytoma
Angina
Intracranial mass
Recent intracranial surgery

Source: *The practice of electroconvulsive therapy: recommendations for treatment, training and privileging*. 2nd ed. Washington, DC: American Psychiatric Association; 2001.

However, it is not without complications. In 300 cases of pregnant patients who received ECT, 28 had complications consisting of transient fetal arrhythmias, abdominal pain, mild vaginal bleeding, and self-limited contractions. As pregnancy progresses, there is increased risk of aspiration, hypotension due to aortocaval compression, and respiratory alkalosis.⁴² Therefore, preparations should include hydration, aspiration prophylaxis, and rapid sequence induction and intubation (if indicated), uterine tilt, and vigilance in avoiding hyperventilation. In the third trimester one should consider tocodynamometry and pelvic examination.^{42,43,44}

Obesity

A retrospective review looked at ECT performed on obese patients (BMI >29) in two major medical centers. Fifty obese patients received 660 ECT treatments using methohexital and succinylcholine. Patients were supine with the back elevated 15–30 degrees and were fasted overnight. No clinical cases of aspiration were recorded, leading to the conclusion that it is safe to anesthetize obese patients for ECT without aspiration prophylaxis and/or tracheal intubation.⁴⁵

Folk's study in 2000 suggested that aspiration prophylaxis should be considered in obese patients undergoing ECT.⁴⁶ If one is to strictly follow the guidelines for patients with a full stomach, then a rapid sequence induction with cricoid pressure and tracheal intubation must follow. This would subject the patient to laryngoscopy and intubation 2–3 times per week, possibly leading to the associated sore throat, swelling, and other forms of airway trauma. Furthermore, the stimulation during laryngoscopy and intubation would produce a greater cardiovascular response.⁴⁵ This remains a controversial issue that deserves further investigation.

Pacemakers

There is a lack of consensus when it comes to the management of patients with pacemakers. There is concern that during administration of the electrical stimulus itself or the fasciculations that result from succinylcholine there could be malfunctioning of the device. Two retrospective studies suggest that these concerns are unwarranted. Despite this there is no common agreement as to how to program pacemakers so that function is maintained. The ACC/AHA has specific recommendations for patients with pacemakers who will undergo ECT: determine which arrhythmia the pacemaker is controlling, assess the comorbidities, and interrogate the device before the procedure.⁴⁷

In one retrospective study 10 patients with pacemakers had undergone 147 treatments. All had dual-chamber pacemakers and nine had a rate-responsive device. Sodium pentothal or propofol and succinylcholine were used for all treatments and none of the pacemakers was reprogrammed or disabled beforehand. In 146 of the 147 treatments there was no malfunction of the pacemaker or instability hemodynamically. During one treatment where asystole was recorded on the ECG the finding was later attributed to artifact.⁴⁸

Although magnets are used frequently during surgery, pacemaker response can be unreliable and is often dependent upon the age of the battery. In Dolenc's retrospective study, 493 treatments were administered to patients with pacemakers and implantable cardioversion/defibrillators undergoing ECT. None of the pacemaker settings were altered prior to procedure yet there was no disturbance in pacemaker function. It should be noted that all patients had evaluation of the pacemaker or defibrillator device before and after each treatment.⁴⁹

Therefore, studies have borne out that ECT can be administered safely to patients with pacemakers and/or defibrillator devices if evaluated by a cardiologist beforehand and there is verification of a properly functioning device.

MORBIDITY AND MORTALITY

When ECT was first introduced it had a mortality rate of 0.1% (1 per 1000 treatments) and a complication rate as high as 40%. Complications included laryngospasm, circulatory insufficiency, tooth damage, vertebral compression fractures, status epilepticus, peripheral nerve palsy, skin burns, prolonged apnea and arrhythmias.⁷ Today the mortality related death rate is 1 per 10,000 patients or 1 per 80,000 treatments. The majority of complications fall into three categories: cardiac, respiratory, or prolonged seizure activity; and they occur either during treatment or immediately following treatment (see Table 26.5). The majority of deaths involve cardiovascular events.¹¹

In a retrospective study of 2,279 patients who underwent 17,394 ECT treatments, 0.92% of the patients (21 patients) had some type of complication during their first series of treatments, with arrhythmias accounting for the vast majority. There were no permanent or irreversible complications, and none of the deaths that occurred within 30 days following treatment were directly related to the therapy itself. When prolonged seizure was removed from the statistics, the complication rate fell to 0.6% per series and 0.08% per treatment. Patients ranged in age from 43 to 74 years, with the majority being ASA classification III. Additionally, all of the patients who had cardiac related events had underlying heart disease.⁵⁰

Arrhythmias are the most common complications seen with ECT. These arrhythmias are benign and most often resolve spontaneously. One must evaluate the degree of risk relative to the potential benefits of ECT, even in those ASA IV patients.¹¹ Huuhka et al. used holter monitoring 24 hours before and 24 hours after ECT treatment to record the incidence of arrhythmia. They observed that the most common arrhythmias observed after the procedure (described as non-malignant or transient) were as frequent as those observed before the procedure.⁵¹

Case reports have documented pulmonary embolism, acute embolic stroke, complications in a patient with severe aortic stenosis, and negative pressure pulmonary edema following ECT.⁵²⁻⁵⁵ However, these complications are rare and can be

TABLE 26.5. *Physiologic Consequences of Electroconvulsive Therapy*

Cerebral effects

Increased cerebral oxygen consumption

Increased cerebral blood flow

Increased intracranial pressure

Cardiovascular effects

Immediate parasympathetic stimulation

Bradycardia

Hypotension

Possible asystole

Late (after 1 minute): Sympathetic stimulation

Tachycardia

Hypertension

Dysthythmias

Increased cardiac output

Increased myocardial consumption

ST and T wave changes on electrocardiogram

Neuroendocrine effects

Elevated levels of corticotrophin, cortisol

Elevated levels of catecholamines

Effect on plasma glucose level

Miscellaneous

Musculoskeletal pain and trauma

Increased intragastric pressure

Increased intraocular pressure

Source: From Russell GB. *Alternate-site anesthesia*. New York, NY: Elsevier; 1997.

maintained at a minimum provided there is (1) adequate pre-procedure evaluation and recognition of medical conditions, which, when possible, are optimized; (2) recognition of comorbidities in the population treated; (3) maintenance of safe anesthetic techniques; and (4) the ability to transfer patients or have backup services if a complication does occur. Because of its short procedure time, low incidence of major cardiac complications, and absence of fluid shifts, it remains a "low-risk" procedure according to the 2007 guidelines issued by the ACC-AHA.⁴⁷

INFORMED CONSENT

Electroconvulsive therapy is unique in that a single consent is obtained for a series of treatments that will be administered over an undetermined period of time. This practice is more feasible especially when a health care proxy is involved. It is imperative that the patient or health care proxy understand that consent can be withdrawn at any time. In institutions

where separate anesthesia consents are the practice, permission must be obtained by a privileged or authorized anesthesia provider and should encompass the series of treatments planned.¹¹

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27 | Pain Management Procedures

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Pain management is the right of every patient and the responsibility of every health care provider. Nowhere is that more obvious than with pain management specialists and with patients seeking assistance at pain clinics across the nation. Often times, the patients referred are those with the most severe pain who have failed more conservative approaches or strictly medical (noninterventional) modalities. In other instances, the patients are referred for concerns of comorbidities or lack of pain management resources such as a clinic and procedure room with fluoroscopic capabilities. While the goal for these percutaneous interventions is improved pain control, they should be considered adjuncts and not replacements for a comprehensive pain management strategy. Most patients benefit from multimodal pain medication strategies, physical therapy, stress management and relaxation training, occupational therapy, acupuncture, or other treatment therapies.

This chapter will prove useful to anesthesiologists and non-anesthesiologists alike in providing an overview and discussion of several of the most common pain procedures encountered in clinical pain management practices today. These procedures are listed in Table 27.1. Each procedure is discussed with an initial description of the strategy, including technical aspects, medical indications, and relevant complications important for the pain management physician to understand. This will be followed by a section on considerations for anesthetic management. While every attempt will be made to ensure thoroughness, readers are referred to sources such as Warfield's *Principles and Practice of Pain Medicine* or Fenton's *Image-Guided Spine Interventions*—both excellent textbooks that provide more information for interventional pain management procedures.

EPIDURAL STEROID INJECTIONS

Epidural steroid injections (ESIs) for radicular complaints have become quite commonplace in the setting of pain management practices. The typical indications are related to signs of irritation and compression of the spinal cord and nerve roots. Symptoms include pain, numbness, tingling, or weakness localized to a dermatomal distribution indicative of the vertebral level where lesions such as inflammation or compression of neural structures may be found. Typically, diagnostic studies such as computed tomography (CT) scans, magnetic reso-

nance images (MRIs), and electromyograms (EMGs) are used to localize and characterize the lesion.

Cervical, thoracic, and lumbar ESIs may be performed at practically any level depending on where the nerve irritation or compression is taking place. The intervention targets the epidural space since all spinal nerves must travel through this space prior to exiting the spine. By bathing the spinal cord and proximal nerve roots with a solution of long-acting depot steroid such as triamcinolone 40–60 mg (with or without dilute local anesthetic), the goal is to minimize inflammation and thereby severity of symptoms. While epidural administration of steroids is off-label use of the drug and there is no evidence that ESIs serve to improve simple back pain (musculoskeletal pain), there is abundant medical literature to support use of ESIs for the management of radicular pain.¹

After proper patient positioning and placement of monitors, local anesthetic skin wheal will be applied to the insertion site. Further local anesthetic may be used to numb the projected tissue track between skin entry and the vertebrae. An epidural needle is then passed through the skin and directed to the translaminar intervertebral space of interest. Fluoroscopic guidance and contrast dye may be used during the procedure to help confirm proper placement. Preprocedure counseling and verbal reassurance at the time of injection often helps allay concerns brought on by transient sensations of pressure or reproduction of symptoms.

With respect to lateral spread of injectate, the dorsal median epidural septum may be an anatomical cause for limitation. With fluoroscopic guidance and contrast dye, it can be reliably overcome by use of a transforaminal approach in lieu of the traditional translaminar approach. In spite of lower drug volumes, transforaminal ESIs (TFESIs) allow for higher concentrations of drug to penetrate at site of lesion by utilizing laterality and promoting more ventral spread. Indications include unilateral radiculopathy secondary to herniated nucleus pulposus, disk prolapse, foraminal stenosis, shingles/acute herpes zoster, and occipital headaches.

Transforaminal ESIs do carry their own risks such as greater exposure to radiation. They rely more on real-time fluoroscopy to reduce risk of intravascular and subarachnoid injection and to ensure proper location for delivery (see Figs. 27.1 and 27.2). Contrast dye is placed and expected to outline the proximal end of the exiting nerve root and spread centrally toward the epidural space. This can be performed

TABLE 27.1. *Pain Procedures*

1. Epidural steroid injections
a. Cervical
b. Thoracic
c. Lumbar
d. Transforaminal
2. Facet interventions
a. Diagnostic facet blocks
b. Radiofrequency ablation
c. Intra-articular facet injections
d. Median branch nerve blocks
3. SIJ interventions
a. SIJ injection
b. Lateral branch nerve blocks
4. Sympathetic blocks
a. Stellate
b. LSB
5. Spinal cord stimulator
a. Trial
b. Implantation (in OR)
6. Neuraxial pumps (briefly)
a. Intrathecal
b. Epidural

LSB, lumbar sympathetic block; OR, operating room; SIJ, sacroiliac joint.

with patients in the supine, oblique, or lateral decubitus position, depending on provider preference and patient comfort. Regardless of patient position, symptoms may take 2 weeks to improve when injecting steroid only and deferring on local anesthetic.

FACET INTERVENTIONS

There are 25 paired facet joints located in the spinal column, and they are involved in movement between adjacent vertebrae. They play a larger role in the cervical and lumbosacral spine, where there is greater freedom for vertebral movement. When facet joints are the etiology of the pain, a facet block injection should be considered. They are a diagnostic tool used to isolate and confirm the lesion. They also serve as a therapeutic option given their analgesic and anti-inflammatory effects for the patient. Like ESIs, facet blocks may be used to manage pain associated with moderate to severe degenerative arthritis of the spine. It is important to remember, however, that the presence of damaged facet joints does not assure the clinician that the facet joint itself is the pain generator of concern. On the other hand, immediate resolution of pain may serve to confirm facet pathology as the source of the pain.

Once diagnostic facet blocks confirm symptomatic facet joints, they may be followed by radiofrequency (RF) ablation or neurotomy for longer lasting, but not necessarily permanent, relief. It is worth noting that because of the increased likelihood of osteoporosis (poor visualization on X-ray/fluoroscopy) and osteophytic growths in people over 65 years, facet blocks



FIGURE 27.1. Anteroposterior view of a left L5/S1 transforaminal epidural steroid injection with spread along the L5 nerve root and central epidural spread.

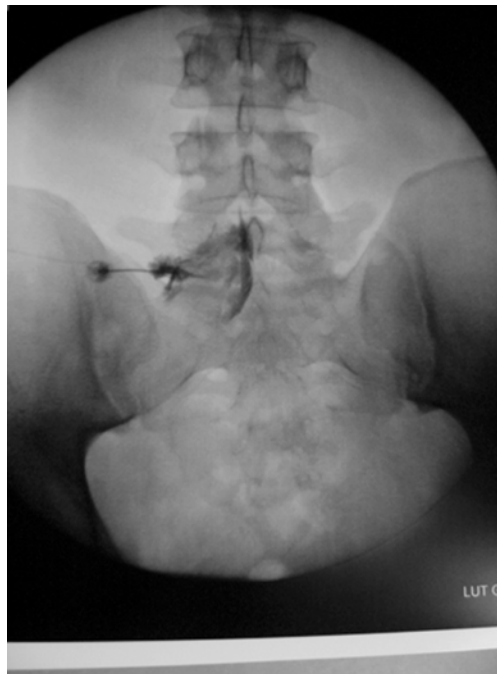


FIGURE 27.2. Anteroposterior view of a left L5/S1 transforaminal epidural steroid injection with spread along the L5 and left S1 nerve root.

and RF ablations can quickly become very challenging. When the facet joint cannot be entered due to anatomical constraints, practitioners may choose to perform median branch nerve blocks and ablations instead. Regardless, facet joint rhizolysis may afford analgesia from months to years.

Procedurally, diagnostic facet blocks and RF ablations (see Figs. 27.3 and 27.4) are similar with addition of electrical testing and then RF lesioning of nerves which innervate the facet joint for 60–90 seconds at 80°C with the ultimate goal being more permanent interruption of the pain signals to the brain. For patient safety, electrical grounding pads must be applied during the ablations. Physicians utilize fluoroscopy to guide the small-diameter 3.5 inch spinal needle toward the transverse process of the vertebrae and into the facet joint capsule. Injectate for the diagnostic block is composed of a small volume of contrast dye, followed by 1–2 cc of local anesthetic directed toward the nerve at each level. Injectate following ablations is usually a mixture of local anesthetic and steroid. Because each facet joint has dual innervations from two vertebral levels, coverage of a single facet joint implies targeting the nerves above and below that joint. Common practice is to limit oneself to no more than six facet joint interventions per visit for bilateral pain or three to four facet joint interventions if the complaint is unilateral.

Because of the frequent use of sedatives/anxiolytics to help patients tolerate the confirmational electrical testing and the electrocautery lesioning of the nerve during ablations, longer postprocedure observations may be required. But following the diagnostic block and rapid discharge, there is a small window of a few hours for duration of action of the local anesthetic. Patients must be counseled to carefully take note of their

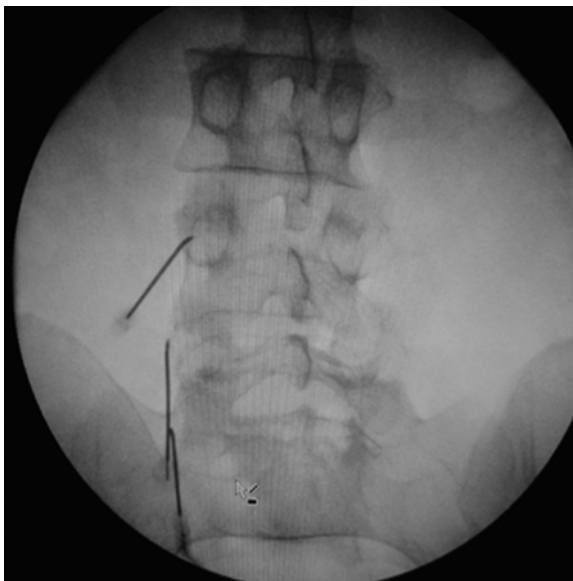


FIGURE 27.3. Left anterior oblique view of needle placement to lesion the L3 and L4 medial branches and the L5 posterior primary ramus on the L3 and L4 transverse process and sacral ala, respectively.

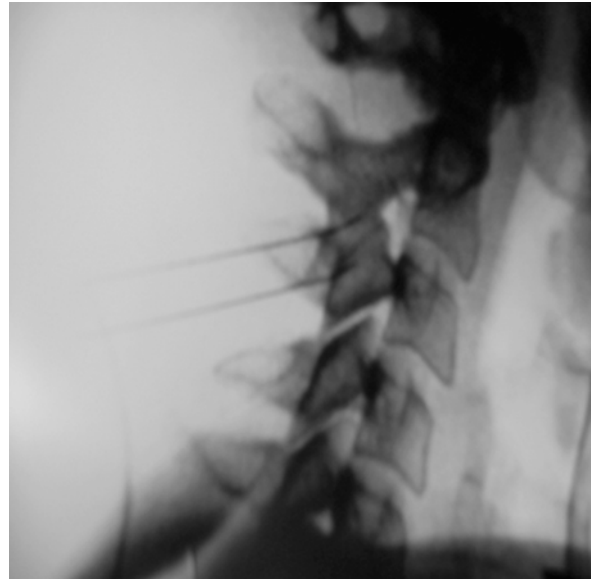


FIGURE 27.4. Lateral view of the upper C-spine with needle tips placed for a diagnostic block of the 3rd occipital nerve.

presenting symptoms and severity during this time. Use of a pain diary facilitates this documentation as well. Greater number of interventions per visit confers greater likelihood of patients noting postprocedure soreness after the local anesthetic wears off. This is associated with bruising or tissue trauma of the local back muscles. A short course of oral non-steroidal anti-inflammatory drugs (NSAIDs) or acetaminophen, in combination with ice packs and rest, often relieve symptoms quickly; however, complaints of exacerbated back pain and increased analgesic consumption may last for 1–2 weeks, especially after ablations. Swelling around the lesioned nerves may even last 6 weeks.

SACROILIAC JOINT INTERVENTIONS

The sacroiliac (SI) joint connects the sacrum and the iliac bone of the pelvis. Inflammation of this joint may lead to low back pain and referred lower extremity pain; classically starting over the buttocks and extending laterally to the hip and thigh. Investigation of SI joint dysfunction, much like facet joint intervention, usually starts with diagnostic blocks. Diagnostic injections may be used to investigate lower back and leg pain suspected to be due to pathology in the SI joint. If positive, interventional pain specialists may move on to the permanent/semi-permanent RF ablation of the lateral branch nerves which innervate the SI joint. Typical indications include inflammation of the synovial lining of the SI joint, traumatic injury, rheumatoid arthritis, and other osteodegenerative or arthritic conditions such as ankylosing spondylitis. Being a difficult clinical diagnosis, SI joint dysfunction is commonly a diagnosis of exclusion.²

The technique for SI joint injection is very similar to that for facet joint injection, with exception to the anatomical target and fluoroguided visualization. Local anesthesia with or without light intravenous sedation is used with the patient prone and the X-ray tube perpendicular to the fluoroscopy table. Skin markings are made to denote the distal portion of the joint, where it is the widest and will allow easiest penetration of delivered drugs. This is followed by a 20–30 degree rotation of the X-ray tube in the cephalad direction, so as to make the posterior and caudal aspect of the SI joint more visible. Next a small-diameter needle (i.e., 22-gauge 3.5 or 5 inch needle) is manipulated into the joint in question using fluoroscopy. Radiopaque dye is often then used to confirm proper needle placement. Typical injectate is 5–10 cc of local anesthetic and steroid mixture (usually 5–10 ml of 0.5% bupivacaine plus triamcinolone 20–40 mg). This is often repeated up to three times per year, but to be optimized each session should be followed by physical therapy regimen and rehabilitation.

Sacroiliac joint injections present some special considerations worth noting. These interventions are known to be much more difficult in the absence of fluoroscopic guidance.¹ The degree of difficulty often is a marker for number of attempts and remanipulations. Like other percutaneous procedures though, there may also be an exacerbation of pain or no noted change in pain afterwards. Other similarities also exist between SI and facet interventions. For ablations, patient safety and use of electrical grounding pad (Bovie pad) is again paramount when using high-frequency energy. Alternating current creates precisely controlled heat, which is then delivered by narrow electrode needles to the affected area, resulting in destruction of pain-sensing nerves. Subsequently, patients should expect the likely ache associated after the ablation-induced tissue trauma. Also because of proximity of the sciatic nerve as it runs anterior to the SIJ, leg weakness for several hours may be seen due to diffusion of local anesthetic.

SYMPATHETIC BLOCKS

Sympathetic blocks are now commonly performed in outpatient settings such as medical offices and ambulatory surgery centers (ASCs). In an effort to control certain pain syndromes, these blocks target disruption of the sympathetic pathways.³ The most common indication is reflex sympathetic dystrophy (RSD), also known as complex regional pain syndrome (CRPS).³ This is primarily limited to stellate ganglion blocks (SGBs) and lumbar sympathetic blocks (LSBs) since they are commonly performed to diagnose and treat CRPS. Radiofrequency ablation may be used after diagnostic blocks when the indication is either sympathetically mediated chronic pain of the upper extremity (stellate ganglionotomy) or sympathetically mediated chronic pain of the lower extremity (lumbar sympathectomy). Patients with lower-extremity neuropathy or peripheral vascular disease sometimes also benefit from LSBs. Celiac plexus blocks, on the other hand, may be used to manage a variety of chronic abdominal pains by interfering with sensory transmission from much of the abdomen.

While these blocks may be guided by endoscopic ultrasound (EUS), CT, or MRI, the most common image guidance is via fluoroscopy.

For SGBs, an obliqued C-arm is used to provide ipsilateral fluoroscopic guidance, and the C7 uncinate process is visualized. A 22- to 25-gauge spinal needle is then advanced through a lidocaine skin wheal toward the vertebral body junction and the base of the uncinate process. Using continuous fluoroscopy to confirm an appropriate nonvascular spread pattern upon injection of contrast, the practitioner can verify correct position of the needle (see Fig. 27.5). In the absence of vascular flow patterns (i.e., rapid arterial washout) of the contrast, one can exclude improper needle placement within the vertebral artery located anteriorly and the common carotid artery located posteriorly. Approximately 5–10 cc of local anesthetic is administered for the diagnostic block.

Lumbar sympathetic blocks are performed using fluoroscopy with the patient again in the prone position having routine physiological monitors (electrocardiogram, blood pressure, and SpO₂) applied. Placement of an abdominal pillow will exaggerate thoracolumbar curvature and facilitate performance of the LSB, as it does the SGB. Entering through a lidocaine skin wheal over the L2 transverse body, a 22-gauge 13 cm spinal needle is advanced until contacting the vertebral body. The needle is then retracted and “walked off” the lateral border of the vertebral body. Proper placement is confirmed by fluoroscopy with the needle tip at the anterior edge of the vertebral body on the lateral view and at the medial border of the ipsilateral pedicle on the anterior/posterior view. In this position the needle tip is expected to be adjacent to the lumbar sympathetic chain, and an aliquot of contrast is delivered to confirm a prevertebral location. Then approximately 10 cc of local anesthetic or lytic solution is injected.

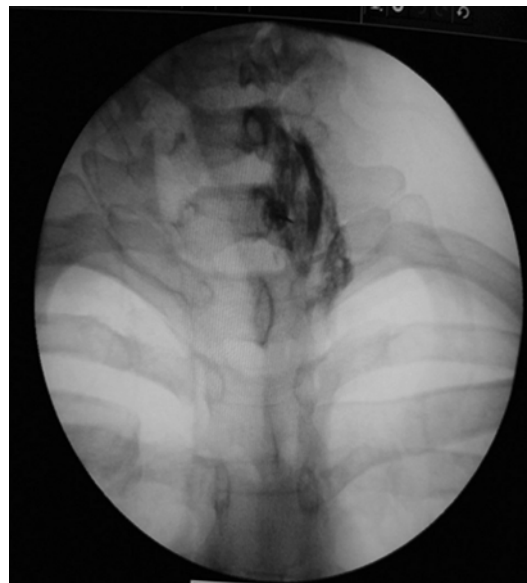


FIGURE 27.5. Anteroposterior view of right stellate ganglion block at T1 level; vertebral artery outlined by contrast.

Following removal of the needle, the patient must be continually monitored for hypotension and reflex tachycardia.

Albeit especially useful for malignant pains such as pancreatic cancer, or severe chronic visceral pains, neurolytic celiac plexus blocks still have not found widespread use outside of tertiary care centers and more highly specialized pain centers. Suffice it to say that even with the advent of EUS, the performance of celiac plexus blocks is still frequently reserved for tertiary care centers and more highly specialized interventional pain management centers.^{3,4}

Sympathetic blocks carry with them specific clinical concerns that should be discussed with the patient as part of the informed consent process prior to the start of the procedure. Stellate ganglion blocks may cause Horner syndrome with ipsilateral face and eyelid droop as well as hoarseness. Lumbar sympathetic blocks may cause one or both of the patient's legs to become warmer than baseline. While relatively common, both these are self-resolving within a few hours. Although rare, other complications include inadvertent needle placement into the vertebral artery or adjacent tissues; to include the vertebral discs, gastrointestinal tract (esophagus), cerebrospinal fluid (CSF), pleura, or neural structures. These complications have resulted in intravascular injection, hematoma formation, seizures, spinal anesthesia, cervical epidural abscess, brachial plexus block, pneumochoylothorax, pneumothorax, temporary blindness, hoarseness, dysphagia, and death.¹ The unusual cardiac complication of left ventricular dysfunction can be seen after left SGB due to disrupted autonomic balance to the heart. When right-sided SGBs disrupt sympathetic outflow to the heart, parasympathetic predominance may be overwhelming, resulting in a dysrhythmic heart rate or even asystolic cardiac arrest.

SPINAL CORD STIMULATORS

Spinal cord stimulators (SCSs) are implantable medical devices used to treat chronic pain of neurologic origin, such as sciatica, intractable back pain (such as failed back surgery syndrome or failed laminectomy syndrome), and diabetic pain. Over the past three decades, they have been used in many of the most challenging pain management cases successfully. These stimulators function by generating an electric pulse near the dorsal surface of the spinal cord, providing a paresthesia sensation that alters the perception of pain by the patient. They are typically used in conjunction with continued conventional medical management.

On occasion, SCSs are permanently implanted to supply a low-intensity impulse to a location in the spinal cord in an attempt to disrupt native pain transmission signals that are being transmitted to the brain. Being an invasive and permanent intervention, this is usually performed after a SCS trial. After a successful SCS trial with marked improvement in pain relief, implantation usually occurs as a scheduled case within the operating room. As such, it will not be discussed in this chapter. See Figures 27.6 and 27.7 for examples of SCS lead placement.

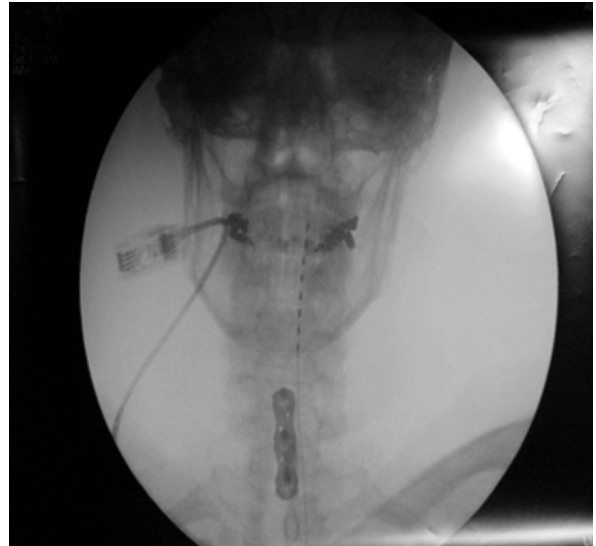


FIGURE 27.6. Anteroposterior view of a right octrode SCS lead at the C2 level, right of midline.

INTRATHECAL/EPIDURAL PUMPS

Both intrathecal pumps and epidural pumps are meant to function as continuous drug infusion systems. They are usually reserved for patients who have severe, debilitating chronic pain that has not responded adequately to traditional treatments. The most common drug delivered is morphine.^{3,4} The infusion catheter is inserted midline at the lower back, terminating in the spinal space and the epidural space, respectively. The infusion pump is placed on one side of the abdomen, above the buttocks, or in the upper back in a pocket under the

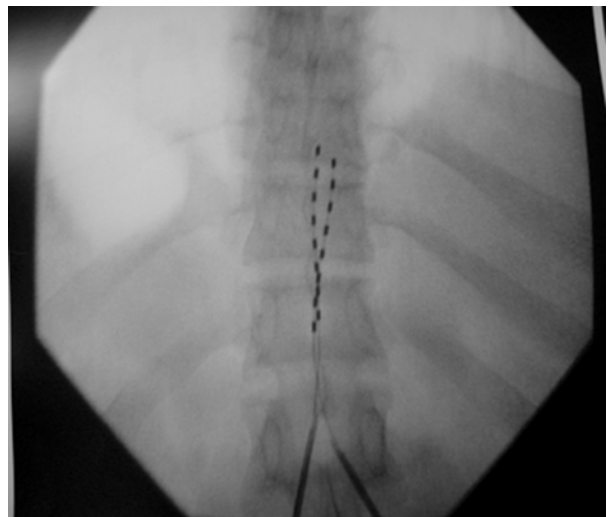


FIGURE 27.7. Anteroposterior view of two octrode leads with the first contact at the bottom of T10. This position will typically cover leg pain.

skin. Typical indications include refractory chronic pain secondary to failed back syndrome, postlaminectomy syndrome, cancer pain, reflex sympathetic dystrophy, and severe osteoporosis or end-stage arthritis.

Consideration of intrathecal and epidural pumps has traditionally been restricted to malignant pains (chronic pain related to underlying cancer). The expected equipment life span is about 3–5 years before anticipating replacement.⁵ Recent developments have led to the consideration of utilizing these pumps in other patient cohorts as well, but these procedures themselves are still primarily performed in the operating room or suite. As such, we will not discuss them at length here for the purposes of this chapter.

COMMON ANESTHETIC CONSIDERATIONS FOR PAIN PROCEDURES OUTSIDE OF THE OPERATING ROOM

While sedation and analgesic options are plentiful for utilization during percutaneous pain techniques, many, if not most of these procedures can be done without sedating the patient. In fact, it is not uncommon for some providers to typically rely on only light sedation for spinal cord stimulators, implantable pumps, and sympathetic blocks (however, some of these procedures may require deep sedation or general anesthesia and may need to be performed in the operating room). Most providers, however, will use sedation for facet procedures, and many will use sedation for both epidural and facet injections. Ultimately, individual provider comfort, clinical discretion, patient health, and patient disposition often come together in deciding whether to use sedation. Thorough preprocedure history and examination are crucial in recognizing and avoiding clinical pitfalls such as preexisting coagulopathies and potentially difficult airways. Other pertinent patient disposition traits include individual pain tolerance and availability of a responsible adult to assist with postprocedure management and transport home. Postintervention care and discharge instructions will be influenced by the degree of sedation achieved (as opposed to the level of sedation targeted) and the potential for altered sensory and motor baselines following the procedure.⁶

The most common anesthesia concerns and pitfalls are important for all interventional pain management specialists. Vagal responses are the most commonly encountered concern following percutaneous pain procedures.⁷ While variances are expected for the vast array of techniques and anatomical locations involved, the incidence may range from less than 1% to over 10% even when limiting inclusion to just translaminar epidural injections.⁸ Several important factors must be considered when trying to explain such disparity. Factors such as typical patient body habitus, procedural experience and interoperator variability, selection of needle type and needle placement, use of fluoroscopy or image guidance with or without radiopaque contrast dyes, and use of sedation may be involved. Avoidance of sedation, lesser degree of patient anatomic variation, and clinical experience may all decrease

the incidence significantly. Oversedation may also be concurrent with loss of airway. When pharmacological sedation is planned, *nil per os* (NPO) guidelines should be enforced in accordance with departmental or institutional standards.

With the exception of stellate ganglion blocks, all the procedures discussed will be likely performed in the prone position. This can complicate airway management and rescue in case of oversedation. This is especially evident when procedures such as cervical medial branch blocks and transforaminal epidural steroid injections (ESIs) are complicated by seizures; similarly when cervical epidurals utilizing local anesthetic are complicated by occurrence of a total spinal anesthetic. While rare, clinicians also must be aware of the potential for stroke and paralysis with interventions such as cervical or lumbar transforaminal ESIs. On the other hand, management of pneumothorax, if seen with thoracic procedures, is not significantly altered by the prone position.⁹

As with all anesthesia care plans, patient safety and monitoring remain top priorities for the pain interventionalist to minimize problems.^{2,7} Standard American Society of Anesthesiology monitors, such as electrocardiogram, noninvasive blood pressure, oxygen saturation, when combined with radiographic monitoring are used to aid in percutaneous procedures. It is important to note, however, that despite reports that fluoroscopically guided interventions prove safer, they are not fail-safe. Many pain procedures have been shadowed by complications despite image guidance.¹ There is no substitute for proper training, clinical expertise, and cautious patient monitoring to ensure patient safety and improve outcomes.

When the improved outcome means less pain and a definite increase in a patient's quality of life, it is easy to see why interventional pain management is so rewarding. This must be tempered by the unarguable reality that while an improvement in symptoms is expected, pain relief is not always immediate or permanent. Analgesic effects may be immediate relief and last for several weeks. On the other hand, the pain symptoms may be worse for a while with improvements come later and last for several weeks. There also may be no change for several days, and then a slow improvement which lasts for several weeks. Sadly, the pain may also be worsened or exacerbated by the procedure, with no improvement perceived by the patient.

More commonly, the patients will complain of local soreness and bruising at the injection site. This is usually self-resolving within a few days. Infection, bleeding, and scarring are all commonly counseled against, but they are also unlikely given close monitoring and precise injections.³ Patients with known clotting abnormalities or who are taking anticoagulants should let their physicians know prior to having any percutaneous interventions performed. Epidural hematomas or any neuraxial hematoma/infection poses significant concern and warrants longer observation times with possible admission to the hospital. This is especially worrisome with the diabetic, septic, and immunocompromised patients.

Postdural puncture headache (PDPH) is a low spinal fluid pressure headache which occurs if the procedure needle (or other instrument) penetrates the dural membrane and results in a persistent CSF leak. Management options include oral

hydration, oral caffeine, an epidural blood patch, intravenous fluids, and analgesics. In most instances, the dural puncture seals with spontaneous resolution of the headache in less than 2 weeks.¹ Should the needle tip deliver injectate directly into the CSF, one must observe for a total spinal anesthetic. Damage to the nerve itself could arise via needle trauma and result in permanent neuralgic pain, numbness, and weakness in variable parts of the body. However, most paresthesias resolve within hours and almost all within 2 weeks.

More rare complications include arachnoiditis, allergic reaction, and intravascular penetration and/or injection.^{1,9} Arachnoiditis is a very painful condition caused by the inflammation of the arachnoid membrane. It is associated with injection of medication into the CSF. Allergic reaction is rare and more often than not is a reaction to the preservative or the contrast and not to the local anesthetic or steroid. Symptomatic and supportive care is the principal management technique. With the use of contrast dyes, vascular puncture is becoming extremely rare. Using less than 1 cc of contrast, improper needle placement may be confirmed whether arterial (rapid washout), venous (slow washout), or even intrathecal (dilution of contrast).

Ultimately there is no substitute for large, randomized, controlled clinical trials to answer the remaining questions regarding interventional pain management. Until those answers are afforded us, providers must continue to optimize pain management using all available resources, including multimodal therapeutics; diagnostic studies such as EMG, CT, or MRI; interventional pain procedures; reassessment visits with thorough history and serial physical exams; documentation of findings; and clinical acumen with a multidisciplinary approach to patient care. The pain interventionalist

will continue to engage a detailed understanding of anatomy and judicious use of real-time fluoroscopy.

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28 | Anesthesia in the Military Setting

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The contributions of pioneers such as Joseph Priestley, Crawford Long, Horace Wells, William T. G. Morton, and John Snow are well known to students of the history of anesthesia. Numerous events in the development of military anesthesia also deserve mention, as the practices of military and civilian anesthesia have existed symbiotically. Except where otherwise noted, these considerations are summarized from Condon-Ralls' "A Brief History of Military Anesthesia."¹ These advances in military anesthetic care have often mirrored more global advances in combat casualty care, as shown in Table 28.1.²

In 1847, during the Mexican War, Edward H. Barton, a surgeon, provided the first-known "modern" American military anesthetic. Using diethyl ether, Dr. Barton anesthetized a soldier in order to amputate both of his legs. An observer commented, "The unfortunate man was soon rendered completely insensible to all pain, and indeed, to everything else, and the limb was removed without the quiver of a muscle." It was another 2 years before ether gained the widespread surgical support within the American military community that it was earning among civilian surgeons, due predominantly to an incomplete understanding of the agent. In the late 1840s, chloroform also gained widespread use, primarily among British surgeons. American military surgeons soon used both agents.

The American Civil War witnessed significant growth in the role of battlefield anesthesia. Jonathan Letterman, the Army of the Potomac's medical director, recommended an assistant surgeon be responsible for anesthesia at the 18 division hospitals, which ultimately improved the standardization of military anesthesia. It was estimated that the Union Army provided anesthesia for at least 80,000 surgical cases. Chloroform was the chosen agent in 76% of these cases, its popularity attributed to a favorable smell, noninflammability, and a lower incidence of vomiting and excitability relative to ether. Chloroform was considered generally safe when used for short durations and in the presence of appropriate levels of room air relative to the concentration of chloroform. Orally administered alcohol and opiates gained widespread use due to their perceived ability to alleviate pain. Cannabis was also occasionally used, particularly for the treatment of tetanus and head injury.

The practice of military anesthesiology as a medical subspecialty came into its own during World War I, though not without significant growing pains. Immediately preceding WWI, specialized training in anesthesia became more prominent,

directing the development of both physician and nurse anesthetists. However, during the early years of WWI, anesthetics were often delivered by inexperienced individuals and were speculated to contribute greatly to otherwise preventable deaths. To counter this, the British army began sending anesthesiologists forward in 1916. At this same time, anesthesiologists were first accepted into the Medical Corps of both the U.S. Army and Navy, and the Army began to send nurses to specialized anesthesia training programs. By 1917, the United States was fighting in WWI, and most American anesthetists were reserve civilian surgeons, nurses, and dentists. Anesthetists remained in short supply throughout the war, and they were commonly overworked and undersupplied. In historical military fashion, the charge to military anesthetists was to make the most of what was available. A variety of new anesthetic delivery systems were developed; the most popular anesthetizing agent was nitrous oxide, followed by ether, chloroform, and ethyl chloride. According to the British, a nitrous oxide-oxygen mixture "in experienced hands... was the ideal anesthetic for such patients, since it fulfilled the three essential conditions—safety, speed, and rapid recovery." The use of intravenous morphine, spinal anesthesia, or local anesthesia was often used in conjunction with, or in place of, general inhalational anesthesia. Additionally, a better understanding of the mechanisms underlying shock allowed for the initial development of blood transfusion therapy.

During World War II, the U.S. military again suffered a shortfall of specialized anesthesia providers despite offering anesthesiology residency training beginning in 1939. Nonetheless, medical, nursing, and dental officers all provided successful anesthetic care. Endotracheal intubation and closed-circuit anesthesia delivery systems gained wide acceptance, and a variety of portable systems were introduced. Commonly used agents included ether, chloroform, ethyl chloride, nitrous oxide, sodium thiopental, procaine, tetracaine hydrochloride, and cocaine. Reversing the preference for nitrous oxide-oxygen seen during WWI, ether was more commonly used in severely injured and shock patients because of its overall tolerance. Spinal and intravenous anesthetics were also employed in the critically injured, particularly when inhalational anesthesia was not available or, more commonly, experienced anesthesia providers were not available. Transfusion therapy continued to gain acceptance, primarily with plasma and whole blood. As the war progressed, whole blood became favored over plasma for the treatment of shock. Other advances included the use of splints to minimize

TABLE 28.1. *Advances in Combat Casualty Care: 1914–2007*

I. WORLD WAR I
A. Use of intravenous fluids and blood transfusions
B. Motorized ambulances
C. Laparotomy for penetrating abdominal wounds
D. Use of surgical specialists
E. Effective topical antiseptics: Carrel-Dakins wound irrigation system
F. Antitetanus serum
G. Radiologic localization of foreign bodies
H. Neurosurgical trauma databank
II. WORLD WAR II
A. General availability of whole blood and plasma
B. Formulaic resuscitation of burn patients
C. Availability of “well trained” surgeons and use of specialty specific auxiliary surgical groups
D. Hierarchical organization of trauma care
E. Use of antibiotics
F. Use of fixed wing aeromedical evacuation
G. Identification of “wet lung in war casualties”
III. KOREAN CONFLICT
A. Fluid resuscitation adequate to correct shock and prevent organ failure
B. Availability of board-certified surgical specialists
C. Forward availability of definitive surgery
D. Use of helicopters for patient transport
E. Primary repair and vascular grafts for injured vessels
F. Use of hemodialysis in theater of operations
G. Identification of high-output renal failure
IV. VIETNAM CONFLICT
A. General use of helicopters for patient transport
B. Monitoring of organ function in theater of operations
1. Blood gas measurements
2. Serum chemistries
C. Portable radiology equipment
D. Use of mechanical ventilators in theater of operations
E. Effective topical antimicrobial chemotherapy for burns
F. Staged intercontinental aeromedical transport of burn patients
G. Identification of acute respiratory distress syndrome
V. OPERATION DESERT SHIELD/STORM
A. Burn team augmentation of evacuation hospitals to provide theater-wide burn care
B. Reactivation of intercontinental burn patient transport system
VI. OPERATION ENDURING FREEDOM AND OPERATION IRAQI FREEDOM
A. Development of a military trauma registry
B. “Low-volume” resuscitation fluids—colloids and red blood cells
C. Hemostatic agents
1. Systemic
2. Topical
D. Use of “damage control” initial surgery
E. Use of endovascular stents
F. Common use of external fixators
G. Improved tourniquets
H. CAD/CAM limb prostheses

CAD/CAM, computer-aided design and manufacturing.

Source: Reprinted with permission from Pruitt BA. The symbiosis of combat casualty care and civilian trauma care: 1914–2007. *J Trauma*. 2008; 64:54–8.

hemorrhage, body heat conservation, gastric emptying to minimize the risk of aspiration, and supplemental oxygen. By the end of WWII, combat deaths attributable to anesthesia had declined considerably versus earlier conflicts. Additionally, the recognition of anesthetists as highly skilled and specialized medical and nursing providers ushered in an era of appreciation for the specialty not previously seen in military medicine.

The Korean War demonstrated more numerous and better trained personnel, as well as more readily available equipment and supplies, though shortfalls were still apparent. The evacuation system was considered worse than in WWII, and medical officers rarely had field medical experience. Much of the standardization in anesthetic care seen in WWII was forgotten by the Korean War, and practitioners often used their personal favored techniques, frequently with their own personal equipment. Intravenous fluid resuscitation and blood transfusion continued to be used successfully, and whole blood transfusion became more prominent. In 1954, the U.S. Army initiated its first 3-year postinternship residency program in anesthesiology. The Army also offered greater training opportunities for nurse anesthetists in the years following the Korean War.

During the Vietnam War, the role of the combat anesthesiologist continued to increase, including specific advances in critical care that were later extended to the civilian sector. An improved evacuation system, continued efforts at better understanding shock and resuscitation, and better availability of whole blood led to a 10-fold improvement in delay from the point of injury to appropriate care in Vietnam relative to WWI. Advanced airway management also became more prominent, including tracheal intubation in 76% of patients receiving general anesthesia. Muscle relaxants were more commonly used, and halothane and methoxyflurane gained increasing acceptance. After 1970, techniques utilizing nitrous oxide-oxygen with muscle relaxants, opioids, and intravenous sedatives were favored, partially due to concerns with halothane hepatitis. Morphine, meperidine, fentanyl, ketamine, and droperidol were also commonly administered. Neuromuscular reversal with neostigmine and atropine gained acceptance. Neuraxial anesthesia, upper-extremity regional nerve blockade, and intravenous regional anesthesia were also employed successfully.

Combat anesthetic care continued through Operations Desert Storm and Desert Shield. Major advances during this conflict primarily involved in-theater care of severely burned patients as well as improved intercontinental evacuation of these patients.²

OPERATION IRAQI FREEDOM/OPERATION ENDURING FREEDOM

Anesthetic care in the current Global War on Terror (GWOT) has mirrored the broad range of injuries seen and has sought to meet the surgical and critical care needs for these wounded patients. In the civilian population, trauma deaths are largely

blunt in nature (84%–90%), whereas in Operation Iraqi Freedom (OIF)/Operation Enduring Freedom (OEF), penetrating trauma has been the mechanism of death in 83% of cases.³ A range of historically less conventional methods for attack by enemy combatants have been employed, complicated further by unclear battleground and front-line demarcations. Blast injuries associated with enemy improvised explosive devices (IEDs) and explosively formed projectiles (EFPs) have contributed significantly to major burns, polytrauma, multiextremity amputation, and traumatic brain injury, each presenting unique challenges to the anesthesia provider.

Holcomb et al. demonstrated that relative to World War II and Vietnam, OIF/OEF has seen a substantial decrease in killed in action, died of wounds, and overall case fatality rates.⁴ These data offer some reassurances regarding military personal protective gear, including improved combat body armor. However, as demonstrated in Table 28.2, the died of wounds rate relative to the case fatality rate is higher in the current conflict relative to WWII and Vietnam, indicating that more American military personnel are surviving long enough to reach medical care. Among potentially survivable injuries, hemorrhage is the primary cause of death, representing 83% of cases.³ This presents significant surgical and anesthetic challenges not previously seen.

The U.S. military currently supports five different levels of integrated patient care, termed Levels I through V. These designations differ from trauma designations used in American civilian hospitals. The Department of Defense describes these levels of care in the *Emergency War Surgery* textbook.⁵ Inherent to these levels of care is consideration for the combat evacuation system. Casualty evacuation (CASEVAC) begins at the point of injury and involves movement of the wounded to a site where they can receive a higher level of care; these patients do not receive care during transport. Medical evacuation (MEDEVAC) also allows for movement of the wounded,

though care is provided en route. Aeromedical evacuation (AE) provides fixed-wing transport of wounded patients and health care providers within a combat theater of operations as well as between the combat theater and supporting areas outside of the combat zone. A Critical Care Air Transport Team (CCATT) provides a higher level of aeromedical evacuation, including a physician intensivist (commonly an anesthesiologist), a critical care or emergency room nurse, and a cardiopulmonary technician.

Level I care is that care which is provided closest to the point of injury. This care is typically qualified as either first-aid or life-saving measures and may be provided by the injured individual, a buddy (“buddy aid”), or a combat lifesaver. Alternatively, a combat emergency medical technician-basic (EMT-B) may be available from an affiliated medical platoon. These soldiers are commonly called combat medics, although a variety of different titles may be applicable depending on the service branch and unit. Level I medical treatment facilities (MTFs), also known as battalion aid stations (BASs), offer triage, immediate first-aid or life-saving treatment, and evacuation capabilities. They are commonly staffed by a single primary care physician and/or a physician assistant in addition to combat medics, and rarely have any surgical capabilities. The Marine Corps offers a similar Level I facility called a shock trauma platoon, which has surgical capabilities limited to life- and limb-saving procedures.^{6,7}

Level II facilities have capabilities unique to the respective branch of service and bridge patients between the point of injury and a Level III facility. Generally, they offer broader care options compared to Level I care, commonly including surgical capabilities and limited inpatient options. In the Army, Level II MTFs continue basic and life-saving care, including PRBC transfusion and limited radiographic, laboratory, and dental options. The forward surgical team (FST) can be mobilized to provide emergency life-saving damage-control surgery; it employs 20 personnel, including general and orthopedic surgeons, anesthesia providers (typically nurse anesthetists), and nursing staff. The FST works in conjunction with the supporting medical company to support two operating room (OR) beds capable of providing 72 hours of continuous surgery and an intensive care unit (ICU) capable of supporting eight patients for up to 6 hours. An FST anesthetic environment is shown in Figure 28.1. As shown in this particular photo, supplies are frequently limited to absolute necessities; in this instance, a Narkomed M anesthesia machine was used for the first OR bed while an Ohmeda draw-over vaporizer was used for the second. Typically, only draw-over vaporizers are available. The Air Force, Navy, and Marine Corps offer branch-specific variations of the FST, each maintaining different levels of mobility, surgical and holding care, and personnel. Each, however, maintains at least one surgeon to support a temporary surgical mission.

Level III facilities are the pinnacle of in-theater combat patient care. They are the ultimate destination of in-theater patient evacuation and serve to further triage patients. Ultimately, wounded American military personnel are either treated and returned to duty or evacuated to a Level IV facility. In the Army, the combat support hospital (CSH) maintains a

TABLE 28.2. Comparison of Proportional Statistics for Battle Casualties, U.S. Military Ground Troops, World War II, Vietnam, Afghanistan/Iraq

	WWII	Vietnam	Total Iraq/ Afghanistan	Afghanistan	Iraq
% KIA	20.2 ^a	20 ^b	13.8 ^c	18.7	13.5*
% DOW	3.5 ^a	3.2 ^b	4.8 ^c	6.7	4.7*
CFR	19.1 ^a	15.8 ^b	9.4 ^c	16.4	9.1*

^{a,b,c}Comparisons between WWII, Vietnam, and Total Iraq/Afghanistan, $p < 0.05$.

*Comparison between Iraq and Afghanistan, $p < 0.05$.

% KIA = $100 \times \text{KIA} / (\text{WIA} - \text{RTD}) + \text{KIA}$

% DOW = $100 \times \text{DOW} / (\text{WIA} - \text{RTD})$

CFR = $100 \times (\text{KIA} + \text{DOW}) / (\text{WIA} + \text{KIA})$

CFR, case fatality rate; DOW, died of wounds; KIA, killed in action; RTD, return to duty;

WIA, wounded in action.

Source: Reprinted with permission from Holcomb JB, Stansbury LG, Champion HR, Wade C, Bellamy RF. Understanding combat casualty care statistics. *J Trauma*. 2006;60:397–401.



FIGURE 28.1. Anesthesia setup for 102nd Forward Surgical Team, FOB Normandy, Iraq. A typical forward surgical team (FST) operating table is partially viewed in the foreground. In the left background is a Narkomed M (Dräger Medical, Germany) anesthesia machine and Propaq model 106 EL (Welch Allyn, Skaneateles Falls, NY) patient monitor. To the right is a Belmont FMS 2000 (Belmont Instrument Corporation, Billerica, MA) rapid fluid infusion device. The second operating bed (not pictured) utilized the Ohmeda U-PAC for delivery of draw-over general anesthesia. (Photo by Clinkscales CP, 2008.)

variety of medical and surgical personnel, including multiple surgical subspecialties, anesthesiologists, and nurse anesthetists to support a broad array of surgical missions. Most surgical patients present with trauma-related concerns requiring life-or-limb-saving intervention, though urgent and elective care may be offered according to the operations tempo. Relative to a Level II facility, a CSH also confers greater radiographic and laboratory capabilities, as well as a comprehensive blood bank and a variety of ancillary support personnel, including pharmacists, nutritionists, and respiratory and physical therapists. Again, the Air Force and Navy offer branch-specific variations of a CSH, each with higher levels of care provided relative to a Level II facility.

Level IV facilities exist outside of the combat zone and offer more definitive medical and surgical care as well as enhanced inpatient and outpatient support. Level IV facilities may serve for longer durations of patient care and rehabilitation prior to a patient's return to duty, or they may serve as yet another stop for continued care prior to ultimate disposition to a Level V facility located in the continental United States or Hawaii. Once at a Level V facility, patients have access to the entirety of military resources, including medical, rehabilitative, and administrative support.

Formal training in anesthesia remains a focus for today's military. Presently, Army, Air Force, and Navy anesthesiology

residencies exist, often training residents from multiple branches concurrently. Residents and attending anesthesiologists alike have opportunities to participate in humanitarian medical missions around the globe, where they often encounter anesthetic challenges unique to the austere environment. These opportunities serve dual purposes in that they extend goodwill between the U.S. military and host nations as well as prepare anesthesiologists for future combat deployments. The Uniformed Services Society of Anesthesiologists (USSA), a component society within the American Society of Anesthesiologists (ASA), was founded in 2003 by COL Paul D. Mongan, M.D. (Ret.). The USSA meets yearly during the annual ASA meeting to further the mission of continued education relevant to the military anesthesiologist. Nurse anesthesia training programs also exist in the Army, Air Force, and Navy with training sites throughout numerous military medical hospitals. Because of their historical and continued contributions to combat anesthesia, military student nurse anesthetists are exposed to a unique curriculum with specific focus on combat-relevant anesthesia practices.

An important consideration for the practice of deployed combat anesthesia is the recognition that the delivery of care is only as good as the supply line. Combat anesthesia providers often practice without many of the conveniences of a civilian practice, particularly in the early stages of a conflict and as they approach the front lines of combat. Many of the standards of anesthetic care are nonetheless maintained, and in this respect, experienced anesthesia providers can make easy adjustments to the combat environment. For instance, airway management remains crucial to the combat anesthesia provider much as it does the civilian practitioner. In the author's recent experience with the 86th Combat Support Hospital in Baghdad, Iraq, many standard and adjunctive airway devices were available, though fewer than were available at home. Nonetheless, appropriate care was provided at all times, and sufficient equipment was available to support the American Society of Anesthesiologists' difficult airway algorithm. Monitoring devices were similarly limited, though adequate, and included the ability to perform arterial pressure waveform transduction and transesophageal echocardiography. Of paramount importance to the combat anesthesia provider is the ability to provide rapid, life-saving resuscitation measures while prompt damage-control surgery is performed. The practice of trauma anesthesia, which is beyond the scope of this chapter, is thus very similar in the combat environment relative to the civilian environment, and the two undoubtedly continue to provide a useful symbiotic relationship. For instance, the recognition of the bloody vicious cycle or lethal triad seen in major trauma, comprised of acidosis, hypothermia, and coagulopathy, was reported in 1981 by the trauma group at the Denver Health Medical Center.⁸ This continues to be a source of significant interest within the military combat and civilian trauma communities alike, and considerable energy is currently being expended to identify ideal modalities for fluid resuscitation, particularly where blood and blood product transfusion is concerned.⁹ As the body of literature and evidence grows, so will the practice of combat anesthesia. The focus of the remainder of this

chapter will be on topics of current interest to the combat anesthesia provider.

DRAW-OVER ANESTHESIA

Combat anesthesia providers commonly employ draw-over vaporizers for delivering general anesthesia, particularly in forward environments. Unfortunately, formal training with the draw-over vaporizer is not a common focus of either military or civilian anesthesiology residencies or civilian CRNA programs. Army CRNA programs in particular, however, provide both didactic and clinical training of this nature. Anesthetic care at Level II combat facilities is routinely provided by nurse anesthetists, and occasionally by anesthesiologists who may not have received formal training with draw-over anesthesia, making an understanding of the equipment and physiologic considerations pertinent to any combat anesthesia provider. Level III and above facilities commonly utilize late-model anesthesia machines that should be familiar to any experienced anesthesia provider.

Draw-over general anesthesia provides many advantages over standard machine-driven general anesthesia: it is light and portable, equipment can be put together rapidly by a single individual, delivery of anesthetic gases is dependent on the patient's spontaneous ventilatory drive, compressed air or oxygen is not mandatory but can be accommodated easily, and electricity is not necessary unless supplemental ventilator support is desired. Additionally, rapid induction and emergence can be achieved easily because the system is non-rebreathing and has a small circuit volume, and scavenging of waste gases is easy to achieve.¹⁰ Presently, the U.S. military uses the Ohmeda Universal Portable Anesthesia Complete (U-PAC) system (Fig. 28.2) with or without an Impact Uni-Vent Eagle 754 portable ventilator (Fig. 28.3). In its basic configuration (Fig. 28.4), the U-PAC includes an inspiratory prevaporizer limb of reservoir tubing, a universal vaporizer, an outlet adaptor, a length of postvaporizer tubing connected to a self-inflating bag, and a second length of postvaporizer tubing connected to a facemask and preceded by a unidirectional non-rebreathing valve. A bacteriostatic gas humidifier can be added between the non-rebreathing valve and facemask, and the facemask can be replaced by a direct connection to an endotracheal tube or similar airway device. In its simplest explanation, draw-over anesthesia allows the patient's spontaneous (or assisted) breaths to "draw" fresh gas from the reservoir tubing into the vaporizer and "over" the selected volatile anesthetic, ultimately delivering a mixture of this volatile anesthetic and fresh gas to the patient.

The vaporizer is temperature compensated, and variable-bypass mechanics allow for precise delivery of anesthetic concentrations. The draw-over vaporizer is demand driven; hence, if the patient's ventilation is not spontaneous or supported, no anesthetic gas will be delivered. The universal vaporizer can support a variety of different inhalational agents, though isoflurane and halothane are most commonly used in today's forward deployed environment. When selecting an agent,

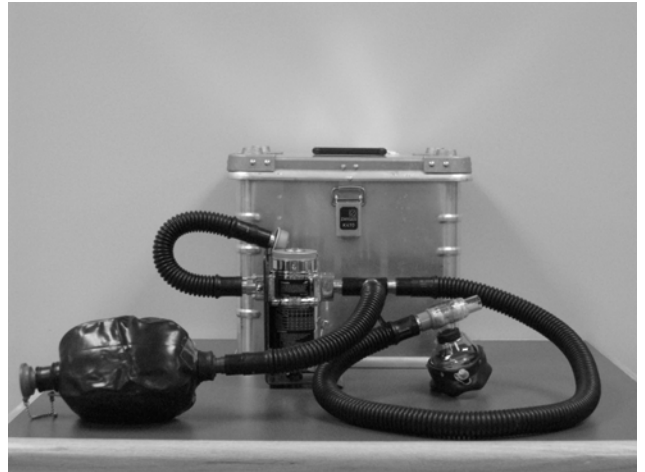


FIGURE 28.2. Standard Ohmeda Universal Portable Anesthesia Complete (U-PAC) system. Foreground: Unmodified Ohmeda U-PAC ready for use. Background: The Ohmeda U-PAC container is compact and lightweight. Dimensions: approximately 15" wide x 15" tall x 10" deep. Weight: approximately 6 kg. (Photo by Clinkscales CP, 2009.)

it should be recalled that halothane carries the added risk of hepatic damage and sensitization of the myocardium to catecholamines, whereas isoflurane is associated with greater vasodilation. Isoflurane preserves cardiac index better, likely due to an associated increase in heart rate. Additionally, halothane is associated with a greater increase in cerebral blood flow compared to isoflurane, while both agents contribute to a reduction in the cerebral metabolic rate for oxygen.¹¹ These characteristics should be considered in the forward combat environment, where patients are likely hypovolemic and potentially have head trauma. Whatever agent is used, anticipate the consumption of approximately 40 ml of anesthetic per hour of vaporizer use, recognizing that delivery may actually need to be far less in the setting of significant hemorrhage and hemodynamic instability.¹²

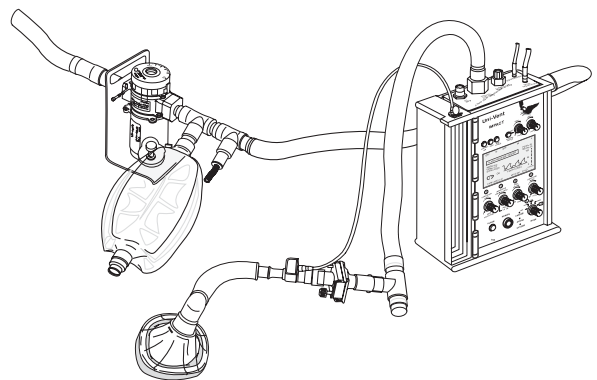


FIGURE 28.3. Draw-over apparatus in combination with ventilator. (From *Emergency War Surgery*, Third United States Revision. Department of Defense, United States of America, 2004.)

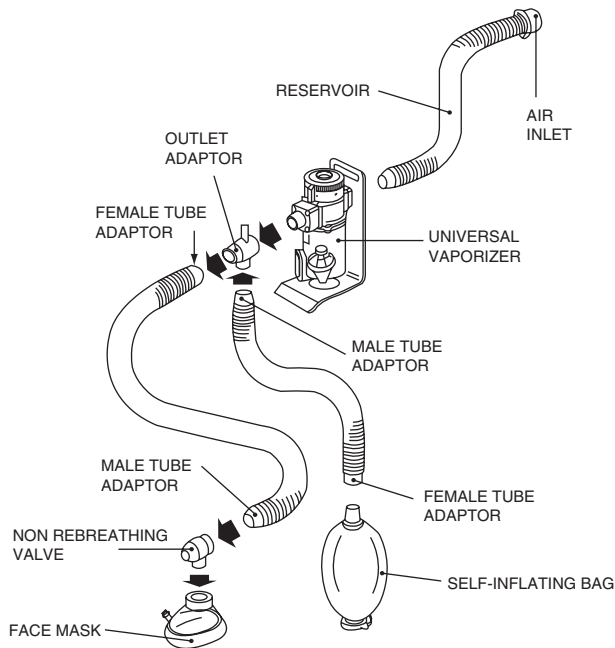


FIGURE 28.4. Breakout view of the Universal Portable Anesthesia Complete Draw-Over Anesthetic System. (Reprinted with permission from Gegel BT. A field-expedient Ohmeda Universal Portable Anesthesia Complete Draw-over Vaporizer setup. *AANA J.* 2008;76:185–187.)

While oxygen is not necessary to provide ventilation using the draw-over apparatus, it can and should be utilized when readily available. Supplementary oxygen can be provided by either pipeline or tank sources or by an oxygen concentrator; a nipple on the vaporizer allows for oxygen entrainment into the inspiratory limb. An oxygen reservoir tube on the pre-vaporizer end of the apparatus allows for further increases in oxygen concentration when attached to a supplementary source. Gegel describes increasing the length of the oxygen reservoir tubing from the standard 18 in, or 46 cm (130 ml), to 36 in, or 91 cm (260 ml), using 22-mm plastic tubing (Fig. 28.5). This further concentrated oxygen supply to the patient and provided an increased margin of safety. Additionally, the factory oxygen reservoir tube was added to the standard length of tubing between the outlet adaptor and self-inflating bag to allow the bag to rest on the floor and be used as a foot pump, freeing the anesthesia provider's hand to perform other functions.¹³ This modification is commonly used in the forward combat environment among American anesthesia providers. Eales et al. describe yet another method for providing more efficient oxygen delivery to patients under draw-over general anesthesia, utilizing a variety of prevaporizer modifications along the inspiratory limb: an oxygen reservoir tube of 300 ml with an end-capped one-way valve, a volume-increasing reservoir bag, and an adjustable pressure limiting valve set to deliver 5 cm H₂O CPAP. This was specifically demonstrated in the setting of high minute ventilation.¹⁴



FIGURE 28.5. Gegel-Mercado Modification to the Ohmeda U-PAC. Note the increased length of reservoir tubing on the inspiratory end, or left, of the vaporizer. This configuration is equipped with an oxygen analyzer and scavenging apparatus (termination of light blue tubing, extending from face mask). It can be further configured to accommodate gas sampling and spirometry. (Photo by Clinkscales CP, 2009.)

Scavenging waste gases is important in any anesthetic delivery system, and draw-over anesthesia is no exception. Tubing can be easily connected to the non-rebreathing valve and extended outside of the operating arena, whether that arena is a tent or other temporary facility or a fixed structure.

The Impact Uni-Vent Eagle 754 portable ventilator can be added to the Ohmeda U-PAC when controlled ventilation is desired. The ventilator sits between the vaporizer and the patient and contains a nonreturn valve that inhibits dangerous back-pressure on the vaporizer; it contains another nonreturn valve on the patient side that prevents back-pressure into the ventilator. Either the induction circuit or the ventilator circuit can support the scavenging of waste gases.⁵

TOTAL INTRAVENOUS ANESTHESIA

Total intravenous anesthesia (TIVA) has gained recent attention from American combat anesthesia providers due to its many inherent advantages. Among these advantages, TIVA is versatile and applicable in a variety of different clinical scenarios, it is accommodating to different drugs and their inherent pharmacologic profiles, it does not require electricity or significant manpower or delivery support, and there is a lower

risk of redistribution hypothermia when ketamine is added to the solution.¹⁵ Total intravenous anesthesia is conducive to natural or artificial airways, spontaneous or assisted ventilation, and a breadth of operative cases ranging from minor and elective to traumatic and emergent. In the combat environment, the major negative regarding TIVA is a lack of familiarity with the practice for many anesthesia providers.¹⁵

The Tri-service Anesthesia Research Group Initiative (TARGIT) on TIVA, formed at Brooke Army Medical Center in 2004 under the leadership of MAJ Ian Black, M.D., has been instrumental in bringing TIVA to the forefront of American combat anesthesia. In 2003, MAJ Mark Meeks, M.D., was the first anesthesiologist to enter Iraq. As a member of the 86th CSH, Dr. Meeks successfully performed many combat anesthetics using ketamine as a sole anesthetic. MAJ Joel McMasters, M.D., also deployed to Iraq in 2003 as an anesthesiologist with the 28th CSH. During his deployment, Dr. McMasters employed many of the first combined total intravenous anesthetics, utilizing propofol, ketamine, and fentanyl, also with great success. LTC Kurt Grathwohl, M.D., was the first Army anesthesiologist to utilize combat TIVA on a large scale, performing over 100 anesthetics using the technique during his deployment with the 359th neurosurgical team, 31st CSH in Baghdad, Iraq in 2004–2005. As an anesthesiologist with the 10th CSH in Iraq in 2006, MAJ Craig McFarland, M.D., performed an estimated 400 anesthetics using TIVA. Figure 28.6 shows Dr. McFarland performing a total intravenous anesthetic on a spontaneously ventilating Iraqi patient undergoing surgery on a traumatically amputated lower extremity. The patient maintained a natural



FIGURE 28.6. Application of total intravenous anesthesia (TIVA) in the deployed environment. The patient, a member of the Iraqi military who served alongside American military forces, is breathing spontaneously via his natural airway with only supplemental oxygen via non-rebreathing face mask. He does not have a regional anesthetic despite having surgery on a traumatically amputated lower extremity. The TIVA mixture is comprised of propofol, ketamine, and fentanyl administered from a single bag 100 ml via a 20 drops/ml dripper. (Photo by McFarland CC, 2006. Used with permission.)

airway and did not require a regional anesthetic (personal communication with McMasters, Grathwohl, and McFarland.) The author has utilized a multitude of different TIVA techniques with great success as well, both as a civilian and combat anesthesiologist. As a result of this growing body of evidence and experience, military anesthesiologists and nurse anesthetists, as well as their civilian counterparts, are becoming increasingly aware of the applicability and benefits of TIVA.

Of the multitude of TIVA formulations available for clinical practice, one of the most commonly employed in the U.S. military environment is a solution containing propofol, ketamine, and fentanyl. In stateside military hospitals, this solution is often administered with ketamine 100 mg (50 mg/ml, 2 ml) and fentanyl 100 μ g (50 μ g/ml, 2 ml) added to propofol 1000 mg (10 mg/ml, 100 ml). This solution, commonly referred to as $P_{10}K_{1}F_{1}$ (reflecting the concentrations of the individual drugs in the solution as mg/ml for propofol and ketamine and μ g/ml for fentanyl), is then infused to the patient using a standard infusion pump at rates of 75–150 μ g/kg per minute of propofol to maintain general anesthesia. Infusion rates may be lowered to maintain sedation when general anesthesia is not desired. Additionally, the amount of ketamine and fentanyl may be tailored to meet specific anesthetic needs. Ketamine is often discontinued after the first 100 mg are delivered to facilitate emergence. Sufentanil and remifentanyl have been successfully substituted for fentanyl in equipotent doses.

In the deployed environment, equipment and supplies are often at a premium, so it has become common practice to exchange lower concentrations of propofol for higher concentrations of ketamine and fentanyl, as described by Mahoney and McFarland.¹⁵ This solution is then administered to the patient using a standard intravenous (IV) dripper, thus negating the need for large quantities of 100 ml vials of propofol as well as mechanical infusion pumps. To establish this solution of $P_{4}K_{2.5}F_{2.5}$, 400 mg of propofol (10 mg/ml, 40 ml), 250 mg of ketamine (50 mg/ml, 5 ml), and 250 μ g of fentanyl (50 μ g/ml, 5 ml) are added to 50 ml of normal saline. When a 20 drop/ml IV dripper is used, and assuming an 80 kg patient, one drop every 3 seconds equates to an infusion of 50 μ g/kg per minute of propofol. Using this information, one drop every 2 seconds establishes an infusion of 75 μ g/kg per minute of propofol, one drop every second establishes an infusion of 150 μ g/kg per minute of propofol, and so forth. Further adjustments can be made based on the individual patient's weight as well as surgical and anesthetic needs. Figure 28.7 demonstrates the equipment necessary to perform this anesthetic technique.

Continuous infusions of intravenous agents offer many advantages over intermittent boluses of the same medications, namely by establishing better control of plasma drug levels within the therapeutic range rather than oscillations above and below the desired levels. This has been long understood particularly in regard to the administration of fentanyl and ketamine.¹⁶ Clinically, this is demonstrated by reliable titration of anesthesia and analgesia, as well as rapid emergence from general anesthesia versus easy maintenance of sedation

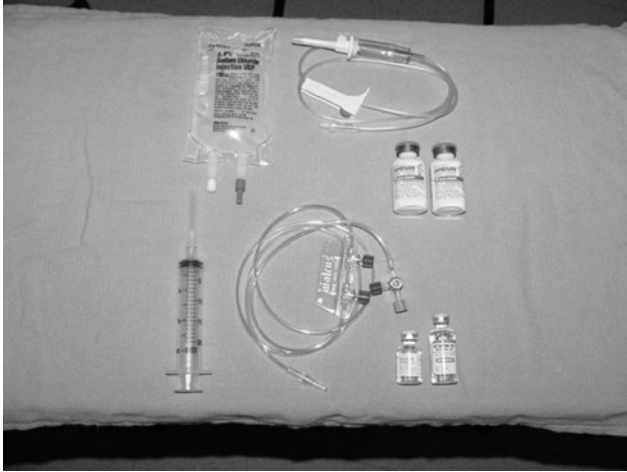


FIGURE 28.7. Equipment and medications needed for suggested combat total intravenous anesthesia (TIVA) setup. From the upper left and working clockwise: 100 ml normal saline bag with 50 cc removed, 20 drops/ml IV dripper, two propofol 10 mg/ml 20 cc vials, ketamine 50 mg/ml 10 cc vial, fentanyl 50 µg/ml 2 cc vial, IV extension tubing, and 20 cc syringe with 18-gauge needle for drawing medications. (Photo by McFarland CC, 2006. Used with permission.)

for transfer to a critical care ward. In recent years, TIVA has demonstrated itself to be at least equivalent to a volatile-based anesthetic in terms of reliability and reproducibility. Recent studies, however, have potentially conferred an advantage upon TIVA that is particularly relevant in the combat environment. In patients experiencing head trauma, further increases in cerebral blood flow and intracranial pressure (ICP) associated with volatile anesthetics may be undesirable despite the associated reductions in cerebral metabolic rate. Cole et al. reviewed numerous prospective studies regarding the use of TIVA in elective intracranial procedures and found that relative to volatile anesthetics in elective intracranial operations, TIVA offered decreased ICP in the setting of increased cerebral perfusion pressure.¹⁷ The extension of these findings to the traumatically injured brain in the combat environment is lacking. Grathwohl et al. retrospectively evaluated neurologic outcome in patients with operative traumatic brain injury and found no benefit with TIVA relative to volatile-based anesthesia; however, by their own estimation there were many confounding variables and limitations to their study, not the least of which was the inability to adequately power and perform a prospective analysis.¹⁸

In addition to propofol's hypnotic and amnestic properties and fentanyl's analgesic properties, the addition of ketamine offers additional hypnotic, dissociative, amnestic, and analgesic properties. Also, the sympathomimetic properties of ketamine may offset the vasodilating effects of propofol, potentially allowing for greater hemodynamic stability. The utility of ketamine in a combat environment has been recognized for many years.^{19,20} In a swine model, a ketamine-based TIVA model was shown to produce less pronounced hypotension in the setting of uncontrolled hemorrhagic shock

relative to an isoflurane anesthetic, albeit at the potential expense of end-organ perfusion.²¹ It is noted, however, that Englehart et al. used doses of ketamine (as well as midazolam) significantly beyond that typically used in TIVA, so the true effect of ketamine on blood pressure and end-organ perfusion in a hemorrhagic shock model remains unknown. Additionally, historical concerns regarding the use of ketamine in the setting of central neurologic injury has been challenged. Himmelseher and Durieux demonstrate Level II clinical evidence in stating that ketamine is not associated with increases in ICP when co-administered in the setting of controlled mechanical ventilation and a GABA-receptor agonist, given the avoidance of nitrous oxide.²² Counter-intuitively, the use of perioperative ketamine may also be associated with a reduced incidence of posttraumatic stress disorder (PTSD) in wounded service members, as demonstrated in a recent study by McGhee et al.²³

ACUTE PAIN MANAGEMENT

Combat anesthesia providers are commonly faced with wounded personnel presenting with a myriad of traumatic injuries. Significant perioperative acute pain is expected, allowing anesthesia providers to have a significant positive effect on patient outcome. Unlike the civilian population, where operative intervention is commonly expected and planned, combat surgery rarely avails itself to preemptive analgesia. Patients wounded in theater are commonly evacuated to successive levels of higher care rapidly, potentially inhibiting methodical evaluation and subsequent and ongoing treatment of acute pain. Additionally, significant pain can result from non-combat-related accidents and injuries.²⁴ As such, combat anesthesia providers face unique challenges. A complete discussion of acute pain management is beyond the scope of this chapter, though the following provides some generic considerations that are applicable in the combat environment.

Though definitive outcome studies evaluating the merits of acute pain management are lacking,²⁵ various physiologic and psychologic benefits associated with adequate pain control are appreciated and can intuitively be assumed to improve patient morbidity and mortality. Specifically, in the presence of poorly controlled pain, oxygenation and ventilation becomes impaired, myocardial oxygen consumption increases, the stress response is increased resulting in a catabolic state, hypercoagulability develops which predisposes patients to thromboembolic events, and immune function is impaired.²⁶ Psychologically, patients feel helpless and experience needless suffering.²⁵ Additionally, poorly controlled acute pain may contribute to the development of PTSD and chronic pain,^{27,28,29} both of which are currently areas of significant concern within the American military medical community.

Noxious stimuli activate nociceptors, leading to the release of numerous local chemical mediators, including substance P, glutamate, aspartate, prostaglandins, serotonin, leukotrienes, bradykinin, and histamine. These nociceptors communicate

with the dorsal horn of the spinal cord via A δ and C first-order pain fibers, where additional chemical mediators are released, including glutamate, aspartate, vasoactive intestinal peptide, calcitonin gene-related peptide, neuropeptide Y, and substance P. At this level, inhibitory mechanisms also exist and may be modulated by γ -aminobutyric acid, glycine, enkephalins, β -endorphins, norepinephrine, dopamine, adenosine, somatostatin, and acetylcholine. Second-order neurons then transmit this data to the brain stem and thalamus via the contralateral spinothalamic tract. Finally, third-order neurons extend from the thalamus to the sensory cortex.^{26,30} Based on this understanding, there is much interest currently in a multimodal approach to the treatment of acute pain, both in the civilian as well as the deployed combat environment. Wounded American military personnel may have the opportunity to ingest a "Combat Pill Pack," which includes acetaminophen, a nonsteroidal anti-inflammatory drug (NSAID) (celecoxib or meloxicam), and an antibiotic (gatifloxacin) at the point of injury, prior to evacuation and medical evaluation. Hartrick describes multimodal pain therapy as the use of multiple pharmacologic and nonpharmacologic analgesic therapies utilizing varying mechanisms of action.³¹ Furthermore, multimodal pain management is believed to not only improve postoperative analgesia but also to reduce the incidence of analgesia-related deleterious side effects.³² Historically, postoperative pain has been treated by a model similar to the World Health Organization's pain ladder for the relief of cancer pain, which begins with nonopioid management with or without an adjuvant, advancing then to the addition of opioid medications and additional adjuvants as pain severity increases.³³ This remains an appropriate response to acute postoperative pain, though in the combat environment, health care providers often rely heavily on opioid medications while underutilizing adjuvant therapies. This may be an incomplete treatment strategy considering the frequent presentation of pain from somatic, visceral, and neuropathic origins.

Classic analgesics that can be useful in a multimodal approach include nonopioid and opioid medications alike. Acetaminophen and NSAIDs exert their action via the inhibition of central prostaglandin synthesis in the case of acetaminophen and a combined inhibition of peripheral and central prostaglandin synthesis in the case of NSAIDs.³⁰ Cyclooxygenase-2 (COX-2)-selective NSAIDs can also be employed, and they generally have a more favorable side effect profile.²⁵ Each of these classes exerts opioid-sparing effects in the treatment of acute pain. However, as acute pain increases in severity, the addition of opioids often becomes necessary. Activation of the μ -receptor primarily accounts for the analgesic effect of opioids as well as many of their deleterious side effects, whereas κ -receptor agonism accounts for analgesia with less respiratory depression.³⁰ In the combat environment, opioids are typically administered by the parenteral route, often by patient-controlled analgesic (PCA) devices. There are many advantages of PCA delivery, as pointed out by Malchow and Black, including patient self-empowerment and satisfaction. However, they continue that studies of PCA delivery provide conflicting data regarding efficacy and patient safety.²⁵ Nonetheless, PCA delivery

remains a viable option, and the American Society of Regional Anesthesia and Pain Medicine (ASRA) has recently released a consensus statement identifying PCA as superior to nurse-administered parenteral opioids in regard to patient outcomes.³² Table 28.3 shows various starting points for an opioid PCA regimen. Numerous opioid medications also exist for enteral dosing. Of these, methadone deserves special mention because of its antagonism of NMDA receptors and inhibition of serotonin reuptake in addition to opioid receptor activation.²⁵ Because of these unique properties among opioids, methadone can be invaluable in a multimodal treatment regimen. Also unique to methadone, though, is its variable pharmacologic profile that can contribute to delayed onset of side effects due to gradual accumulation of the drug, including a peak risk of mortality 5 days after starting the medication in previously opioid-naïve patients.²⁵

Among nonopioid adjuvant medications, many can be utilized successfully in the combat environment. Ketamine exerts its action via antagonism of the excitatory neurotransmitter glutamate by binding to and modifying the NMDA receptor and can be given as an adjunctive analgesic during operative analgesia or in the postoperative period.³⁴ Ketamine can be bolused in 10–20 mg IV doses to provide rapid analgesia; due to the potential development of psychomimetic effects, however, it is prudent to consider coadministration with a benzodiazepine. Alternatively, ketamine can be combined with a morphine PCA delivery system (morphine 1 mg + ketamine 1 mg per demand bolus) to provide safe and ongoing analgesia.³⁵ Clonidine functions in acute pain management via its actions at the α -2 receptor in the locus ceruleus as well as via its inhibitory actions at the spinal cord level.²⁵ Clonidine is quite versatile and can be administered orally, transdermally, intravenously, neuraxially, and as an adjunct to peripheral nerve blockade. Oral and transdermal routes are most common; orally, 0.1–0.2 mg given once or twice daily versus a 0.1–0.2 mg transdermal patch is a reasonable starting point. Sedation and hemodynamic instability are potential concerns, particularly in predisposed patients. Gabapentin and pregabalin are anticonvulsants that can be used as analgesic adjuvants; their mechanism of action is not completely understood, though they may regulate excitatory neurotransmitters at the spinal cord level by activating noradrenergic receptors.^{25,36} Both agents are given by the oral route. Gabapentin is commonly started at 300 mg three times daily, with gradual

TABLE 28.3. *Recommendations for Opioid Delivery by PCA*

Drug	mg/ml	Load (mg)	Basal (mg/hr)	PCA Dose (mg)	Lockout (min)
Morphine	1	5–10	0–1	1–3	6–12
Hydromorphone	0.2	1–2	0–0.2	0.2–0.6	6–10
Fentanyl (μ g)	25	100–200	0–25	20–30	6–10

Source: Reprinted with permission from Malchow RJ, Black IH. The evolution of pain management in the critically ill trauma patient: emerging concepts from the global war on terrorism. *Crit Care Med.* 2008;36:S346–357.

escalation to a maximum dose of 1200 mg three times daily. Pregabalin is commonly started at 75 mg twice daily and increased to 150 mg twice daily. Clinically, pregabalin may be associated with less sedation than gabapentin. Tricyclic antidepressants (TCAs) block the reuptake of norepinephrine and serotonin, which are active mediators of spinal inhibitory pathways. Additionally, they provide sedation and are useful as a sleep aid. As such, they can be a valuable addition to a multimodal plan. Amitriptyline is typically started at 10–25 mg orally at bedtime and gradually increased to 50 mg. Tricyclic antidepressants present a broad side effect profile, necessitating close follow-up by prescribing health care providers. Mexiletine is an oral analog to lidocaine; in addition to its antiarrhythmic properties, it can be beneficial in acute pain treatment due to blockade of sodium channels and action at the spinal NMDA receptors.^{25,37} Intravenous lidocaine and oral mexiletine are thus potentially useful agents in the treatment of acute pain, particularly of neuropathic origin. Side effect limitations include sedation, fatigue, nausea, and dizziness.³⁸ There may also be concerns about the introduction of cardiac conduction abnormalities.²⁵ Mexiletine can be started orally at 150 mg twice daily and gradually increased to 300–450 mg twice daily. Malchow and Black suggest an intravenous lidocaine test prior to beginning oral treatment with mexiletine, ostensibly to assess for expected continued response.²⁵

REGIONAL ANESTHESIA AND ANALGESIA

Regional anesthesia has been utilized in combat situations throughout the twentieth century and continues to be utilized in the current GWOT. Though used by American military anesthesiologists in combat as early as WWI, spinal anesthesia did not emerge as an accepted and common practice until Vietnam. Similarly, epidural anesthesia and peripheral nerve blockade in the combat environment also emerged during the Vietnam War.¹ These techniques remain valuable adjuncts in today's combat environment. In the words of Schulz-Stübner, "Regional analgesia using single-injection regional blocks and continuous neuraxial and peripheral catheters can play a valuable role in a multimodal approach to pain management in the critically ill patient to achieve optimum patient comfort and to reduce physiologic and psychological stress."³⁹ In their review of pain management for the critically ill patient, Malchow and Black identify numerous measures of improved patient outcomes with regional analgesia, including lessened lengths of stay, improved physiologic performance, and decreased mortality in addition to improved pain scores.²⁵

There is evidence that epidural analgesia eases management and improves comfort, without necessarily reducing mortality, in the critical care population. Specific surgical populations encountered in the combat environment that this statement applies to include chest trauma and thoracic, abdominal, major vascular, and major orthopedic surgery.³⁹ Neuraxial techniques can be employed in the combat environment,

though concerns with hemorrhage-induced hypotension and hemodynamic instability as well as coagulopathy associated with trauma may impede the use of these techniques. In the combat trauma patient, it is often prudent to allow the initial surgical course to proceed utilizing a general anesthetic; upon completion of damage-control surgery, initial resuscitation, and complete evaluation of the patient's presentation and expected hospital course, re-assessment for continual epidural analgesia might be considered. The author frequently placed thoracic and lumbar epidural catheters in trauma patients utilizing this formula. Bolus injections of local anesthetics into the epidural space may not be desirable in the setting of recently completed or ongoing fluid resuscitations, though infusions of local anesthetics are likely to be better tolerated. Opioids may be added to the epidural solution as allowed by the patient's ventilatory and mental states.

In 2003, while deployed with the 21st CSH in Balad, Iraq, COL Chester "Trip" Buckenmaier III, M.D., placed the first successful in-theater continuous peripheral nerve block catheter in a wounded soldier. Soon thereafter, the Army Regional Anesthesia & Pain Management Initiative (ARAPMI) was founded at Walter Reed Army Medical Center in Washington, D.C., to advance the practice of regional anesthesia and acute pain management in both the military and civilian environments. Additionally, the ARAPMI maintains the Regional Anesthesia Tracking System (RATS), which allows anesthesia providers to track a patient's pain control from the point of injury, often in theater, to a stateside military hospital. The ARAPMI also works in conjunction with the tri-service collaborative group Military Advanced Regional Anesthesia & Analgesia (MARAA) to provide combat acute pain management support. The MARAA handbook, available for free online download at <http://www.arapmi.org/maraa-book-project.html>, is an excellent resource for acute pain management in the combat environment.⁴⁰

Peripheral nerve blockade can be provided by a single-shot technique or continuous infusion via an indwelling catheter. In the combat environment, wounded American military personnel often do not stay in-theater for prolonged periods of time, as evacuation to a higher echelon of care proceeds quickly after initial surgical intervention. As such, time constraints may make placement of an indwelling catheter more challenging, so a single-shot technique may be preferred. Figure 28.8 demonstrates the equipment needed for a single-shot peripheral nerve block, as well as a block being performed by the author on a sedated pediatric patient. Ultrasound capabilities are presently available throughout the combat theater, though machines may be older and thus less "user friendly" compared to newer models. Table 28.4 lists local anesthetic considerations for peripheral nerve blocks, including recommendations for infusion rates and PCA demand options when indwelling catheters are placed. Indwelling catheters unquestionably have a role in perioperative combat analgesia provided the additional time necessary for placement is allowed by the surgical and evacuation timeframe. In Figure 28.9, the author placed an ultrasound-guided brachial plexus catheter utilizing the supraclavicular approach



FIGURE 28.8. Placement of single-shot peripheral nerve blocks in theater is quick, easy, and beneficial. (a) The photo on the left shows the equipment that may be used for a peripheral nerve block, including ultrasound, a nerve stimulator, an appropriately sized insulated beveled stimulating needle, local anesthetic mixture, skin prep, and sterile gloves. (b) With the assistance of LTC Joseph O'Sullivan, CRNA, PhD, the author places an ultrasound-guided interscalene brachial plexus block in a noncombatant Iraqi pediatric patient who underwent upper-extremity fasciotomies after a snake bite. The patient was sedated with ketamine and midazolam. (Photos by Clinkscales CP, 2008. Permission obtained for inclusion in photo from LTC Joseph O'Sullivan, CRNA, PhD.)

in a sedated Iraqi woman admitted to the hospital for contracture releases resulting from full-thickness burns. These catheters should be placed under strict sterile conditions, and adequate patient education and follow-up is mandatory. When sufficient time is not available, a prolonged block can

TABLE 28.4. Recommendations for Infusion Volumes for Peripheral Nerve Blockade

Technique	Adult Single Injection (ml, 0.5% Ropivacaine) ^a	Continuous Infusion (ml/hr, 0.2% Ropivacaine)	PCA Bolus Rate (ml/bolus, 0.2% Ropivacaine, 20 min lockout)
Interscalene	30–40 ml	8–10 ml	2–3 ml
Supraclavicular	30–40 ml	8–10 ml	2–3 ml
Infraclavicular	30–40 ml	8–10 ml	2–3 ml
Paravertebral	3–5 ml per level	8–10 ml	2–3 ml
Lumbar plexus	25–30 ml	6–8 ml	2–3 ml
Femoral	20–25 ml	6–8 ml	2–3 ml
Sciatic (anterior or posterior approach)	20–25 ml	6–8 ml	2–3 ml
Sciatic (lateral or posterior popliteal approach)	35–40 ml	8–10 ml	2–3 ml

^aConsider adding a vasoconstrictor as a vascular marker; prolongation of the block is an added benefit. The author adds 1:400,000 epinephrine (2.5 µg epinephrine/ml local anesthetic solution).

^bFor a longer-lasting block, 0.5% bupivacaine can be substituted for ropivacaine. The block can be prolonged further by adding tetracaine to the solution; the author typically adds lyophilized tetracaine 10 mg per 20 ml existing solution.

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be achieved by administering bupivacaine 0.5% and a vasoconstrictor such as 1:400,000 epinephrine. It should be recalled that the cardiotoxicity of bupivacaine is greater than ropivacaine, so appropriate preparation is necessary. The addition of tetracaine to this solution can prolong the single-shot block further when added to this bupivacaine/epinephrine solution. The author commonly added lyophilized tetracaine 10 mg to every 20 ml of solution. The goal was to safely establish peripheral nerve blockade for sufficient duration to allow the patient to be evacuated to Landstuhl Regional Medical Center in Germany where more definitive acute pain management could be started.

When providing peripheral nerve blockade for combat patients, the same risks exist as those for noncombat patients. However, there might be a greater likelihood of undiagnosed injuries and comorbidities, necessitating close attention and care by the anesthesia provider. Additionally, considering the common “dirty” nature of combat injuries, particular attention should be paid to sterile technique in recognition of the potential for increased risk of infection. Additionally, prompt recognition and treatment of local anesthetic toxicity should be available. In Baghdad, Iraq, intralipid 20% solution was



FIGURE 28.9. Placement of an ultrasound-guided supraclavicular brachial plexus catheter in a sedated patient. The author places a catheter in the brachial plexus utilizing the supraclavicular approach. The patient was a burned noncombatant Iraqi civilian female. She received her burn care at Ibn Sina Hospital in Baghdad, Iraq, and was later readmitted for contracture release. (Photo by Clinkscales CP, 2008.)

readily available for lipid rescue, though it was not needed during the author's deployment.

CONCLUSION

Military anesthesia provides many unique and challenging situations, particularly in the current age of unconventional warfare. The role of the anesthesia provider has been redefined throughout American warfare and will certainly continue to evolve alongside the U.S. military machine and its global involvement. Providers learn to adapt to their environments and improvise care according to the conveniences available, all the while maintaining standards of care that ensure the best possible care to American military personnel and others. As emerging data and technologies become available, the practice of combat anesthesia will almost certainly change in order to continue providing high-level care to the very deserving military community.

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29 | Anesthetic Considerations in Homeland Disasters

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A disaster is the result of the adverse interaction between a human-made or natural hazard and the environment, resulting in widespread human and/or structural damage that exceeds local capacity to respond in a timely and adequate manner, primarily due to chaos and uncertainty. A health or medical disaster refers to the extent of human injury, illness, or death caused by a disaster and the damage sustained by medical facilities; consequently, the needs of surviving injured or ill and of uninjured survivors will determine the resources required to provide necessary emergency health and medical services to prevent further morbidity and mortality. Depending on the magnitude of human or health system damage, a disaster can be classified as either a mass (hundreds) or catastrophic (thousands) casualty event. A casualty of a disaster is not only the person who suffers direct injury or illness but also the person who experiences an adverse mental health or medical consequence due to lack of access to medical care, or one who experiences an interruption in basic societal services such as food, water, shelter, electricity, and so on, all of which define the disaster-affected population.

One of the important principles of Disaster Medicine is that no two disasters are alike. Consequently, the character of medical disaster response will vary depending on the causes, circumstances, injury or illness mechanisms (i.e., traumatic vs. nontraumatic), as well as the quantity and severity of injuries and illnesses generated by the disaster. Therefore, to provide effective emergency medical services response, health care workers and the health care system as a whole must be prepared to respond to a variety of disaster scenarios, to do it quickly, and to be able to adapt to constantly changing situations during the event. This requires special training in disaster medicine and disaster management competencies.¹

Health and medical disaster response differs depending on whether the crisis occurs in a civilian or military context. In war, planning, preparation, and organization for medical care of wounded but otherwise healthy young soldiers (combat casualty care) is different than the care of injured or sick civilians of all ages, many with preexisting comorbidities, in homeland disasters. Moreover, military medical operations are strategically planned well in advance of the initiation of hostilities, and combat casualty care is executed at various echelons (levels of care) by well-trained military medics and medical and surgical teams. US Armed forces surgical teams operate in

well-equipped and staffed modern field hospitals, providing a level of care nearly equivalent to a level 1 trauma center in the United States. The latter is certainly not the case in homeland disasters, which are sudden impact events managed in an ad hoc manner by civilian responders, many of whom have never worked or trained as a team, let alone in a disaster. Additionally, civilian responders are often physically present in the disaster affected area and become or fear becoming victims themselves or fear for their families. Nevertheless, modern field anesthesia and surgical techniques, procedures and equipment in combat casualty care and in civilian disasters are similar.

Based on these assumptions and in keeping with the theme of this book, this chapter will focus primarily on anesthetic considerations in homeland disasters likely to require the presence of the anesthesiologist in the out-of-hospital or pre-hospital environment. Although most anesthesiologists are adept at handling multiple trauma casualties in the familiar setting of the operating room, even during disasters, this fact does not necessarily apply to anesthesiologists' expertise in the management of casualties of earthquakes or chemical or biological incidents outside the operating room.² In order to understand the context within which anesthesiologists might be asked to function in the out-of-operating room setting during disaster response, we will devote a part of this monograph to a brief review of the disaster management functions of prehospital emergency medical services (EMS)/trauma systems. We will also describe the reorganization of hospital and intensive care services necessary to handle a surge of incoming critically injured or ill casualties. Our focus will be the role of the anesthesiologist, working in partnership with community or local EMS/trauma system and its network of hospitals, since the local EMS/ambulance system constitutes the functional unit of disaster medical response in the United States. We will end with a brief description of the major challenges we face in the delivery of intensive care services in mass and catastrophic casualty disasters.

PREHOSPITAL EMERGENCY MEDICAL SERVICES/ TRAUMA DISASTER MANAGEMENT FUNCTIONS

In a medical disaster, mass casualty management requires a series of medical activities or functions that are quantitatively

and qualitatively different than in the everyday emergency situation or multicasualty incident (MCI), such as a bus or train accident. Ideally, these disaster management functions are most effective for lifesaving when they are implemented in a timely manner by well-organized, experienced EMS/trauma services systems consisting of trained bystanders, first responders, ground and air ambulance EMT/paramedic units, trauma teams/hospitals, and network of community hospitals, pre-existing in the community. However, it is important to note that the standard of care in mass casualty and catastrophic disaster events will differ markedly from everyday EMS/trauma care. In mass casualty events, the objective is no longer to achieve emergency care within the “golden hour,” instead, to do so within the “golden 24 hours.” As a result, “preventable” deaths may occur. What follows is a detailed description of the organizational framework for EMS/trauma systems and the specific disaster management functions that further define the differences between the medical response to multicasualty events and disasters.

Command, Control, and Coordination (Incident Command System)

The incident command system (ICS) and the national incident management system (NIMS) are comprehensive organizational structures designed to enable effective command and control (leadership), and coordination or management of a crisis situation requiring emergency response. It attempts to do this by integrating the facilities, equipment, personnel, procedures, and communications used for the response into a common hierarchical administrative framework.³ The main advantage of NIMS is that it is used to manage both short- and long-term field disaster operations for a broad spectrum of emergencies by all levels of government in the United States, including many private sector businesses and nongovernment organizations, and by EMS trauma systems and hospitals.

At the community level, the mayor or his designee assumes command and control in a disaster, in coordination with county emergency managers, fire, police, and EMS, as well as county health officials. In a mass casualty (i.e., 9/11) or catastrophic disaster in the homeland (i.e., Hurricane Katrina), the “National Response Framework” is activated, in which case one of the federal agencies (Department of Homeland Security, Department of Health and Human Services, Centers for Disease Control and Prevention, Department of Defense) assumes ‘lead agency’ status for command and control.⁴ According to this plan, emergency operations centers (EOC) at all levels of government are activated, thus becoming the epicenters of command, control, cooperation, and coordination within each jurisdiction (Local, State and Federal).

The EOC is a physical location equipped with high-tech telecommunications and information technology gear such as satellite telephones and reconnaissance, computers, Internet, television monitors, and integrated geospatial information systems designed to maintain “situational awareness” of the event by all participants.⁵ Disaster coordinators at the EOC relieve on-scene commanders of the burden of external

coordination to secure resources. In a nutshell, the core functions of an EOC include coordination, communications, resource dispatch and tracking, and information collection, analysis, and dissemination.

Communication

Effective communication involves both the mode and the infrastructure required to alert local and, if judged necessary, regional, state or federal civilian authorities to the fact that a disaster situation is unfolding. It includes the telecommunications network and backup systems needed to ensure rapid notification and the uninterrupted transmission of essential information regarding the details of a disaster situation to achieve maximum “situational awareness” by all involved, at all times. Effective communication facilitates the timely dispatch of first responders, search and rescue, and ambulance units to the scene. It also activates external disaster plans among local medical facilities, and, if deemed necessary, alerts neighboring EMS systems and hospitals. Communication failure or miscommunication or the inability of all responders to communicate on the same frequency is the leading cause of delays in the delivery and coordination of emergency medical care in disaster.

Needs Assessment

Needs assessment is the process by which key decision makers become informed of the medical requirements generated by a disaster. “Needs” refers to the amount of materiel and manpower resources required to effectively meet demand. It is based on the health and medical needs of the injured and the uninjured survivors. One of the major problems in the technical field of needs assessment is the development of methods and procedures to rapidly and accurately determine the total affected population; total number of killed and injured; number of hospitals destroyed and disabled, as well as those still operating; type and severity of injuries; and types and quantities of medical service, medical supplies, and pharmaceuticals needed. It is essential to determine the “tipping point,” the point at which local resources are exceeded, thereby requiring outside support and supplies.^{6,7}

These decisions are critical for lifesaving efforts, because time is a risk factor for death and disability. They are usually the responsibility of local authorities (i.e., the mayor, governor or their designees, usually made in conjunction with the incident commander and local health and EMS officials). Delays in initiating or inaccuracy of needs assessments is a major cause of delays in the timely delivery of emergency care and, as a result, may lead to preventable deaths and disabilities, especially among the critically injured. This was a major failure after the 2005 Hurricane Katrina.⁸

Urban Search and Rescue

Urban search and rescue is the process of detecting, identifying, extricating, and gathering or collecting victims from the scene

of injury or illness (i.e., extrication from under rubble). It may also include transport to a nearby staging area or casualty collection point within the tactical area of operations, where further harm is avoided and from which patients are initially stabilized, prepared for transport, and loaded onto transport vehicles. In the case of chemical release or infectious biological agents, patients are decontaminated in pre-designated areas by emergency responders who are equipped with the proper personal protective gear (Fig. 29.1), prior to transportation to a treatment facility or placed in isolation units, thus protecting rescuers and other individuals from lethal exposure.

Triage

Once casualties are rescued, cleared from the immediate disaster area, and transported to a casualty collection point or a medical facility, triage and stabilization is performed. Triage is the method by which the type, extent, and severity of injury or illness sustained by a disaster victim is prioritized for treatment.^{9,10} During triage, initial stabilization may be provided to prevent further or rapid deterioration in the patient's status.

Field Medical Care

Field medical care is the spectrum of emergency medical or surgical lifesaving interventions applied in the out-of-hospital setting by bystanders, first responders, and emergency medical personnel on casualties of disaster. The objective is to contain or control damage prior to transport. Usually, field medical



FIGURE 29.1. Positive air pressure respirator gear.

care, especially “resuscitative surgery” or “damage control surgery” is performed only when the type and severity of illness or injury threaten life or limb, precluding safe transport to a treatment facility. In general, there are four main types of field medical care or damage control interventions:

Life-supporting first aid (LSFA): Involves the delivery of basic first aid by uninjured survivors or co-victims and is aimed at initiating the life support chain.¹¹ It entails the following basic maneuvers: (1) calling for help; (2) knowing when to approach a victim in a hazardous environment; (3) maintaining a patent airway in an unconscious but breathing patient (triple airway maneuver); (4) external hemorrhage control; (5) positioning for shock; (6) rescue pull; and (7) CPR (if indicated).

Basic rescue or extrication: Involves the simple extrication of victims from vehicles or those buried under light rubble and is performed with minimal supplies or improvised tools.¹²

Basic trauma life support (BTLS): Constitutes the second step in the life support chain involving the application of advanced first aid techniques, such as the following: airway control with or without adjuncts, external hemorrhage control, immobilization of unstable limb fractures, placement of peripheral intravenous lines, wound dressing, initial burn treatment, and other lifesaving maneuvers by trained first responders.

Advanced trauma life support (ATLS): The application of lifesaving emergency medical or surgical treatment to critically injured patients by physicians, usually including the following: definitive airway management with endotracheal intubation and/or assisted ventilation; central venous line placement for fluid resuscitation; administration of vasoactive medication and antidotes; and in the case of traumatic injuries, chest tube placement, wound suturing, and other lifesaving medical/surgical interventions.

Resuscitative surgery: Involves the application of major surgical procedures such as emergency exploratory laparotomy, thoracotomy, craniotomy; wound debridement, limb amputations, among others, performed in the out-of-hospital setting usually to prevent loss of life or limb due to external or internal bleeding, gangrene, compartment syndrome, and so on.

Transport

In major disasters casualties are usually not transported in ambulances. Instead uninjured or lightly injured co-victims carry it out using whatever means is available for transport. Bystanders are usually the relatives, friends, or neighbors of the injured. Once professional rescuers and emergency medical personnel initiate their operations, transport of critically injured casualties is done by land or air ambulance (helicopters) from casualty collection points close to the disaster zone to treatment facilities outside the tactical area of operations; whenever possible, and especially when extended transport times are anticipated, casualties are accompanied by health care professionals with, at minimum, advanced trauma or cardiac life support expertise. The lack of ambulances, helicopters, and so on, and traffic jams or disruption of roads and highways to and

from the disaster area are frequent causes of delay in the transport of casualties.

Definitive Medical/Surgical Care

Definitive medical/surgical care is the delivery of specialized definitive or corrective emergency medical or surgical treatment in a permanent medical facility. These treatments are carried out by physicians, surgeons, nurses, and other health care professionals for the purpose of stabilizing or reversing life-threatening illness or injury and/or to prevent long-term disability or death.

Disaster Evaluation

Disaster evaluation is a continuum of activities that includes disaster response assessment and research involving evaluation and epidemiologic methodology.¹³⁻¹⁵ The short-term aim is the acquisition and translation of knowledge and experience or skill gained in a disaster to other individuals or institutions for the purpose of facilitating the application of a learned set of new facts or adequate performance of a given task or set of practical skills. These become the so-called lessons learned during a disaster event for the purpose of revising/improving disaster planning, preparedness, mitigation, and response programs with the long-term aim of reducing morbidity and mortality in future disasters. Currently, Disaster Evaluation is the weakest link in the disaster management portfolio because it is not institutionalized or governed by universal standards.

Disaster Preparedness

In the broadest sense, disaster preparedness is the development and implementation of a set of disaster prevention, mitigation, and response plans or programs, usually based on hazard risk analysis, vulnerability analysis, casualty estimates, and hospital surge capacity analysis. Disaster preparedness is strengthened by the incorporation of lessons learned through the systematic scientific evaluation of actual events, as well as through exercises and simulation.

HOSPITAL DISASTER MANAGEMENT FUNCTIONS

Hospital response during a homeland disaster is driven by the hospital's external disaster response plan, whose organization should incorporate the incident management system as modified for hospital operations.

Today, the majority of hospital external disaster plans, when activated, invariably direct anesthesiologists to report to the familiar environment of the operating room (OR), irrespective of the disaster type. These plans are outdated and will need revision to account for the most effective use of anesthesiologists and anesthesia services when operative surgical services are not in great demand, such as influenza (H1N1 or H5N1) epidemic, and terrorist chemical or biological attack. These revisions are warranted because of

the technical skill set and expertise of anesthesiologists, which is rooted in resuscitation (life support management) and crisis management. Anesthesiologists will inevitably play a lifesaving role in these types of disasters; most likely, in the out of the operating room setting.

The Joint Commission for Accreditation of Health Care Organizations provides some direction but limited detail regarding hospital disaster plans or hospital disaster management functions. However, the hospital incident management system has been developed to organize hospital disaster response activities around a set of specific and measurable objectives that define the hospital's performance in the event of a disaster.¹⁶ In general terms, the following items cover primary objectives/functions:

1. Pre-establish a clear chain of command based on the hospital incident management system to lead and coordinate the hospital's response.

2. Provide a plan for the acquisition and deployment of necessary medical equipment, supplies, and pharmaceuticals.

3. Provide a plan for emergency backup lifeline (power, gas, water, food) and personnel recall (medical and nonmedical) to allow continuous operations for, at minimum, 24 hours.

4. Once activated, rapidly reorganize resources to convert to disaster operations by recalling and reassigning personnel to deal promptly and effectively with a surge of casualties (casualty estimates and surge capacity needs to be determined beforehand).

5. Pre-establish mutual aid and liaison agreements with neighboring hospitals/EMS systems in the event surge capacity is exceeded.

6. While the event is unfolding, coordinate and maintain open channels of communication with prehospital EMS systems, hospitals, local and state health authorities, families of casualties, the media, and so on through periodic updates or situation reports.

7. Provide a transport plan for the transfer/discharge of stable inpatients or diversion of disaster casualties to other health care institutions, nursing homes, outpatient facilities, and so on.

8. Establish a plan for documentation of admission and care provided to casualties by hospital personnel and a plan for inpatient tracking, both before and after admission.

9. Designate triage and treatment areas within the hospital with prioritization of care, as follows:

- a. Casualty reception, triage areas (usually the emergency room and adjacent areas), with patients segregated according to infectious disease status.

- b. Decontamination/isolation areas (in the event of casualties of chemical, biological, radiological attack or pandemic influenza)

- c. Areas for the diagnosis, treatment, or stabilization of patients who have life-threatening conditions (RED) such as acute respiratory failure (ARF), who require intensive care for immediate and continuous physiologic monitoring, medical or surgical intervention, and or mechanical ventilation (Fig. 29.2)

- d. Areas for the diagnosis, treatment, or stabilization of patients having urgent conditions (YELLOW) who will be referred for follow-up care

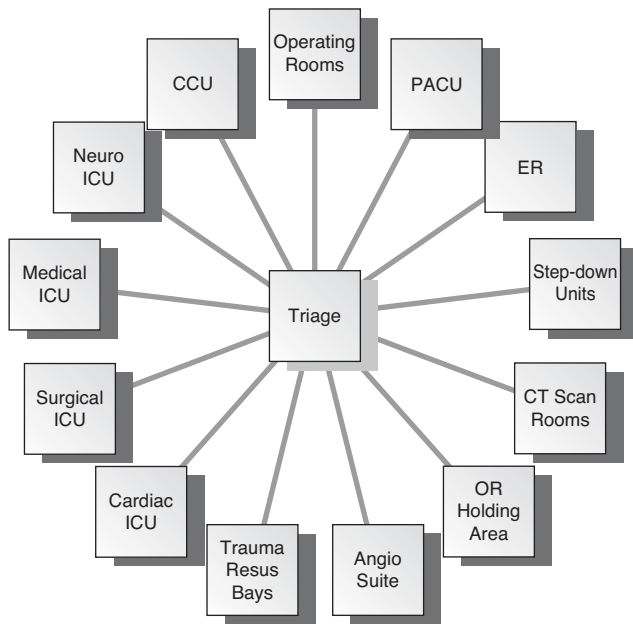


FIGURE 29.2. Alternate intensive care treatment areas. CCU, cardiac care unit; CT, computed tomography; ER, emergency room; ICU, intensive care unit; OR, operating room; PACU, postanesthesia care unit.

- e. Areas for the treatment of patients with non-urgent conditions (GREEN), with referral for later definitive diagnosis, treatment, and comprehensive care
- f. Areas for the reception of moribund or dead casualties (GRAY/BLACK) for pain management and pastoral services.
- g. Selection of alternate treatment areas (outside the hospital) in the event the hospital must be evacuated or cannot provide services. (In some situations hospital personnel may be compelled to evacuate the facility and to deliver medical and surgical services in the out-of-hospital setting, severely hampering the hospital's ability to function.)
10. After the event, perform evaluation of performance.
11. Revise external disaster plan and provide training based on knowledge gained through experience, after action reports and evaluation.

MAJOR EARTHQUAKE (THE JANUARY 12, 2010 EARTHQUAKE IN HAITI)

The January 12, 2010 earthquake that struck Port-au-Prince caused over 200,000 deaths, hundreds of thousands of injuries requiring immediate surgical intervention, and a population of 1.5 million internally displaced. The University of Miami Miller School of Medicine Global Institute/Project Medishare, the Jackson Memorial Hospital's Ryder Trauma Center, and the Department of Anesthesia dispatched a surgical scout team within 24 hours to initiate emergency medical response and perform needs assessment.

The primary goal of relief efforts in Port-au-Prince became lifesaving surgical care to save life and limb. However, medical

facilities were either destroyed or disabled. In the first 72 hours, there was no pressurized oxygen, precluding the sustained delivery of general anesthesia for surgery. The University of Miami surgical team set up a trauma unit in a makeshift tent facility at the airport. Because of the absence of oxygen or the ability to deliver general anesthesia, members of the Division of Regional Anesthesia and Acute Pain Management of the Department of Anesthesia were dispatched to Haiti to provide regional block anesthesia, primarily for extremity surgery.¹⁷ In the first few days following the earthquake this team performed hundreds of regional nerve blocks for emergency orthopedic surgery, including limb amputations, stump revisions, and wound debridements. This medical team operated out of a storage tent facility until medical supplies, anesthesia equipment, and oxygen arrived and makeshift operating rooms were organized.

Type of Injuries

In Haiti, as in other earthquake disasters, the prevalent injury type and cause of death was crush injury from building collapse.¹⁷⁻²¹ Casualties with severe crush injury of the head, chest, and abdomen were already dead or in the advanced stages of dying by the time international relief teams arrived. The majority of seriously injured casualties that survived the first 24 hours had crush injury of the limbs, with fractures of the long bones (humerus, femoral, tibia-fibula), pelvic fractures, spine injuries, crush syndrome, extremity compartment syndrome, open fractures with infected and gangrenous wounds, burns, and sepsis. Less severe injuries included minor blunt head, chest, and abdominal trauma and lacerations, rib fractures, closed fractures of the extremities, burns, and facial and scalp lacerations.

Emergency Medical Management

The type of medical activities and surgical interventions throughout the Haiti relief effort consisted primarily of the following: triage, basic and advanced trauma life support, improvised medical record keeping, expectant care, first aid, fracture management, placement of intravenous lines, airway management, fluid resuscitation and rehydration, antibiotic and tetanus prophylaxis, orthopedic surgery, open wound and burn care, wound debridement, spine and neurological surgery, disposal of amputated limbs, regional anesthesia and pain management, and preparation and transport of critically ill patients for transport to hospitals in Miami and South Florida.

Anesthetic Management

In general, the provision of advanced trauma surgical care in the first 24 hours is extremely difficult in most major earthquake disasters, if not impossible, even in developed nations. Among the limitations is the destruction or disabling of hospital facilities, and interruption of lifelines (electricity, water, gas). In our experience in Haiti, besides the nearly complete

destruction or disabling of medical facilities, it was the lack of oxygen and general anesthetics that posed the major limiting factor in the delivery of surgical care in the first 24 hours. As an alternative, surgery and acute pain management was achieved with regional block anesthesia combined with the intravenous administration of ketamine and midazolam sedation in a makeshift tent outdoors. This regimen worked extremely well for both adults and children. Moreover, regional block anesthesia (primarily interscalene, axillary, sciatic, and femoral nerve blocks) significantly reduced opioid use and its side effects, thereby markedly reducing the need for postoperative monitoring and nursing care. More importantly, this approach facilitated life- and limb-saving surgery when the need was greatest, the first 7–10 days. As a result, the University of Miami field surgical team was able to do much more in less time with less medical staff.¹⁷

Our recent experience in Haiti has taught us that a surgical team equipped with the supplies and expertise necessary to perform single shot block anesthesia is essential for the delivery of surgical anesthesia in the out-of-hospital setting, especially during the early stages of earthquake disasters, or in other disasters requiring emergency orthopedic procedures. Mobile surgical teams should incorporate regional anesthesia capability for future disaster response.

TOXIC CHEMICAL AGENT RELEASE (THE 1984 BHPAL CHEMICAL INCIDENT) OR ATTACK (THE 1995 AUN SHINRIKYO TOKYO SARIN GAS ATTACK)

Chemical weapon agents are classified as persistent or non-persistent, on the basis of the time the agent remains toxic after release (Table 29.1). Chemical agents considered non-persistent are gaseous, such as chlorine, or highly volatile agents such as sarin and most other nerve agents. These agents which dissipate after only a few minutes or hours. Historically, nonpersistent chemical warfare agents were intended for military targets that were to be taken over and controlled very quickly. These types of agents pose an inhalation hazard. Persistent agents such as the nonvolatile liquid agent VX and blister agents remain in the environment for as long as several days. VX is an oily liquid that does not easily evaporate. To inflict maximum damage and long-term disruption of a population, terrorists may opt to use persistent agents.

Chemical agents are also organized into several categories according to the manner in which they affect the human body. The names and number of categories vary slightly from source to source, but in general, types and characteristics of chemical weapon agents are illustrated in Table 29.1.

Type of Injuries

The release of a large quantity of a highly toxic chemical agent in a major city has an immediate and devastating effect on the population of that city and surrounding areas (Table 29.2). In addition to the direct detrimental effects on people and animals, an inadvertent chemical release or intentional attack will

overwhelm the city's medical care system. The primary injury is to the respiratory system, requiring urgent airway and respiratory therapy in a monitored environment. The convergence of large numbers of exposed acutely ill, walking ill, and moribund victims at hospitals creates demands for hospitalization and intensive care that rapidly exceed medical resources. Types and quantities of medications and supplies needed to treat casualties may not be available in standard medical or pharmaceutical stocks. Medical care providers, nursing personnel, and laboratory personnel require protection against exposure, and autopsy and interment of remains present uncommon hazards.

Emergency Medical Management

Physiological effects of toxic chemicals depend on the agent, route (lung or skin), and duration of exposure.²² The effects of exposure to vapor are not the same as those from skin contact. Exposure to a small vapor cloud affects the eyes, the nose, and the airways producing miosis, rhinorrhea, bronchorrhea, and bronchoconstriction. Minute quantities on skin will cause localized sweating and less commonly fasciculations. On initial exposure, if sweating and fasciculations do not occur, or are not noticed, gastrointestinal symptoms may develop: nausea and vomiting, with or without diarrhea. Skin exposure to microdroplets floating in a chemical cloud may not be noticed and its effects may be delayed for hours. Massive or prolonged exposure produces a sudden loss of consciousness, seizures, flaccid paralysis, apnea, and death. The most likely cause of death is from paralysis of the respiratory muscles and severe depression of the central nervous system (CNS).²³

The immediate life-threatening effects of toxic chemical exposure are found in the respiratory system. Airway injury occurs at all levels of the respiratory tract with varying latency, depending on the circumstances, concentration, and duration of the exposure. Airway reaction to an irritating compound is a massive outpouring of secretions that cause difficulty breathing to complete airway obstruction. There may be laryngeal, bronchial, and bronchiolar spasm; a reduction in compliance; and pulmonary edema. Suction devices are needed to clear secretions and vomitus. Early endotracheal intubation is advisable since it is difficult to assess the level of exposure or the extent of airway or lung injury, and lung injury may progress rapidly to complete obstruction or pulmonary edema.

After securing the airway, 100% oxygen should be administered, unless oxygen and its resupply are limited in the contaminated zone. Initially, manually assisted lung ventilation and oxygenation with filter, bag, and mask are instituted, followed later by mechanical ventilation. Portable mechanical ventilators may be needed for prolonged decontamination or during evacuation and transport from the contaminated zone. A ventilator that filters the toxic ambient atmosphere with an air mix ratio of approximately 50% oxygen should be used in the hazardous zone.

Aggressive monitoring of vital signs is indicated, although equipment limitations will determine the sophistication of

TABLE 29.1. *Types and Clinical Characteristics of Major Chemical Weapon Agents*

<i>Class</i>	<i>Agent</i>	<i>Mechanism of Injury</i>	<i>Signs and Symptoms</i>	<i>Onset</i>	<i>Persistence</i>
Nerve	Cyclosarin (GF) Sarin (GB) Soman (GD) Tabun (GA) VX	Inactivates acetyl cholinesterase, resulting in accumulation of acetylcholine in the victim's synapses, triggering muscarinic and nicotinic effects	Miosis Blurred vision Headache Nausea, vomiting, diarrhea Copious secretions/sweating Muscle twitching/fasciculation Dyspnea Seizures Loss of consciousness	Vapors: seconds to minutes Skin: 2 to 18 hours	VX is persistent and a contact hazard; other agents in this class are non-persistent and present mostly inhalation hazards
Cyanide	Most arsines Cyanogen chloride Hydrogen cyanide	Arsine: Causes intravascular hemolysis that may lead to renal failure Cyanogen chloride/hydrogen cyanide: Cyanide blocks oxygen utilization. The cells then convert to anaerobic respiration, creating excess lactic acid and metabolic acidosis	Cherry-red skin Cyanosis Confusion Nausea Air hunger Seizures Metabolic acidosis	Immediate	Nonpersistent and an inhalation hazard
Vesicant	Sulfur mustard (HD, H) Nitrogen mustard (HN-1, HN-2, HN-3) Lewisite (L) Phosgene oxime (CX)	Agents are acid-forming compounds that damage skin and the respiratory system, resulting in airway burns and respiratory complications.	Severe skin, eye and mucosal pain and irritation Erythema/blisters that heal slowly and may become infected Tearing, conjunctivitis, corneal damage Mild respiratory distress to marked airway compromise	Mustards vapors: 4 to 6 hours, eyes and lungs affected more rapidly; Skin: 2 to 48 hours Lewisite: Immediate	Persistent and a contact hazard
Choking	Chlorine Hydrogen chloride Nitrogen oxides Phosgene	Similar mechanism to blister agents in that the compounds are acids or acid-forming, but action is more pronounced in the respiratory system, flooding it and resulting in asphyxiation; survivors often suffer chronic breathing problems	Airway irritation Eye and skin irritation Dyspnea Cough Sore throat Chest tightness Wheezing Bronchospasm	Immediate to 3 hours	Non-persistent and an inhalation hazard

TABLE 29.2. *Estimates of Casualties Generated by the Release of Four Tons of Toxic Chemical Agent Two Kilometers Upwind of a City of 500,000 people*

Agent	Estimated Cases	Estimated Deaths
Sarin	15,000	300
VX	50,000	5000
VX aerosol	120,000	12,000

Source: Adapted from Health Aspects of Chemical and Biological Weapons. Report of WHO Group Consultants, WHO, Geneva, 1970.

monitoring modalities, especially when large numbers of people have been exposed. Inevitably, reliance on basic clinical monitoring modalities, such as mental status (GCS), respiratory and pulse rate, blood pressure, skin color and appearance, and pupil size will guide the response to antidotes. Many chemical agents give rise to toxic pulmonary edema and bronchospasm. It has been suggested that high doses of methylprednisolone should be given as soon as possible after exposure to pulmonary edematogens.²⁵ However, the use of systemic or inhaled corticosteroids to treat chemical intoxications is somewhat controversial. This is due to the fact that steroids have proved to be of value in the management of severe bronchospasm, but whether they can prevent pulmonary edema is unclear.

Acute respiratory failure due to pulmonary edema may be latent; therefore, special care should be taken to carefully monitor pulmonary function during evacuation and transport to medical facilities or during interhospital transport. Early aggressive respiratory therapy reduces the risk of adult respiratory distress syndrome (ARDS) and ARF.

Nerve agents (NAs) are potent organophosphate compounds that are similar to but more toxic than insecticides. In 1994, when sarin was released by terrorists in Matsumoto, Japan, and again in 1995 in Tokyo subways, 12 people were killed, and over 4,000 sought treatment.²⁶

Nerve agents produce biological effects by inhibiting acetyl cholinesterase (AChE).²³ This inhibition prevents the hydrolysis of the neurotransmitter acetylcholine and subsequently leads to the overstimulation of end-organs with cholinergic receptors.²² Major affected organs and tissues include the exocrine glands, smooth and striated muscles, and the nerves in the central nervous system and at ganglia. Other than the severity and extent of signs and symptoms and estimate of RBC AChE activity,^{27,28} there is no quick method to assess the degree of exposure to NAs.

Medical management consists of ventilator support, administration of antidotes, and for severe cases (i.e., seizures), an anticonvulsant.²⁹ Intense bronchoconstriction may result in high airway pressure with difficulty ventilating. One antidote for mild exposures is atropine 2 mg intramuscular (IM) repeated every 20 minutes until the patient is fully atropinized (atropinization is characterized by the appearance of flushed and dry skin, increased heart rate, and reduced bronchoconstriction and bronchorrhea). The pediatric dose for mild exposures is 0.02 mg/kg IM. In moderate to severe cases the dose of atropine is increased to 2 mg IV every 5–10 minutes for adults, and 2.0 mg or 0.02 to 0.1 mg/kg for children.

Atropine works by inhibiting the effects of excessive acetylcholine at the synaptic site. Patients exposed to NA may require very large doses of atropine for successful treatment.

While atropine is effective in attenuating many of the symptoms of NA exposure, it does nothing to stop the effects of the NA on the AChE itself.²⁷ For that, another agent is required, such as the oxime 2-pralidoxime chloride (PAM), which reactivates the AChE by competing with the NA for the active site on the AChE. PAM will allow the AChE to resume almost normal activity.²⁸ The adult dosage of PAM for mild cases is 1–2 g IM as a single dose. The pediatric dose for mild cases is 15–25 mg/kg IM. For moderate to severe exposures, the dose is the same but is usually given intravenously. PAM should be given over 30 minutes; rapid administration may cause significant elevations in blood pressure. PAM doses should be repeated hourly in case of progressive worsening or persistent signs of toxicity.²³

Time is of the essence in treating patients exposed to NA for reasons other than the obvious need for rapid medical attention. The bonds formed between the NA and AChE will rapidly “age” and become resistant to deactivators, starting right after exposure.³⁰ Oximes are effective only if the agent-enzyme complex has not aged.³¹ Complete aging may take minutes (GD) to hours (VX). Since in most cases the exact agent is unknown, PAM should be given for any NA exposure regardless of time. Once AChE is irreversibly inactivated, it must be replaced by cellular production. This occurs at different rates in blood (RBC turnover is 1% per day) and tissue and may take up to 6 weeks in patients who did not receive treatment.^{30,32} Due to the inactivation of various AChE, drugs that depend on AChE for breakdown, such as succinylcholine, remifentanyl, esmolol, and mivacurium, should not be used in patients exposed to NA.

Another organ system affected by significant NA exposure is the CNS. Seizures are common and an early sign of significant exposure. Benzodiazepines (Valium 10 mg) and scopolamine (0.25 mg every 4–6 hours for mild cases, and 0.25 mg, repeated in 30 minutes, followed every 4–6 hours for moderate and severe cases) can be used to suppress the CNS effects of NA. Scopolamine has a sedative effect in addition to a central anticholinergic effect due to its quaternary chemical structure that penetrates the blood–brain barrier. Benzodiazepines stop and can prevent seizures while aiding in mechanical ventilation. Prophylaxis treatment with pyridostigmine per os (30 mg, 3 times/day for a population at risk) can be an effective partially protective measure against NA intoxication.^{23,33,34} There are reports of potential long-term neuromyasthenic injury from chronic pyridostigmine, including its potential role in Gulf War syndrome.³⁶

Pulmonary intoxicants are substances that damage the parenchyma of the lung. The damage caused by a gaseous substance usually manifests as pulmonary edema, although there may be some direct tissue damage with some compounds in this category. In contrast, sulfur mustard damages the airway with little parenchymal damage. The best known and most studied of these compounds is phosgene (carbonyl chloride, designated as CG). Phosgene is widely used in industry with hundreds of thousands of tons manufactured annually.

The first 30 minutes after exposure to low concentrations of phosgene may produce a mild cough, a sense of chest discomfort, and dyspnea. These compounds may also cause minor and transient irritation of the eyes and upper airways upon contact. In the lung they damage the alveolar-capillary membrane and allow fluid to leak through. These effects are often delayed and coughing (with production of clear, frothy fluid) may begin 2 to 72 hours after exposure. Generally, the shorter the onset time the more severe the illness. The onset of pulmonary edema within 2–6 hours after exposure is predictive of severe injury.²²

There is no specific antidote for these compounds. Management consists of supportive care, primary pulmonary care, and assisted ventilation and oxygen until the lung parenchyma heals.³⁵ In some cases airway injury develops rapidly and progresses to ARDS, requiring prolonged respiratory support. Hypovolemia and hypotension may result from the intravascular fluid loss. Steroids have not been found to be useful in treating phosgene-induced lung damage.²²

Vesicants are substances that cause vesicles, or blisters, and may be of animal, vegetable, or mineral origin. These agents include sulfur mustard, nitrogen mustard, lewisite (an arsenical agent), and phosgene oxime (CX is not a true vesicant since it produces solid lesions). The one of most concern as a chemical weapon is sulfur mustard. This substance was a major casualty producer in World War I; it produced more chemical casualties than all other chemical agents combined and was extensively used in the Iran-Iraq war in the 1980s.²²

Mustard gas damages and eventually kills cells, probably by disrupting DNA, although its exact mechanism is still unclear. It damages organs, and it especially affects the eyes, skin, and lungs and will cause significant damage in either vapor or liquid form.²² Absorbed mustard damages bone marrow, lymphoid tissue, and gastrointestinal mucosa, damage similar to that produced by radiation. At first, contact with mustard causes no effects. After a brief period or mild exposure, erythema may occur accompanied by pruritus, burning, and tingling. After an onset time of 2 to 24 hours the characteristic lesions (blisters) appear on the skin. The eyes (the most sensitive organ to mustard) become reddened with possibly more severe damage to follow, and airway mucosa is damaged beginning in the upper airway with a dose-dependent descent. After a large skin exposure, lesions may be characterized by a central zone of necrosis surrounded by blisters.³⁷ Bone marrow damage from mustard exposure may lead to reduced resistance to infection. Mustard may be differentiated from other vesicant agents by the fact that other blistering vesicants, such as lewisite, cause pain in minutes after exposure, while mustard will not cause pain until lesions occur. There is no antidote for mustard exposure.^{37,38} The only effective means of preventing or decreasing damage after exposure is rapid decontamination within 1–2 minutes. Management consists of relief of symptoms with emphasis on prevention of infection. Health care workers must wear protective gear to avoid being contaminated.

Cyanide has a reputation as a rapidly acting, toxic substance. The two types in military use are hydrogen cyanide (AC) and cyanogen chloride (CK). To be lethal, the concentration must

be high. Cyanide owes its lethal effect to its ability to inhibit oxidative phosphorylation at the mitochondrial level, thus interrupting energy production. Exposures even slightly below lethal doses cause few side effects. Hundreds of thousands of tons of cyanide are manufactured annually for many industrial uses. Cyanide has been used for centuries as an agent for suicide and homicide. The Nazis, in World War II, used Zyklon B, hydrocyanic acid adsorbed onto a dispersible base, to kill millions of civilians and enemy soldiers in its camps as well as on the battlefield.^{39,40} In chemical warfare its use is limited because of its volatility and the amount required to produce biological effects. However, cyanide agents in sufficient concentration can have a devastating effect.

Methyl isocyanide was accidentally released from a Union Carbide plant in Bhopal, India, on December 2nd and 3rd in 1984, killing between 1750 and 2000 people and injuring another 50,000.⁴¹ Cyanide inhibits intracellular enzymes and prevents cells from using oxygen. Effects from cyanide gas or vapor occur quickly. Within seconds of inhalation of a lethal amount of gas or vapor, consciousness is lost; then seizures begin, followed by apnea and death within 8–10 minutes. Antidotes are effective if administered before signs of irreversible damage. Amyl nitrate followed by sodium nitrite converts hemoglobin to methemoglobin, which effectively removes cyanide from the intracellular enzyme. Thiosulfate combines with cyanide to form thiocyanate, a nontoxic compound if liver clearance is normal. Ventilation support is often required while the antidotes begin working.⁴²

Anesthetic Management

If anesthesia is to be administered to exposed patients at the incident site, specialized equipment is required. The most basic equipment includes apparatus for delivering inhalational, intravenous, and regional anesthetics and for providing oxygenation and ventilation support. Depending on the circumstances, respiratory equipment can be simple and portable or sophisticated and stationary. If necessary, regional anesthesia is preferred because it can be done quickly and limits the need for extensive monitoring equipment. Regional anesthetics can allow anesthesiologists to monitor conscious patients with lesser-trained personnel, thus freeing the anesthesiologist to tend to other patients in the immediate area. Regional anesthesia would, however, only be acceptable for patients with limited agent exposure, especially in the case of a nerve agent. For a more detailed discussion of field anesthesia techniques and equipment, please refer to Chapter 28.

INFECTIOUS AGENT (THE 2001 ANTHRAX ATTACK) OR PANDEMIC INFLUENZA EPIDEMIC (THE 2009 H1N1 EPIDEMIC)

Many bacteria, fungi, viruses, rickettsial agents, and toxins have been mentioned in the literature as possible biological agents. Those mentioned most often include *Bacillus anthracis* (anthrax), botulinum toxin, *Yersinia pestis* (plague), ricin,

Staphylococcal enterotoxin B (SEB), and Venezuelan equine encephalitis virus (VEE). All can be dispersed as aerosols, which may remain suspended (in certain weather conditions) for hours. If inhaled, small particles will penetrate into distal bronchioles and terminal alveoli of victims—particles larger than 5 µm are filtered out in the upper airway. Weather conditions are important for the success of these agents. Favorable conditions include inversion conditions with wind speeds of 5 to 10 miles per hour and nighttime or early morning hours. Table 29.3 compares the effects of a chemical or biological attack on a major city.

Type of Injuries

The medical response to a biological weapon attack depends on whether preventative measures were taken before exposure and whether the symptoms of exposure are present. Before exposure, active immunization or prophylaxis with antibiotics may prevent illness in those exposed. Active immunization may be effective against several potential biological warfare agents. After exposure, active or passive immunization as well as pretreatment with therapeutic antibiotics or antiviral drugs may attenuate symptoms. After the onset of illness, what remains for medical providers to do is to diagnose the disease and institute general or specific treatment. Several excellent vaccines and antitoxins exist to counteract the agents of bacterial warfare (Table 29.4).

Emergency Medical Management

Signs and symptoms of biological agents are insidious. The first responder will be an alert clinician or public health professional who recognizes an increasing or unusual pattern of illness in the community. The prospect of secondary spread must be considered with many biological agents, and plans to deal with a highly contagious agent must be in place beforehand.

If contamination is suspected but symptoms are unclear, assume the worst. Clues that biological agents have been released include an unexplained increase in respiratory cases or deaths and dead and dying animals. Epidemiological clues

include diseases with the wrong mode of transmission in an inappropriate geographic distribution or that infect a new population.

Several biological agents act strictly as toxins. These can often be confused with chemical agents such as NAs. The differential diagnosis of chemical nerve agents, botulinum toxin, and Staphylococcal enterotoxin B intoxication is presented in Table 29.5.

Identification of a patient with anthrax or a confirmed exposure to *B. anthracis* should prompt an epidemiologic investigation. The highest priority is to identify at-risk persons and initiate appropriate interventions to protect them. The exposure circumstances are the most important factors that direct decisions about prophylaxis. Persons with an exposure or contact with an item or environment known or suspected to be contaminated with *B. anthracis*—regardless of laboratory tests results—should be offered antimicrobial prophylaxis. Exposure or contact, not laboratory test results, is the basis for initiating such treatment. Culture of nasal swabs is used to detect anthrax spores. Nasal swabs can occasionally document exposure, but they cannot rule out exposure to *B. anthracis*.⁴³

Antimicrobial Treatment

A high index of clinical suspicion and rapid administration of effective antimicrobial therapy are essential for prompt diagnosis and effective treatment of anthrax. Limited clinical experience is available and no controlled trials in humans have been performed to validate current treatment recommendations for inhalational anthrax. Based on studies in non-human primates and other animal and in vitro data, ciprofloxacin or doxycycline should be used for initial intravenous therapy until antimicrobial susceptibility results are known. Because of the mortality associated with inhalational anthrax, two or more antimicrobial agents predicted to be effective are recommended; however, controlled studies to support a multiple drug approach are not available. Other agents with in vitro activity suggested for use in conjunction with ciprofloxacin or doxycycline include rifampin, vancomycin, imipenem, chloramphenicol, penicillin and ampicillin, clindamycin, and clarithromycin; but other than for penicillin, limited or no data exist regarding the use of these agents in the treatment of inhalational *B. anthracis* infection. Cephalosporins and trimethoprim-sulfamethoxazole should not be used for therapy.⁴³

Toxin-mediated morbidity is a major complication of systemic anthrax. Corticosteroids have been suggested as adjunct therapy for inhalational anthrax associated with extensive edema, respiratory compromise, and meningitis.⁴³

For cutaneous anthrax, ciprofloxacin and doxycycline also are first-line therapy. As for inhalational disease, intravenous therapy with a multidrug regimen is recommended for cutaneous anthrax with signs of systemic involvement, for extensive edema, or for lesions on the head and neck. In cutaneous anthrax, antimicrobial treatment may render lesions culture negative in 24 hours, although progression to eschar formation

TABLE 29.3. *Estimates of Casualties Generated by Releasing Four Tons of Chemical or Fifty Kilograms of Biological Active Agent Two Kilometers Upwind of a City of 500,000 people*

Agent	Cases	Deaths
Sarin	15,000	300
VX	50,000	5000
VX aerosol	120,000	12,000
Plague	75,000	41,000
Anthrax	125,000	95,000

Source: Adapted from Health Aspects of Chemical and Biological Weapons. Report of WHO Group Consultants, WHO, Geneva, 1970.

TABLE 29.4. *Types and Characteristics of Biological Warfare Agents*

<i>Disease</i>	<i>Dissemination Mode</i>	<i>Man-to-Man Route</i>	<i>Incubation</i>	<i>Lethality</i>	<i>Vaccine</i>	<i>Antibacterial Therapy</i>
Anthrax	Spores in aerosol	No	1–6 days	High	Yes	Ciprofloxacin Doxycycline
Brucellosis	Food/supply/aerosol	No	Days to months	Low	Yes	Doxycycline Rifampin
Cholera	Aerosol/food/water	Negligible	1–5 days	Moderate	Yes	Tetracycline
Plague	Aerosol/vectors	High	2–3 days	Very high	Yes	Tetracycline Rifampin
Tularemia	Aerosol	No	2–10 days	Moderate	Yes	Doxycycline Tetracycline
Typhoid	Food/water/aerosol	Negligible	7–21 days	Moderate	Yes	Tetracycline
Smallpox	Aerosol/water	High	7–17 days	High	Yes	Vaccinia/immune globulin

Source: Adapted from NATO Handbook on the Medical Aspects of NBC Defensive Operations, Department of the Army, the Navy, and the Air Force, February 1996.

still occurs.^{43,44} Some experts recommend that corticosteroids be considered for extensive edema or swelling of the head and neck region associated with cutaneous anthrax. Cutaneous anthrax is typically treated for 7–10 days. Although infection may produce an effective immune response, a potential for reactivation of latent infection may exist. Therefore, persons with cutaneous anthrax should be treated for 60 days.

Prophylaxis for inhalational anthrax exposure includes the use of either ciprofloxacin or doxycycline as first-line agents. High-dose penicillin (e.g., amoxicillin or penicillin VK) may be an option for antimicrobial prophylaxis when ciprofloxacin or doxycyclines are contraindicated. The likelihood of beta-lactamase induction events that would increase the penicillin MIC is lower when only small numbers of vegetative cells are present, such as during antimicrobial prophylaxis.

DIFFERENTIAL DIAGNOSIS BETWEEN CHEMICAL AND INFECTIOUS AGENTS

Responses to biological and chemical agents are different. In a biological attack, quick diagnosis of the agent is critical. Most chemical events are acute at onset and are treated as emergencies by the police, fire, emergency medical services personnel, or hazardous materials teams. First responders must be well-trained, decontamination procedures must be in place, and a disaster plan should be well practiced. Preventing injury to first responders requires intense training and a high index of suspicion. Differentiating between chemical and biological weapons can be difficult as waves of patients succumb to these agents. An attack with biological weapons, although less likely than a chemical attack, will be much more difficult to identify early and could initiate an epidemic that sickens or kills large numbers of U.S. citizens before medical intervention can be organized. Few physicians have ever seen a case of anthrax, smallpox, or plague, so diagnosis of the epidemic is

certain to be delayed. The laboratory capabilities for diagnosis and measuring the antibiotic sensitivity of potential organisms are likewise limited, further delaying diagnosis and the implementation of control measures. An attack would not be obvious for days to weeks depending on the incubation period of the disease. By then, modern transportation would have dispersed widely the population of victims. For contagious agents such as smallpox and plague, this implies ever-widening spread of disease.

If contamination is suspected but symptoms are unclear, assume the worst. Clues that biological agents have been released include an unexplained increase in respiratory cases or deaths.

INTENSIVE CARE SERVICES IN DISASTER

The need for hospital beds—specifically, intensive care beds and especially the personnel and material resources to support those patients—is one of the most important limiting factors of the emergency medical response, often requiring outside assistance.⁴⁵ In each of the disaster scenarios described in this chapter, blunt or penetrating trauma, airway injury, acute respiratory failure, ARDS, crush syndrome or acute renal failure from severe crush injury represent the predominant injury or disease mechanisms requiring intensive care. Therefore, lifesaving potential will be largely determined by the ability to promptly secure an airway and provide an adequate number of intensive care (monitored) beds, hemodialysis or continuous veno-venous hemofiltration, and sufficient mechanical ventilators and respiratory care services.⁴⁶ Unfortunately, intensive and respiratory care resources will be quickly overwhelmed in most communities because they are in such limited supply on a daily basis. It is a major premise of this discussion that anesthesiologists and the anesthesia care team will not be limited to providing traditional operating room based anesthesia services, but will also be called upon for

TABLE 29.5. *Differential Diagnosis of Chemical Nerve Agent, Botulinum Toxin, and Staphylococcal Enterotoxin B (SEB) Intoxication*

	<i>Chemical Agent</i>	<i>Botulinum Toxin</i>	<i>SEB</i>
Time to symptoms	Minutes	24–72 hours	3–12 hours
Central nervous system	Convulsions, muscle twitching	Progressive paralysis	Headaches, aches
Cardiovascular	Bradycardia	Normal rate	Normal to fast
Respiratory	Dyspnea	Progressive paralysis	Cough, dyspnea
Gastrointestinal	Pain, diarrhea	Constipation	Nausea, vomiting
Ocular	Miosis	Droopy eyelids	Conjunctival injection
Salivary	Profuse/watery saliva	Difficult swallowing	Increased salivation
Death	Minutes	2–3 days	Unlikely
Response to atropine/ 2-pralidoxime chloride (PAM)	Yes	No	Reduction in symptoms

Source: Franz D. *Defense against toxin weapons*. Bethesda, MD: US Army Medical Research and Material Command; 1997.

reserve respiratory and intensive care staffing and services outside the operating room during a major earthquake, chemical or biological attack on the homeland, or in pandemic influenza. Therefore, anaesthesiology education and training programs must include the management of victims of terrorist chemical or biological attack, as well as the ability to function in the out-of-hospital setting in disaster. Likewise, Departments of Anesthesia should develop contingency plans in the event staff are needed in the field and intensive care areas. As described in this chapter detailed plans to manage a surge of critically ill or injured patients is an essential component of hospital disaster planning and preparedness.^{45,46,47} Figure 29.2 shows suggested hospital intensive care unit (ICU) and overflow areas where physiologic monitors are usually found. The establishment of an institutional “Critical Care Crisis Team” may aid in the development of such plans.

Since a plan for the provision of critical care services cannot wait until casualty figures become definitive, it is recommended that surge capacity for disaster response be graduated and standardized on a local, city-wide, regional, and national basis. This may best be organized by implementing a national registry of intensive care beds, resources, and services, as we do now for general hospital beds among hospitals that are members of the National Disaster Medical System (NDMS). Each institution would report the number of ICU beds, type of ICU bed (i.e., burn, cardiovascular, neurological, etc.), ICU occupancy rates, average length of ICU stay, ICU bed surge capacity, ICU staffing (physicians, nurses, respiratory therapists), and numbers of mechanical ventilators and other supplies and services that could be made available over a specified period of time.

We have already experienced the H1N1 flu epidemic and learned many lessons regarding the provision of intensive care services in these situations. However, a recent study of the H1N1 flu epidemic in Australia and New Zealand estimated a 23%–45% increase in the ICU utilization over normal annual use.⁴⁸ The lessons learned with the H1N1 epidemic

will be applicable also to the intensive care management of casualties of natural disasters, as well as chemical and biological weapon attack.

CONCLUSIONS

As a nation we face significant challenges in developing the capability to provide health and medical services to casualties of a major earthquake, terrorist use of a chemical or biological weapon, or pandemic flu in the United States. The probability that a major earthquake or a chemical or biological attack will occur in the near future in a densely populated city in the United States causing thousands of critically ill or injured casualties is high. Based on previous disaster events, uninjured survivors (bystanders) will be the first to respond followed later by emergency personnel from local prehospital EMS systems and hospitals. However, the public at large, first responders, professional rescuers, and their institutions are often unprepared to deal with a surge of casualties. Therefore, mass training of the public in life supporting first aid (LSFA) and basic rescue techniques is essential and has been proven to increase life saving potential.¹⁹ In order to cover a critical mass of the lay public in the United States, it may be advisable for LSFA training to be linked with driver licensing and renewal, and cars equipped with first aid kits.

Anesthesiology residency programs have not systematically incorporated all disaster management competencies into education and training curricula, nor require demonstration of ability to function in the OOR setting under crisis conditions.

In summary, the aim of disaster preparedness and response is to reduce chaos and uncertainty during a disaster. In homeland disaster scenarios which may result in mass injury or illness, as described in this chapter, anesthesiologists will inevitably play a crucial lifesaving role not only within the

traditional confines of the operating room and intensive care units, but also in the OOR setting. Therefore, to broaden disaster response capability among anesthesiologists, it may be prudent for the field of anesthesiology to revise resident education and training curricula to include disaster medicine and management competencies, treatment protocols for chemical and biological agent and combine simulation-based learning modalities to recreate the OOR setting and relevant disaster scenarios. The times we are living in behoove us to rethink our traditional role in disaster response and plan for new exigencies.

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30 | Anesthetic Considerations during Flight

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As the average age and number of passengers carried on a single flight increase,¹ it becomes increasingly likely that physicians will be called upon more frequently to provide assistance to fellow travellers in medical distress. While the cabin crew handle approximately 70% of in-flight requests for medical assistance²—the commonest problems being diarrhea and nausea³—consultation is sought from passengers with some medical training in the remaining 30% of cases.⁴ Physicians who respond to in-flight medical events within the United States are broadly protected against claims for malpractice by “Good Samaritan” legislation,⁵ provided that the actions they take are the ones that other competent persons with similar training would take under similar circumstances. The statute covers only those volunteering (making no charge for) their assistance. There is no legal duty under U.S. law to provide medical care to a person with whom no preexisting patient–doctor relationship exists. Judges in the United Kingdom have held a similar position.⁶ However, other countries, including France and Australia, do impose a legal obligation to assist even when no prior relationship exists. Regardless of legal obligations, a strong ethical imperative exists to assist a person in extremis. DeLaune et al.⁷ found that when a physician was involved in the decision to divert a flight for medical reasons, the patient was ultimately admitted to hospital 49% of the time; without physician assistance, admission resulted only 15% of the time. Overall, the commonest incidents are gastrointestinal problems, followed by vasovagal syncopal events, cardiac events, neurological events, respiratory distress, and trauma, with some minor frequency variation across various studies.^{8–13} Trauma commonly consists of injuries caused by luggage items falling from overhead storage bins, but it also includes burns from spillage of hot liquids.³ With regard to in-flight deaths, the commonest causes appear to be cardiac disorders and stroke.¹⁴

The type of in-flight treatment can fall into one of three categories, depending on the acuity of the patient. The first category is that of an acutely life-threatening event requiring immediate treatment, such as an acute coronary syndrome or asthma attack. The last category is that of the straightforward, nonthreatening presentation such as diarrhea or the symptoms of hyperventilation secondary to situational anxiety. In this category, only minimal intervention or reassurance is required. The middle category presents the greatest dilemma in management

because the presentation is more uncertain. The patient may appear acutely unwell and in some distress, for example, the onset of acute abdominal pain in a woman of child-bearing age. It may not be possible to provide a definitive diagnosis and the differential may include conditions that would need urgent intervention in a hospital. In these cases, it is best to determine whether symptomatic treatment can be used safely until definitive care is available. The decision to divert a flight for medical reasons does not lie with the responding physician but rather with the captain of the aircraft; the physician acts solely in an advisory capacity. When the diagnosis and management of the patient is in doubt, it is very helpful to be able to receive a second opinion from another physician. Most airlines provide the capability to contact a ground-based support physician; a large number contract with an independent medical services provider. The largest of these is MedAire’s service MedLink, which provides global radio access to consultation with attending emergency physicians based at Good Samaritan Regional Medical Center in Phoenix, Arizona. MedAire maintains a database of medical facilities around the world and assists with planning a diversion or arranging the hand-off of continuing patient care to local medical services on arrival. We recommend a low threshold for using radio consultation services, unless the diagnosis and management are straightforward and unlikely to require further care.

The environment of the commercial aircraft poses some special challenges to the patient and to the responding anesthesiologist:

1. *Decreased oxygen pressure:* the decrease in atmospheric pressure with altitude is accompanied by a decrease in partial pressure of oxygen and, consequently, in arterial oxygen saturation. Pressurization on commercial flights is not to sea level, but rather to an altitude commonly ranging from 5000 to 8000 feet (1524 to 2438 meters) above sea level; at 8000 feet, arterial oxygen saturation will be around 90%. The decrease in partial pressure of oxygen during flight may provoke distress in patients with compromised cardiovascular and/or respiratory function (Fig. 30.1); it can also trigger a sickling crisis in susceptible patients.¹⁵

2. *Decreased barometric pressure:* during ascent gas expands, while its volume decreases during descent. Therefore, during ascent, expanding gas unable to escape from body

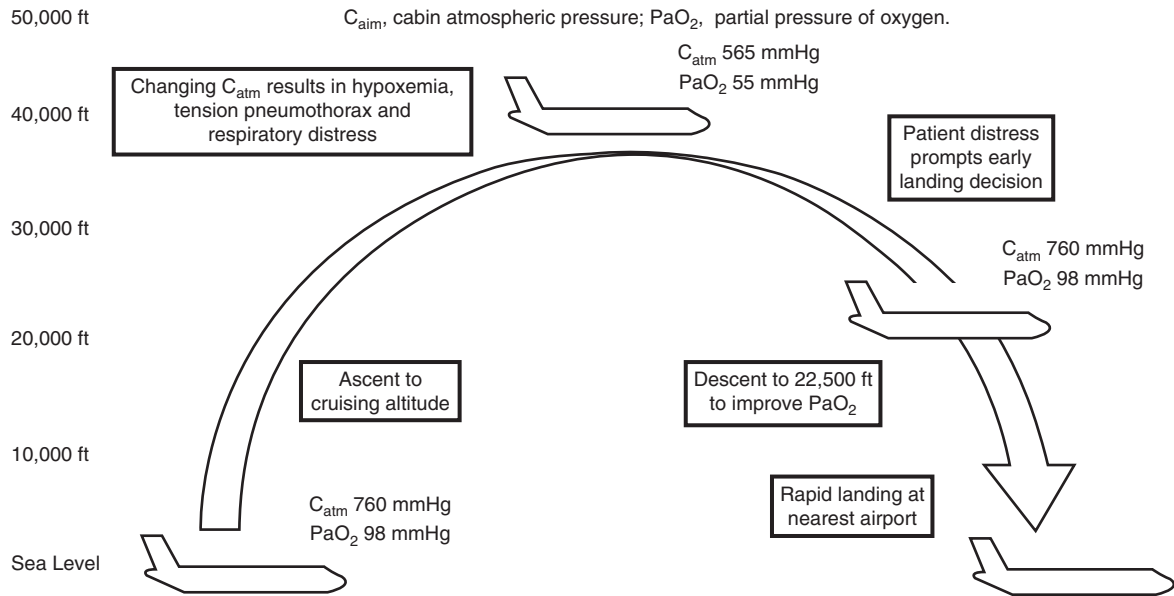


FIGURE 30.1. A clinical scenario of in-flight hypoxia and tension pneumothorax developing during ascent and responding to a decrease in altitude. Cabin pressure can be maintained at sea level up to 22,500 ft. (Reprinted with permission from ML Cheatham and K Safcsak. Air travel following traumatic pneumothorax: when is it safe? *Am Surg.* 1999;65(12):1160–1164.)

cavities may exert pressure on surrounding structures. The volume of trapped gas can increase by 30%,³ which is of particular concern for patients who may have pneumothorax,¹⁷ pneumocephalus, or ileus. A similar inability to equilibrate pressure during descent is a common cause of ear, nose, and throat problems. Changes in barometric pressure may also affect the operation of medical equipment.

3. *Decreased humidity:* the higher the altitude, the cooler and, consequently, the drier the air. On a commercial aircraft it typically ranges between 10% and 20%. This may dry secretions and worsen a patient's respiratory status.

4. *Confined space:* the dimensions and crowding of a commercial aircraft pose a particular challenge. Prolonged immobilization may predispose to deep vein thrombosis. In addition, it is often difficult to obtain a suitable level of privacy for a physician to perform a thorough history and physical examination, and it may be difficult to lay the patient flat.

5. *Noise:* this may not only prevent patient's examination (for example, blood pressure cannot always be determined by auscultation with a stethoscope and it may have to be palpated), but it can also interfere with effective communication with patient and/or crew.

6. *Fatigue:* all the stresses of flight, including jet lag, contribute to fatigue and can worsen a patient's clinical condition and impair the judgment of the physician.

7. *Vibration:* particularly in older and smaller aircrafts. It may increase metabolic rate in a patient equivalent to the level of gentle exercise.

8. *Inertial forces:* acceleration and deceleration along longitudinal axis during take-off and landing have the potential to be detrimental to a patient with head and/or spinal cord trauma. Having the patient's head facing aft (towards the tail

of the plane) during flight, when possible, may help in this regard. Furthermore, a patient needs to be secured with extra padding on vulnerable areas.

U.S. airlines have been required since 1998 to carry basic first aid kits and also an expanded in-flight medical kit for use by medical professionals.⁵ Additionally, an automated external defibrillator has been required since April 2004. The mandated minimum contents of these kits are shown in Table 30.1a,b. The kits are tailored for use by the general practitioner without training in emergency airway management because there is a concern that mandating medications and equipment that require specialized training may lead to harm.¹⁸ Airlines may provide more than the minimum equipment, and the airline Qantas does provide intubating equipment on long-haul flights.¹⁴ Of concern to anesthesiologists may be the need to maintain an unprotected airway for a protracted period of time in an unconscious or unresponsive patient when definitive airway management equipment is unavailable. Supplemental oxygen is almost always available for use, although the devices by which it can be administered may be limited to a simple face mask or nasal cannulae. The cabin pressure can often be brought to sea level by reducing the flight altitude to 22,500 feet or less; the cabin pressurization system can usually correct the internal pressure to sea level up to this flight altitude but not from the more common cruising altitudes above 30,000 feet.

In summary, anesthesiologists responding to an in-flight request for medical assistance should consider the following recommendations (modified from ref. 19):

1. Properly identify yourself and state your medical qualifications. Some airlines require proof of your medical qualifications.

TABLES 30.1. *Mandated Minimum Medical Equipment for U.S. Airlines**FIRST-AID KITS*

According to the new rule for aircraft registered in the U.S. there must be 1–4 onboard first-aid kits depending upon the number of passenger seats. In general, each first-aid kit must contain the following:

Contents	Quantity
Adhesive bandage compresses, 1-inch	16
Antiseptic swabs	20
Ammonia inhalants	10
Bandage compresses, 4-inch	8
Triangular bandage compresses, 40-inch	5
Arm splint, noninflatable	1
Leg splint, noninflatable	1
Roller bandage, 4-inch	4
Adhesive tape, 1-inch standard roll	2
Bandage scissors	1

EMERGENCY MEDICAL KIT.

Contents	Quantity
Sphygmomanometer	1
Stethoscope	1
Airways, oropharyngeal (3 sizes): 1 pediatric, 1 small adult, 1 large adult or equivalent	3
Self-inflating manual resuscitation device with 3 masks (1 pediatric, 1 small adult, 1 large adult or equivalent)	3
CPR mask (3 sizes), 1 pediatric, 1 small adult, 1 large adult, or equivalent	3
IV Admin Set: Tubing w/2 Y connectors	1
Alcohol sponges	2
Adhesive tape, 1-inch standard roll adhesive	1
Tape scissors	1 pair
Tourniquet	1
Saline solution, 500 cc	1
Protective nonpermeable gloves or equivalent	1 pair
Needles (2-18 ga., 2-20 ga., 2-22 ga., or sizes necessary to administer required medications)	6
Syringes (1-5 cc, 2-10 cc, or sizes necessary to administer required medications)	4
Analgesic, non-narcotic, tablets, 325 mg	4
Antihistamine tablets, 25 mg	4
Antihistamine injectable, 50 mg, (single close ampule or equivalent)	2
Atropine, 0.5 mg, 5 cc (single dose ampule or equivalent)	2
Aspirin tablets, 325 mg	4
Bronchodilator, inhaled (metered dose inhaler or equivalent)	4
Dextrose, 50%/50 cc injectable, (single dose ampule or equivalent)	1
Epinephrine 1:1000; 1 cc, injectable, (single dose ampule or equivalent)	2
Epinephrine 1:10,000, 2 cc, injectable, (single dose ampule or equivalent)	2
Lidocaine, 5 cc, 20 mg/ml, injectable (single dose ampule or equivalent)	2
Nitroglycerine tablets, 0.4 mg	10
Basic instructions for use of the drugs in the kit	1

Source: From 105th U.S. Congress. Aviation Medical Assistance Act of 1998. HR2843 ed Pub L No 105–170:1998.

2. Obtain as complete a history as possible, inform the passenger and family members (if present) of your impression, and obtain consent before initiating any form of examination or treatment. Assume implied consent in the case of an incapacitated passenger.

3. If consent has been given, carry out an appropriate physical examination.

4. Request an interpreter if the passenger you are assisting does not speak your language.

5. Inform the flight crew of your clinical impression.

6. If the passenger's condition is serious, request that the aircraft be diverted to the nearest appropriate airport. On-ground medical support staff, if available, will help determine the best location for diversion.

7. Establish communication with on-ground medical support staff, if available.

8. Respect the ground-based physician's expertise and experience in managing in-flight medical events.

9. Document in writing your findings, impression, treatment, and communication with the flight crew and on-ground medical support.

10. Do not use any treatment that you do not feel confident administering. Keep in mind that "Good Samaritan" statutes protect you only from liability for actions that other competent persons with similar training would take under similar circumstances.

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31 | Anesthesia Considerations in Dental Practice

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Dental anxiety and fear are commonly the result of painful and negative experiences at the dentist during childhood.¹ Classical conditioning during unpleasant treatment experiences in childhood often leads to avoidance of the dentist into adulthood. This subsequently results in poorer oral health. Fearful adult patients commonly recall painful experiences where anesthesia was not used. It is for these reasons that some kind of dental anesthesia is used in almost all procedures.

Dental anesthesia is indicated for most procedures of the oral cavity. Soft tissue (mucosal tissues such as the buccal mucosa and gingiva), teeth, and the pulp tissue (composed of nerve fibers, vasculature, lymphatics, and connective tissue inside of the tooth), and supporting structures of the tooth (bone and periodontal ligament) are all necessary structures to be anesthetized. Choice of tissue to be anesthetized depends on the goal of the procedure.

Restorative procedures (amalgam and composite restorations, inlays, onlays), prosthetic procedures (crowns and veneers), endodontic procedures (root canals, apicoectomy or root-end surgery, pain diagnosis), periodontal procedures (scaling and root planing, crown lengthening, sinus lift, connective tissue grafting, guided bone regeneration, gingivectomy), and oral surgery procedures (extractions, implant placement, incision and drainage, and biopsy) all will require anesthesia to reduce patient pain and anxiety.

ARMAMENTARIUM

The Basic Dental Syringe

There are three components needed to administer regional anesthesia in the maxilla and mandible: the dental syringe, needle, and anesthetic cartridge. The most common dental syringe is generally stainless steel, aspirating, and breech loading. The main body of the syringe consists of the barrel where the anesthetic cartridge is loaded from the side. Attached to the barrel is a finger grip where the index and middle fingers provide counterforce to the thumb, which is inserted through the thumb ring (Fig. 31.1a,b). The operator will be able to provide force toward the needle to inject solution at the site or away from the needle to aspirate and check for unwanted,

intravascular placement. The plunger consists of the thumb ring, piston, and harpoon, which will engage the rubber stopper of the anesthetic cartridge. The needle adaptor sits at the end of the barrel where the needle hub is threaded into place. The only parts of the dental syringe that are removable are the thumb ring and the needle adaptor.

Dental needles for the basic dental syringe have a self-threading, plastic hub and are stainless steel. The needles most commonly used are 25, 27, or 30 gauge in short or long variations. A short, 30-gauge needle (25 mm in length) is most commonly used for maxillary injection and mandibular infiltration and is coded by the color blue. A long, 27-gauge needle (40 mm in length) is most commonly used for mandibular nerve block anesthesia and is coded by the color yellow. Short needles are not recommended for mandibular inferior alveolar nerve blocks because they can, but rarely do, break from the hub and need to be retrieved. Variation on length often occurs, depending on the manufacturer.

The dental anesthetic cartridge consists of a glass cylinder with a rubber stopper at one end and an aluminum cap with a diaphragm at the other (Fig. 31.2). The harpoon of the piston engages the rubber stopper after it has been loaded into the barrel and the needle is self-threaded onto the hub to pierce the diaphragm. The cartridges come prefilled with either 1.7 or 1.8 cc of solution, depending on the manufacturer. The anesthetic solution most likely contains the local anesthetic, a vasoconstrictor (epinephrine or levonordefrin), preservative for the vasoconstrictor (sodium bisulfite), sodium chloride, and distilled water.

Anesthetics

Local anesthetics are the most commonly used drugs in dentistry. It is estimated that more than 6 million lidocaine cartridges are used per week.² Injectable anesthetics used in the dental setting are almost always amide-type drugs. There are currently no ester drugs being produced for dental use, but this class of anesthetic was used in the past. Some factors for selection of dental anesthetics include duration and type of the procedure, contraindications for specific anesthetics or the presence of vasoconstrictors, need for hemostasis, and need for postsurgical pain control.

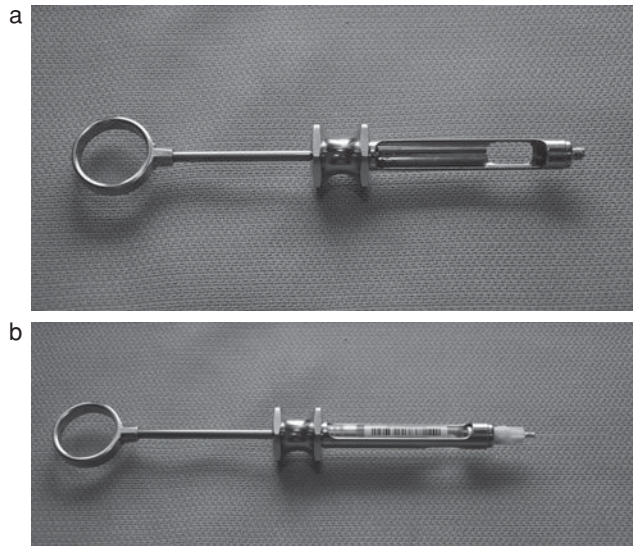


FIGURE 31.1(a) The dental syringe consists of the main body, plunger with thumb ring and harpoon, and the needle adaptor. (b) The anesthetic cartridge is loaded from the side and a needle is threaded onto the hub.

Although not all dental procedures involve working on or inside of the teeth, dental anesthetics are classified by the duration of anesthesia for the pulp tissue.

Pulpal anesthesia is particularly important in procedures such as restorations, crown preparation, root canals, scaling, and root planning and surgery.

Dental anesthetics are categorized on their duration of pulpal anesthesia. Short-acting anesthetics will provide, on average, 30 minutes of pulpal and hard-tissue anesthesia. Intermediate-acting anesthetics will provide up to 60 minutes

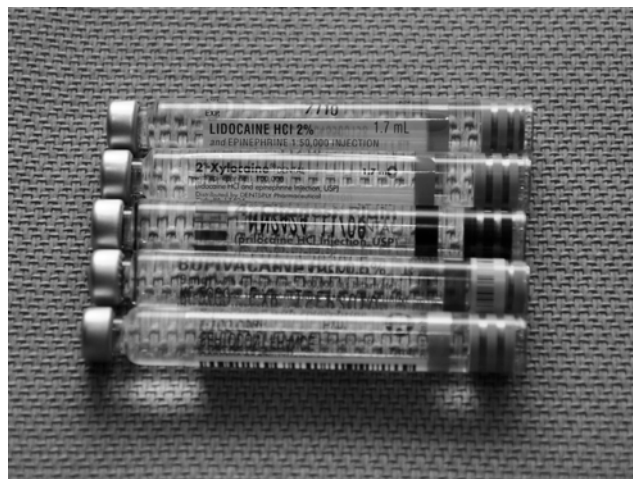


FIGURE 31.2. Typical dental anesthetic cartridges are glass cylinders with rubber stoppers at one end and an aluminum cap with a diaphragm at the other.

of pulpal anesthesia and long-acting anesthetics can provide up to 3 hours of pulpal anesthesia if given as a nerve block.³ Short-acting anesthetics may be useful for certain procedures, such as a soft-tissue biopsy. Intermediate-acting anesthetics are most widely used in the dental setting. They will generally provide enough time to complete the procedure without leaving the patient anesthetized for an extended period of time. Long-acting anesthetics such as bupivacaine (Marcaine, Sensorcaine) are useful in situations where the patient is experiencing acute inflammation of the pulp tissue and/or painful swelling that cannot be attended to immediately. The patient is often anesthetized to be made comfortable until he or she can be seen later in the day or the following day, or until an appropriate diagnosis can be made. Long-acting anesthetics also are often administered at the end of a surgical procedure to delay the onset of pain and allow for oral anti-inflammatory and pain medications to take effect.

Vasoconstrictors will benefit the patient by increasing the depth and duration of anesthesia and decreasing bleeding and the potential for systemic toxicity. Vasoconstrictors used are typically epinephrine in a 1:100,000 concentration or levonordefrin. Concentrations of epinephrine are available in 1:50,000 for increased hemostasis during surgical procedures, such as apicoectomy, extraction, or implant placement. The dental syringe is designed for aspiration so that these vasoconstrictors are not accidentally injected into vasculature. Patients will generally feel tachycardia and may experience facial skin blanching on direct injection into vasculature. In patients where epinephrine can be used but on a limited basis, a 1:200,000 preparation is available.

The question of when to use a vasoconstrictor remains debatable. Bader and colleagues concluded that the use of epinephrine in local anesthetics had infrequent adverse outcomes.⁴ Use of a dental anesthetic without epinephrine may lead to decreased depth and/or duration of anesthesia, therefore leading to a decrease in pain control. Increased sensation of pain may increase levels of endogenous catecholamines, particularly norepinephrine.⁵ In turn, norepinephrine release increases blood pressure and potentiates cardiotoxic effects.⁶ It has been demonstrated that norepinephrine levels, used as a measure of stress, can be significantly elevated when the concentration of vasoconstrictor is decreased.⁷ Some argue that the use of a vasoconstrictor with local anesthetic is important in cardiovascular patients because this will minimize levels of pain and stress and thus decrease the sympathetic drive, resulting in decreased release of norepinephrine and secondary epinephrine.

When the use of epinephrine or other vasoconstrictors is contraindicated, prilocaine (plain) or mepivacaine (Carbocaine) without epinephrine is used. Vasoconstrictors are sometimes contraindicated in patients with severe cardiovascular disease. Generally, 0.036–0.045 mg epinephrine (the amount contained in approximately 2–3 cartridges) is considered safe in patients with mild to moderate cardiovascular disease.⁸ Bisulfites are present in anesthetic cartridge solutions as preservatives for the vasoconstrictors. Patients who have a bisulfite allergy will also benefit from use of these plain preparations.

Topical Anesthetics

Topical anesthetics are used to reduce pain at the puncture site in dental injections, thus theoretically reducing patient anxiety.⁹ They are also used to relieve the pain of superficial mucosal lesions such as aphthous ulcerations or oral herpetic lesions. Common ester-type agents such as 20% benzocaine gel or ointment are used to mask needle puncture pain, whereas viscous gels or solutions such as lidocaine (20-40 mg/ml) are used to reduce painful intraoral ulcerations, permitting patients to masticate and swallow more easily. A patient who has a strong gag reflex may benefit from topical anesthetic sprays or lozenges typically found over-the-counter as sore throat-related pain relievers. This application can be helpful in obtaining initial diagnostic radiographs prior to infiltration or nerve block anesthesia.

Common topical anesthetic drugs include benzocaine, butacaine sulfate, cocaine hydrochloride, dyclonine hydrochloride, lidocaine, and tetracaine hydrochloride. Agents prepared as gels, viscous gels, ointments, and adhesive patches are best suited for preinjection anesthesia because they limit the area of anesthesia. For widespread topical anesthesia, solution rinses and aerosol sprays are helpful. Topical anesthetics for prolonged topical pain relief are formulated as lozenges, pastes, and film-forming gels.

The clinical effectiveness of topical anesthetics to reduce pain at the site of needle penetration is debatable. While some argue that this is effective, others have found that topical anesthesia before needle penetration was no different than the placebo in reducing pain. One researcher found that topical anesthetic reduced patients' anticipation of pain but did not reduce the sensation of pain.¹⁰ Kincheloe et al.¹¹ reported that patients with high expectations of pain experienced more pain than those with low expectations, and that topical anesthesia had no effect on the pain experienced. The psychological effect may outweigh its clinical effectiveness.

ADMINISTRATION OF LOCAL ANESTHESIA

Basic Injection Procedure

The dental patient is generally placed in the supine position with the exception of those who cannot tolerate it. A topical anesthetic, most commonly 20% benzocaine gel, is placed with a cotton swab on the dry oral mucosa for superficial anesthesia. The patient will assist the dentist by holding onto or biting down on the cotton swab. Approximately 2 minutes or more are required to achieve enough topical anesthesia to reduce the pain on needle puncture.¹²

The cotton swab is removed and the needle is inserted in one smooth, continuous motion to the area. Finger rests on nearby teeth or stable facial structures are used to ensure minimal movement once the needle is placed. After arrival at the target site, the operator aspirates to ensure proper placement and avoid intravascular injection. Rapid injection is avoided to decrease counterpressure and pain.¹³ Increased pressure on injection may be necessary in areas where the oral mucosa is

attached or tightly bound to the underlying periosteum. These areas are most frequently encountered at the hard palate and incisive papillae. A sudden give or bleeding on withdrawal of the needle may indicate an intravascular injection in the area of the hard palate. Introduction of the needle into a foramen is avoided because this may result in temporary damage to nerves or vessels resulting in paresthesias or hematomas. Injection directly into areas of infection are to be avoided because this may cause further spread of the infection. Block anesthesia or infiltration medial and distal to the site of infection is more appropriate in this instance.

Maxillary Anatomy and Anesthesia

Maxillary teeth consist of third molars (commonly referred to as wisdom teeth), second molars, first molars, first and second premolars, canines, lateral incisors, and central incisors. Starting from the upper right side of the mouth, these eight teeth are commonly referred to as the upper right quadrant (URQ) and correspond to teeth #1-8, moving posteriorly to anteriorly. The upper left quadrant (ULQ) corresponds to teeth #9-16 starting from the midline and moving posteriorly.

Innervation to the maxillary teeth stems from the second division or maxillary nerve of the trigeminal nerve or cranial nerve V. The superior dental plexus is formed by three branches of the maxillary nerve: the posterior superior alveolar nerve (PSA), the middle superior alveolar nerve (MSA), and the anterior superior alveolar nerve (ASA). The superior dental plexus gives innervation to the pulp and the supporting structures of the teeth: the maxillary bone, periosteum, periodontal ligament surrounding each tooth, interdental papillae, and buccal gingiva. Maxillary palatal innervation stems from the greater palatine nerve (coming from the sphenopalatine ganglion), which descends through the greater palatine canal and exits through the greater palatine foramen. The posterior palatal gingiva is innervated by this nerve. The anterior portion of the hard palate is innervated by the nasopalatine nerve, which leaves the sphenopalatine ganglion through the sphenopalatine foramen and exits out the incisive foramen.

Maxillary molar teeth (#1-3 and #14-16) most always have three roots, two roots that face in a buccal direction, referred to as the mesiobuccal root and the distobuccal root, and a palatal root that faces toward the palate. Maxillary premolar teeth (#4, 5, 12, 13) may have one, two, or very rarely three roots. More commonly, the maxillary second premolar has one root, and the maxillary first premolar has two roots. If more than one premolar root exists, the roots are situated with one buccal and the other palatal. Maxillary canines, lateral incisors, and central incisors most always have one root that is centered within the alveolus.

Injection for the purpose of anesthetizing a singular maxillary tooth depends on supraperiosteal infiltration of anesthetic through the porous bone lamina to target terminal nerve endings rather than a direct nerve block. Injections are generally given both in the buccal vestibule of the mouth parallel to the long axis of the corresponding tooth and additionally on the palate (Figs. 31.3 and 31.4). The supplemental palatal



FIGURE 31.3. Maxillary infiltration injection is given near the tooth apex, parallel to the long axis of the corresponding tooth.

injection will ensure that any roots that are directed back toward the palate will be adequately anesthetized. The target area is at or above the apex or tip of the root of the tooth.

For anesthesia of all maxillary molars, specifically the most posterior molars, a PSA injection may be necessary. The PSA nerve branches from the infraorbital nerve before it reaches the orbit. The branches of the PSA nerve pass down the maxillary tuberosity and enter to innervate the maxillary molars. A short, 30-gauge needle is used. In both the PSA and maxillary buccal infiltration, bone is not contacted: therefore, the injection is likely not to cause pain. The injection site is the height of the maxillary buccal fold adjacent to the second maxillary molar. The needle is placed in an upwards, inwards, and backwards direction (Fig. 31.5). In a certain percentage of patients, the mesiobuccal root of the maxillary first molar will not be anesthetized with the PSA, and an additional infiltration will

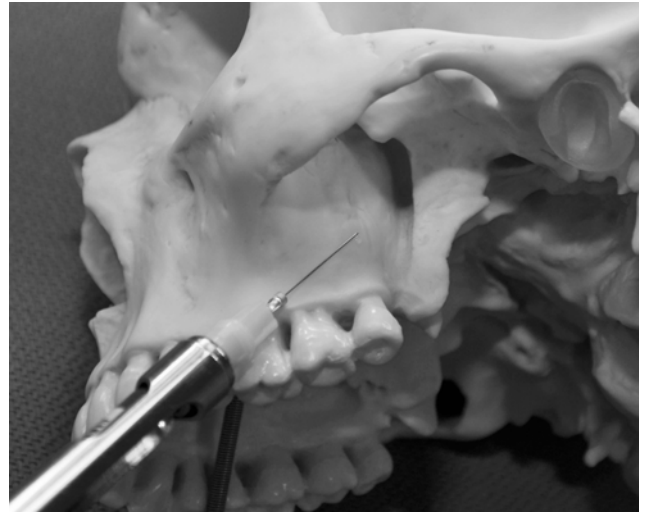


FIGURE 31.5. The posterior superior alveolar nerve (PSA) injection is given in an upwards, inwards, and backwards direction.

be necessary; this is likely accounted for by innervation by the MSA nerve. The operator also must always aspirate before injecting, because the pterygoid plexus of veins is nearby. Injection into the pterygoid plexus of veins is likely to result in a hematoma. A supplemental palatal (greater palatine) injection will be necessary to achieve anesthesia of the palatal root of most maxillary molars (Fig. 31.6).

The premolar teeth (#4, 5, 12, 13) are innervated by the superior dental plexus. Innervation of the premolar teeth by the MSA is an anatomical anomaly, but when present it is responsible for sensation to the pulp tissue, buccal gingiva, and periosteum and potentially the mesiobuccal root of the

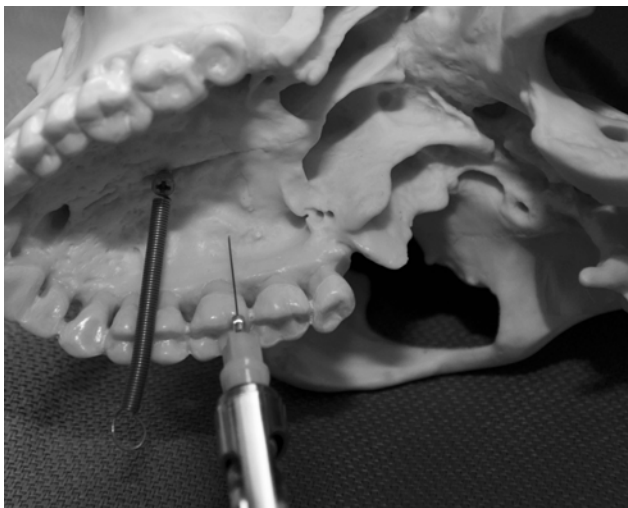


FIGURE 31.4. A supplemental palatal injection is given at or above the apex of the root of the tooth.

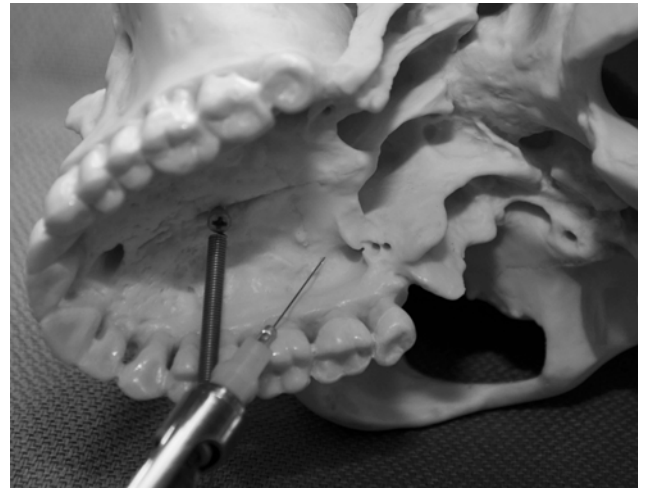


FIGURE 31.6. A supplemental greater palatine injection may be necessary to achieve anesthesia of the palatal root of most maxillary molars.

first maxillary molar. Anesthesia is achieved by injection into the buccal vestibule parallel to the root surface of the tooth in an axial direction. The anesthetic will successfully diffuse through the bone because the buccal plate of bone is generally thin in the maxillary premolar area. A supplemental palatal injection may be necessary if a second or palatal root exists and is directed back toward the palate.

Central incisors, lateral incisors, and canines are innervated by ASA nerve that branches from the infraorbital nerve. There are anastomoses between the right and left sides of the ASA nerves. Single-tooth anesthesia is achieved by injection into the buccal vestibule apical and parallel to the long axis of the tooth (Fig. 31.7). This will anesthetize the tooth, the buccal gingiva, and the periosteum. Anesthesia of the anterior hard palate is achieved by supplemental injection of the nasopalatine nerve.

Anesthesia of the entire anterior region, including the two premolars, is achieved by an infraorbital nerve block. In addition to the teeth, the skin of the upper lip, lateral nose, and lower eyelid is anesthetized. Anesthetic is deposited at the roof of the infraorbital foramen parallel to the maxillary first premolar, and digital pressure is applied over the foramen for a duration of 1–2 minutes.

Alternatively, pulpal anesthesia of the same five maxillary anterior teeth also can be achieved by the anterior middle superior alveolar (AMSA) nerve block. In this technique, anesthesia of soft tissue and bone of the hard palate from the third molar to the central incisor is achieved in addition to the buccal soft tissue and bone. Anesthesia of the facial skin is not achieved because the infraorbital nerve is not anesthetized. Anesthesia is injected into the soft tissue of the hard palate halfway along an imaginary line from the papilla between the first and second premolars to the midline of the palate.¹⁴

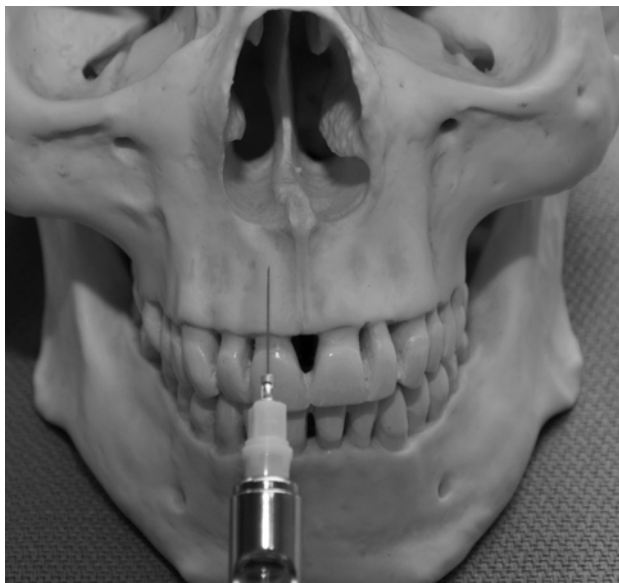


FIGURE 31.7. Single-tooth anesthesia is achieved by injection near root apex parallel to the long axis of the tooth.

Mandibular Anatomy and Anesthesia

Mandibular teeth consist of third molars (most commonly referred to as wisdom teeth), second molars, first molars, first and second premolars, canines, lateral incisors, and central incisors. Starting from the lower left side of the mouth, these eight teeth are commonly referred to as the lower left quadrant (LLQ) and correspond to teeth #17–24 moving posteriorly to anteriorly. The lower right quadrant (LRQ) corresponds to teeth #25–32 starting from the midline and moving posteriorly.

Innervation to the mandibular teeth stems from the third division or mandibular nerve of the trigeminal nerve or cranial nerve V. The inferior alveolar nerve passes down along the medial side of the mandibular ramus and enters the mandibular foramen. Once the inferior alveolar nerve passes into the mandibular foramen, it travels through the inferior alveolar canal, giving off branches to the mandibular teeth and forming the inferior dental plexus. The inferior alveolar nerve gives off a branch called the mental nerve that exits the inferior alveolar canal at the mental foramen. The mental foramen is situated between and inferior to the first and second premolars. The mental nerve gives sensory innervation to the buccal gingiva and mucosa between the midline and the second premolar as well as to the skin of the chin and lower lip. The buccal gingiva and mucosa between the second premolar and the second molar is innervated by the buccal nerve. Also known as the long buccal nerve, this nerve is a sensory branch of the mandibular nerve that passes along the medial side of the mandibular ramus. Passing together with the inferior alveolar nerve, the lingual nerve branches to innervate the lingual gingiva and the mucosa of the floor of the mouth. The terminal branches of the lingual nerve enter the tongue and provide sensory innervation to the anterior two-thirds of the tongue.

The inferior alveolar nerve block is the most important and most common nerve block given in the mandible. This block will provide anesthesia for an entire quadrant of the mandible. Successful injection will anesthetize the molars, premolars, canine, and incisor teeth. The patient is instructed to open maximally and the operator feels for the coronoid notch of the mandible. The thumb or dental mirror is placed in this area to retract the cheek while providing a reference point. The pterygomandibular raphe (joint of the buccinator and the posterior pharyngeal muscles) is identified. The dental syringe is positioned at an angle from the contralateral premolar, parallel to the occlusal plane and inserted into the pterygomandibular raphe at a point that intersects the thumb or dental mirror. The needle is advanced until bone is gently contacted and then withdrawn slightly. The goal of the block is to deposit anesthetic solution in the area of the mandibular nerve before it enters the mandibular canal (Fig. 31.8). A small amount of anesthetic solution may be administered on injection, but the vast majority should not be injected until the operator aspirates to avoid intravascular injection. It is common to concomitantly anesthetize the lingual nerve due to its proximity to the mandibular nerve. The buccal nerve, however, will require a separate injection.



FIGURE 31.8. Anesthetic solution is deposited in the area of the inferior alveolar nerve before it enters the mandibular canal.

Anesthesia of the buccal gingiva and soft tissue in the mandibular molar region is often needed in addition to the mandibular teeth, lingual gingiva, and tongue. This will require a supplemental block of the long buccal nerve. The target is the buccal nerve as it passes over the anterior aspect of the ramus (Fig. 31.9). The cheek is retracted and anesthesia is injected into the vestibule just distal and buccal to the last molar tooth. The needle is progressed horizontally and in a distal direction.

Anesthesia of the premolar teeth is still best accomplished by the mandibular nerve block; however, block of the mental nerve may be a viable alternative. The mental nerve branches from the inferior alveolar nerve and exits at the mental foramen to



FIGURE 31.9. The long buccal nerve is targeted as it passes over the anterior aspect of the ramus.

give sensation to the buccal gingiva, mucosa, lower lip, and skin. The mental foramen is usually positioned between, and inferior to the first and second mandibular premolar teeth. The target area for this block is the area of the mental foramen (Fig. 31.10). The mental foramen is palpated with the index finger, and the needle is directed toward the mental foramen. Digital pressure may be used for a few minutes to help the anesthetic diffuse into the foramen.

While a nerve block is essential for anesthesia of the molar teeth, mandibular incisor teeth may be anesthetized by infiltration technique. As opposed to the posterior mandible, the anterior mandible has relatively thin and porous laminar bone and therefore infiltration is a viable option. Because bone thickness varies in each individual, mandibular block may be necessary if infiltration is unsuccessful. Anesthesia of the mandibular incisor teeth is achieved by targeting the incisive nerve, a branch of the inferior alveolar nerve. The needle is injected from a lateral approach or along the long axis of the tooth (Fig. 31.11). Resistance may be felt due to muscle attachment. Supplemental block of the sublingual nerve (a branch of the lingual nerve) may be necessary for anesthesia of the lingual gingival and mucosa of the floor of the mouth.

Alternative Mandibular Blocks

The Gow-Gates technique and Vazirani-Akinosi closed mouth technique are both alternative nerve blocks to the more common inferior alveolar or mandibular nerve block.

The Gow-Gates technique may be useful when an initial attempt at the inferior alveolar nerve block is unsuccessful. In this technique, the patient opens maximally and the mesiolingual cusp of the maxillary second molar is identified. The needle is advanced distally and parallel to an imaginary line drawn from the intratragic notch of the ear to the corner of the mouth. The auriculotemporal, inferior alveolar, buccal,

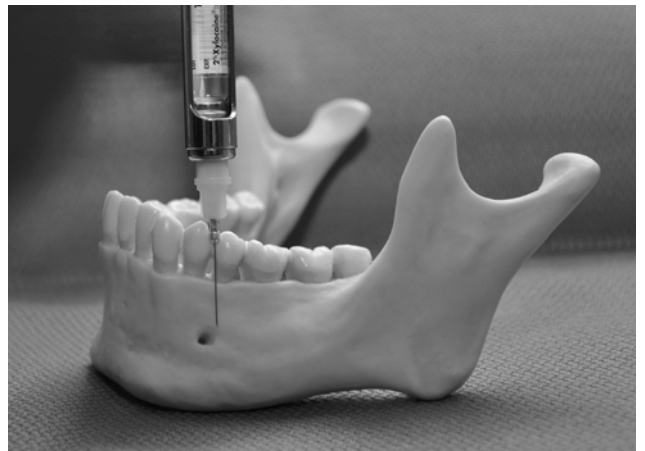


FIGURE 31.10. The mental nerve block serves as an alternative to the inferior alveolar nerve block. Anesthetic is deposited in the vestibule between the first and second premolars in the area of the mental foramen.



FIGURE 31.11. Anterior mandibular infiltration is given near the tooth apex, parallel to the long axis of the corresponding tooth.

mental, incisive, mylohyoid, and lingual nerves are targeted. This results in anesthesia of the ipsilateral quadrant of mandibular teeth, buccal and lingual hard and soft tissues, the anterior two-thirds of the tongue, and floor of the mouth. Additionally, the skin over the zygoma, posterior aspect of the cheek and temporal region are anesthetized.¹⁵

The Vazirani-Akinosi block is most useful when the patient has minimal opening due to trismus from swelling or dysfunction of the temporomandibular joint. The gingival margin and mucogingival junction above the maxillary second and third molars, the pterygomandibular raphe, and maxillary tuberosity serve as landmarks. The patient is asked to close gently on the posterior teeth. A 25-gauge, long needle is used to access the pterygomandibular space (Fig. 31.12). The inferior alveolar and its subdivided branches, as well as lingual and mylohyoid nerves are anesthetized in this block. Mandibular teeth to the midline, the body of the mandible, the inferior portion of the mandibular ramus, the buccal mucosa, anterior two-thirds of the tongue, floor of the mouth, and the lingual mucosa (lingual and sublingual nerves) are affected.^{16,17}

SPECIAL CONSIDERATIONS IN DENTAL ANESTHESIA

The “Hot” Tooth

A tooth that is particularly difficult to anesthetize is known as a “hot” tooth. Oral bacteria that have found their way through the enamel and dentin to the pulp space either from tooth caries, fracture, periodontal disease, or trauma (heat or desiccation from tooth preparation or pulpal exposure) may

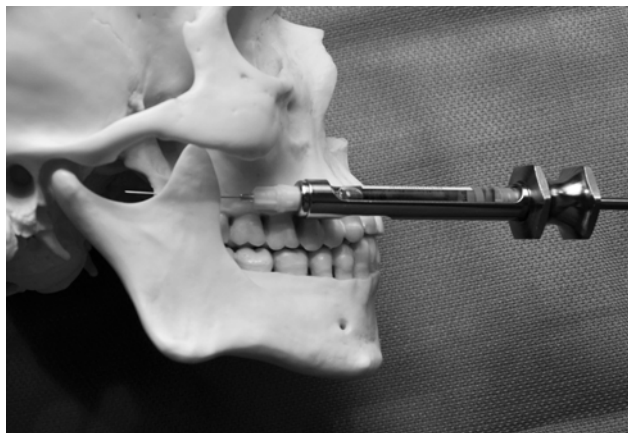


FIGURE 31.12. Example of the target area for the Vazirani-Akinosi block.

cause an irreversible inflammation of the pulp. Irreversible pulpitis will ultimately lead to pulp necrosis. Bacteria and subsequent inflammation will initially be confined to the pulp chamber within the crown of the tooth, but then will progress down the root canals, causing inflammation of the periapex and periodontal ligament.¹⁸

Between the progression of irreversible pulpitis to pulp necrosis, the patient might complain of intense pain, including, but not limited to, hyperalgesia (increased response to a hot or cold stimulus) and spontaneous pain. The pain may be sharp or dull with a throbbing nature and may be intermittent or continuous. The patient may also experience referred pain to nearby teeth, the opposing arch, temple, or ear. Percussion of the tooth will, in later stages, produce intense pain (allodynia). Patients often state that they avoid chewing on the affected side of the mouth or that even slight provocation by the tongue will cause pain.

Reader sites five theories as to why patients with irreversible pulpitis do not achieve pulpal anesthesia even after nerve blocks or infiltrations.¹⁹ For mandibular teeth, the inferior alveolar nerve block is not always successful. Secondly, in the presence of an abscess or cellulitis, a lowered pH value of inflamed tissues reduces the available base form of anesthetic to penetrate the nerve membrane. Therefore, some argue that there is less of the ionized form within the nerve to obtain anesthesia. This theory may explain anesthetic failure with infiltrations but would be hard to justify with nerve blocks because the site of administration is distant from the site of inflammation. Another theory states that nerves coming from inflamed tissues have altered resting potentials and decreased excitability thresholds. Therefore, it is possible that local anesthetic agents do not prevent impulse transmission due to these lowered excitability thresholds.

Parente et al. found an increased expression of sodium channels in pulp tissue diagnosed with irreversible pulpitis.²⁰ A tetrodotoxin-resistant (TTXr) class of sodium channels have been shown to be resistant to the action of local anesthetics.²¹ Lastly, patients who are in pain are already sensitized

to pain and apprehensive, which may lower their pain threshold. When nerve block or infiltration anesthesia fails, alternative delivery methods such as intraligamentary or intraosseous injection technique may increase chances of success, especially for the “hot” tooth.

Alternative Delivery Methods for Dental Anesthesia

Failure of the traditional methods for anesthetizing the dental pulp may require additional techniques. Even when the Vazirani-Akinosi and Gow-Gates techniques are employed as alternative methods for the inferior alveolar nerve block, the severely inflamed or “hot” tooth may need additional anesthesia. The intraligamentary, intraosseous, and intrapulpal techniques offer routes that may serve as alternatives to the conventional infiltration and regional block routes.

The intraligamentary injection, also known as the periodontal ligament (PDL) injection, is achieved by forcefully wedging an extra-short needle into the gingival sulcus and into the periodontal ligament between the tooth and the crestal bone surrounding the tooth (Fig. 31.13A). The needle is directed axially and apically. The anesthetic solution reaches the periapical tissues through the marrow spaces surrounding the tooth rather than apically through the periodontal ligament. Therefore, the intraligamentary injection is somewhat of a misnomer as it actually most resembles an intraosseous injection.²² The solution is injected under high pressure with either a regular dental syringe or a specially designed injector (Fig. 31.13B). Resistance is the most important factor for successful intraligamentary anesthesia.²³ Several specially designed injectors are available to facilitate delivery, and improvements to decrease the pain on injection continue to be made.

Advantages of this injection include potential single-tooth anesthesia, usage of smaller doses of anesthetic, alternative method for failed anesthesia, and decreased potential for hemorrhage or hematoma formation in mandibular anesthesia in patients with a predisposition to bleeding.²⁴ Disadvantages for the patient include production of a bacteremia, rapid entry of vasoconstrictor and local anesthetic into the circulation,



FIGURE 31.13A. The intraligamentary injection device helps create a high-pressure injection.

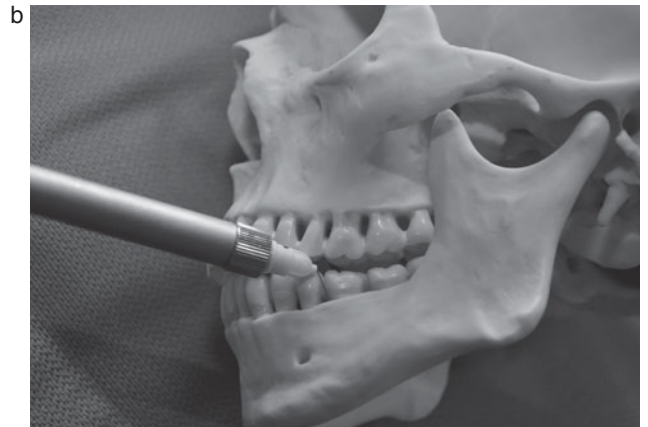


FIGURE 31.13B. The intraligamentary injection is achieved by wedging the needle between the tooth and the crestal bone.

damage to surrounding tooth tissues, peri- and postinjection discomfort, and potential damage to unerupted teeth in pediatric patients.²⁴

The intraosseous injection technique consists of perforating the attached buccal gingiva and cortical bone 2 millimeters apical to, distal to, and in line with the interdental papillae. In modern intraosseous systems, a perforator is used to access the cancellous bone or marrow space. The perforator is removed and a guide-sleeve is placed into the perforation to retain the location of the perforation. The anesthetic is then delivered through a 27-gauge needle directed by the guide-sleeve into the appropriate space.

Advantages of intraosseous anesthesia include use of smaller dosages, smaller regional anesthesia, and use as alternative method when traditional nerve block or infiltration is unsuccessful. Disadvantages include difficulty of injection and placement, rapid entry of local anesthetic and vasoconstrictor such as epinephrine or levonordefrin, postinjection discomfort, or potential tooth damage.²⁴

Intrapulpal anesthesia is only indicated after all other techniques have been employed but have failed in cases where the pulp tissue is severely, irreversibly inflamed. A small hole is made with a round bur into the roof of the pulp chamber of the tooth and a needle is inserted either into the chamber or into a root canal space. The most important factor for successful intrapulpal anesthesia is injection under pressure. Back flow of the anesthetic indicates that not enough pressure is generated to achieve anesthesia. If the entire chamber has been unroofed and an injection with strong pressure is not possible, injection into each individual root canal may be necessary.²⁵ The main advantage of intrapulpal anesthesia is that it can be used as a last resort when all other forms of blocks, infiltrations, and injections have failed. The main disadvantage is that this technique can be very painful for the patient. On successful injection, the patient will generally feel sharp pain that will subside quickly.

Computer-controlled local anesthetic delivery systems have found their way into the dental marketplace and represent

innovative methods to provide patients with a more comfortable injection experience. These systems can be effective for all injections that are traditionally performed with a standard aspirating syringe. Computer-controlled devices are designed to deliver anesthetic at a slow, but constant rate with compensation for variation in resistance to flow. The slow, controlled flow is helpful in reducing pain and therefore patient anxiety.²⁶

The WAND (Milestone Scientific, Livingston, NJ) was among the first of these devices and received the American Dental Association Seal of Acceptance in May 1998. In 2007, the STA (Single Tooth Anesthesia) system (Milestone Scientific) was introduced into the market as a system that incorporates "pressure feedback," thereby allowing dentists to administer injections accurately and painlessly into the periodontal ligament space, effectively anesthetizing a single tooth. This injection will profoundly anesthetize the patient within 1 or 2 minutes, allowing for a significant savings of waiting time. The patient will suffer neither pain nor collateral anesthesia in the cheek, lips, or tongue at any time. The STA system is also capable of performing all of the injections that are achieved with a dental syringe. These devices generally consist of a small plastic handle that is held like a pen to which a needle is attached. Anesthetic is delivered to the needle through plastic tubing from a traditional anesthetic cartridge that is inserted into a computer-controlled pump unit. The dentist controls delivery and aspiration by a foot pedal, but the rate of delivery is controlled by the device.

COMPLICATIONS IN DENTAL ANESTHESIA

Complications during dental anesthesia, although not common, may occur. These include nerve trauma, vascular injury, intravascular, intraglandular or intramuscular injection, self-inflicted injury to oral tissues, and allergy to local anesthetic.

Nerve damage during injection may result in permanent anesthesia or prolonged paresthesias. The rate of permanent anesthesia following inferior alveolar and/or lingual nerve block varies from a high of 1 in 20,000 blocks to a low of 1 in 850,000 blocks.^{27,28} Nerve damage has been noted with every type of local anesthetic used in dentistry. Recent controversy over the use of articaine (septocaine) has promoted research to determine whether a higher incidence of permanent anesthesia or paresthesia is associated with this drug. Pogrel et al. found that lidocaine was associated with 35% of permanent nerve blocks, whereas articaine was associated with 30% of cases. Contrary to this study, Hass and Lennon found a five-fold increase in paresthesia when articaine was used over lidocaine.²⁹

Injection into a highly vascular area may result in vascular damage and hemorrhage with hematoma formation. This is most commonly found with the PSA nerve block. Hematoma formation can also occur with an inferior alveolar nerve block if the needle is directed too high.³⁰ Injection into a vein will result in delayed bleeding with minimal damage. Injection into an artery, however, will produce rapid bleeding with

direct hematoma formation and extensive intraoral and extraoral swelling.

Misdirection too posteriorly on insertion of the needle during an inferior alveolar nerve block may result in accidental injection into the parotid gland. The facial nerve, cranial nerve VII, which controls the muscles of facial expression, is embedded in the parotid gland. Anesthesia of the facial nerve will result in a Bell's palsy. The patient will complain of the inability to close the eye on the affected side in addition to paralysis of the muscles of facial expression. The operator should assure the patient that muscle control will resume on dissipation of the anesthetic. Also, an eye patch may be provided to prevent ocular dryness because the inability to blink will result in continuous tearing.

Accidental intravascular injection may result in little or no anesthetic effect. If a vasoconstrictor is present in the anesthetic solution, this may cause tachycardia. Intravenous or intra-arterial injections can occur with any nerve block but are most likely to occur with the inferior alveolar, mental, or posterior superior alveolar nerve block.³¹ Injection without aspiration may also lead to systemic local anesthetic toxicity.

Accidental intramuscular injection into the medial pterygoid and temporalis muscles is common when attempting the inferior alveolar nerve block. Accidental injection into muscle may cause anesthetic failure because the muscle will act as a barrier and increase the distance of diffusion to the target nerve. Trismus or spasm of the jaw muscles is likely to occur as a delayed reaction to muscle injury. The patient will complain of pain on opening and limited range of opening. Anti-inflammatory medications may be prescribed to alleviate pain, and stretching exercises may be of benefit. The patient is assured that this will pass as the muscles come out of spasm and relax over time.

It is common for the patient to experience anesthesia far beyond the time necessary to complete the planned dental procedure. All patients, specifically pediatric patients, are warned against eating on the affected side and consuming hot foods or beverages because self-inflicted traumatic injuries or burns may result. These injuries often occur without awareness to the patient.

Allergy to local anesthetic is known to be extremely rare with true immunological reactions representing only 1% of adverse reactions to local anesthetic.³² If a true allergic reaction to local anesthetic is suspected, timely referral to an allergy specialist is needed. A thorough history and samples of potential allergens are to be sent with the patient.³³

SEDATION AND ANXIETY CONTROL IN DENTISTRY

While local anesthetics are the foundation for pain control in dentistry, the anxious and fearful patient may need additional medications or sedation for a nontraumatic dental experience. Control of the anxious patient not only increases patient acceptance of procedures but also allows the dentist to operate in a more safe and timely manner. Dentists most commonly use oral medications for mild anxiolysis. Moderate sedation,

inhalation sedation with nitrous oxide, and deep and general anesthesia are also employed but require additional training and monitoring.

Oral benzodiazepines are commonly used for mild to moderate anxiolysis. Generally, the patient is prescribed two dosages for the dental procedure. One dosage is taken 1 hour before bedtime on the night prior to the procedure to ensure a good night's sleep. The other tablet is taken 1 hour before the appointment. Patients are prohibited from bringing themselves to or taking themselves home from appointments. Alprazolam, lorazepam, diazepam, and triazolam are popular choices. Prescription of these medications is often a guess because the effective dosage for each patient is unknown and variable. These medications also have long latent periods, unreliable absorption, and can have a prolonged duration of action. Titration of triazolam with appropriate monitoring of vital signs has become a popular method for providing adequate sedation. With in-office titration, the practitioner must be cautious not to cross the line between mild/moderate sedation and deep sedation/general anesthesia. Because triazolam has the additional side effect of anterograde amnesia, the patient may not remember much of the dental visit.

Inhalation anesthesia is most commonly achieved with a maximum titration ratio of 70:30 nitrous oxide to oxygen. Advantages of this method are the ability for reliable titration, rapid adjustment of the depth of sedation, and quick recovery. The most significant disadvantage is that nitrous oxide may not be as potent as the other sedative medications. While oral sedation and nitrous oxide may be administered by the operating dentist, intravenous sedation is more commonly administered by an in-office dental anesthesiologist.

Intravenous sedation is achieved almost entirely by a combination of five drugs, which fall into three categories. Diazepam and midazolam are benzodiazepines that are commonly used. Pentobarbital is a popular barbiturate that is used, while morphine and meperidine are frequently used opioid analgesics. Intravenous sedation is often the most predictable method for most patients because medications can be titrated to effective blood levels with appropriate monitoring. General anesthesia is most always unnecessary for basic in-office dental procedures. Clearly the risks far outweigh the benefits. Complicated oral and maxillofacial procedures, full-mouth reconstruction, and periodic care for medically compromised patients or patients with severe disabilities may be performed under general anesthesia in a hospital operating room setting.

CONCLUSION

Administration of anesthesia is appropriate in almost all dental procedures. Elimination of pain during the procedure will help allay patient fear and anxiety and will facilitate patient cooperation while promoting better compliance with future appointments and oral health maintenance. Knowledge of appropriate anesthetic agents and traditional and alternative techniques will help ensure adequate anesthesia. Management of complications

related to anesthesia and the ability to reduce anxiety and provide sedation for patients will allow for more comfortable, predictable, and efficient procedures.

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32 Ultra-Rapid Opiate Detoxification

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Drug abuse is at epidemic proportions throughout the United States, with an estimated total economic cost of nearly \$378 billion. The illegal use of opiates, especially prescription drugs, is on the rise in the United States. In recent years, opiate-induced deaths have increased in particular because of more potent drugs and easier accessibility. The continuing rise in abuse of opiates has placed greater emphasis on detoxification treatment modalities. Use of prescription pain relievers with or without a doctor's prescription or only for the experience or feeling they cause ("nonmedical" use) is, after marijuana use, the second most common form of illicit drug use in the United States.¹ When used appropriately under medical supervision, hydrocodone (e.g., Vicodin), oxycodone (e.g., OxyContin), morphine, and similar prescription pain relievers provide indispensable medical benefit by reducing pain and suffering, but when taken without appropriate direction and oversight, these medications can cause serious adverse consequences and produce dependence and abuse. Approximately 324,000 emergency department visits in 2006 involved the nonmedical use of pain relievers (including both prescription and over-the-counter pain medications).²

When individuals wish to detoxify from opiate dependence, several options are available, including both conventional and newer, more rapid approaches.

CONVENTIONAL DETOXIFICATION

Conventional treatments for opiate abuse include several treatment models, all of which have extremely low success rates. Methadone administration involves substitution of a legally accepted opiate for one that is being illegally abused. Methadone is a full opioid agonist at μ -receptor sites. Thus, one negative aspect of methadone is its potential to produce or maintain dependence on opioids, such that patients experience withdrawal if a daily dose is missed, and detoxification can be a lengthy and difficult process, discouraging all attempts.³ Additionally, because of its full agonist action, there is no ceiling to the level of respiratory depression or sedation that methadone can induce. Methadone overdose can therefore be fatal. Despite its many advantages (legality and cheap availability), methadone maintenance appears to have limited suitability for some patients, including time constraints and continued need for medication and dependence.

These factors may restrict the ability of methadone to attract certain users into treatment, and the examination of alternative medications to broaden the range of pharmacotherapies has been the focus of research in recent years.

Buprenorphine is a partial agonist and exerts weaker opioid effects at opioid receptor sites. Buprenorphine and methadone maintenance were compared in a series of impressive studies using fixed doses of the drugs.³ Results were mixed. Some of the fixed dose studies showed no difference in efficacy, whereas others showed superiority for methadone and yet others showed the reverse. The investigators in these fixed dose studies frequently concluded that the doses of buprenorphine or methadone chosen were too low or that poor induction regimes led to poor retention. A series of variable (or flexible) dose studies have been conducted and shown essentially the same results for the two drugs, failing to identify a clearly superior agent.

RAPID OPIATE DETOXIFICATION

Rapid opiate detoxification is a 3-day process involving large amounts of an opiate antagonist, such as naloxone or naltrexone.^{4,5} However, there are problems associated with all of these treatments. While methadone treatment has high initial relapse rates, rapid opiate detoxification elicits severe withdrawal symptoms.

ULTRA-RAPID OPIATE DETOXIFICATION

Ultra-rapid opiate detoxification (UROD) entails anesthetizing a patient and precipitating withdrawal during unconsciousness.⁶ The procedure, accompanied by appropriate aggressive therapy, shortens the withdrawal period experienced by opiate-dependent patients and diminishes much of the subjective discomfort. One advantage of UROD is that the withdrawal period is markedly shortened to about 4–8 hours versus up to several months for conventional treatments. The patient is anesthetized during the acute withdrawal period and thus does not experience the unpleasant consequences of acute detoxification.

Withdrawal syndrome refers to a constellation of symptoms, including restlessness, rhinorrhea, lacrimation, diaphoresis,

myosis, piloerection, and cardiovascular changes due to increased catecholamine release. The catecholamine surge caused by induction of the withdrawal syndrome in UROD has life-threatening implications. Clonidine, an α_2 receptor agonist, reduces these catecholamine surges.^{7,8} This drug reduces the severity of the withdrawal syndrome in rats; however, controversy remains *in vivo* as to the precise role and effects of clonidine in UROD, perhaps due in part to individual effects of chronic opiate administration⁷⁻¹⁰

THE ALTERED NEUROPHYSIOLOGY OF OPIATE DEPENDENCY

Exogenous administration of opioids in humans reduces the production and release of endogenous opioid substances. Used regularly over a period of months or longer, opioids cause physical dependence and neural adaptation by interaction with central nervous system and systemic opioid receptors. Paradoxically, the treatment of opioid dependence can be carried out with opioid receptor agonists, partial agonists, and antagonists. Methadone is an opioid agonist that meets the needs of opioid-dependent neurons. Methadone has a long half-life and thus occupies receptors longer than agents with shorter half-lives. Partial agonists, such as buprenorphine, may treat opioid dependency by not inducing a full clinical effect when binding to the opioid receptor. Naltrexone, an orally administered opioid antagonist, blocks the opioid receptor and blunts opioid cravings and euphoria. Neural adaptation of the central nervous system due to exogenous opioids may be reversed with naltrexone or other antagonists.¹¹

ANCILLARY AGENTS AND AVAILABLE TREATMENTS

A variety of methods have been utilized for the treatment of opioid withdrawal before patients begin long-term opioid-free and naltrexone programs. Most widely accepted is a slow, supervised detoxification process in which methadone is substituted for the abused opiate, as mentioned earlier. Methadone maintenance therapy merely replaces an opioid having a short half-life with another that has a longer half-life of approximately 23 hours. This substitution can stabilize general and psychological health, and social functioning. Once a patient is on a methadone maintenance program, the drug is slowly tapered, to minimize withdrawal and potential complications. Substitution therapy with methadone has a high initial dropout rate (30%–90%) and an early relapse rate.¹²⁻¹⁴ Alternative pharmacological detoxification programs include the use of clonidine with or without methadone, midazolam, trazadone, or buprenorphine.^{15,16} For those patients who elect to undergo UROD for methadone, a 2-week period of oral hydromorphone with discontinuation of methadone followed by UROD has been completely successful and safe. Placing an individual on methadone under a classic UROD technique of 4–8 hours alone would be illogical in as much as it takes 5–6 half-lives for a drug to be effectively eliminated from the body (e.g., 5–9 days).

Opioid antagonists, such as naloxone, naltrexone, or nalmefene, accelerate the process of detoxification. These substances bind the opioid receptor and block these sites from interacting with the agonists. Once opiate antagonism is established, introduction of an opiate has no effect.¹⁷

A rapid detoxification protocol allows a faster introduction of opioid antagonist maintenance therapy with a subsequent reduction in relapse rates.¹⁸ The acute short-lasting opioid withdrawal syndrome can be more severe than that associated with a more conventional withdrawal. These symptoms are very rarely life threatening but are sufficiently adverse and act as a major deterrent to opioid-dependent patients who want to lose dependency.¹⁹ To mitigate these symptoms, outpatient programs have used α_2 agonists (clonidine, dexmedetomidine), partial agonists (buprenorphine), benzodiazepines (diazepam, midazolam), and antidepressants (trazadone) to assist during detoxification. The process takes place over a week, and patients are then converted to the use of a maintenance antagonist.²⁰

Symptoms associated with the withdrawal syndrome, such as restlessness, rhinorrhea, lacrimation, diaphoresis, myosis, piloerection, and cardiovascular changes, are mediated through increased sympathetic activity. Thirty-fold increases in the levels of epinephrine and lesser increases in norepinephrine can be observed during withdrawal from opioids.²¹ During opioid withdrawal, neural activity in the locus ceruleus, the major noradrenergic nucleus in the brain, is greatly increased. This surge is responsible for many of the symptoms seen during withdrawal.^{22,23} Clonidine has been shown effective in suppressing noradrenergic hyperactivity, relieving withdrawal symptoms.²⁴ Without clonidine or an equivalent α_2 -agonist agent, UROD would cause large increases in both total and fractionated catecholamine levels, which have the potential to cause unacceptable morbidity and mortality rates.

INDICATIONS FOR DETOXIFICATION

The only indication for detoxification is a proven dependence on opiates demonstrated by sufficient history and by blood, urine, or hair testing. To avoid a Munchausen syndrome, or Munchausen by proxy, positive tests should be documented prior to scheduling the procedure. Drug testing is also useful to identify other drugs that the patient may be using and to evaluate the credibility of the patient (e.g., when supplemental information from friends or relatives indicates that the patient has neglected to inform the physician of cocaine or amphetamine abuse).

In chronic pain patients, detoxification may be indicated when pain medication use escalates without improving Visual Analog Pain Scales or when the patient is having difficulty in weaning off medication. Detoxification may be offered as a safe alternative to complete dismissal from the practice.

CONTRAINDICATIONS

Several situations may exist when UROD is not indicated as the detoxification method of choice. For example, pregnancy, acute hepatitis (greater than five times control values for AST

and GGT), acute cocaine ingestion, psychosis, lack of informed consent, myocardial infarction within 6 months, and cerebrovascular accident within 2 months are all conditions that constitute at least relative contraindications. If a chronic pain patient wishes to detoxify and become free from dependence on narcotics, then there must be documented pain-free intervals or, again, the procedure is contraindicated. Detoxification of a pain patient who has no pain-free intervals results in a patient in excruciating pain where the only relief mechanism is through nerve block or neurolysis.

Because several of the medications used in the detoxification process may prolong the QTc interval, patients with preexisting prolonged QT syndrome or other conduction abnormality may be at increased risk of developing the Torsade de pointes syndrome and sudden death.

PSYCHIATRIC CLEARANCE

Psychiatric evaluation is an important prerequisite prior to detoxification. The patient must freely express a desire to become detoxified. There must be no evidence of suicidal or homicidal ideation. All other psychiatric illness must be well defined and, in the opinion of the psychiatrist, under good control. Aftercare plans should also be in place before embarking in any detoxification attempt.

It is important that there is a clearly delineated aftercare plan that has been verified in writing. The importance for the patient and the anesthesiologist of outlining a workable post-procedure plan that can be enforced both on the part of the patient and the medical care team and becomes reality cannot be overemphasized.

PREANESTHETIC TESTING

The key issues in preanesthetic preparation are to identify end-organ damage caused by substance abuse. While routine testing may well exclude electrocardiography in a young individual, cocaine abuse can cause myocardial fibrosis and is therefore an appropriate screen with the realization that abnormal findings may be apparent for months after cessation of drug intake. It is, however, important to obtain results of this test as baseline information. Opiate use within 36 hours of the procedure is a contraindication to UROD due to the high level of circulating catecholamines that are stimulated by the detoxification process itself. A well-publicized death in a private hospital in England of a patient undergoing UROD may have been related more to a last minute "fix" of heroin rather than to negligent treatment.^{25,26}

Heroin abuse by the intravenous route is plagued by cross-contamination with other viruses such as HIV, HBV, and HCV, as well as bacteria. Evaluation of liver function and careful cardiac examination are necessary to rule out acute hepatitis and bacterial endocarditis. Tuberculosis is also very common among intravenous drug abusers and chest X-ray is indicated.

Routine screening exams such as complete blood count and electrolytes are often helpful in evaluation. The finding

of a low white cell count without a prior history of HIV infection requires further investigation, or a patient with elevated blood urea nitrogen (BUN) and creatinine levels may have renal damage from heroin nephropathy. Excretion of anesthetic drugs may be impaired, and the dosage should be adjusted accordingly.

THE METHODOLOGY OF ULTRA-RAPID OPIATE DETOXIFICATION

As noted earlier, the process is designed to detoxify an individual while maintaining cardiovascular stability, a lack of awareness, and analgesia. A review of 20 patients undergoing UROD during general anesthesia detailed successful management.²⁷

Premedication

High-dose clonidine blockade is incrementally introduced to attenuate the systemic effects of withdrawal.²⁴ This can start the night before the procedure with the application of a transdermal patch of clonidine or by oral dosing. The goal is to reduce the blood pressure to the lower limit of normal. Vitamin C can be utilized, typically in a dose of 1–2 grams, to acidify the urine and accelerate opiate elimination from the body. A suppository the night before will reduce the likelihood of diarrhea intraoperatively and postoperatively. Antiemetic medications and sedatives can also be administered. Glycopyrrolate may be added at a dose of 0.2–0.4 mg. Adequate fluid replacement is essential and should exceed the calculated maintenance by 3–4 times until the deficit is replaced.

Monitoring

Appropriate monitoring includes at a minimum 5-lead, 2 channel electrocardiography (leads II and V), noninvasive blood pressure, pulse oximetry, neuromuscular blockade, capnography, temperature, and a brain wave monitor to titrate depth of anesthesia. There are currently over a dozen brands of these monitors available throughout the United States. The safest location to perform ultra-rapid detoxification is an intensive care unit, although it has been utilized in a variety of settings, including the operating room, the recovery room, and lesser level units. Post procedure, patients in an intensive care unit setting, in general, receive the best nursing and superior levels of monitoring, and this location should be considered a prime choice.

Induction and Maintenance

All narcotics decrease gastric emptying and increase gut transit time. Residual volumes of 300 cc to 500 cc are not uncommon. Thus, rapid sequence induction with cricoid pressure is indicated. Anesthesia may be induced with propofol (2–3 mg/kg) and succinylcholine or rocuronium. After confirmation of endotracheal tube placement by capnography and auscultation, an orogastric tube is passed to empty the stomach.

Metoclopramide should not be used, because its effects are antagonized by narcotics; moreover, it is associated with hypertension due to catecholamine release. General anesthesia may be continued with a combination of midazolam, sevoflurane, and isoflurane or propofol infusion, titrated to full general anesthetic depth, for example, a bispectral index (BIS) value between 40 and 60. Indeed, any technique that does not involve drugs to which the patient is addicted is acceptable. Spontaneous ventilation may be used as part of the determination as to when the patient has completed detoxification. Upon initial administration of the antagonist, minute ventilation usually doubles. The initial peak minute ventilation is recorded. When the minute ventilation declines to 80% of the peak value, detoxification is usually completed. As with any other anesthetic procedure, monitoring and documentation must be continued for the duration of the process, which is usually 4–6 hours. A procedure is deemed complete when no signs of withdrawal are seen following a final injection of naloxone 0.4 mg intravenously.

Choice of the Antagonist

After hemodynamic stability has been established, a test dose of the antagonist is given (e.g., naloxone 0.4 mg) to determine the degree of hemodynamic stability that has been achieved. Signs of withdrawal such as piloerection, yawning, kicking movements, tearing, hypertension, or tachycardia developing over a 5-minute period indicate the need for deeper anesthesia and additional clonidine.

Any antagonist, such as naloxone (typically up to 20 mg), naltrexone (up to 50 mg), or nalmeferme (up to 8 mg) can be used for detoxification. All antagonists have a very high binding coefficient as compared to the agonists, for example, naltrexone binds 34 times more than morphine.

Some questions have arisen regarding the risk of pulmonary edema using naloxone in opiate-dependent patients. The presumed cause of the edema is an adrenergic crisis with a massive surge in catecholamines, an effect elegantly documented in a study by Kienbaum et al.²⁸ In the presence of clonidine, however, there is no surge in catecholamine plasma levels and no significant cardiovascular changes.²⁹

POSTOPERATIVE PROBLEMS

Part of the definition of an addictive substance is the presence of a withdrawal syndrome when the substance is abruptly discontinued. Related to opioids, the syndrome consists of drug cravings, piloerection, yawning, sympathetic hyperactivity (tachycardia, diaphoresis), myalgias and bone pain, nausea, vomiting and diarrhea, and insomnia. A syndrome of “protracted abstinence” is also described that occurs after 3 weeks and lasts until around week 10, which is characterized by restlessness, irritability, insomnia, and hypertension. After detoxification, attention is turned to each component as it occurs.

Naltrexone reduces the feelings of craving. The neuropharmacology is unclear, but reproducibility is marked and

suggests that long-term therapy is indicated. It should be noted that with long-term naltrexone therapy, liver function tests need to be monitored.

In general, the patient should be kept warm and be allowed frequent warm soaking showers. Clonidine reduces sympathetic hyperactivity and should be continued through the protracted abstinence syndrome.

Irritability may be managed with psychotherapy, benzodiazepines (in small amounts), and antidepressants such as trazadone or paroxetine.

Immediately following detoxification, patients feel exhausted and extremely weak. They typically describe flu-like symptoms. Other complications related mainly to the gastrointestinal tract follow quickly and may last for days. Slight variations in hemodynamic status or other signs of withdrawal may be treated with small amounts of adjunct medications such as midazolam, ketorolac, or clonidine. Oral naltrexone maintenance may be started as soon as the patient is awake and tolerating fluids, although administration may be delayed because of vomiting. Additional methods of enforced abstinence are discussed later in this chapter.

Procedure-Related Emesis

Emesis is a prominent component of the withdrawal syndrome. The use of prophylactic antiemetic agents such as ondansetron and ranitidine is necessary. In fact, chemotherapy-level prophylaxis is required to prevent intraoperative emesis. Ondansetron is superior in this application since ranitidine in higher doses may be associated with tachycardia, vomiting, insomnia, and elevation of liver enzymes. It should be noted that while the presence of the endotracheal tube prevents large pieces of food from entering the trachea, intubation is not a guarantee against aspiration.

Procedure-Related Diarrhea

Diarrhea should be treated with octreotide, a synthetic polypeptide related to somatostatin. It acts by inhibiting some anterior pituitary hormones, suppressing the exocrine and endocrine functions of the pancreas, inhibiting gastric acid and vasointestinal peptide secretion, suppressing serotonin secretion, and inhibiting gastrointestinal motility. This last function is the most useful in treating the explosive diarrhea that occurs during withdrawal.³⁰

Narcotic-based remedies including loperamide should be avoided since there is some uptake into the systemic circulation that may increase the signs of withdrawal. Systemic absorption is small but significant and may produce unwanted central nervous system side effects.

Insomnia

The number-one reason for failure of detoxification in the first 2 weeks post procedure is insomnia. Narcotics disrupt the normal sleep–wake cycle,³¹ and many addicts require narcotics to sleep. The long-term disruption of normal sleep–wake

cycle cannot be corrected rapidly. Melatonin levels and the normal circadian rhythm typically take at least a week to become re-established. Gabapentin has been utilized for its dual effect of sedation as well restoring psychological balance.³²

Orally administered melatonin (3 mg) can help as can benzodiazepines and antihistamines (diphenhydramine). Hypnosis and alternative relaxation techniques can also be used. Self-hypnosis can be taught fairly easily to addicts.

It is important, however, not to start prescribing large amounts of benzodiazepines, since these drugs also have addictive potential and do not lead to a restorative sleep pattern. As part of the preprocedure informed consent, the patient must be made aware of the potential for insomnia.

Other Complications

Muscle cramps, bone pain, and low back pain complaints are treated with nonsteroidal anti-inflammatory drugs (NSAIDs) or a cyclooxygenase 2 inhibitor, which has few or no gastrointestinal side effects and does not interfere with coagulation. Many patients describe wide swings of mood, including depression and agitation. It is important to discuss with the therapist this potential issue. Many protocols include starting an antidepressant for 1–3 months post detoxification procedure. Positioning during general anesthesia can become an issue. It is strongly suggested that an egg crate mattress be utilized and positioning be evaluated at regular intervals, much as in the case of a lengthy operating procedure under a general anesthetic.

ENFORCED ABSTINENCE

Since most relapses occur within the first 2 weeks, removing the patient's ability to choose opiate abuse for several weeks increases the success rate as defined as abstinence for 1 year. Subcutaneous pellets of naltrexone, injectable depot naltrexone, and injections of nalmefene have all been used to this end.

Naltrexone pellets are custom formulated and placed subcutaneously through a small incision.³³ Depending on the formulation and the content of pellets placed, significant plasma levels of naltrexone have been demonstrated for up to 6 months.

In a 3.4 g sustained-release naltrexone preparation produced by GoMedical Industries (Perth, Western Australia), the period of significant plasma antagonist levels were documented to extend to approximately 188 days (plasma levels greater than 2 ng/ml). At least two opiate-dependent addicts tried to overcome the blockade during this period and experienced no effect.

Similar success with naltrexone pellets has been reported by Foster et al.³⁴ and by Carreno et al.³⁵ They studied patients for several months post implant and found no relapse. However, Hamilton et al. reported six cases in 2002 where complications arose from this technique, including prolonged opioid withdrawal, drug toxicity, withdrawal from cross-addiction to benzodiazepines and alcohol, aspiration pneumonia, and death.³⁶

Injectable depot naltrexone (Vivitrol, Cephalon) was originally developed to provide abstinence in alcohol abuse. As an off-label use, a single monthly injection provides opiate blockade for a month.

The U.S. Food and Drug Administration (FDA) recently warned of the risk of adverse injection site reactions in patients receiving naltrexone (Vivitrol).³⁷ "Physicians should instruct patients to monitor the injection site and contact them if they develop pain, swelling, tenderness, induration, bruising, pruritus, or redness at the injection site that does not improve or worsens within two weeks. Physicians should promptly refer patients with worsening injection site reactions to a surgeon." The FDA has received 196 reports of injection site reactions, including cellulitis, induration, hematoma, abscess, sterile abscess, and necrosis. Sixteen patients required surgical intervention ranging from incision and drainage in the cases of abscesses to extensive surgical debridement in cases that resulted in tissue necrosis.

Injectable depot naltrexone should be administered as an intramuscular (IM) gluteal injection and not intravenously, subcutaneously, or inadvertently into fatty tissue. Health care providers should ensure that the naltrexone injection is given correctly with the prepackaged 1½-inch needle that is specifically designed for this drug.

Similarly, Nalmefene administered intramuscularly at a dose of 8 mg provides antagonist blockade for a week. However, its use in this manner has only been reported anecdotally.

DOES ULTRA-RAPID DETOXIFICATION HAVE A FUTURE?

Ultra-rapid detoxification is a controversial procedure with many prominent addictionologists in opposition. Unfortunately, they do not have a successful substitute. While buprenorphine has some utility in changing patients from pure agonist addiction, achieving complete detoxification does not occur in a majority of cases.³⁸

Collins et al. presented a randomized trial of UROD compared to two other conventional detoxification techniques in heroin addicts.³⁹ They studied a total of 106 treatment-seeking heroin-dependent patients, aged 21 through 50 years, who were randomly assigned to 1 of 3 inpatient withdrawal treatments (anesthesia-assisted rapid opioid detoxification with naltrexone induction, buprenorphine-assisted rapid opioid detoxification with naltrexone induction, and clonidine-assisted opioid detoxification with delayed naltrexone induction) over 72 hours followed by 12 weeks of outpatient naltrexone maintenance with relapse prevention psychotherapy. Patients were included if the American Society of Anesthesiologists physical status score was I or II, there were no major comorbid psychiatric illness, and they were not dependent on other drugs or alcohol. The main outcome measures studied were withdrawal severity scores on objective and subjective scales, proportions of patients receiving naltrexone, completion of inpatient detoxification, and retention in treatment and the proportion of opioid-positive urine specimens. The authors found that mean

withdrawal severities were comparable across the three treatments. Compared with clonidine-assisted detoxification, the anesthesia- and buprenorphine-assisted detoxification interventions had significantly greater rates of naltrexone induction (94% anesthesia, 97% buprenorphine, and 21% clonidine), but the groups did not differ in rates of completion of inpatient detoxification. Treatment retention over 12 weeks was not significantly different among groups with 7 of 35 (20%) retained in the anesthesia-assisted group, 9 of 37 (24%) in the buprenorphine-assisted group, and 3 of 34 (9%) in the clonidine-assisted group. Induction with 50 mg of naltrexone significantly reduced the risk of dropping out (odds ratio, 0.28; 95% confidence interval, 0.15–0.51). There were no significant group differences in proportions of opioid-positive urine specimens. The anesthesia procedure was associated with three potentially life-threatening adverse events. The authors concluded that “these data do not support the use of general anesthesia for heroin detoxification and rapid opioid antagonist induction.”

There are several major flaws in this article. For example, there was a failure to pretreat with high-dose antiemetics and high-dose clonidine. By using the antiemetic only as a rescue dose, the objective withdrawal scales were falsely elevated. Similarly, failure to provide adequate high doses of clonidine led to high objective and subjective withdrawal scales. There was also a failure to treat opiate-dependent patients as at risk for aspiration, which apparently resulted in pneumonia in one patient and diabetic ketoacidosis in another. Even though 80% of patients were lost to follow-up, statistical analysis was still performed. However, if just three more anesthesia patients had completed the trial, statistical significance would have been achieved. The other major issue to bear in mind was that this study was conducted in heroin addicts and not in pain patients.

CONCLUSION

The utility of UROD rests in the ability to detoxify a patient comfortably and using enforced abstinence techniques to assure sobriety for an extended period of time. The procedure requires a motivated patient with a psychosocial support structure in place. It is not a cure for addiction; however, with the extremely low success rate of conventional treatments for opiate addiction, it is an important therapeutic technique and an important tool for detoxification in selected patients.

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33 | Telemedicine, Teleanesthesia, and Telesurgery

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This chapter is intended as an overview for the anesthesiologist or administrator who is asking the following questions:

- What changes should we expect from the acceptance of telemedicine practice and technologies in the 2010 Healthcare Bill?
- Should I consider using telemedicine in my healthcare system?
- Can I use aspects of telemedicine in my outside-of-operating-room sites?
- Are there any dangers?
- What are the advantages?
- If I want to enter the field, what are the implied and/or expected infrastructure costs at both ends?

INTRODUCTION

Telemedicine is the result of an information technology revolution, which is producing major changes in medical practice. Many images are now presented in digital format: including computed tomography (CT) scans, ultrasound scans, magnetic resonance imaging (MRI), endoscopy, and also vital sign wave forms. All these images require highly trained individuals to obtain maximum benefit (information extraction) from this content. For example, graphs of somatosensory evoked potentials (SSEPs) are relatively easy to generate, but the interpretation of “spinal cord being intact, or not” is not that easy, and a “super-specialized” expert is needed for interpretation.

Digital images can be reproduced and presented anywhere in the world in “real time,” and support can be provided. Remote assistance (e.g., via telesurgery under teleanesthesia) can help the physician to “dissolve time and space”.²

Many areas of telehealth (in the broadest sense of the word) have very successfully enabled not only physician-to-physician consultations, but also patient assessment and treatment. Whereas the early emphasis in telemedicine was to provide advanced health care where it was not available (e.g., military

and disaster scenarios), it is now utilized when cost constraints are insurmountable. For instance, telemedicine can mean less travel and cost for the patient, reduced need for extra staff and resources at smaller hospitals, and improved mobility and “efficiency of health care workers who can essentially move from patient to patient and “see” the next patient with the switch of a button.

This chapter encompasses the following:

- The definition and scope of tele-healthcare (telemedicine in its broadest sense)
- Major recent advances in the field of telemedicine (medical practice and systems technologies)
- State of the art of telemedicine, telesurgery and teleanesthesia
 - Discussion of future plans for reimbursement of telemedicine by Medicare and Medicaid and the ramifications for technological development in this arena. Implications of health care reform for telemedicine
 - New directions in anesthesiology practice based on the usage of telemedicine technologies

DEFINITIONS AND TERMINOLOGY

In this chapter, we will use the term “telemedicine” to describe the entire range of tele-healthcare. Therefore, we will use this term to include distinct disciplines such as telesurgery, teleanesthesia, tele-internal-medicine, *tele-any-discipline*.

Definitions

For the U.S. Congress, the term *telemedicine* means:

a telecommunications link to an end user through the use of eligible equipment that electronically links health professionals or patients and health professionals at separate sites in order to exchange health care information in audio, video, graphic, or other format for the purpose of providing improved health care services.

This is most likely the definition that will prevail and become the standard definition after the approval of the 2010 Healthcare Bill.

Historically, there are hundreds of definitions of teleanesthesia as found in academic literature. For instance, Sood et al. presented a compilation of 104 perspectives on definitions.¹ Each telemedicine publication and each organization tried to provide its own definition. It is actually quite complex to produce a comprehensive definition of telemedicine, as any definition will have to encompass at least the three basic elements as outlined by the *Index Medicus* definitions in Table 33.1, which includes health occupation aspects, information technology principles, as well as aspects of the delivery of health care.

Since 1992, telemedicine has been included in MEDLINE's MeSH (Medical Subject Headings) under three separate sections (see Table 33.1):

- i. Health occupations
- ii. Information science and telecommunications
- iii. Delivery of health care

While telepathology and teleradiology are still the only disciplines that have been included in the *Index Medicus* listings, it is to be expected that multiple other disciplines will soon be listed (e.g., teleanesthesia, teledermatology, telesurgery, and even subspecialties such as teleurology).

The definitions of the other disciplines will most likely be based upon, and follow the structure of these two similar definitions as outlined in *Index Medicus*:

Teleradiology: The electronic transmission of radiological images from one location to another for the purposes of interpretation and/or consultation. Users in different locations may simultaneously view images with greater access to secondary consultations and improved continuing education.

Telepathology: Transmission and interpretation of tissue specimens via remote telecommunication, generally for the purpose of diagnosis or consultation, but it may also be used for continuing education.

As intimated in both the above definitions and the drafts of the 2010 Healthcare Bill, it appears that telemedicine will have a major effect on medical education, and medical education will benefit greatly from the telemedicine developments. Expensive simulation laboratories at large universities and institutions can provide robotic simulated patients for rural health care workers to practice common procedures (e.g., advanced cardiac life support [ACLS] and basic life support [BLS]) as well as uncommon crises (e.g., malignant hyperthermia.) With such a system, the trainees do not know whether they are working on real patients, images of real patients, or physiology generated by simulated patients. Therefore, an *Index Medicus* term for medical education using telemedicine principles and infrastructure will be needed, as this real-time interactive training (using physiologically modeled patients) is totally different from "distance education."

TABLE 33.1 *Index Medicus outline*

All MeSH Categories
Disciplines and Occupations Category
Health Occupations
Medicine
Telemedicine
Telepathology
Teleradiology
All MeSH Categories
Information Science Category
Information Science
Communications Media
Telecommunications
Telemedicine
Remote Consultation
Telepathology
Teleradiology
All MeSH Categories
Health Care Category
Health Services Administration
Patient Care Management
Delivery of Health Care
Telemedicine
Remote Consultation
Telepathology
Teleradiology
Previous Indexing:
<ul style="list-style-type: none"> • Telecommunications (1976–1992)
See also:
<ul style="list-style-type: none"> • Telemetry

Terminology

Many of the terms and definitions related to telemedicine might be unfamiliar. We have therefore provided Table 33.2 with the terminology and examples as used in telemedicine.

Lessons from Practicing Telemedicine Physicians

Technology-enabled delivery of health care at a distance utilizing telemedicine, telehealth, telepresence, telecare, e-health, decision support systems,³ and a myriad of other described information technologies has been slow to diffuse into American health care,⁴ despite many examples of improved efficiency, enhanced clinical care, and user satisfaction. Previous telehealth initiatives have provided lessons learned at various levels in industry, regulatory bodies, health care organizations, provider groups, and patient experiences that

TABLE 33.2. *Explanation of Terminology of Telemedicine, with Examples*

	<i>Examples</i>	<i>Pros</i>	<i>Cons</i>	<i>Anesthesia Considerations</i>
Decision support systems	Drug interaction alerts Clinical guideline alignment	Decrease practice variation	Validated Systems not well developed or widely available	TIVA Pharmacodynamics Automated preop triage Ventilator management Closed loop systems
Networks/multipoint collaboration	Electronic ICU Acute stroke management	VTC widely available and acceptable Coordinated information system integration	Expensive, complex, infrastructure sustainment	Anesthesia surgery preop Conferences Multipoint outpatient monitoring
POTS (plain old telephone service)	Home care monitoring	Familiar, acceptable, and available, low cost	No integrated documentation. Slow data transmission	Patient follow-up interviews
Store and forward Asynchronous	International consultation Austere environments Dermatology Radiology Pathology	Flexible scheduling Time zone independent	No interactive queries No real-time data	Preoperative evaluation Data and questionnaire information
Synchronous Audio/video/other	Critical care Surgical mentoring Mental health Neurosurgery Preoperative evaluation	Interactive queries Continuous monitoring	Scheduling Enhanced privacy considerations	Preoperative assessment Remote monitoring OR/Non-OR Postoperative care
Robotics/haptics	Surgery Rehabilitation Pharmacy	Remote procedures	Incompletely developed	Medication administration

ICU, intensive care unit; OR, operating room; TIVA, total intravenous anesthesia; VTC, video-tele-conferencing.

can guide the analysis and implementation of effective processes in health care. In the quest to improve the efficiency of medical care, leveraging technology to address specific identified “choke points” in the delivery of care remains the cornerstone of successful initiatives. It is essential that those telehealth initiatives should articulate clear and measurable objectives with explicit value-added solutions. Organizational and practitioner factors that have a determinant effect on, and predict successful program implementation, include (1) technology, (2) acceptance, (3) financing, (4) organization, and (5) policy and legislation.⁵ A rich body of literature exists regarding the implementation, value propositions, and practical operation of telehealth solutions, across disciplines as diverse as radiology, dermatology, critical care, stroke management, cardiology, prehospital care, mental health, and postoperative care. Practitioner acceptance has been extensively analyzed⁶, and several essential factors emerge as predictors of successful implementation of enduring telehealth strategies.

APPROACHES TO TELEHEALTH SOLUTIONS¹

Alignment of available technology with a specific identified need requires knowledge of available core technologies and telehealth implementation strategies. “Best fit” technology solution frameworks consider available methods and workflow models, including asynchronous/store and forward; synchronous audio/video/data streams; decision support systems; robotics; multipoint versus point-to-point; and others. Frequently, hybrid solutions are best matched to identified needs and capabilities (see Table 33.2).

One compilation of reported successful telemedicine programs identified the characteristics of sustainable programs⁷;

¹ A further excellent source for information is: Missouri TeleHealth Network and TeleMedicine Society Site index: http://telehealth.muhealth.org/site_index.html
Lessons learned: http://telehealth.muhealth.org/evaluation/eval_lessons.html
Publications: http://telehealth.muhealth.org/evaluation/eval_publications.html

- 1) Local service delivery problems have been clearly stated.
- 2) Telemedicine has been seen as a benefit.
- 3) Telemedicine has been seen as a solution to political and medical issues.
- 4) There was collaboration between promoters and users.
- 5) Issues regarding organizational and technological arrangements have been addressed.
- 6) The future operation of the service has been considered.

PRACTICAL CONSIDERATIONS FOR TELEMEDICINE PRACTITIONERS

Health care providers who utilize technology solutions, including telemedicine, have well-defined acceptance behaviors.⁸ System characteristics that are associated with provider acceptance of newly introduced technology are not surprising. Flexibility and usability, education and training, and goodness of fit between the technology and the clinical workflow and resources are key elements for user acceptance. Technology acceptance is a function of alignment with traditional practice workflow, evidence regarding benefits of information technology (IT), organizational support, and system-specific issues such as usability of computer interfaces. Design and introduction of telemedicine practice must carefully consider these factors. Doctors are hesitant to adopt technologies that impose changes in usual practice patterns during implementation, as evidenced by the experience with electronic medical records. The requirement of additional time needed to perform the task with the new technology is a major barrier to physician technology acceptance.¹⁰

Patient acceptance of integrated telemedicine delivery of services cannot be overlooked. Patients are in fact very willing to accept care delivered by remotely located practitioners when there are savings in time, travel, and improved access to specialty services.

Remote delivery of anesthesia services has not been well studied and has proliferated to a lesser degree than other disciplines. However, a number of practical elements learned in telehealth solutions for acute care can be considered for application in teleanesthesia care delivery.

Physician Factors

- Provide technical personnel to support physician's seamless use of audio, video, and computer interfaces. This usually requires a dedicated technology facilitator who participates in the episode of care. Such technology facilitators are most effective if they have medical training. Anesthesia technicians, emergency medical technicians (EMTs), respiratory therapy technicians, nurses, and other specialists are often highly effective in these roles. These workers are the glue that holds together all telemedicine programs. Bootstrap programs that rely on enthusiastic motivated individual champion physicians for program management and facilitation provide

the spark for, but seldom sustain, successful telemedicine operations.

- Scheduling and coordination of time-efficient telemedicine interactions are one key to physician acceptance and effectiveness. Optimal program performance requires advanced coordination at both the provider and patient terminus of the telemedicine care system.

- Workflow changes must be minimized, and simply locating any telemedicine interface (e.g., telemedicine suite, telemedicine computer, telemedicine video-telephone-conferencing [VTC], etc.) in a location that assures easy access and rapid return to usual care activities is essential. One strategy is to co-locate telemedicine interfaces in familiar work areas such as the postanesthesia care unit (PACU), operating room, or preoperative clinic.

- Telecare requires collaboration between interdisciplinary providers at two or more geographically distinct locations. A fundamental principle of effective collaboration is that of trust and knowledge of mutual capabilities. Collaboration across telehealth interfaces removes interpersonal elements that can facilitate trust and can have an adverse effect on effective collaboration. Periodic face-to-face meetings with collaborating providers and telehealth system personnel are essential for ongoing program review, performance improvement, and maintenance of trust relationships necessary for successful delivery of telecare. Shared health care information systems data (laboratory results, radiology, records) enhance collaborative outcomes.

- Scripted protocols for the delivery of care facilitate effective and efficient telecare. Whether providing routine scheduled comprehensive care (e.g., preoperative evaluation or outpatient endoscopy monitoring) or emergency consultative care (e.g., critical care consultation, remote trauma care), protocol-based communication tools are essential.

- Physician documentation of remotely delivered care is structured to reflect the nature, limitations, and advantages of the remote care episode.

Patient Factors

- Telecare is presented to patients as a mode of care that is a fully integrated element of total care. Consent to participate is requested by some organizations, but many telecare providers simply provide descriptive information to patients regarding the delivery of specific telehealth services. Some telehealth initiatives such as home monitoring require patients to interact directly with the technology. Careful consideration of simplicity, comprehensive support, and user training is required for these systems to provide effective care.

Skeptics frequently ask the following type of question: "How can you possibly provide good care when you cannot examine the patient?"

An appropriate answer follows: A majority of health care delivery and decision making requires cognitive and interpersonal skills, relying on history and data analysis. Specialty-specific decision making depends on specialty-specific knowledge. Physical examination is but one element of data

gathering, which in most instances can be gathered by an on-site provider, and in some circumstances can be conducted remotely. Use of a stethoscope, observation of respiratory patterns, gait, neurologic function, and many other examination elements can be conducted remotely, using simple tools. Diagnostic monitoring devices can transmit EKG, cardiac rhythm, vital signs, and a variety of other physiologic signals. For example, entirely adequate assessment of Mallampati classification can be directly obtained using simple telemedicine tools. Performance of procedures is developing as an element of telecare (e.g., robotic surgery), although it still remains nascent. Telementoring of procedures is well established, and it can safely expand the scope of less experienced and remotely located providers. Telepresence of remotely located practitioners is frequently incorporated in remote specialist consultation services.

In conclusion, telemedicine as a tool for telecare is effective when the tool is optimally matched to the need, when the tool is fully supported by a robust infrastructure envelope, and when providers are an integral element of the implementation of new telemedicine processes.

Current State of the Art: Clinical Aspects

Since antiquity, physicians and clinician practitioners have always asked for help from one another. Initially, help was garnered by visiting, personal communication, and/or writing letters. As hospitals developed and medical practitioners were gathered at one site, help and professional discussions became more immediate. For instance, this included asking each other questions, having discussions, and asking for input/help in the hallway, the coffee lounge, and so on. As technology advanced, the use of a telephone for questions became ubiquitous. As medical knowledge expanded, it became necessary to develop specialization, with the need for even more referrals and communication. However, this occurred in an asynchronous mode, meaning that the referring physician was not “present” when the specialist saw the patient. With the use of physician extenders, especially in underpopulated areas, where a full complement of medical services is not viable, it is becoming necessary to have the local health care worker “see” the patient at the same time as the remote (referred to) physician. Such a consultation is where telemedicine is coming into its own. As video capture technology has become increasingly available, cheaper, robust, and with increased definition, off-line (asynchronous) technology is being replaced with video-conferencing.

Radiology and pathology have been performing telemedicine because the tasks performed by these specialists were mainly asynchronous. These tasks were accepted as valid by being described in *Index Medicus* in 1992. As the technology has improved, it is now possible to perform virtually synchronous consultations, as the huge digital files involved can be sent rapidly over the Internet.

On a purely technical and instrumentation level, the telephone has been used for many years to send interactive electronic signals, such as remote checking of an electronic heart pacemaker. Telemetry (wireless monitoring of vital signs at a

distance) has been used for ambulatory patients in a hospital setting (e.g., monitoring for arrhythmias in patients after a myocardial infarction), as well as for monitoring patients during transport to a critical care center (e.g., in an ambulance or a helicopter). Telemetry, while still used in its own right, is now also considered to be a subset of the infrastructure of telemedicine.

From this history, it can be seen that telemedicine has been quite successfully employed in a variety of ways. Telemedicine is becoming increasingly acceptable, not only to health care workers but also to the general public. This acceptance has also been approved by politicians. In 2009 there were 24 separate telemedicine bills introduced in the U.S. Senate and House of Representatives. Most of those bills have been included in the final versions of House and Senate bills. At the time of this writing, it is unclear which version will prevail, but since the two bills make references to similar definitions and programs, it is very likely that the most inclusive text will be used. If the 2010 Healthcare Reform Bill passes, the covered population will increase by a couple of millions and in effect will create a shortage of practitioners that is expected to be mitigated by improvements in processes and more efficient delivery of medical care. The legislators expect that telehealth solutions will become an enabler factor in the success of U.S. health care.

TELEANESTHESIA

The first use of the word *teleanesthesia* in the *title* of a publication that we could find was in a book chapter by Murray and Vaduva¹² in 1997 entitled “Telemedicine, Telesurgery and Teleanesthesia.” The first use of the word *teleanesthesia* in an *abstract* listed under the peer-reviewed articles in *Index Medicus* (www.PubMed.org), was an article by Sloan in 1967 with the title “An Improved Tele-thermometer.”¹⁴

Several articles since then have described successful uses of various forms of teleanesthesia. For instance, Cone et al. demonstrated the ability to direct an anesthetic in a remote location using satellite communication. Remote critical care services have developed as a widely utilized care model to overcome specialist shortages and enhance clinical and financial outcomes.¹⁵ Systems have been utilized over vast time zone and geographic distances¹⁶ and are widely used in regional health care systems.^{24,25}

The process surrounding the actual anesthetic in the operating room is really quite complex. There are many steps (pre- and postoperatively) that need to be completed with high levels of accuracy and reliability. Duplicating and re-engineering all these steps for the use with telemedicine principles is even more challenging and complex. However, as the U.S. Congress expects (Table 33.3), having all the steps “computerized” may actually increase safety because all steps are in one place, and it is clear which steps are missing (i.e., which steps have not yet been performed).

— Not all steps of the anesthesia process need necessarily to be performed as “teleanesthesia.”

TABLE 33.3. *Examples of Advantages of Telemedicine as Described in the Legislation HR 2068 Related to Remote Patient Management Services (“Telemedicine”)*

Points 1 and 2:

More effective and efficient care and management

- Refers to chronic diseases (which are the most costly)
- Care and management made more effective and efficient
- Because more consistent and real time fashion
- Because clinical health care information more available

Points 3 and 4:

Minimizes travel and other advantages

- Improves quality of care because it “removes barriers of transport” (rural)
- Reduces needs for visits—office, ED, hospitalizations (latter = costly)
- Reduces need for face-to-face interactions
- Results in less missed work

Point 5:

Reduces costly hospitalizations (this point is not often considered)

- Health care provider has prompt (timely) clinical data
- More timely/appropriate therapeutic interventions
- Specifically mentioned are congestive heart failure, diabetes, cardiac arrhythmias, epilepsy, sleep apnea (diabetes and sleep apnea are associated with obesity)

— Only selected steps (pre- and/or postoperatively) might be used in the telemedicine format.

— For instance, the preoperative visit and evaluation¹¹ and postoperative follow-up could be quite safely performed using telemedicine principles with great potential cost and time savings for the patients and their families, for the physicians, and the health care system.

— It is quite feasible to combine telemedicine aspects with standard “physician present in the OR” types of anesthesia (especially pre- and postoperative evaluation and follow-up are “ripe” for this methodology).

Much of the anesthesia process (preoperative work-up/visit and examination, consent, postoperative follow-up, etc.) can be performed using *standard, existing* telemedicine infrastructure and principles.

Therefore, for our discussion on teleanesthesia, we will focus more on the future, that is, on the actual administration and control of the anesthetic agents, monitoring, and depth of anesthesia.

While we are aware of research projects involving automated robotic placement of the intravenous cannula, and robots following infrared heat and carbon dioxide signals to place an endotracheal tube, for the foreseeable future, we envision a trained human (“helper”) performing these tasks (most likely under telesupervision of a physician at the controlling base).

Administration of intravenous agents could be accomplished by one or more of several options:

— A trained human locally at the patient’s bedside (self-directed, under supervision, and/or guided by a remote supervisor)

— A digital syringe or infusion pump, controlled directly by local personnel, or controlled remotely by the main-base physician/advisor

— Target controlled infusion (TCI) for anesthesia. The digital infusion device runs a pharmacokinetic model and aims to maintain a constant plasma (“blood”) concentration of the anesthetic agent(s).

— Close-loop feedback systems. Physiological parameters from the patient, with a fuzzy logic control system, determine the infusion rate(s).

For the pharmacokinetic, model-driven administration schemes, the models will run locally, as well as in the form of a backup, at the supervisory/home base. Should communication be temporarily lost, the two models on the two computers will resynchronize.

α. Monitoring: Present-day *physiological monitors* mostly handle the data internally as digital data, and the data are presented to the anesthesia personnel in a variety of formats. It is already feasible to present all this data at a distance (anywhere in the world), in near-real time. Some *clinical* monitoring signs and symptoms (e.g., signs of shock: cold, clammy, sweaty extremities with poor peripheral perfusion in fingers, etc.) can be provided by additional monitors, for example, peripheral to central temperature gradient, skin resistance/impedance monitors (also called “lie detectors”) to measure “sweatiness,” amplitude of pulsatile oxygen saturation monitors (SPO₂) in the fingers and toes, and so on.¹³ However, there are as yet no monitors to replace the overall impression of an experienced clinician (“the patient looks gravely ill”), and a high definition overall visual image of the patient would still be useful when needed.

β. Depth of anesthesia: Processed electroencephalogram (EEG) signals would be advisable to monitor the depth of anesthesia. However, such monitoring requires an electrically “clean” environment to reliably and accurately collect and interpret the ± 1 microvolt signals of the raw EEG. In rural areas, the electrical supply might fluctuate and not be sufficiently stable to provide stable signals. Stray currents will tend to “swamp” the low-voltage EEG signal and render the processing algorithms useless. Therefore, backup *clinical* monitoring should be available. For instance, some clinical signs of light anesthesia such as sweating and forehead frowning (“frowning”) can be addressed by the telemedicine techniques outlined above, for example, high-definition continuous video stream.

In conclusion, all the essential ingredients for teleanesthesia already exist. However, they need to be combined in a usable and robust configuration. In the meantime, aspects of teleanesthesia such as preoperative evaluation are expected to be the first subsets to become widely used as they will save

cost and time. Teleanesthesia is eminently available to support other aspects of telemedicine such as pain therapy and telesurgery. Teleanesthesia will develop hand in hand with, and fulfill the needs of, telesurgery because the patient has to remain motionless for the surgery to proceed expeditiously.

TELESURGERY

The modern era of telesurgery was made possible when endoscopic (“laparoscopic”) surgery systems were transformed from analog signals to being digitally based.

— With early analog devices, the surgeon (“proceduralist”) had to view the image through a single eyepiece—only one person at a time could see the image

— With digital images, the images were displayed on a monitor (or “digital computer screen”). It was an easy further step to duplicate the image on a screen next door, or the local lecture hall for teaching purposes, or with development of the Internet, on a screen anywhere in the world and telementoring became possible.

— With the advent of reliable networks and robotic devices, the distant surgeon could not only advise and tutor but could also actively *participate*; that is, the actions (movements) of the distant surgeon could be faithfully replicated by the robotic device at the patient’s side.

— Examples of telerobotic surgery and telesurgery include the following:

— Dr. Rick Satava strongly promoted the concept of telesurgery. In 1994 he enabled remote telementoring for laparoscopic urological surgery.¹⁷ At the Association of the United States Army AUSA meeting in Washington, DC, during October 1995, he followed up with another telesurgery project. As a proof of principle, a cholecystectomy was performed in an animal preparation using remote robotic techniques incorporating a fully wired system (solid wire).

— Cheah et al. described the first two international telesurgical, telementored, robot-assisted laparoscopic cholecystectomies performed in the world, between the Johns Hopkins Institute, Baltimore, Maryland, and the National University Hospital, Singapore.¹⁸

— In an article under the title “Hands across the Ocean for World’s First Trans-Atlantic Surgery” Kent described Dr. Gagner as the surgeon who performed a cholecystectomy from New York, New York, on a patient in Strasbourg, France, in 2001.¹⁹ Marescaux et al. give more details about the technology.²⁰

— Dr. Tim Broderick, in 2005, performed the first mobile telesurgery (also a cholecystectomy) in the United States. The surgeon was in Ohio while the patient was in California.²¹

Following the success of the performance of a transatlantic surgery (cholecystectomy), the leader of the team, Jacques Marescaux, said the operation ushered in “... the third revolution we’ve seen in the field of surgery in the past 10 years... It lays the foundations for the globalization of surgical procedures,

making it possible to imagine that a surgeon could perform an operation on a patient anywhere in the world...”²⁰

While telesurgery has advanced even past the proof-of-principle stage, there are still several challenges remaining that need to be addressed before telesurgery becomes fully established. One of the surprising limitations is actually the speed of light, which is also the speed of electrons on the Internet. This limitation of the speed of an electrical signal causes a significant delay in the “sense of touch,” or haptics, when manipulating a remote object. Some characteristics of haptics are as follows:

1. Haptics, as generated by a force feedback device, ideally should be rendered at 1 millisecond intervals (1000 Hz). The average human can readily compensate for a delay of up to 25 milliseconds. Thereafter, it becomes difficult to perform any complex manual task requiring a fine sense of touch. This is in contrast to the eye that can compensate for delays of up to 125 milliseconds (e.g., the old 8 mm movies ran at 8–15 frames per second). They were a bit jerky, but the eye compensated quite well. This is where the speed of light becomes a limitation over longer distances (e.g., New York to San Francisco). Furthermore, the information technology infrastructure has a switching overhead, which causes further delays. Anvari found that surgeons, with practice, could compensate (albeit with a slower performance) for a delay of up to 500 milliseconds, but the error rate increased with greater delays in the feedback speed.²²

2. Therefore, it is to be expected that surgeries with mainly visual inputs (e.g., with minimal haptic requirements) would be the first operations to be tested and performed (e.g., the cholecystectomy performed from New York to France).¹⁹

3. Another limitation is financial: the capital investment for the initial setup is quite large. Therefore, telesurgery is expected to be used only where the new technology will save money, thus providing a positive net present value (NPV) at an acceptable return on investment (ROI).

4. Robotics and telesurgery have much in common; in both cases the operator is working with an image. The operator might be in the same room, might be in the room next door, or might be miles away. In some definitions, “robotic surgery” is equated with “telesurgery”—the operator is removed from the patient (i.e., not touching the patient but connected to the patient only by information technology infrastructure and wires).

Of note is that these haptic characteristics and limitations also apply to manual tasks performed under the rubric of teleanesthesia, such as insertion of intravenous lines and tracheal intubation.

State of the Art: Technology Aspects

Telemedicine is already happening today. In the last several years, the information technology industry has improved, having now well-defined roles of service providers. This enables the society to rely more and more on geographically distributed mission-critical applications. Data warehouses,

with direct connection to the Internet backbone, have proliferated and become ubiquitous; new data compression protocols make possible transmissions of live audio and video broadcasts; and Internet connections are stable, enabling the delivery of reliable services anywhere in the world. Due to the proliferation of high-speed Internet connections close to the point of service, in the office or at home, it is currently possible to have live video conferences across the globe. What is even more remarkable, the Internet penetrated rapidly into the third-world countries, making it possible to deliver medical care to any remote location from sites with advanced medical expertise, technology, and available qualified personnel.

Although the required technology is currently available, the telehealth industry is still only at the brink of widespread adoption. We will attempt to familiarize the medical practitioner interested in this field with the basic requirements of a telehealth system.

TESTING RELIABILITY OF TELEHEALTH SYSTEMS

What we take for granted in a face-to-face doctor-patient relationship turns out to require a complex set of checks and balances in telemedicine. A telemedicine system must be “robust,” with each individual subsystem functioning well. Overall, the system must function properly and should have the ability for self-recovery from exceptional behaviors.

The success of the Internet is mostly based on the fact that regardless of the application, the entire technology that makes the Internet possible is completely transparent and requires no care, input, or even understanding at the user level. The telemedicine practitioners will have to rely on products supported by engineers specializing in testing and maintaining the reliability of the several Internet layers. With the help of those experts (e.g., network administrators), and product services like firewalls, antivirus tools, routers, and so on, we have already come to rely on the Internet as a viable and ubiquitous tool.

Yet, as we add telemedicine applications on top of this infrastructure, we need to develop testing equipment and methodologies that will ensure safe usage of the entire system. In this process there is a need for development of software models to describe the functionality of subsets of the system. Those models will allow the testers to modify parameters that will influence the output of the model, so it behaves as the “real thing.” When all the models are combined, the entire system could be tested by varying individual parameters or set points to simulate a desired or undesired behavior for the entire system. Only after those models and subsequent simulators are in place, can we develop methodologies of testing the entire system *before* delivering tele-healthcare to humans.

Depending on the complexity of the telemedicine application, those models, simulators, and testing methodologies will require various complexity levels. The medical practitioners will have to familiarize themselves with the entire system and with methods of testing its functionality.

ETHICAL IMPLICATIONS

An individual rendering medical aid to a needy person is required to stay at the scene until more advanced medical assistance is needed, a rescuer of equal or higher ability takes over, or it is unsafe to continue to give aid. The rules governing those requirements are covered in Good Samaritan laws in countries using an English common law system and duty-to-rescue laws in countries using a civil law system. According to those legal principles, there is a requirement to render medical care until the transfer of responsibility is possible.

In the context of telemedicine, the transfer of responsibility during medical aid is done from the local technician to the remote practitioner, or one remote practitioner to another remote practitioner. Historically, this transfer between caregivers is done routinely and seamlessly. Therefore, not much attention is given to this process. Yet, while providing medical care using telemedicine, technical problems may arise that in turn could create legal implications. Due to Internet infrastructure design, the physical channel may not be available at all times; thus, there are moments during transitions from one channel to another when it is not possible to know if a successful transfer has been made or if the current channel is reliable.

A further point to consider is that the doctor-patient trust relationship is affected. While working with geographically scattered teams during the performance of medical care, using telemedicine technologies, the role of the primary care physician (PCP) is altered. From the patient’s perspective, does it need to be an implicit trust from the patient to the “team,” or does the trust stay with a single responsible person? Since the physical channel can never be guaranteed to be 100% reliable, should the PCP be at the patient’s side? If this is the case, is it then implied that a lesser qualified individual will be in charge during the procedure? Implicit in this question, does the patient need to trust the system? If the patient does need to trust a *technological system*, how could or should this trust be established? While there have been some publications on the ethics of telemedicine,² these are questions that will have to be addressed in more depth as telemedicine advances.

Business Model Implications

Any time a new technology is adopted there is an effect on the way that business is conducted. The penetration of telemedicine technologies in the medical care field is expected to affect the current practices and standard operating procedures. The next five sections of this chapter are aimed at familiarizing medical practitioners and administrators interested in the value of this field with the basic implications arising from the use of a telehealth system.²³

² Telesurgery: an ethical appraisal—van Wynsberghe and Gastmans: “... telesurgery will become available to the rest of industrialized society as a treatment option...” Available at: <http://jme.bmj.com/cgi/content/full/34/10/e22>. Accessed on September 23, 2009.

Market Size and Segmentation

Telemedicine, telesurgery, and teleanesthesia are quite acceptable to most patients as *last resort* options for delivering medical care. For instance, when asked, patients prefer to interact with a human rather than with technology. Yet if the question is rephrased in terms of an option of last resort, they always say, "Yes, I will accept remote medical care, if I have no other options, especially if it is about a life and death crisis event." Because of the special situations where telemedicine is a surrogate to face-to-face medical care, an investor who wants to enter this market will want to know how many such systems are needed (market size), what medical situations will require this technology (market segments), where are those systems going to be installed (geographical distribution), and what kind of benefit would those systems bring to the health care industry.

Estimate the Gap between the Availability of Medical Care in Rural and Metropolitan Areas. The first market segment that comes to mind revolves around geographical distribution of patients and doctors. Although the balance of supply and demand of medical care works in all markets, the high costs related to hospitals create an imperfect geographical distribution of medical centers, with more centers in densely populated areas and fewer in rural areas. The higher the cost of equipment and facilities, the lower the chance that specialized medical care would be available to lesser populated zones. Telemedicine has the potential of leveling the gap in the availability of medical care between rural areas and metropolitan areas on two dimensions: distance to state-of-the-art facilities practically vanishes, and the concentration of medical practitioners becomes less acute when using telemedicine techniques.

Although the lower population concentration in rural areas does not justify the capital investment for state-of-the-art facilities and human expertise, due to large numbers of U.S. voters residing in the rural areas, there will be a continued political pressure to invest in the required IT infrastructure to facilitate telehealth care. This point is confirmed by the legislative efforts in the proposed 2010 Healthcare Bill regarding telemedicine networks in medically underserved areas to address health disparities.

Absorb Peak Load during Critical Events. The second market segment that will benefit from telemedicine is related to the capacity of current hospitals and their ability to absorb peak load during critical events. The examples go from accidents involving a large number of people (e.g., train wrecks), to natural disasters (e.g., earthquakes, pandemics, hurricanes, tsunamis), to human-made-disasters (e.g., biological disasters from industrial accidents), high casualty warfare, and limited availability of specialists.

Although not common, such disasters require that current health care facilities have available, at any moment, a certain spare capacity that can absorb the spike in demand for short periods of time. Due to the "golden hour rule," this

capacity must be available for triage and first response medical care.

Unfortunately, with the continuous pressure imposed on the hospitals to cut costs to survive financially, there is a tendency to reduce the spare capacity to a minimum. The presence of telehealth technologies at the emergency facilities could reduce the need of maintaining a large spare capacity, thus reducing the costs of operation for those hospitals. The legislative efforts in the proposed 2010 Healthcare Bill will award grants for projects that will create telehealth networks to link rural hospitals', health care providers to other hospitals', providers and patients for the purpose of eliminating shortage of health professionals in geographically underserved areas.

Costs for Personnel Overtime Payments. The third market segment that will benefit from the spread of telemedicine is related to the medical facilities that incur high costs for personnel overtime payments. Due to the ability of telemedicine technologies to traverse time zones, there is a new opportunity for health care facilities to balance shift loads and costs by using medical personnel from different time zones in such way that evening and night shifts will be staffed by medical personnel working in daytime shifts. This segment addresses only economic issues, and its outcome is in contradiction with the desire of patients to be treated by a human at the "bedside." We foresee that the pressure from the medical industry will be very high to overcome the desire of patients and unless ethical, safety, and legal aspects are opposing it, the practice of outsourcing to different time zones during highly paid shifts will follow the pattern of radiology personnel reading X-rays. The legislative efforts in the proposed 2010 Healthcare Bill will create community-based collaborative care networks that will operate as a consortium of health care providers with a joint governance structure to expand capacity and after-hours availability of services and ensure delivery of urgent care.

Personnel Cover for Scarce Super-Specialization Cases. The fourth market segment is represented by lack of super-specialized personnel. Not all hospitals have the patient volume to support the appointment of sufficient personnel to be available around the clock for cases that may occur only occasionally (e.g., neuromonitoring). The legislative efforts in the 2010 Healthcare Bill are addressing the need for continuing education to reduce professional isolation of health care professionals in underserved communities by enabling the development of infrastructure for collaborative conferences.

Market Penetration

As of today, telemedicine is used by a small group of "early adopters." In general, those individuals are motivated by the need to differentiate themselves from the rest of the society, are open to adaptation, and are not sensitive to high price costs. They have access to technology infrastructure,

are technically savvy, and will build a career based on their pioneering advantage. Early adopters of telemedicine technologies will enjoy a competitive advantage in their medical field stemming from expertise and a higher market share acquired in early periods. The next wave of adopters is defined as “early majority,” and they will start using telemedicine when current obstacles such as unclear legislation, reimbursement, medical coding, and so on will be resolved either by government-mandated legislation or court case clarifications. The legislative efforts in the 2010 Healthcare Bill will accelerate the penetration of telemedicine infrastructure. We predict that in the next few years there will be a “gold rush” in the medical device industry that will attempt to capture a larger share of the market and establish a de facto standard for a particular technology.

Conclusion

The IT support personnel provide services that include around-the-clock (“24/7”) support, almost 100% uptime, direct access to the Internet’s backbone with consequently very fast communication speeds at higher bandwidth, and very good data security. The latter includes controlled physical access to the servers, data protection, backups, antivirus software, firewalls, and so on. Delivery of data streams for video and audio channels is a norm, with insignificant transmission lag. We all use web-based conferences with full duplex (“live” and bidirectional) sound and video images across continents. This technology and infrastructure are eminently capable of fully supporting telemedicine.

At the time of this writing, Internet “net neutrality” was established as a principle by the federal administration. As a result, the Federal Communications Commission will take further actions to formalize rules and add new mandates that will keep online traffic moving freely in an egalitarian fashion. A consequence of this decision is that the general Internet will treat all participants equally, and it will not be able to differentiate and support the very high bandwidth required for telemedicine over regular Internet channels. For this reason, we envision that the businesses providing telemedicine applications will have to lease or own dedicated physical lines to provide the necessary high bandwidth. Early attempts to establish such dedicated networks are signaled by business initiatives like the new legislative framework for net neutrality proposed by Google and Verizon in August 2010.

In summary, after selecting appropriate technology, telemedicine will be successful, if its implementation follows a few important pointers:

Similar to the general principle of computerizing any process, it is important that telemedicine services be integrated into the way the local organization performs its tasks. It must be easier to perform the tasks with the new technology; otherwise it will not be accepted. Existing tasks and procedures (scheduling, billing, medical record keeping, preparation for patient encounters, etc.) should be seamlessly integrated into the telemedicine system.

The telemedicine system should not be forced upon either the distant site or the local site. Cooperative relationships with providers, administrators, and clinical staff should be developed at both ends.

Highly skilled staff (“technology facilitators”) should be immediately available to support the telemedicine infrastructure at both ends. Reliability is absolutely critical—the Internet connection must always be up. Ease of use is critical: there must be a seamless infrastructure. Testing must involve not only clinical testing but also engineering testing of the system and the infrastructure.

In the final instance, physicians and other health care workers, adapt well to telehealth technologies that help them do their job more efficiently. From the clinician’s point of view, when telehealth is just as easy as providing in-person care, the telemedicine technology will be able to fulfill its great promise.

TELEMEDICINE IN THE PROPOSED 2010 HEALTH CARE BILL

During the last few years we observed a large legislative effort that mentioned telemedicine. At the time of this writing in January 2010, the legislative effort to introduce a Healthcare Reform Act has two bills passed by the U.S. Senate and House of Representatives. We predict that the final bill will contain the most inclusive text of the two bills. In the remaining part of this chapter, we will review the most relevant proposals regarding telemedicine and will attempt to capture the sense of Congress in the House Bill H.R. 3962 and Senate Bill H.R. 3590.

In the H.R. 3962 bill, the House proposes the appointment of a Telehealth Advisory Committee comprising five practicing physicians, two non-physicians, and two administrators of TeleHealth programs.

Reimbursement

The House opens the possibility of reimbursement for practitioners engaging in delivery of medical care using telemedicine infrastructures, by allowing agencies that provide off-site interpretation to directly bill Medicare for the services provided and by including the use of telehealth in defining the face-to-face encounter with a patient. In the H.R. 3590 bill the Senate takes a similar approach when defining the wellness and prevention services, which are “*coordinated, maintained or delivered by a health care provider, a wellness and prevention plan manager, or a health, wellness or prevention services organization that conducts health risk assessments or offers ongoing face-to-face, telephonic or web-based intervention efforts for each of the program’s participants.*”

Encourage Participation

To encourage the cooperation of providers, the Senate creates a Shared Savings Program that promotes accountability and encourages investment in infrastructure and redesigned care

processes for high-quality and efficient service delivery. Under this program, groups of providers of services and suppliers may work together to manage and coordinate care for Medicare fee-for-service beneficiaries through an accountable care organization (ACO) and will be eligible to receive payments for shared savings. "The ACO shall define processes to promote evidence-based medicine and patient engagement, report on quality and cost measures, and coordinate care, such as through the use of telehealth, remote patient monitoring, and other such enabling technologies."

Pilot Programs

Both Senate and House bills take a cautious position on adoption of telehealth solutions by creating test sites and models to identify successful solutions. The Senate proposes the creation of a Center for Medicare and Medicaid Innovation with the purpose of testing innovative payment and service delivery models addressing populations with deficits in care leading to poor clinical outcomes, as well as for the purpose of reducing expenditures while preserving or enhancing quality of care. A potential opportunity is identified as "*supporting care coordination for chronically-ill applicable individuals at high risk of hospitalization through a health information technology-enabled provider network that includes care coordinators, a chronic disease registry, and home telehealth technology.*"

Continuing Education

In its bill, the Senate creates a program to support the continuing education needs for health professionals in underserved communities by making available grants to improve health care, increase retention, increase representation of minority faculty members, enhance the practice environment, and provide information dissemination and educational support to reduce professional isolation through the timely dissemination of research findings using relevant resources through distance learning, continuing educational activities, collaborative conferences, and electronic and telelearning activities.

Collaboration

Both Senate and House bills grant funds to community-based collaborative care networks to expand the capacity to provide care at any participating provider through the use of telemedicine technologies to provide access to after-hours services, on weekends, or as an urgent care alternative to an emergency department.

Future Changes in the Practice of Anesthesiology

The acceptance of telecommunication technologies as a vehicle to link health professionals and patients at separate geographical sites for the purpose of providing health care services is going to change the playing ground for all health care providers.

Anesthesiology as a medical specialty will be affected, too. The introduction of telemedicine technologies, combined with the possibility of obtaining reimbursement for services rendered to patients outside of the hospital settings, will increase the "size of the pie" for anesthesia personnel. In some areas, anesthesiologists are ready to start providing telehealth right now without a need of big changes, yet in other areas such as using teleanesthesia to assist telesurgery it will take more time to develop reliable technologies, business procedures, and practices that will enable such interventions.

The current legislative efforts for health care reform are driven to a large extent by rapidly escalating costs, which are to a large degree the result of an aging population and increased chronic disease management costs. In the mind of the legislators, chronic disease is a focus area because of its immense social and economic effect and will be increasingly targeted for funding. We see this as an easy-to-penetrate field where anesthesiologists can expand rapidly by providing pain management, anesthesia, analgesia and sedation through telemedicine infrastructures. In the near future, anesthesiologists will be involved in prescribing home health pain control services and durable medical equipment such as remotely operated infusion pumps. This will increase the opportunities for anesthesiologists to participate in care of patients in geographically remote and rural locations by supervising the delivery of drugs and conducting required medication reviews without the need for an expensive office visit. The promotion of telenursing initiatives in health care reform legislation could provide opportunities for physician extenders, such as advanced practice nurses and certified registered nurse anesthetists (CRNAs) to support physician outreach through telemedicine. This will have immediate application in perioperative areas such as pre- and postoperative evaluations, and other areas such as chronic pain management and medication reconciliation.

The 2010 Healthcare Bill can provide the required legal framework and open the possibilities for funding pilot programs that will fulfill the great promise of telemedicine and teleanesthesia. It is up to hospital managers, department chairs, and anesthesiologists to seize the moment and develop new health care models, procedures, and technologies. Teleanesthesia is an area where many successful careers will be made, and we are looking forward in the next few years to see an explosion of academic articles in this field.

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Appendix 1 | Preuse Checking of Anesthesia Equipment

A. Y. KUMAR, MD

A major contributory cause of anesthesia misadventure has been the use of anesthesia machines and/or breathing systems that have not been adequately checked by an anesthesiologist before use. The following is the U.S. Food and Drug Administration (FDA) recommended preuse checkout procedure.

ANESTHESIA APPARATUS CHECKOUT RECOMMENDATIONS, ROCKVILLE, MD: U.S. FOOD AND DRUG ADMINISTRATION; 1993

This checkout, or a reasonable equivalent, should be conducted before the administration of anesthesia. These recommendations are only valid for an anesthesia system that conforms to current and relevant standards and includes an ascending bellows ventilator and at least the following monitors: capnograph, pulse oximeter, oxygen analyzer, respiratory volume monitor (spirometer), and breathing system pressure monitor with high- and low-pressure alarms. This is a guideline that users are encouraged to modify to accommodate differences in equipment design and variations in local clinical practice. Such local modifications should undergo appropriate peer review. Users should refer to the operator's manual for the manufacturer's specific procedures and precautions, especially the manufacturer's low-pressure leak test (step 5).

EMERGENCY VENTILATION EQUIPMENT

*1. Verify that backup ventilation equipment is available and functioning.

HIGH-PRESSURE SYSTEM

- *2. Check oxygen cylinder supply.
 - a. Open O₂ cylinder and verify at least half full (about 1000 psi).
 - b. Close cylinder.
- *3. Check central pipeline supplies.
 - a. Check that hoses are connected and pipeline gauges read about 50 psi.

LOW-PRESSURE SYSTEM

- *4. Check initial status of low-pressure system.
 - a. Close flow control valves and turn vaporizers off.
 - b. Check fill level and tighten vaporizer's filler caps.
- *5. Perform leak check of machine low-pressure system.
 - a. Verify that the machine master switch and flow control valves are OFF.
 - b. Attach "suction bulb" to common (fresh) gas outlet.
 - c. Squeeze bulb repeatedly until fully collapsed.
 - d. Verify bulb stays fully collapsed for at least 10 seconds.
 - e. Open one vaporizer at a time and repeat "c" and "d" as above.
 - f. Remove suction bulb, and reconnect fresh gas hose.
- *6. Turn on machine master switch and all other necessary equipment.
- *7. Test flowmeters
 - a. Adjust flow of all gases through their full range, checking for smooth operation of floats and undamaged flowtubes.
 - b. Attempt to create a hypoxic O₂/N₂O mixture and verify correct changes in flow and/or alarm.

SCAVENGING SYSTEM

- *8. Adjust and check scavenging system.
 - a. Ensure proper connections between the scavenging system and both APL (pop-off) valve and ventilator relief valve.
 - b. Adjust waste gas vacuum (if possible).
 - c. Fully open APL valve and occlude Y-piece.
 - d. With minimum O₂ flow, allow scavenger reservoir bag to collapse completely, and verify that absorber pressure gauge reads about zero.
 - e. With the O₂ flush activated, allow the scavenger reservoir bag to distend fully, and then verify that absorber pressure gauge reads <10 cm H₂O.

BREATHING SYSTEM

- *9. Calibrate O₂ monitor.
 - a. Ensure monitor reads 21% in room air.
 - b. Verify low O₂ alarm is enabled and functioning.
 - c. Reinstall sensor in circuit and flush breathing system with O₂.
 - d. Verify that monitor now reads greater than 90%.
- 10. Check initial status of breathing system.
 - a. Set selector switch to “bag” mode.
 - b. Check that breathing circuit is complete, undamaged, and unobstructed.
 - c. Verify that CO₂ absorbent is adequate.
 - d. Install breathing circuit accessory equipment (e.g., humidifier, PEEP valve) to be used during the case.
- 11. Perform leak check of the breathing system.
 - a. Set all gas flows to zero (or minimum).
 - b. Close APL (pop-off) valve and occlude Y-piece.
 - c. Pressurize breathing system to about 30 cm H₂O with O₂ flush.
 - d. Ensure that pressure remains fixed for at least 10 seconds.
 - e. Open APL (pop-off) valve and ensure that pressure decreases.

MANUAL AND AUTOMATIC VENTILATION SYSTEMS

- *12. Test ventilation systems and unidirectional valves.
 - a. Place a second breathing bag on Y-piece.
 - b. Set appropriate ventilator parameters for next patient.
 - c. Switch to automatic ventilation (Ventilator) mode.
 - d. Fill bellows and breathing bag with O₂ flush and then turn ventilator ON.
 - e. Set O₂ flow to minimum, other gas flows to zero.
 - f. Verify that during inspiration bellows delivers appropriate tidal volume and that during expiration bellows fills completely.
 - g. Set fresh gas flow to about 5 l/min.
 - h. Verify that the ventilator bellows and simulated lungs fill and empty appropriately without sustained pressure at end expiration.
 - i. Check for proper action of unidirectional valves.
 - j. Exercise breathing circuit accessories to ensure proper function.
 - k. Turn ventilator OFF and switch to manual ventilation (Bag/APL) mode.
 - l. Ventilate manually and assure inflation and deflation of artificial lungs and appropriate feel of system resistance and compliance.
 - m. Remove second breathing bag from Y-piece.

* If an anesthesia provider uses the same machine in successive cases, these steps (1 to 9) do not need to be repeated or may be abbreviated after the initial checkout.

MONITORS

- 13. Check, calibrate, and/or set alarm limits of all monitors:
 - Capnometer
 - Oxygen analyzer
 - Pressure monitor with high and low airway alarms
 - Pulse oximeter
 - Respiratory volume monitor (Spirometer)

FINAL POSITION

- 14. Check final status of machine
 - a. Vaporizers off
 - b. APL valve open
 - c. Selector switch to “Bag”
 - d. All flowmeters to zero
 - e. Patient suction level adequate
 - f. Breathing system ready to use

AUTOMATED CHECKOUT

Clinicians often fail to check their equipment thoroughly, are not successful in detecting machine faults, or they do not check their machines at all. Despite extensive instruction, anesthesia residents, at best, could only perform 81% of a checkout procedure. Hence, automated checkout is incorporated in newer machines (Datex-Ohmeda S/5 ADU, Dräger Julian, NM 6000, Fabius GS). They are unique in having a system checkout routine that is electronic and automated. The operator follows instructions to activate flows of gases, occlude the breathing circuit during the leak check, switch from manual to mechanical ventilation, open and close the pop off valve, or manually check various functions (suction, or emergency oxygen cylinder supply). It covers all the steps of the FDA checklist. The system checkout is logged, but it may be bypassed in an emergency.

Despite these automated procedures, not every fault, obstruction, crossed connection, disconnection, or incompetent valve may be detected. It may not be obvious to the clinician as to what the machine is testing. Hence, in addition to automated checkouts, anesthesiologists must develop appropriate manual checklists to suit the apparatus being used. The anesthesia delivery systems have evolved to the point that one checkout procedure is not applicable to all anesthesia delivery systems currently on the market. Hence, the “ASA (American Society of Anesthesiologists) sub-committee on equipment and facilities” in 2008 has recommended a template for developing checkout procedures that are appropriate for each individual anesthesia machine design and practice setting (see Table A.1 and Table A.2). Items that are not evaluated by the automated checkout need to be identified, and supplemental manual checkout procedures included as needed. Adaptation of the preanesthesia checkout to local needs, assignment of responsibility for the checkout procedures, and training are the responsibilities of the individual

TABLE A1.1. *Summary of Checkout Recommendations by Frequency and Responsible Party (TO BE COMPLETED DAILY).*

<i>Item To Be Completed</i>	<i>Responsible Party</i>
Item #1: Verify auxiliary oxygen cylinder and self-inflating manual ventilation device are available and functioning.	Provider and tech
Item #2: Verify patient suction is adequate to clear the airway.	Provider and tech
Item #3: Turn on anesthesia delivery system and confirm that ac power is available.	Provider or tech
Item #4: Verify availability of required monitors, including alarms.	Provider or tech
Item #5: Verify that pressure is adequate on the spare oxygen cylinder mounted on the anesthesia machine.	Provider and tech
Item #6: Verify that the piped gas pressures are ≥ 50 psig.	Provider and tech
Item #7: Verify that vaporizers are adequately filled and, if applicable, that the filler ports are tightly closed.	Provider or tech
Item #8: Verify that there are no leaks in the gas supply lines between the flowmeters and the common gas outlet.	Provider or tech
Item #9: Test scavenging system function.	Provider or tech
Item #10: Calibrate, or verify calibration of, the oxygen monitor and check the low oxygen alarm.	Provider or tech
Item #11: Verify carbon dioxide absorbent is not exhausted.	Provider or tech
Item #12: Breathing system pressure and leak testing.	Provider and tech
Item #13: Verify that gas flows properly through the breathing circuit during both inspiration and exhalation.	Provider and tech
Item #14: Document completion of checkout procedures.	Provider and tech
Item #15: Confirm ventilator settings and evaluate readiness to deliver anesthesia care. (ANESTHESIA TIME OUT)	Provider

anesthesia department. These guidelines and examples of institution-specific procedures for current anesthesia delivery systems are available on the ASA Web site (see listing at the end of this chapter).

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TABLE A1.2. *Summary of Checkout Recommendations by Frequency and Responsible Party (TO BE COMPLETED PRIOR TO EACH PROCEDURE).*

<i>Item to Be Completed</i>	<i>Responsible Party</i>
Item #2: Verify patient suction is adequate to clear the airway.	Provider and tech
Item #4: Verify availability of required monitors, including alarms.	Provider or tech
Item #7: Verify that vaporizers are adequately filled and if applicable that the filler ports are tightly closed.	Provider
Item #11: Verify carbon dioxide absorbent is not exhausted.	Provider or tech
Item #12: Breathing system pressure and leak testing.	Provider and tech
Item #13: Verify that gas flows properly through the breathing circuit during both inspiration and exhalation.	Provider and tech
Item #14: Document completion of checkout procedures.	Provider and tech
Item #15: Confirm ventilator settings and evaluate readiness to deliver anesthesia care. (ANESTHESIA TIME OUT)	Provider

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WEBSITES

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Appendix 2 | Malignant Hyperthermia

MH Hotline
1-800-644-9737
Outside the US:
1-315-464-7079

Effective May 2008

EMERGENCY THERAPY FOR MALIGNANT HYPERTHERMIA

DIAGNOSIS vs. ASSOCIATED PROBLEMS

<p>Signs of MH:</p> <ul style="list-style-type: none"> • Increasing ETCO₂ • Trunk or total body rigidity • Masseter spasm or trismus • Tachycardia/tachypnea • Mixed Respiratory and Metabolic Acidosis • Increased temperature (may be late sign) • Myoglobinuria 	<p>Sudden/Unexpected Cardiac Arrest in Young Patients:</p> <ul style="list-style-type: none"> • Presume hyperkalemia and initiate treatment (see #6) • Measure CK, myoglobin, ABGs, until normalized • Consider dantrolene • Usually secondary to occult myopathy (e.g., muscular dystrophy) • Resuscitation may be difficult and prolonged 	<p>Trismus or Masseter Spasm with Succinylcholine</p> <ul style="list-style-type: none"> • Early sign of MH in many patients • If limb muscle rigidity, begin treatment with dantrolene • For emergent procedures, continue with non-triggering agents, evaluate and monitor the patient, and consider dantrolene treatment • Follow CK and urine myoglobin for 36 hours. • Check CK immediately and at 6 hour intervals until returning to normal. Observe for dark or cola colored urine. If present, liberalize fluid intake and test for myoglobin • Observe in PACU or ICU for at least 12 hours
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ACUTE PHASE TREATMENT

- 1 GET HELP. GET DANTROLENE – Notify Surgeon**

 - Discontinue volatile agents and succinylcholine.
 - Hyperventilate with 100% oxygen at flows of 10 L/min. or more.
 - Halt the procedure as soon as possible; if emergent, continue with non-triggering anesthetic technique.
 - Don't waste time changing the circle system and CO₂ absorbant.
- 2 Dantrolene 2.5 mg/kg rapidly IV through large-bore IV, if possible**

To convert kg to lbs for amount of dantrolene, give patients 1 mg/lb (2.5 mg/kg approximates 1 mg/lb).

 - Dissolve the 20 mg in each vial with at least 60 ml sterile, preservative-free water for injection. Prewarming (not to exceed 39° C.) the sterile water may expedite solubilization of dantrolene. However, to date, there is no evidence that such warming improves clinical outcome.
 - Repeat until signs of MH are reversed.
 - Sometimes more than 10 mg/kg (up to 30 mg/kg) is necessary.
- 3 Bicarbonate for metabolic acidosis**

 - 1-2 mEq/kg if blood gas values are not yet available.
- 4 Cool the patient with core temperature >39°C.** Lavage open body cavities, stomach, bladder, or rectum. Apply ice to surface. Infuse cold saline intravenously. Stop cooling if temp. <38°C and falling to prevent drift < 36°C.
- 5 Dysrhythmias** usually respond to treatment of acidosis and hyperkalemia.

 - Use standard drug therapy **except calcium channel blockers, which may cause hyperkalemia or cardiac arrest in the presence of dantrolene.**
- 6 Hyperkalemia** – Treat with hyperventilation, bicarbonate, glucose/insulin, calcium.

 - Bicarbonate 1-2 mEq/kg IV.
 - For **pediatric**, 0.1 units insulin/kg and 1 ml/kg 50% glucose or for **adult**, 10 units regular insulin IV and 50 ml 50% glucose.
 - Calcium chloride 10 mg/kg or calcium gluconate 10-50 mg/kg for life-threatening hyperkalemia.
 - Check glucose levels hourly.
- 7 Follow ETCO₂, electrolytes, blood gases, CK, core temperature, urine output and color, coagulation studies.** If CK and/or K⁺ rise more than transiently or urine output falls to less than 0.5 ml/kg/hr, induce diuresis to > 1 ml/kg/hr and give bicarbonate to alkalinize urine to prevent myoglobinuria-induced renal failure. (See D below)

 - Venous blood gas (e.g., femoral vein) values may document hypermetabolism better than arterial values.
 - Central venous or PA monitoring as needed and record minute ventilation.
 - Place Foley catheter and monitor urine output.


POST ACUTE PHASE

- 1** Observe the patient in an ICU for at least 24 hours, due to the risk of recrudescence.
- 2** Dantrolene 1 mg/kg q 4-6 hours or 0.25 mg/kg/hr by infusion for at least 24 hours. Further doses may be indicated.
- 3** Follow vitals and labs as above (see #7)

 - Frequent ABG as per clinical signs
 - CK every 8-12 hours; less often as the values trend downward
- 4** Follow urine myoglobin and institute therapy to prevent myoglobin precipitation in renal tubules and the subsequent development of Acute Renal Failure. CK levels above 10,000 IU/L is a presumptive sign of rhabdomyolysis and myoglobinuria. Follow standard intensive care therapy for acute rhabdomyolysis and myoglobinuria (urine output >2 ml/kg/hr by hydration and diuretics along with alkalization of urine with Na-bicarbonate infusion with careful attention to both urine and serum pH values).
- 5** Counsel the patient and family regarding MH and further precautions; refer them to MHAUS. Fill out and send in the Adverse Metabolic Reaction to Anesthesia (AMRA) form (www.mhreg.org) and send a letter to the patient and her/his physician. Refer patient to the nearest Biopsy Center for follow-up.

CAUTION: This protocol may not apply to all patients; alter for specific needs.

Non-Emergency Information
MHAUS
 PO Box 1069 (11 East State Street)
 Sherburne, NY 13460-1069
Phone
 1-800-986-4287
 (607-674-7901)
Fax
 607-674-7910
Email
info@mhaus.org
Website
www.mhaus.org



Since 1981

Dedicated to Patient Safety

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FIGURE A2.1. Emergency therapy for malignant hyperthermia. (Reprinted with permission from the Malignant Hyperthermia Association of the United States [MHAUS]. For more information, go to <http://www.mhaus.org>.)

Appendix 3 | Selected American Society of Anesthesiologists Guidelines

Statement of the Anesthesia Care Team is reprinted with permission of the American Society of Anesthesiologists, 520 N. Northwest Highway, Park Ridge, Illinois 60068-2573.

STATEMENT ON THE ANESTHESIA CARE TEAM

Committee of Origin: Anesthesia Care Team
(Approved by the ASA House of Delegates on October 18, 2006, and last amended on October 21, 2009)

Anesthesiology is the practice of medicine including, but not limited to, preoperative patient evaluation, anesthetic planning, intraoperative and postoperative care and the management of systems and personnel that support these activities. In addition, anesthesiology involves perioperative consultation, the prevention and management of untoward perioperative patient conditions, the treatment of acute and chronic pain, and the care of critically ill patients. This care is personally provided by or directed by the anesthesiologist.

In the interest of patient safety and quality of care, the American Society of Anesthesiologists believes that the involvement of an anesthesiologist in the perioperative care of every patient is optimal. Almost all anesthesia care is either provided personally by an anesthesiologist or is provided by a nonphysician anesthesia provider directed by an anesthesiologist. The latter mode of anesthesia delivery is called the Anesthesia Care Team and involves the delegation of monitoring and appropriate tasks by the physician to nonphysicians. Such delegation should be specifically defined by the anesthesiologist and should also be consistent with state law or regulations and medical staff policy. Although selected tasks of overall anesthesia care may be delegated to qualified members of the Anesthesia Care Team, overall responsibility for the Anesthesia Care Team and the patients' safety rests with the anesthesiologist.

Core Members of the Anesthesia Care Team

The Anesthesia Care Team includes both physicians and non-physicians. Each member of the team has an obligation

to accurately identify themselves and other members of the team to patients and family members. Anesthesiologists should not permit the misrepresentation of nonphysician personnel as resident physicians or practicing physicians. The nomenclature below is appropriate terminology for this purpose.

Physicians:

ANESTHESIOLOGIST—director of the anesthesia care team—a physician licensed to practice medicine who has successfully completed a training program in anesthesiology accredited by the ACGME, the American Osteopathic Association or equivalent organizations.

ANESTHESIOLOGY FELLOW—an anesthesiologist enrolled in a training program to obtain additional education in one of the subspecialties of anesthesiology.

ANESTHESIOLOGY RESIDENT—a physician enrolled in an accredited anesthesiology residency program.

Nonphysicians:

NURSE ANESTHETIST—a registered nurse who has satisfactorily completed an accredited nurse anesthesia training program.

ANESTHESIOLOGIST ASSISTANT—a health professional who has satisfactorily completed an accredited anesthesiologist assistant training program.

STUDENT NURSE ANESTHETIST—a registered nurse who is enrolled in an accredited nurse anesthesia training program.

ANESTHESIOLOGIST ASSISTANT STUDENT—a health professions graduate student who has satisfied the required coursework for admission to an accredited school of medicine and is enrolled in an accredited anesthesiologist assistant training program.

Although not considered core members of the Anesthesia Care Team, other health care professionals make important contributions to the perianesthetic care of the patient (see **Addendum A**).

Definitions

ANESTHESIA CARE TEAM—Anesthesiologists supervising resident physicians in training and/or directing qualified nonphysician anesthesia providers in the provision of anesthesia care wherein the physician may delegate monitoring and appropriate tasks while retaining overall responsibility for the patient.

QUALIFIED ANESTHESIA PERSONNEL/PRACTITIONER—Anesthesiologists, anesthesiology fellows, anesthesiology residents, oral surgery residents, anesthesiologist assistants and nurse anesthetists. An exception is made by some clinical training sites for non-physician anesthetist students (see “Non-physician Anesthetist Students” below).

SUPERVISION AND DIRECTION—Terms used to describe the physician work required to oversee, manage and guide both residents and nonphysician anesthesia providers in the Anesthesia Care Team. For the purposes of this statement, supervision and direction are interchangeable and have no relation to the billing, payment or regulatory definitions that provide distinctions between these two terms (see **Addendum B**).

SEDATION NURSE AND SEDATION PHYSICIAN ASSISTANT—A licensed registered nurse, advanced practice nurse or physician assistant (PA) who is trained in compliance with all relevant local, institutional, state and/or national standards, policies or guidelines to administer prescribed sedating and analgesic medications and monitor patients during minimal sedation (“anxiolysis”) or moderate sedation (“conscious sedation”), but not deeper levels of sedation or general anesthesia. Sedation nurses and sedation physician assistants may only work under the direct supervision of a properly trained and privileged medical doctor (M.D. or D.O.).

Safe Conduct of the Anesthesia Care Team

In order to achieve optimum patient safety, the anesthesiologist who directs the Anesthesia Care Team is responsible for the following:

1. **Management of personnel**—Anesthesiologists should assure the assignment of appropriately skilled physician and/or nonphysician personnel for each patient and procedure.

2. **Preanesthetic evaluation of the patient**—A preanesthetic evaluation allows for the development of an anesthetic plan that considers all conditions and diseases of the patient that may influence the safe outcome of the anesthetic. Although nonphysicians may contribute to the preoperative collection and documentation of patient data, the anesthesiologist is responsible for the overall evaluation of each patient.

3. **Prescribing the anesthetic plan**—The anesthesiologist is responsible for prescribing an anesthesia plan aimed at the greatest safety and highest quality for each patient. The anesthesiologist discusses with the patient (when appropriate), the anesthetic risks, benefits and alternatives, and obtains informed consent. When a portion of the anesthetic care will be performed by another qualified anesthesia provider, the

anesthesiologist should inform the patient that delegation of anesthetic duties is included in care provided by the Anesthesia Care Team.

4. **Management of the anesthetic**—The management of an anesthetic is dependent on many factors including the unique medical conditions of individual patients and the procedures being performed. Anesthesiologists should determine which perioperative tasks, if any, may be delegated. The anesthesiologist may delegate specific tasks to qualified nonanesthesiologist members of the ACT providing that quality of care and patient safety are not compromised, but should participate in critical parts of the anesthetic and remain immediately physically available for management of emergencies regardless of the type of anesthetic (see **Addendum B**).

5. **Postanesthesia care**—Routine postanesthesia care is delegated to postanesthesia nurses. The evaluation and treatment of postanesthetic complications are the responsibility of the anesthesiologist.

6. **Anesthesia consultation**—Like other forms of medical consultation, this is the practice of medicine and should not be delegated to nonphysicians.

Safe Conduct of Minimal and Moderate Sedation Utilizing Sedation Nurses and PA’s

The supervising doctor is responsible for all aspects involved in the continuum of care—pre-, intra-, and post-procedure. While a patient is sedated, the responsible doctor must be physically present and immediately available in the procedure suite. Although the supervising doctor is primarily responsible for pre-procedure patient evaluation, sedation practitioners must be trained adequately in pre-procedure patient evaluation to recognize when risk may be increased, and related policies and procedures must allow sedation practitioners to refuse to participate in specific cases if they feel uncomfortable in terms of any perceived threat to quality of care or patient safety.

The supervising doctor is responsible for leading any acute resuscitation needs, including emergency airway management. Therefore, ACLS (PALS or NALS where appropriate) certification must be a standard requirement for sedation practitioners and for credentialing and privileging the non-anesthesiologist physicians that supervise them. However, because non-anesthesia professionals do not perform controlled mask ventilation or tracheal intubation with enough frequency to remain proficient, their training should emphasize avoidance of over-sedation much more than treatment of the same.

Supervision of Nurse Anesthetists by Surgeons

Note: In this paragraph “surgeon(s)” may refer to any appropriately trained, licensed and credentialed nonanesthesiologist who may supervise nurse anesthetists.

General, regional and monitored anesthesia care all expose patients to risks. Nonanesthesiologist physicians may not

possess the expertise that uniquely qualifies and enables anesthesiologists to manage the most clinically challenging medical situations that arise during the perioperative period. While a few surgical training programs provide some anesthesiology specific education (e.g., some oral and maxillofacial residencies), no surgical, dental, podiatric or any other nonanesthesiology training programs provide enough training specific to anesthesiology to enable their graduates to provide the level of medical supervision and clinical expertise that anesthesiologists provide. However, surgeons can still significantly add to patient safety and quality of care by assuming medical responsibility for all perioperative care when an anesthesiologist is not present. Anesthetic and surgical complications often arise unexpectedly and require immediate medical diagnosis and treatment. Even if state law or regulation says a surgeon is not “required” to supervise nonphysician anesthesia providers, the surgeon may be the only medical doctor on site. Whether the need is preoperative medical clearance or intraoperative resuscitation from an unexpected complication, the surgeon, both ethically and according to training and ability, should be expected to provide medical oversight or supervision of all perioperative health care provided, including nonphysician nurse anesthesia care. To optimize patient safety, careful consideration is required when surgeons can be expected to be the only medical doctor available to provide oversight of all perioperative care. This is especially true in freestanding surgery centers and surgeons’ offices where, in the event of unexpected emergencies, consultation with other medical specialists frequently is not available. In the event of unexpected emergencies, lack of immediately available and appropriately trained physician support can reduce the likelihood of successful resuscitation. This should always be a consideration when deciding which procedures should be performed in these settings, and on which patients, particularly if the individual supervising the nurse anesthetist is not a medical doctor with training appropriate for providing critical perioperative medical management.

Non-Physician Anesthetist Students

Definition: AA students, SRNAs, dental anesthesia students, or possibly other student types satisfactorily enrolled in nationally accredited training programs. Anesthesiologists should be dedicated to providing optimal patient safety and quality of care to every patient undergoing anesthesia and also to education of anesthesia students that is commensurate with that dedication. The ASA Standards for Basic Anesthetic Monitoring sets forth the minimum conditions necessary for the safe conduct of anesthesia. Standard #1 of that document states that, “Qualified anesthesia personnel shall be present in the room throughout the conduct of all general anesthetics, regional anesthetics and monitored anesthesia care.” The definitions above are inadequate to address the issue of safe patient care during the training of non-physician anesthetist students. Further clarification of the issues involved is in the best interests of patients, students, and the anesthesia

practitioners involved in the training of non-physician anesthetists.

Distinction between situations where students may be alone with patients: During supervision of non-physician anesthetist students it may become necessary to leave them alone in operating rooms or procedure rooms (OR/PR) to accommodate needs of brief duration. This should only occur if judged to cause no significant increased risk to the patient.

This practice must be distinguished from that of scheduling non-physician students to patients as the primary anesthesia provider, meaning no fully trained anesthesia practitioner also assigned to the case and expected to be continuously present monitoring the anesthetized patient. While the brief interruption of 1:1 student supervision may well be necessary for the efficient and safe functioning of a department of anesthesiology, the use of non-physician students in place of fully trained and credentialed anesthesia personnel is not endorsed as best practice by the American Society of Anesthesiologists. While the education of non-physician anesthetist students is an important goal, patient safety remains paramount. Therefore, the conduct of this latter type of practice must meet certain conditions intended to protect the safety and rights of patients and students, as well as the best interests of all other parties directly or indirectly involved (i.e., involved qualified practitioners, patients’ families, institutions, etc.).

1. All delegating anesthesiologists and the department chairperson must deem these nonphysician student anesthetists fully capable of performing all duties delegated to them, and all students being delegated to must express agreement with accepting any responsibility delegated to them.

2. **Privileging**—A privileging process must precede this practice to officially and individually label each student as qualified to be supervised 1:2 by a qualified anesthesia practitioner who remains immediately physically available. Students must not be so privileged until they have completed a significant predetermined portion of both their didactic and clinical training that may reasonably be assumed to make this practice consistent with expected levels of safety and quality (if at all, at the earliest the last 3-4 months of student training). Privileging must be done under the authority of the Chief of Anesthesiology and in compliance with all federal, state, professional organization and institutional requirements.

3. **Case Assignment and Supervision**—These students must be supervised on a one-to-one or on a one-to-two ratio. Assignment of cases with regards to students must always be done in a manner that assures the best possible outcome for patients and the best education of students and therefore must be commensurate with the skills, training, experience, knowledge and willingness of each individual non-physician anesthesia student. Care should be taken to avoid placing students in situations that they are not fully prepared for. It is expected that most students will get their experience caring for high risk patients under the continuous supervision of fully trained anesthesia personnel. This is in the best interest of both education and patient safety. As students are incompletely trained, the degree of continuous supervision must be at a higher level

than that required for fully trained and credentialed AAs and NAs. If an anesthesiologist is engaged in the supervision of non-physician students, he/she must remain immediately physically available throughout the conduct of the involved anesthetics, meaning not leaving the OR/PR suite to provide other services or clinical duties that are commonly considered appropriate concurrent activities while directing fully trained and credentialed AAs or NAs.

4. Backup support—If an anesthesiologist is concurrently supervising two non-physician anesthesiologists students assigned as primary anesthesia providers (meaning the only anesthesia personnel continuously present with a patient), the anesthesiologist could be needed simultaneously in both rooms. To mitigate this potential risk, one other qualified anesthesia practitioner must also be assigned and must remain immediately physically available if needed (e.g., alone on call anesthesiologist should not be supervising more than one student without appropriately trained and credentialed back up immediately available).

5. Informed Consent—The Chief of Anesthesia is responsible for assuring that every patient (or their guardian) understands through a standardized departmental informed consent process that they may be in the OR/PR with only a non-physician student physically present, although still directed by the responsible anesthesiologist. As it is in the best interest of all involved parties, documentation of this aspect of informed consent must be included in the informed consent statement.

6. Disclosure to Professional Liability Carrier—To be assured of reliable professional liability insurance coverage for all involved (qualified anesthesia practitioners, their employers and the institution), the Chief of Anesthesia must notify the responsible professional liability carrier(s) of the practice of allowing non-physician anesthesia students to provide care without continuous direct supervision by a fully trained, credentialed and qualified anesthesia practitioner.

ADDENDUM A:

Other personnel involved in perianesthetic care:

POSTANESTHESIA NURSE—a registered nurse who cares for patients recovering from anesthesia.

PERIOPERATIVE NURSE—a registered nurse who cares for the patient in the operating room.

CRITICAL CARE NURSE—a registered nurse who cares for patients in a special care area such the intensive care unit.

OBSTETRIC NURSE—a registered nurse who provides care to laboring patients.

NEONATAL NURSE—a registered nurse who provides cares to neonates in special care units.

RESPIRATORY THERAPIST—an allied health professional who provides respiratory care to patients.

CARDIOVASCULAR PERFUSIONISTS—an allied health professional who operates cardiopulmonary bypass machines.

Support personnel whose efforts deal with technical expertise, supply and maintenance:

ANESTHESIA TECHNOLOGISTS AND TECHNICIANS
ANESTHESIA AIDES
BLOOD GAS TECHNICIANS
RESPIRATORY TECHNICIANS
MONITORING TECHNICIANS

ADDENDUM B:

Commonly Used Billing Rules and Definitions

ASA recognizes the existence of commercial and governmental payer rules applying to billing for anesthesia services and encourages its members to comply with them whenever possible. Some commonly prescribed duties include:

- Performing a preanesthetic history and physical examination of the patient;
- Prescribing the anesthetic plan;
- Personal participation in the most demanding portions of the anesthetic, including induction and emergence, where applicable;
 - Delegation of anesthesia care only to qualified anesthesia providers;
 - Monitoring the course of anesthesia at frequent intervals;
 - Remaining physically available for immediate diagnosis and treatment while medically responsible;
- Providing indicated postanesthesia care, and;
- Performing and documenting a post-anesthesia evaluation.

ASA also recognizes the lack of total predictability in anesthesia care and the variability in patient needs that can, in particular and infrequent circumstances, make it less appropriate from the viewpoint of overall patient safety and quality to comply with all payment rules in each patient at every moment in time. Reporting of services for payment must accurately reflect the services provided. The ability to prioritize duties and patient care needs, moment to moment, is a crucial skill of the anesthesiologist functioning safely within the anesthesia care team. Anesthesiologists must strive to provide the highest quality of care and greatest degree of patient safety to ALL patients in the perioperative environment at ALL times.

MEDICAL “DIRECTION” by anesthesiologists—A billing term describing the specific anesthesiologist work required in and restrictions involved in billing payers for the management and oversight of nonphysician anesthesia providers. This pertains to situations where anesthesiologists are involved in not more than four concurrent anesthetics. See individual payer manuals for specifics.

MEDICAL “SUPERVISION” by anesthesiologists—Medicare payment policy contains a special payment formula for “medical supervision” which applies “when the anesthesiologist is involved in furnishing more than four procedures concurrently or is performing other services while directing the concurrent procedures.” [Note: The word “supervision” may

also be used outside of the Anesthesia Care Team to describe the perioperative medical oversight of nonphysician anesthesia providers by the operating practitioner/surgeon. Surgeon provided supervision pertains to general medical perioperative patient management and the components of anesthesia care that are medical and not nursing functions (e.g., determining medical readiness of patients for anesthesia and surgery, and providing critical medical management of unexpected emergencies).]

Standards for Basic Anesthetic Monitoring is reprinted with permission of the American Society of Anesthesiologists, 520 N. Northwest Highway, Park Ridge, Illinois 60068-2573.

STANDARDS FOR BASIC ANESTHETIC MONITORING

Committee of Origin: Standards and Practice Parameters

(Approved by the ASA House of Delegates on October 21, 1986, and last amended on October 20, 2010)

These standards apply to all anesthesia care although, in emergency circumstances, appropriate life support measures take precedence. These standards may be exceeded at any time based on the judgment of the responsible anesthesiologist. They are intended to encourage quality patient care, but observing them cannot guarantee any specific patient outcome. They are subject to revision from time to time, as warranted by the evolution of technology and practice. They apply to all general anesthetics, regional anesthetics and monitored anesthesia care. This set of standards addresses only the issue of basic anesthetic monitoring, which is one component of anesthesia care. In certain rare or unusual circumstances, 1) some of these methods of monitoring may be clinically impractical, and 2) appropriate use of the described monitoring methods may fail to detect untoward clinical developments. Brief interruptions of continual[†] monitoring may be unavoidable. These standards are not intended for application to the care of the obstetrical patient in labor or in the conduct of pain management.

STANDARD I

Qualified anesthesia personnel shall be present in the room throughout the conduct of all general anesthetics, regional anesthetics and monitored anesthesia care.

OBJECTIVE

Because of the rapid changes in patient status during anesthesia, qualified anesthesia personnel shall be continuously present to monitor the patient and provide anesthesia care. In the event there is a direct known hazard, e.g., radiation, to the anesthesia personnel which might require intermittent remote

observation of the patient, some provision for monitoring the patient must be made. In the event that an emergency requires the temporary absence of the person primarily responsible for the anesthetic, the best judgment of the anesthesiologist will be exercised in comparing the emergency with the anesthetized patient's condition and in the selection of the person left responsible for the anesthetic during the temporary absence.

STANDARD II

During all anesthetics, the patient's oxygenation, ventilation, circulation and temperature shall be continually evaluated.

OXYGENATION

Objective

To ensure adequate oxygen concentration in the inspired gas and the blood during all anesthetics.

Methods

1). Inspired gas: During every administration of general anesthesia using an anesthesia machine, the concentration of oxygen in the patient breathing system shall be measured by an oxygen analyzer with a low oxygen concentration limit alarm in use.*

2). Blood oxygenation: During all anesthetics, a quantitative method of assessing oxygenation such as pulse oximetry shall be employed.* When the pulse oximeter is utilized, the variable pitch pulse tone and the low threshold alarm shall be audible to the anesthesiologist or the anesthesia care team personnel.* Adequate illumination and exposure of the patient are necessary to assess color.*

VENTILATION

Objective

To ensure adequate ventilation of the patient during all anesthetics.

Methods

1). Every patient receiving general anesthesia shall have the adequacy of ventilation continually evaluated. Qualitative clinical signs such as chest excursion, observation of the reservoir breathing bag and auscultation of breath sounds are useful. Continual monitoring for the presence of expired carbon dioxide shall be performed unless invalidated by the nature of the patient, procedure or equipment. Quantitative monitoring of the volume of expired gas is strongly encouraged.*

2). When an endotracheal tube or laryngeal mask is inserted, its correct positioning must be verified by clinical assessment and by identification of carbon dioxide in the expired gas. Continual end-tidal carbon dioxide analysis, in use from the time of endotracheal tube/laryngeal mask placement, until extubation/removal or initiating transfer to a postoperative care location, shall be performed using a quantitative method such as capnography, capnometry or mass spectroscopy.* When capnography or capnometry is utilized, the end tidal CO₂ alarm shall be audible to the anesthesiologist or the anesthesia care team personnel.*

3). When ventilation is controlled by a mechanical ventilator, there shall be in continuous use a device that is capable of detecting disconnection of components of the breathing system. The device must give an audible signal when its alarm threshold is exceeded.

4). During regional anesthesia and monitored anesthesia care, the adequacy of ventilation shall be evaluated by continual observation of qualitative clinical signs and/or monitoring for the presence of exhaled carbon dioxide.

CIRCULATION

Objective

To ensure the adequacy of the patient's circulatory function during all anesthetics.

Methods

1). Every patient receiving anesthesia shall have the electrocardiogram continuously displayed from the beginning of anesthesia until preparing to leave the anesthetizing location.*

2). Every patient receiving anesthesia shall have arterial blood pressure and heart rate determined and evaluated at least every five minutes.*

3). Every patient receiving general anesthesia shall have, in addition to the above, circulatory function continually evaluated by at least one of the following: palpation of a pulse, auscultation of heart sounds, monitoring of a tracing of intra-arterial pressure, ultrasound peripheral pulse monitoring, or pulse plethysmography or oximetry.

BODY TEMPERATURE

Objective

To aid in the maintenance of appropriate body temperature during all anesthetics.

† Note that "continual" is defined as "repeated regularly and frequently in steady rapid succession" whereas "continuous" means "prolonged without any interruption at any time."

* Under extenuating circumstances, the responsible anesthesiologist may waive the requirements marked with an asterisk (*); it is recommended that when this is done, it should be so stated (including the reasons) in a note in the patient's medical record.

METHODS

Every patient receiving anesthesia shall have temperature monitored when clinically significant changes in body temperature are intended, anticipated or suspected.

Statement on Non-Operating Room Anesthetizing Locations is reprinted with permission of the American Society of Anesthesiologists, 520 N. Northwest Highway, Park Ridge, Illinois 60068-2573.

STATEMENT ON NONOPERATING ROOM ANESTHETIZING LOCATIONS

Committee of Origin: Standards and Practice Parameters

(Approved by the ASA House of Delegates on October 15, 2003 and amended on October 22, 2008)

These guidelines apply to all anesthesia care involving anesthesiology personnel for procedures intended to be performed in locations outside an operating room. These are minimal guidelines which may be exceeded at any time based on the judgment of the involved anesthesia personnel. These guidelines encourage quality patient care but observing them cannot guarantee any specific patient outcome. These guidelines are subject to revision from time to time, as warranted by the evolution of technology and practice. ASA Standards, Guidelines and Policies should be adhered to in all nonoperating room settings except where they are not applicable to the individual patient or care setting.

1. There should be in each location a reliable source of oxygen adequate for the length of the procedure. There should also be a backup supply. Prior to administering any anesthetic, the anesthesiologist should consider the capabilities, limitations and accessibility of both the primary and backup oxygen sources. Oxygen piped from a central source, meeting applicable codes, is strongly encouraged. The backup system should include the equivalent of at least a full E cylinder.

2. There should be in each location an adequate and reliable source of suction. Suction apparatus that meets operating room standards is strongly encouraged.

3. In any location in which inhalation anesthetics are administered, there should be an adequate and reliable system for scavenging waste anesthetic gases.

4. There should be in each location: (a) a self-inflating hand resuscitator bag capable of administering at least 90 percent oxygen as a means to deliver positive pressure ventilation; (b) adequate anesthesia drugs, supplies and equipment for the intended anesthesia care; and (c) adequate monitoring equipment to allow adherence to the "Standards for Basic Anesthetic Monitoring." In any location in which inhalation anesthesia is to be administered, there should be an anesthesia machine equivalent in function to that employed in operating rooms and maintained to current operating room standards.

5. There should be in each location, sufficient electrical outlets to satisfy anesthesia machine and monitoring equipment requirements, including clearly labeled outlets connected to an emergency power supply. In any anesthetizing location determined by the health care facility to be a “wet location” (e.g., for cystoscopy or arthroscopy or a birthing room in labor and delivery), either isolated electric power or electric circuits with ground fault circuit interrupters should be provided.*

6. There should be in each location, provision for adequate illumination of the patient, anesthesia machine (when present) and monitoring equipment. In addition, a form of battery-powered illumination other than a laryngoscope should be immediately available.

7. There should be in each location, sufficient space to accommodate necessary equipment and personnel and to allow expeditious access to the patient, anesthesia machine (when present) and monitoring equipment.

8. There should be immediately available in each location, an emergency cart with a defibrillator, emergency drugs and other equipment adequate to provide cardiopulmonary resuscitation

9. There should be in each location adequate staff trained to support the anesthesiologist. There should be immediately available in each location, a reliable means of two-way communication to request assistance.

10. For each location, all applicable building and safety codes and facility standards, where they exist, should be observed

11. Appropriate postanesthesia management should be provided (see Standards for Postanesthesia Care). In addition to the anesthesiologist, adequate numbers of trained staff and appropriate equipment should be available to safely transport the patient to a postanesthesia care unit.

Guidelines for Office-Based Anesthesia is reprinted with permission of the American Society of Anesthesiologists, 520 N. Northwest Highway, Park Ridge, Illinois 60068-2573.

GUIDELINES FOR OFFICE-BASED ANESTHESIA

Committee of Origin: Ambulatory Surgical Care
(Approved by the ASA House of Delegates on
October 13, 1999, and last affirmed on October 21,
2009)

These guidelines are intended to assist ASA members who are considering the practice of ambulatory anesthesia in the office setting: office-based anesthesia (OBA). These recommendations focus on quality anesthesia care and patient safety in the office. These are minimal guidelines and may be exceeded at any time based on the judgment of the involved anesthesia personnel. Compliance with these guidelines cannot guarantee any specific outcome. These guidelines are subject to periodic revision as warranted by the evolution

of federal, state and local laws as well as technology and practice.

ASA recognizes the unique needs of this growing practice and the increased requests for ASA members to provide OBA for health care practitioners* who have developed their own office operatories. Since OBA is a subset of ambulatory anesthesia, the ASA “Guidelines for Ambulatory Anesthesia and Surgery” should be followed in the office setting as well as all other ASA standards and guidelines that are applicable.

There are special problems that ASA members must recognize when administering anesthesia in the office setting. Compared with acute care hospitals and licensed ambulatory surgical facilities, office operatories currently have little or no regulation, oversight or control by federal, state or local laws. Therefore, ASA members must satisfactorily investigate areas taken for granted in the hospital or ambulatory surgical facility such as governance, organization, construction and equipment, as well as policies and procedures, including fire, safety, drugs, emergencies, staffing, training and unanticipated patient transfers.

ASA members should be confident that the following issues are addressed in an office setting to provide patient safety and to reduce risk and liability to the anesthesiologist.

Administration and Facility

Quality of Care

- The facility should have a medical director or governing body that establishes policy and is responsible for the activities of the facility and its staff. The medical director or governing body is responsible for ensuring that facilities and personnel are adequate and appropriate for the type of procedures performed.
- Policies and procedures should be written for the orderly conduct of the facility and reviewed on an annual basis.
- The medical director or governing body should ensure that all applicable local, state and federal regulations are observed.
 - All health care practitioners* and nurses should hold a valid license or certificate to perform their assigned duties.
 - All operating room personnel who provide clinical care in the office should be qualified to perform services commensurate with appropriate levels of education, training and experience.
 - The anesthesiologist should participate in ongoing continuous quality improvement and risk management activities.
 - The medical director or governing body should recognize the basic human rights of its patients, and a written document that describes this policy should be available for patients to review.

* See National Fire Protection Association. Health Care Facilities Code 99; Quincy, MA: NFPA, 1993.

* defined herein as physicians, dentists and podiatrists

Facility and Safety

- Facilities should comply with all applicable federal, state and local laws, codes and regulations pertaining to fire prevention, building construction and occupancy, accommodations for the disabled, occupational safety and health, and disposal of medical waste and hazardous waste.
- Policies and procedures should comply with laws and regulations pertaining to controlled drug supply, storage and administration.

Clinical Care

Patient and Procedure Selection

- The anesthesiologist should be satisfied that the procedure to be undertaken is within the scope of practice of the health care practitioners and the capabilities of the facility.
- The procedure should be of a duration and degree of complexity that will permit the patient to recover and be discharged from the facility.
- Patients who by reason of pre-existing medical or other conditions may be at undue risk for complications should be referred to an appropriate facility for performance of the procedure and the administration of anesthesia.

Perioperative Care

- The anesthesiologist should adhere to the “Basic Standards for Preanesthesia Care,” “Standards for Basic Anesthetic Monitoring,” “Standards for Postanesthesia Care” and “Guidelines for Ambulatory Anesthesia and Surgery” as currently promulgated by the American Society of Anesthesiologists.
- The anesthesiologist should be physically present during the intraoperative period and immediately available until the patient has been discharged from anesthesia care.
- Discharge of the patient is a physician responsibility. This decision should be documented in the medical record.
- Personnel with training in advanced resuscitative techniques (e.g., ACLS, PALS) should be immediately available until all patients are discharged home.

Monitoring and Equipment

- At a minimum, all facilities should have a reliable source of oxygen, suction, resuscitation equipment and emergency drugs. Specific reference is made to the ASA “Statement on Nonoperating Room Anesthetizing Locations.”
- There should be sufficient space to accommodate all necessary equipment and personnel and to allow for expeditious access to the patient, anesthesia machine (when present) and all monitoring equipment.
- All equipment should be maintained, tested and inspected according to the manufacturer’s specifications.

- Back-up power sufficient to ensure patient protection in the event of an emergency should be available.
- In any location in which anesthesia is administered, there should be appropriate anesthesia apparatus and equipment which allow monitoring consistent with ASA “Standards for Basic Anesthetic Monitoring” and documentation of regular preventive maintenance as recommended by the manufacturer.
- In an office where anesthesia services are to be provided to infants and children, the required equipment, medication and resuscitative capabilities should be appropriately sized for a pediatric population.

Emergencies and Transfers

- All facility personnel should be appropriately trained in and regularly review the facility’s written emergency protocols.
- There should be written protocols for cardiopulmonary emergencies and other internal and external disasters such as fire.
- The facility should have medications, equipment and written protocols available to treat malignant hyperthermia when triggering agents are used.
- The facility should have a written protocol in place for the safe and timely transfer of patients to a prespecified alternate care facility when extended or emergency services are needed to protect the health or well-being of the patient.

Standards for Postanesthesia Care is reprinted with permission of the American Society of Anesthesiologists, 520 N. Northwest Highway, Park Ridge, Illinois 60068-2573.

STANDARDS FOR POSTANESTHESIA CARE

Committee of Origin: Standards and Practice Parameters

(Approved by the ASA House of Delegates on October 27, 2004, and last amended on October 21, 2009)

These standards apply to postanesthesia care in all locations. These standards may be exceeded based on the judgment of the responsible anesthesiologist. They are intended to encourage quality patient care, but cannot guarantee any specific patient outcome. They are subject to revision from time to time as warranted by the evolution of technology and practice.

STANDARD I

ALL PATIENTS WHO HAVE RECEIVED GENERAL ANESTHESIA, REGIONAL ANESTHESIA OR MONITORED ANESTHESIA CARE SHALL RECEIVE APPROPRIATE POSTANESTHESIA MANAGEMENT.³

³ Refer to *Standards of Perianesthesia Nursing Practice 2008–2010*, published by ASPAN, for issues of nursing care.

1. A Postanesthesia Care Unit (PACU) or an area which provides equivalent postanesthesia care (for example, a Surgical Intensive Care Unit) shall be available to receive patients after anesthesia care. All patients who receive anesthesia care shall be admitted to the PACU or its equivalent except by specific order of the anesthesiologist responsible for the patient's care.

2. The medical aspects of care in the PACU (or equivalent area) shall be governed by policies and procedures which have been reviewed and approved by the Department of Anesthesiology.

3. The design, equipment and staffing of the PACU shall meet requirements of the facility's accrediting and licensing bodies.

STANDARD II

A PATIENT TRANSPORTED TO THE PACU SHALL BE ACCOMPANIED BY A MEMBER OF THE ANESTHESIA CARE TEAM WHO IS KNOWLEDGEABLE ABOUT THE PATIENT'S CONDITION. THE PATIENT SHALL BE CONTINUALLY EVALUATED AND TREATED DURING TRANSPORT WITH MONITORING AND SUPPORT APPROPRIATE TO THE PATIENT'S CONDITION.

STANDARD III

UPON ARRIVAL IN THE PACU, THE PATIENT SHALL BE RE-EVALUATED AND A VERBAL REPORT PROVIDED TO THE RESPONSIBLE PACU NURSE BY THE MEMBER OF THE ANESTHESIA CARE TEAM WHO ACCOMPANIES THE PATIENT.

1. The patient's status on arrival in the PACU shall be documented.

2. Information concerning the preoperative condition and the surgical/anesthetic course shall be transmitted to the PACU nurse.

3. The member of the Anesthesia Care Team shall remain in the PACU until the PACU nurse accepts responsibility for the nursing care of the patient.

STANDARD IV

THE PATIENT'S CONDITION SHALL BE EVALUATED CONTINUALLY IN THE PACU.

1. The patient shall be observed and monitored by methods appropriate to the patient's medical condition. Particular attention should be given to monitoring oxygenation, ventilation, circulation, level of consciousness and temperature. During recovery from all anesthetics, a quantitative method of assessing oxygenation such as pulse oximetry shall be employed in the initial phase of recovery.* This is not intended for application during the recovery of the obstetrical

patient in whom regional anesthesia was used for labor and vaginal delivery.

2. An accurate written report of the PACU period shall be maintained. Use of an appropriate PACU scoring system is encouraged for each patient on admission, at appropriate intervals prior to discharge and at the time of discharge.

3. General medical supervision and coordination of patient care in the PACU should be the responsibility of an anesthesiologist.

4. There shall be a policy to assure the availability in the facility of a physician capable of managing complications and providing cardiopulmonary resuscitation for patients in the PACU.

STANDARD V

A PHYSICIAN IS RESPONSIBLE FOR THE DISCHARGE OF THE PATIENT FROM THE POSTANESTHESIA CARE UNIT.

1. When discharge criteria are used, they must be approved by the Department of Anesthesiology and the medical staff. They may vary depending upon whether the patient is discharged to a hospital room, to the Intensive Care Unit, to a short stay unit or home.

2. In the absence of the physician responsible for the discharge, the PACU nurse shall determine that the patient meets the discharge criteria. The name of the physician accepting responsibility for discharge shall be noted on the record.

STATEMENT ON GRANTING PRIVILEGES FOR ADMINISTRATION OF MODERATE SEDATION TO PRACTITIONERS WHO ARE NOT ANESTHESIA PROFESSIONALS

Committee of Origin: Ad Hoc Committee on Credentialing (Approved by the ASA House of Delegates on October 25, 2005, and amended on October 18, 2006)

The American Society of Anesthesiologists is vitally interested in the safe administration of anesthesia. As such, it has concern for any system or set of practices, used either by its members or the members of other disciplines that would adversely affect the safety of anesthesia administration. It has genuine concern that individuals, however well intentioned, who are not anesthesia professionals may not recognize that sedation and general anesthesia are on a continuum and thus deliver levels of sedation that are, in fact, general anesthesia without having the training and experience to recognize this state and respond appropriately.

* Under extenuating circumstances, the responsible anesthesiologist may waive the requirements marked with an asterisk (*); it is recommended that when this is done, it should be so stated (including the reasons) in a note in the patient's medical record.

The intent of this statement is to suggest a framework for granting privileges that will help ensure competence of individuals who administer or supervise the administration of moderate sedation. Only physicians, dentists or podiatrists who are qualified by education, training and licensure to administer moderate sedation should supervise the administration of moderate sedation. This statement can be used by any facility—hospital, ambulatory care or physician’s, dentist’s or podiatrist’s office—in which an internal or external credentialing process is required for administration of sedative and analgesic drugs to establish a level of moderate sedation.

REFERENCES

ASA has produced many documents over the years related to the topic addressed by this statement, among them the following:

Guidelines for Delineation of Clinical Privileges in Anesthesiology (Approved by ASA House of Delegates on October 15, 1975, and last amended on October 15, 2003)

Statement on Qualifications of Anesthesia Providers in the Office-Based Setting (Approved by ASA House of Delegates on October 13, 1999, and last affirmed on October 27, 2004)

Statement on Safe Use of Propofol (Approved by ASA House of Delegates on October 27, 2004)

Guidelines for Office-Based Anesthesia and Surgery (Approved by ASA House of Delegates on October 13, 1999, and last affirmed on October 27, 2004)

Guidelines for Ambulatory Anesthesia and Surgery (Approved by ASA House of Delegates on October 11, 1973, and last affirmed on October 15, 2003)

Outcome Indicators for Office-Based and Ambulatory Surgery (ASA Committee on Ambulatory Surgical Care and Task Force on Office-Based Anesthesia, April 2003)

AANA-ASA Joint Statement Regarding Propofol Administration (April 14, 2004)

Practice Guidelines for Sedation and Analgesia by Nonanesthesiologists (Approved by ASA House of Delegates on October 25, 1995, and last amended on October 17, 2001)

Continuum of Depth of Sedation – Definition of General Anesthesia and Levels of Sedation/Analgesia (Approved by ASA House of Delegates on October 13, 1999, and last amended on October 27, 2004)

Practice Guidelines for Preoperative Fasting and the Use of Pharmacologic Agents to Reduce the Risk of Pulmonary Aspiration: Application to Healthy Patients Undergoing Elective Procedures (Approved by ASA House of Delegates on October 21, 1998, and effective January 1, 1999)

The Ad Hoc Committee on Sedation Credentialing Guidelines for Nonanesthesiologists took the contents of the above documents into consideration when developing this statement.

DEFINITIONS

ANESTHESIA PROFESSIONAL—An anesthesiologist, certified registered nurse anesthetist (CRNA) or anesthesiologist assistant (AA).

NONANESTHESIOLOGIST SEDATION PRACTITIONER—A licensed physician (allopathic or osteopathic), dentist or podiatrist who has not completed postgraduate training in anesthesiology but is specifically trained to personally administer or supervise the administration of moderate sedation.

SUPERVISED SEDATION PROFESSIONAL—A licensed registered nurse, advanced practice nurse or physician assistant who is trained to administer medications and monitor patients during moderate sedation **under the direct supervision of a nonanesthesiologist sedation practitioner or an anesthesiologist.**

CREDENTIALING—The process of documenting and reviewing a practitioner’s credentials.

CREDENTIALS—The professional qualifications of a practitioner including education, training, experience and performance.

PRIVILEGES—The clinical activities within a health care organization that a practitioner is permitted to perform based on the practitioner’s credentials.

GUIDELINES—A set of recommended practices that should be considered but permit discretion by the user as to whether they should be applied under any particular set of circumstances.

* **MODERATE SEDATION**—“Moderate Sedation/Analgesia (“Conscious Sedation”) is a drug-induced depression of consciousness during which patients respond purposefully to verbal commands, either alone or accompanied by light tactile stimulation. No interventions are required to maintain a patent airway, and spontaneous ventilation is adequate. Cardiovascular function is usually maintained.”

* **DEEP SEDATION**—“Deep Sedation/Analgesia is a drug-induced depression of consciousness during which patients cannot be easily aroused but respond purposefully following repeated or painful stimulation. The ability to independently maintain ventilatory function may be impaired. Patients may require assistance in maintaining a patent airway, and spontaneous ventilation may be inadequate. Cardiovascular function is usually maintained.”

* **RESCUE**—“Rescue of a patient from a deeper level of sedation than intended is an intervention by a practitioner proficient in airway management and advanced life support. The qualified practitioner corrects adverse physiologic consequences of the deeper-than intended level of sedation (such as hypoventilation, hypoxia and hypotension) and returns the patient to the originally intended level of sedation.”

* The definitions marked with an asterisk are extracted verbatim from “Continuum of Depth of Sedation—Definition of General Anesthesia and Levels of Sedation/Analgesia (Approved by ASA House of Delegates on October 13, 1999, and amended on October 27, 2004).

* GENERAL ANESTHESIA—“General Anesthesia is a drug-induced loss of consciousness during which patients are not arousable, even by painful stimulation. The ability to independently maintain ventilatory function is often impaired. Patients often require assistance in maintaining a patent airway, and positive pressure ventilation may be required because of depressed spontaneous ventilation or drug-induced depression of neuromuscular function. Cardiovascular function may be impaired.”

STATEMENT

The following statement is designed to assist health care organizations develop a program for the delineation of clinical privileges for practitioners who are not anesthesia professionals to administer sedative and analgesic drugs to establish a level of moderate sedation. (Moderate sedation is also known as “conscious sedation.”) The statement is written to apply to every setting in which an internal or external credentialing process is required for granting privileges to administer sedative and analgesic drugs to establish a level of moderate sedation (e.g., hospital, freestanding procedure center, ambulatory surgery center, physician’s, dentist’s or podiatrist’s office, etc.). The statement is not intended nor should it be applied to the granting of privileges to administer deep sedation or general anesthesia.

The granting, reappraisal and revision of clinical privileges should be awarded on a time-limited basis in accordance with rules and regulations of the health care organization, its medical staff, organizations accrediting the health care organization and relevant local, state and federal governmental agencies.

I. NONANESTHESIOLOGIST SEDATION PRACTITIONERS

Only physicians, dentists or podiatrists who are qualified by education, training and licensure to administer moderate sedation should supervise the administration of moderate sedation. Nonanesthesiologist sedation practitioners may directly supervise patient monitoring and the administration of sedative and analgesic medications by a **supervised sedation professional**. Alternatively, they may personally perform these functions, with the proviso that the individual monitoring the patient should be distinct from the individual performing the diagnostic or therapeutic procedure (see *ASA Guidelines for Sedation and Analgesia by Nonanesthesiologists*).

A. Education and Training

The nonanesthesiologist sedation practitioner who is to supervise or personally administer medications for moderate sedation should have satisfactorily completed a formal training program in: (1) the safe administration of sedative and analgesic drugs used to establish a level of moderate sedation, and (2) rescue of patients who exhibit adverse physiologic

consequences of a deeper-than-intended level of sedation. This training may be a part of a recently completed residency or fellowship training (e.g., within two years), or may be a separate educational program. A knowledge-based test may be used to verify the practitioner’s understanding of these concepts.** The following subject areas should be included:

1. Contents of the following ASA documents that should be understood by practitioners who administer sedative and analgesic drugs to establish a level of moderate sedation:

- *Practice Guidelines for Sedation and Analgesia by Nonanesthesiologists*
- *Continuum of Depth of Sedation – Definition of General Anesthesia and Levels of Sedation/Analgesia*

2. Appropriate methods for obtaining informed consent through pre-procedure counseling of patients regarding risks, benefits and alternatives to the administration of sedative and analgesic drugs to establish a level of moderate sedation.

3. Skills for obtaining the patient’s medical history and performing a physical examination to assess risks and comorbidities, including assessment of the airway for anatomic and mobility characteristics suggestive of potentially difficult airway management. The nonanesthesiologist sedation practitioner should be able to recognize those patients whose medical condition suggests that sedation should be provided by an anesthesia professional.

4. Assessment of the patient’s risk for aspiration of gastric contents as described in the *ASA Practice Guidelines for Preoperative Fasting*: “In urgent, emergent or other situations where gastric emptying is impaired, the potential for pulmonary aspiration of gastric contents must be considered in determining (1) the target level of sedation, (2) whether the procedure should be delayed or (3) whether the trachea should be protected by intubation.”

5. The pharmacology of (1) all sedative and analgesic drugs the practitioner requests privileges to administer to establish a level of moderate sedation, (2) pharmacological antagonists to the sedative and analgesic drugs and (3) vasoactive drugs and antiarrhythmics.

6. The benefits and risks of supplemental oxygen.

7. Proficiency of airway management with facemask and positive pressure ventilation. This training should include appropriately supervised experience in managing the airways of patients, or qualified instruction on an airway simulator (or both).

8. Monitoring of physiologic variables, including the following:

- a. Blood pressure
- b. Respiratory rate
- c. Oxygen saturation by pulse oximetry
- d. Electrocardiographic monitoring. Education in electrocardiographic (EKG) monitoring should include instruction in the most common arrhythmias seen during

** The post-test included with the *ASA Sedation/Analgesia by Nonanesthesiologists* videotape (ASA Document #30503-10PPV) may be considered for this purpose.

sedation and anesthesia, their causes and their potential clinical implications (e.g., hypercapnia), as well as electrocardiographic signs of cardiac ischemia.

e. Depth of sedation. The depth of sedation should be based on the ASA definitions of “moderate sedation” and “deep sedation.” (See above)

f. Capnography—if moderate sedation is to be administered in settings where patients’ ventilatory function cannot be directly monitored (e.g., MRI suite).

9. The importance of continuous use of appropriately set audible alarms on physiologic monitoring equipment.

10. Documenting the drugs administered, the patient’s physiologic condition and the depth of sedation at regular intervals throughout the period of sedation and analgesia, using a graphical, tabular or automated record.

11. If moderate sedation is to be administered in a setting where individual(s) with advanced life support skills will not be immediately available (1-5 minutes; e.g., code team), then the nonanesthesiologist sedation practitioner should have advanced life support skills such as those required for American Heart Association certification in Advanced Cardiac Life Support (ACLS). When granting privileges to administer moderate sedation to pediatric patients, the nonanesthesiologist sedation practitioner should have advanced life support skills such as those required for certification in Pediatric Advanced Life Support (PALS).

When the practitioner is being granted privileges to administer sedative and analgesic drugs to pediatric patients to establish a level of moderate sedation, the education and training requirements enumerated in #1-9 above should be appropriately tailored to qualify the practitioner to administer sedative and analgesic drugs to pediatric patients.

B. Licensure

1. The nonanesthesiologist sedation practitioner should have a current active, unrestricted medical, osteopathic, dental or podiatric license in the state, district or territory of practice. (Exception: practitioners employed by the federal government may have a current active license in any U.S. state, district or territory.)

2. The nonanesthesiologist sedation practitioner should have a current unrestricted Drug Enforcement Administration (DEA) registration (schedules II-V).

3. The credentialing process should require disclosure of any disciplinary action (final judgments) against any medical, osteopathic or podiatric license by any state, district or territory of practice and of any sanctions by any federal agency, including Medicare/Medicaid, in the last five years.

4. Before granting or renewing privileges to administer or supervise the administration of sedative and analgesic drugs to establish a level of moderate sedation, the health care organization should search for any disciplinary action recorded in the National Practitioner Data Bank (NPDB) and take appropriate action regarding any Adverse Action Reports.

C. Practice Pattern

1. Before granting initial privileges to administer or supervise administration of sedative and analgesic drugs to establish a level of moderate sedation, a process should be developed to evaluate the practitioner’s performance. For recent graduates (e.g., within two years), this may be accomplished through letters of recommendation from directors of residency or fellowship training programs which include moderate sedation as part of the curriculum. For those who have been in practice since completion of their training, this may be accomplished through communication with department heads or supervisors at the institution where the individual holds privileges to administer moderate sedation. Alternatively, the nonanesthesiologist sedation practitioner could be proctored or supervised by a physician, dentist or podiatrist who is currently privileged to administer sedative and analgesic agents to provide moderate sedation. The facility should establish an appropriate number of procedures to be supervised.

2. Before granting ongoing privileges to administer or supervise administration of sedative and analgesic drugs to establish a level of moderate sedation, a process should be developed to re-evaluate the practitioner’s performance at regular intervals. For example, the practitioner’s performance could be reviewed by an anesthesiologist or a nonanesthesiologist sedation practitioner who is currently privileged to administer sedative and analgesic agents to provide moderate sedation. The facility should establish an appropriate number of procedures that will be reviewed.

D. Performance Improvement

Credentialing in the administration of sedative and analgesic drugs to establish a level of moderate sedation should require active participation in an ongoing process that evaluates the practitioner’s clinical performance and patient care outcomes through a formal program of continuous performance improvement.

1. The organization in which the practitioner practices should conduct peer review of its clinicians.

2. The performance improvement process should assess up-to-date knowledge as well as ongoing competence in the skills outlined in the educational and training requirements described above.

3. The performance improvement process should monitor and evaluate patient outcomes and adverse events.

II. SUPERVISED SEDATION PROFESSIONAL

A. Education and Training

The supervised sedation professional who is granted privileges to administer sedative and analgesic drugs under supervision of a nonanesthesiologist sedation practitioner or anesthesiologist and to monitor patients during moderate

sedation can be a registered nurse who has graduated from a qualified school of nursing or a physician assistant who has graduated from an accredited physician assistant program. They may only administer sedative and analgesic medications on the order of an anesthesiologist or nonanesthesiologist sedation practitioner. They should have satisfactorily completed a formal training program in 1) the safe administration of sedative and analgesic drugs used to establish a level of moderate sedation, 2) use of reversal agents for opioids and benzodiazepines, 3) monitoring of patients' physiologic parameters during sedation, and 4) recognition of abnormalities in monitored variables that require intervention by the nonanesthesiologist sedation practitioner or anesthesiologist. Training should include the following:

1. Contents of the following ASA documents:
 - *Practice Guidelines for Sedation and Analgesia by Nonanesthesiologists*
 - *Continuum of Depth of Sedation – Definition of General Anesthesia and Levels of Sedation/Analgesia*
2. The pharmacology of (1) all sedative and analgesic drugs the practitioner requests privileges to administer to establish a level of moderate sedation, and (2) pharmacologic antagonists to the sedative and analgesic drugs.
3. The benefits and risks of supplemental oxygen.
4. Airway management with facemask and positive pressure ventilation.
5. Monitoring and recognizing abnormalities of physiologic variables, including the following:
 - a. Blood pressure
 - b. Respiratory rate
 - c. Oxygen saturation by pulse oximetry
 - d. Electrocardiographic monitoring
 - e. Depth of sedation. The depth of sedation should be based on the ASA definitions of "moderate sedation" and "deep sedation." (See above)
 - f. Capnography—if moderate sedation is to be administered in settings where patients' ventilatory function cannot be directly monitored.
6. The importance of continuous use of appropriately set audible alarms on all physiologic monitors.
7. Documenting the drugs administered, the patient's physiologic condition and the depth of sedation at regular intervals throughout the period of sedation and analgesia, using a graphical, tabular or automated record.

B. Licensure

1. The supervised sedation professional should have a current active nursing license or physician assistant license or certification, in the U.S. state, district or territory of practice. (Exception: practitioners employed by the federal government may have a current active license in any U.S. state, district or territory.)

2. Before granting or renewing privileges for a supervised sedation professional to administer sedative and analgesic drugs and to monitor patients during moderate sedation, the

health care organization should search for any disciplinary action recorded in the National Practitioner Data Bank (NPDB) and take appropriate action regarding any Adverse Action Reports.

C. Practice Pattern

1. Before granting ongoing privileges to administer sedative and analgesic drugs to establish a level of moderate sedation, a process should be developed to re-evaluate the supervised sedation professional's performance. The facility should establish performance criteria and an appropriate number of procedures to be reviewed.

D. Performance Improvement

Credentialing of supervised sedation professionals in the administration of sedative and analgesic drugs and monitoring patients during moderate sedation should require active participation in an ongoing process that evaluates the health care professional's clinical performance and patient care outcomes through a formal program of continuous performance improvement.

1. The organization in which the practitioner practices should conduct peer review of its supervised sedation professionals.

2. The performance improvement process should assess up-to-date knowledge as well as ongoing competence in the skills outlined in the educational and training requirements described above.

STATEMENT ON GRANTING PRIVILEGES FOR DEEP SEDATION TO NON-ANESTHESIOLOGIST SEDATION PRACTITIONERS

Committee of Origin: *Ad Hoc* on Non-Anesthesiologist Privileging (Approved by the ASA House of Delegates on October 20, 2010)

1. INTRODUCTION

The American Society of Anesthesiologists is vitally interested in the safe administration of all anesthesia services including moderate and deep sedation. As such, it has concern for any system or set of practices, used either by its members or the members of other disciplines that would adversely affect the safety of anesthesia or sedation administration. It has genuine concern that individuals, however well intentioned, who are not anesthesia professionals may not recognize that sedation and general anesthesia are on a continuum, and thus deliver levels of sedation that may, in fact, be general anesthesia without having the training and experience to respond appropriately.

ASA believes that anesthesiologist participation in all deep sedation is the best means to achieve the safest care. ASA acknowledges, however, that Medicare regulations permit some non-anesthesiologists to administer or supervise the administration of deep sedation. This advisory should not be considered as an endorsement, or absolute condemnation, of this practice by ASA but rather to serve as a potential guide to its members who may be called upon by administrators or others to provide input in this process. This document provides a framework to identify those physicians, dentists, oral surgeons or podiatrists who may potentially qualify to administer or supervise the administration of deep sedation.

This document applies only to the care of patients undergoing procedural sedation, and it may not be construed as privileges to intentionally administer general anesthesia. Unrestricted general anesthesia shall only be administered by anesthesia professionals within their scope of practice (anesthesiologists, certified registered nurse anesthetists and anesthesiologist assistants). If the patient loses consciousness and the ability to respond purposefully, the anesthesia care is a general anesthetic, irrespective of whether airway instrumentation is required.

When deep sedation is intended, there is a significant risk that patients may slip into a state of general anesthesia (from which they cannot be aroused by painful or repeated stimulation). Therefore, individuals requesting privileges to administer deep sedation must demonstrate their ability to (1) recognize that a patient has entered a state of general anesthesia and (2) maintain a patient's vital functions until the patient has been returned to an appropriate level of sedation.

Definitions of terms appear at the end of this document. Of special note, for purposes of this document the following definitions are relevant:

1.1 Anesthesia Professional: An anesthesiologist, anesthesiologist assistant (AA), or certified registered nurse anesthetist (CRNA).

1.2 Non-anesthesiologist Sedation Practitioner: A licensed physician (allopathic or osteopathic); or dentist, oral surgeon, or podiatrist who is qualified to administer anesthesia under State law; who has not completed postgraduate training in anesthesiology but is specifically trained to administer personally or to supervise the administration of deep sedation.

2. ADVISORY

This advisory is designed to assist health care facilities in developing a program for the delineation of clinical privileges for practitioners who are not anesthesia professionals to administer sedative and analgesic drugs to establish a level of deep sedation. They are written to apply to every setting in which an internal or external privileging process is required for granting privileges to administer sedative and analgesic drugs to establish a level of deep sedation (e.g., hospital, freestanding procedure center, ambulatory surgery center,

physician's or dentist's office, etc.). These recommendations do not lead to the granting of privileges to administer general anesthesia.

The granting, reappraisal and revision of clinical privileges will be awarded on a time-limited basis in accordance with rules and regulations of the health care facility, its medical staff, organizations accrediting the health care facility, and relevant local, state and federal governmental agencies.

NON-ANESTHESIOLOGIST SEDATION PRACTITIONERS

Note: The *Hospital Anesthesia Services Condition of Participation 42 CFR 482.52(a)* limits the administration of deep sedation to "qualified anesthesia professionals" within their scope of practice. CMS defines these personnel specifically as an anesthesiologist; non-anesthesiologist MD or DO; dentist, oral surgeon, or podiatrist who is qualified to administer anesthesia under State law; CRNA, and AA. See also the *Ambulatory Surgery Center Condition for Coverage 42 CFR 416.42(b)*.

Only physicians and other practitioners specifically permitted by CMS, above, who are qualified by education, training and licensure to administer deep sedation may administer deep sedation or supervise the administration of deep sedation when administered by CRNAs. Because training is procedure specific, the type and complexity of procedures for which the practitioner may administer or supervise deep sedation must be specified in the privileges granted.

Any professional who administers and monitors deep sedation must be dedicated to that task. Therefore, the non-anesthesiologist sedation practitioner who administers and monitors deep sedation must be different from the individual performing the diagnostic or therapeutic procedure (see ASA Guidelines for Sedation and Analgesia by Non-anesthesiologists).

3. EDUCATION AND TRAINING

The non-anesthesiologist sedation practitioner will have satisfactorily completed a formal training program in (1) the safe administration of sedative and analgesic drugs used to establish a level of deep sedation, and (2) rescue of patients who exhibit adverse physiologic consequences of a deeper-than-intended level of sedation. This training may be a formally recognized part of a recently completed Accreditation Council for Graduate Medical Education (ACGME) residency or fellowship training (e.g., within two years), or may be a separate deep sedation educational program that is accredited by Accreditation Council for Continuing Medical Education (ACCME) or equivalent providers recognized for dental, oral surgical and podiatric continuing education, and that includes the didactic and performance concepts below. A knowledge-based test is necessary to objectively demonstrate the knowledge of

concepts required to obtain privileges. The following subject areas will be included:

3.1 Contents of the following ASA documents (or their more current version if subsequently modified) that will be understood by practitioners who administer sedative and analgesic drugs to establish a level of deep sedation

3.1.1 Practice Guidelines for Sedation and Analgesia by Non-Anesthesiologists. *Anesthesiology* 2002: 96; 1004-1017.

3.1.2 Continuum of Depth of Sedation; Definition of General Anesthesia and Levels of Sedation/Analgesia (ASA HOD 2004, amended 2009)

3.1.3 Standards for Basic Anesthetic Monitoring (Approved by the ASA House of Delegates on October 21, 1986, and last amended on October 25, 2005)

3.1.4 Practice Guidelines for Preoperative Fasting and the Use of Pharmacologic Agents to Reduce the Risk of Pulmonary Aspiration: Application to Healthy Patients Undergoing Elective Procedures (Approved by ASA House of Delegates on October 21, 1998, and effective January 1, 1999)

3.2 Appropriate methods for obtaining informed consent through pre-procedure counseling of patients regarding risks, benefits and alternatives to the administration of sedative and analgesic drugs to establish a level of deep sedation.

3.3 Skills for obtaining the patient's medical history and performing a physical examination to assess risks and comorbidities, including assessment of the airway for anatomic and mobility characteristics suggestive of potentially difficult airway management. The non-anesthesiologist sedation practitioner will be able to recognize those patients whose medical condition requires that sedation needs to be provided by an anesthesia professional, such as morbidly obese patients, elderly patients, pregnant patients, patients with severe systemic disease, patients with obstructive sleep apnea, or patients with delayed gastric emptying.

3.4 Assessment of the patient's risk for aspiration of gastric contents as described in the ASA Practice Guidelines for Preoperative Fasting. In urgent, emergent or other situations where gastric emptying is impaired, the potential for pulmonary aspiration of gastric contents must be considered in determining

3.4.1 The target level of sedation

3.4.2 Whether the procedure should be delayed

3.4.3 Whether the sedation care should be transferred to an anesthesia professional for the delivery of general anesthesia with endotracheal intubation.

3.5 The pharmacology of

3.5.1 All sedative and analgesic drugs the practitioner requests privileges to administer to establish a level of deep sedation

3.5.2 Pharmacological antagonists to the sedative and analgesic drugs

3.5.3 Vasoactive drugs and antiarrhythmics.

3.6 The benefits and risks of supplemental oxygen.

3.7 Recognition of adequacy of ventilatory function: This will include experience with patients whose ventilatory drive

is depressed by sedative and analgesic drugs as well as patients whose airways become obstructed during sedation. This will also include the ability to perform capnography and understand the results of such monitoring. Non-anesthesiologist practitioners will demonstrate competency in managing patients during deep sedation, and understanding of the clinical manifestations of general anesthesia so that they can ascertain when a patient has entered a state of general anesthesia and rescue the patient appropriately.

3.8 Proficiency in advanced airway management for rescue: This training will include appropriately supervised experience to demonstrate competency in managing the airways of patients during deep sedation, and airway management using airway models as well as using high-fidelity patient simulators. The non-anesthesiologist practitioner must demonstrate the ability to reliably perform the following:

3.8.1 Bag-valve-mask ventilation

3.8.2 Insertion and use of oro- and nasopharyngeal airways

3.8.3 Insertion and ventilation through a laryngeal mask airway

3.8.4 Direct laryngoscopy and endotracheal intubation

This will include clinical experience on no less than 35 patients or equivalent simulator experience (See ACGME reference). The facility with oversight by the Director of Anesthesia Services will determine the number of cases needed to demonstrate these competencies, and may increase beyond the minimum recommended.

3.9 Monitoring of physiologic variables, including the following:

3.9.1 Blood pressure.

3.9.2 Respiratory rate.

3.9.3 Oxygen saturation by pulse oximetry with audible variable pitch pulse tone.

3.9.4 Capnographic monitoring. The non-anesthesiologist practitioner shall be familiar with the use and interpretation of capnographic waveforms to determine the adequacy of ventilation during deep sedation.

3.9.5 Electrocardiographic monitoring. Education in electrocardiographic (EKG) monitoring will include instruction in the most common dysrhythmias seen during sedation and anesthesia, their causes and their potential clinical implications (e.g., hypercapnia), as well as electrocardiographic signs of cardiac ischemia.

3.9.6 Depth of sedation. The depth of sedation will be based on the ASA definitions of "deep sedation" and "general anesthesia." (See below).

3.10 The importance of continuous use of appropriately set audible alarms on physiologic monitoring equipment.

3.11 Documenting the drugs administered, the patient's physiologic condition and the depth of sedation at five-minute intervals throughout the period of sedation and analgesia, using a graphical, tabular or automated record which documents all the monitored parameters including capnographic monitoring.

3.12 The importance of monitoring the patient through the recovery period and the inclusion of specific discharge criteria for the patient receiving sedation.

3.13 Regardless of the availability of a “code team” or the equivalent, the non-anesthesiologist practitioner will have advanced life support skills and current certificate such as those required for Advanced Cardiac Life Support (ACLS). When granting privileges to administer deep sedation to pediatric patients, the non-anesthesiologist practitioner will have advanced life support skills and current certificate such as those required for Pediatric Advanced Life Support (PALS). Initial ACLS and PALS training and subsequent retraining shall be obtained from the American Heart Association or another vendor that includes “hands-on” training and skills demonstration of airway management and automated external defibrillator (AED) use.

3.14 Required participation in a quality assurance system to track adverse outcomes and unusual events including respiratory arrests, use of reversal agents, prolonged sedation in recovery process, larger than expected medication doses, and occurrence of general anesthesia, with oversight by the Director of Anesthesia services or their designee.

3.15 Knowledge of the current CMS Conditions of Participation regulations and their interpretive guidelines pertaining to deep sedation, including requirements for the pre-anesthesia evaluation, anesthesia intra-operative record, and post-anesthesia evaluation.

Separate privileging is required for the care of pediatric patients. When the non-anesthesiologist practitioner is granted privileges to administer sedative and analgesic drugs to pediatric patients to establish a level of deep sedation, the education and training requirements enumerated in #1-15 above will be specifically defined to qualify the practitioner to administer sedative and analgesic drugs to pediatric patients.

4. LICENSURE

4.1 The non-anesthesiologist sedation practitioner will have a current active, unrestricted medical, osteopathic, or dental license in the state, district or territory of practice. (Exception: practitioners employed by the federal government may have a current active license in any U.S. state, district or territory.)

4.2 The non-anesthesiologist sedation practitioner will have a current unrestricted Drug Enforcement Administration (DEA) registration (schedules II-V).

4.3 The privileging process will require disclosure of any disciplinary action (final judgments) against any medical, osteopathic or dental license by any state, district or territory of practice and of any sanctions by any federal agency, including Medicare/Medicaid, in the last five years.

4.4 Before granting or renewing privileges to administer or supervise the administration of sedative and analgesic drugs to establish a level of deep sedation, the health care organization shall search for any disciplinary action recorded in the National Practitioner Data Bank (NPDB) and take appropriate action regarding any Adverse Action Reports.

5. PERFORMANCE EVALUATION

5.1 Before granting initial privileges to administer or supervise administration of sedative and analgesic drugs to establish a level of deep sedation, a process will be developed to evaluate the practitioner’s performance and competency. For recent graduates (e.g., within two years), this may be accomplished through letters of recommendation from directors of residency or fellowship training programs that include deep sedation as part of the curriculum. For those who have been in practice since completion of their training, performance evaluation may be accomplished through specific documentation of performance evaluation data transmitted from department heads or supervisors at the institution where the individual previously held privileges to administer deep sedation. Alternatively, the non-anesthesiologist sedation practitioner could be proctored or supervised by a physician or dentist who is currently privileged to administer sedative and analgesic agents to provide deep sedation. The Director of Anesthesia Services with oversight by the facility governing body will determine the number of cases that need to be performed in order to determine independent competency in deep sedation.

5.2 Before granting ongoing privileges to administer or supervise administration of sedative and analgesic drugs to establish a level of deep sedation, a process will be developed to re-evaluate the practitioner’s performance at regular intervals. Re-evaluation of competency in airway management will be part of this performance evaluation. For example, the practitioner’s performance could be reviewed by an anesthesiologist or a non-anesthesiologist sedation practitioner who is currently privileged to administer deep sedation. The facility will establish an appropriate number of procedures that will be reviewed.

6. PERFORMANCE IMPROVEMENT

Privileging in the administration of sedative and analgesic drugs to establish a level of deep sedation will require active participation in an ongoing process that evaluates the practitioner’s clinical performance and patient care outcomes through a formal facility program of continuous performance improvement. The facility’s deep sedation performance improvement program will be developed with advice from and with outcome review by the Director of Anesthesia Services.

6.1 The organization in which the practitioner practices will conduct peer review of its clinicians.

6.2 The performance improvement program will assess up-to-date knowledge as well as ongoing competence in the skills outlined in the educational and training requirements described above.

6.3 Continuing medical education in the delivery of anesthesia services is required for renewal of privileges.

6.4 The performance improvement program will monitor and evaluate patient outcomes and adverse or unusual events.

6.5 Any of the following events will be referred to the facility quality assurance committee for evaluation and performance evaluation:

6.5.1 Unplanned admission

6.5.2 Cardiac arrest

6.5.3 Use of reversal agents

6.5.4 Use of assistance with ventilation requiring bag-valve-mask ventilation or laryngeal or endotracheal airways.

6.5.5 Prolonged periods of oxygen desaturation (<85% for 3 minutes)

6.5.6 Failure of the patient to return to 20% of pre-procedure vital signs

7. DEFINITIONS

ANESTHESIA PROFESSIONAL—An anesthesiologist, anesthesiologist assistant (AA), or certified registered nurse anesthetist (CRNA).

NON-ANESTHESIOLOGIST SEDATION PRACTITIONER—A licensed physician (allopathic or osteopathic); or dentist, oral surgeon, or podiatrist who is qualified to administer anesthesia under State law; who has not completed postgraduate training in anesthesiology but is specifically trained to administer personally or to supervise the administration of deep sedation.

PRIVILEGES—The clinical activities within a health care organization that a practitioner is permitted to perform.

PRIVILEGING—The process of granting permission to perform certain clinical activities based on credentials, experience, and demonstrated performance

CREDENTIALS—The professional qualifications of a practitioner including education, training, experience and performance

CREDENTIALING—The process of obtaining, verifying, and assessing the qualifications of a practitioner to provide care or services in or for a healthcare organization.

PROCEDURAL SEDATION—The administration of sedative and analgesic drugs for a non-surgical diagnostic or therapeutic procedure.

Definitions of the continuum of sedation:

* **MODERATE SEDATION**—“Moderate Sedation/Analgesia (“Conscious Sedation”) is a drug-induced depression of consciousness during which patients respond purposefully to verbal commands, either alone or accompanied by light tactile stimulation. No interventions are required to maintain a patent airway, and spontaneous ventilation is adequate. Cardiovascular function is usually maintained.”

* **DEEP SEDATION**—“Deep Sedation/Analgesia is a drug-induced depression of consciousness during which patients cannot be easily aroused but respond purposefully following repeated or painful stimulation. The ability to independently maintain ventilatory function may be impaired. Patients may require assistance in maintaining a patent airway, and spontaneous ventilation may be inadequate. Cardiovascular function is usually maintained.”

* **RESCUE**—“Rescue of a patient from a deeper level of sedation than intended is an intervention by a practitioner proficient in airway management and advanced life support. The qualified practitioner corrects adverse physiologic consequences of the deeper-than-intended level of sedation (such as hypoventilation, hypoxia and hypotension) and returns the patient to the originally intended level of sedation. It is not appropriate to continue the procedure at an unintended level of sedation.”

* **GENERAL ANESTHESIA**—“General Anesthesia is a drug-induced loss of consciousness during which patients are not arousable, even by painful stimulation. The ability to independently maintain ventilatory function is often impaired. Patients often require assistance in maintaining a patent airway, and positive pressure ventilation may be required because of depressed spontaneous ventilation or drug-induced depression of neuromuscular function. Cardiovascular function may be impaired.”

*The definitions marked with an asterisk are extracted verbatim from “Continuum of Depth of Sedation – Definition of General Anesthesia and Levels of Sedation/Analgesia” (Approved by ASA House of Delegates on October 13, 1999, and amended on October 21, 2009).

Expanded definitions of moderate and deep sedation can be found in the CMS Interpretive Guidelines.

8. REFERENCES

The American Society of Anesthesiologists has produced many documents over the years related to the topic addressed by this advisory, among them the following (in alphabetical order):

- AANA-ASA Joint Statement Regarding Propofol Administration (April 14, 2004)
- Continuum of Depth of Sedation – Definition of General Anesthesia and Levels of Sedation/Analgesia (Approved by ASA House of Delegates on October 13, 1999, and last amended on October 21, 2009).
- Distinguishing Monitored Anesthesia Care (“MAC”) from Moderate Sedation/Analgesia (Conscious Sedation). (Approved by the ASA House of Delegates on October 27, 2004 and last amended on October 21, 2009)
- Guidelines for Ambulatory Anesthesia and Surgery (Approved by ASA House of Delegates on October 11, 1973, and last amended on October 22, 2008)
- Guidelines for Delineation of Clinical Privileges in Anesthesiology (Approved by ASA House of Delegates on October 15, 1975, and last amended on October 22, 2008)
- Guidelines for Office-Based Anesthesia and Surgery (Approved by ASA House of Delegates on October 13, 1999, and last affirmed on October 21, 2009)
- Outcome Indicators for Office-Based and Ambulatory Surgery (ASA Committee on Ambulatory Surgical Care and Task Force on Office-Based Anesthesia, April 2003)
- Practice Guidelines for Preoperative Fasting and the Use of Pharmacologic Agents to Reduce the Risk of Pulmonary

Aspiration: Application to Healthy Patients Undergoing Elective Procedures. *Anesthesiology* 1999; 90: 896-905.

Practice Guidelines for Sedation and Analgesia by Non-anesthesiologists. *Anesthesiology* 2002; 96: 1004-1017.

Standards for Basic Anesthetic Monitoring (Approved by the ASA House of Delegates on October 21, 1986, and last amended on October 20, 2010)

Statement on Granting Privileges for Administration of Moderate Sedation to Practitioners Who Are Not Anesthesia Professionals (Approved by the ASA House of Delegates on October 25, 2005, and last amended on October 18, 2006)

Statement on Qualifications of Anesthesia Providers in the Office-Based Setting (Approved by ASA House of Delegates on October 13, 1999, and last amended on October 21, 2009)

Statement on Safe Use of Propofol (Approved by ASA House of Delegates on October 27, 2004 and amended on October 21, 2009)

In addition the following references may be considered:

ACGME Emergency Medicine residency program guidelines for number of intubations needed:
http://www.acgme.org/acWebsite/RRC_110/110_guidelines.asp#res

American Academy of Pediatrics, American Academy of Pediatric Dentistry, Cote CJ, Wilson S, and the Workgroup on Sedation. Guidelines for Monitoring and Management of Pediatric Patients During and After Sedation for Diagnostic and Therapeutic Procedures: An Update. *Pediatrics* 2006; 118: 2587-2602.

Centers for Medicare and Medicaid Services Revisions to Interpretive Guidelines for Hospital Condition of Participation, December 11, 2009.
<http://www.cms.gov/surveycertificationgeninfo/pmsr/itemdetail.asp?itemid=CMS1231690>

Centers for Medicare and Medicaid Services Revisions to Interpretive Guidelines for Ambulatory Surgery Centers Condition for Coverage, December 30, 2009.
<https://www.cms.gov/transmittals/downloads/R56SOMA.pdf>

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