Atlas of Laparoscopic Surgery

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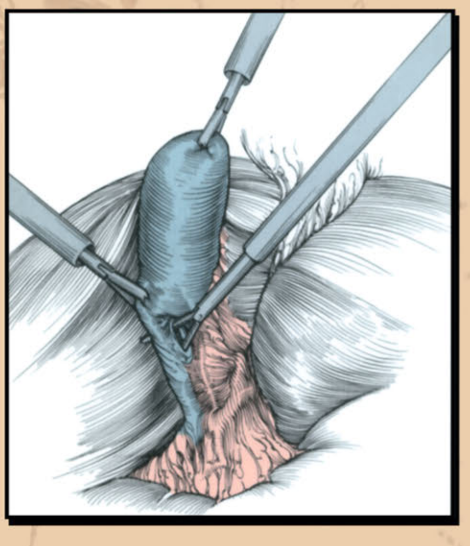
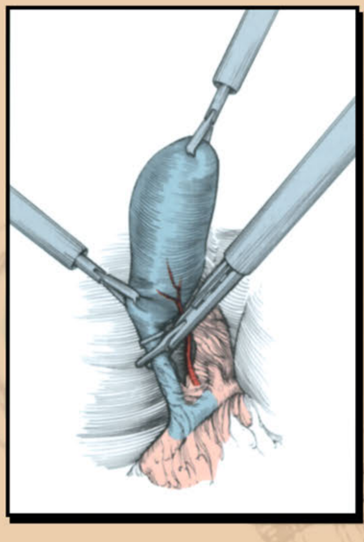
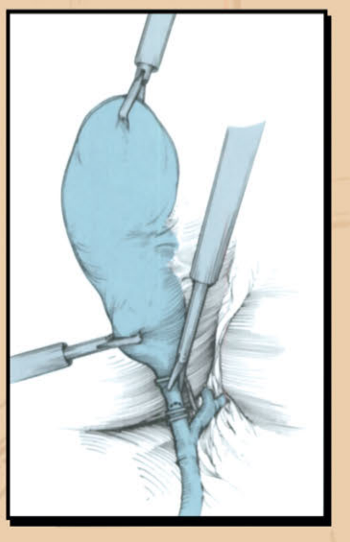

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Foreword

The field of laparoscopic surgery has progressed at an astonishing pace, and new techniques are continuously being devised. The impetus for the widespread application of this method was initiated by Mouret in 1987 in his performance of cholecystectomy by the laparoscopic approach. The great majority of gallbladders are now being removed by laparoscopic cholecystectomy with quite favorable results.

It is generally agreed that the laparoscopic approach for many surgical procedures is less invasive, produces less trauma to tissues and organs, is associated with less postoperative discomfort, and is accompanied by a more rapid return of the patient to normal. Moreover, while the instrumentation and equipment used in laparoscopic procedures are often individualized and more expensive, recent studies have shown that this approach can be cost-effective in comparison with standard open surgical procedures, and especially with the short hospital stay.

The authors of this text have primarily drawn from their experiences in laparoscopic surgery at the Duke–US Surgical Endosurgical Center at the Duke University Medical Center. This is the site of considerable developmental research on innovative instrumentation and studies to devise and assess new procedures. The center is fully equipped with the latest technology available. In addition there is a vivarium that has an experimental surgical unit and facilities for long-term postoperative care. In this setting, a number of new procedures have been devised and evaluated. The center also has an excellent surveillance plan for outcome studies of patients undergoing laparoscopic procedures. This combination of facilities and services has led to significant advances as well as a thorough follow-up of a number of clinical series.

The *Atlas of Laparoscopic Surgery* is composed of 28 chapters with authoritative commentaries and illustrations of a number of surgical procedures amenable to laparoscopic techniques. The chapters are effectively planned, with a thorough discussion of the procedure with the appropriate anatomical, pathophysiological, and differential diagnostic features. The surgical techniques are graphically depicted by a combination of intraoperative illustrations and selected photographs. The legends accompanying each of the illustrations provide an unusually clear description of each step during the procedure in what is essentially a fail-safe approach. A selected bibliography follows each chapter with the most pertinent citations from the literature.

Occasionally a new text appears which makes such a convincing impression that a prediction can be made with confidence. This *Atlas of Laparoscopic Surgery* is a perfect example, as it is composed of a host of procedures that can be effectively achieved by laparoscopy. It is a masterwork by talented contributors and is a *must* for all those involved in the field.

David C. Sabiston, Jr, MD

Preface

The *Atlas of Laparoscopic Surgery* represents the cumulative thoughts of a group of surgeons, predominantly from Duke University Medical Center, in the early 1990s. Our hope is to capture some of the nuances of laparoscopic surgery that we experienced early in the development of advanced laparoscopy. The Editors fully realize that the information presented will undergo changes over the next several years as the field of advanced laparoscopy matures.

We have chosen the word "laparoscopic" in the title of this book as a generic term to include both laparoscopy and thoracoscopy. The text will probably be most beneficial for the minimally invasive general surgeon who occasionally does thoracoscopic work. The authors have made an effort to include alternative techniques to the ones that are frequently used at Duke. The Editors acknowledge that there are many ways to successfully complete most operations, and where a single technique is presented, many other techniques could be substituted. We find that the techniques described are effective and usually quite safe. Efforts have been made to include techniques that are widely applicable for most advanced laparoscopic surgeons, and given the choice between complex versus simple techniques, we tend to use the least complex and shortest operation. Many of the operations, such as the laparoscopic antireflux procedures and laparoscopic gastrostomy and jejunostomy, are specifically detailed to reduce the learning curve for these procedures as much as possible. Although laparoscopic cholecystojejunostomy does not have broad application, the technique as it is described in this chapter has proven successful in our experience. The fields of laparoscopic appendectomy and laparoscopic herniorrhaphy continue to be quite contentious, but the techniques presented in these chapters should be helpful if the readers choose to include these operations in their surgical repertoire. The chapter on pediatric endosurgery is meant mostly as an overview, and the Editors recognize that entire texts have been devoted to this subject.

The Editors would like to thank Dr. David C. Sabiston, Jr, for his foreword and for his great support in the development of endosurgery at Duke University Medical Center. Dr. William C. Meyers is a contributor to this atlas and is also the driving academic force behind most of our endosurgical innovations. Finally, the Editors would like to thank Leon Hirsch and the US Surgical Corporation for their philanthropic support of the Department of Surgery at Duke Hospital in our efforts to advance the surgical knowledge of endosurgery.

Our sincere hope is that this atlas will simplify and organize surgical thought for the advanced laparoscopist. The operations described should be safe, should not require extensive operating time, and should be effective for the diseases described.

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CHAPTER

1

Laparoscopic Instrumentation and Basic Techniques

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Lewis B. Schwartz
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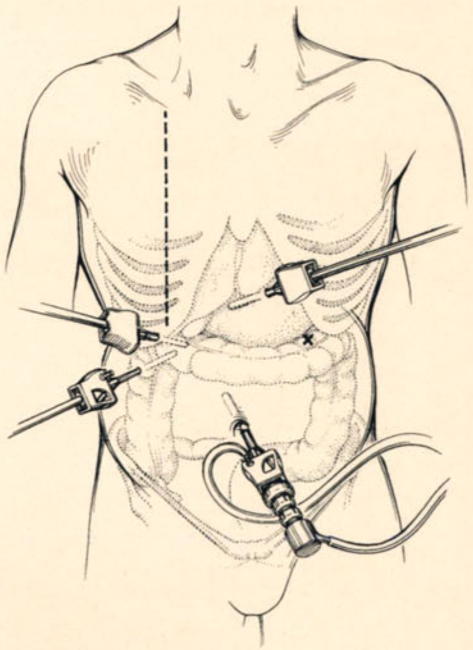


The initial success of laparoscopic cholecystectomy has stimulated surgeons and engineers to design instrument systems and surgical procedures with ever increasing clarity and complexity. Once consigned only to the gallbladder, the laparoscope has now been applied to nearly every organ system in the abdomen, chest, and mediastinum. New instrumentation is being designed and introduced at an exponential rate. In order to perform safe and effective procedures, surgeons must familiarize themselves with the application as well as the potential drawbacks of these new tools. The purpose of this chapter is to provide general guidelines for the use of laparoscopic and thoracoscopic instrumentation and to describe the more recent developments currently at the forefront of videoscopic surgery.

The Operating Room

Perhaps no single factor is more important in videoscopic surgery than the proper training of operating room personnel in the set-up, use, and troubleshooting of the video system. It has been our practice to employ a fully trained individual whose sole responsibility is equipment purchase and maintenance and who has no daily operating room assignment. This serves to limit often-encountered frustrations with new or faulty equipment and also saves a significant amount of operating room time.

Exact details of the design of the laparoscopic operating room obviously depend on the procedure being performed. Nonetheless, some basic concepts are generally applicable and warrant consideration. The success of any videoscopic procedure is highly dependent on the spatial relationship between the surgeon, first assistant, and the video monitors. In general, the primary surgeons' monitor should be placed so that the surgeon is facing both the video monitor and the organ of interest. Monitors must be unobstructed by electrical cords, tubing, anesthesia equipment, and so forth, and it is well worth the time and effort to move the patient or equipment so that the surgeon may enjoy a comfortable and unencumbered view of the screen. A secondary monitor should be placed in a similar manner for the first assistant. Other monitors placed for nurses or observers should be well away from the operating table. Whenever possible, the assistant and surgeon stand facing the same direction so that both individuals can work in the same line of orientation.

At present, most hospitals choose to modify existing operating rooms for videoscopic procedures. Designs are available, however, for construction of dedicated videoscopic surgical suites with ceiling-mounted cameras and other specialized equipment. Ceiling-mounted arms have been developed with attached cabinets for the housing of monitors, light sources, video cassette recorders, and insufflators (Figure 1-1).

Imaging Systems

Almost 200 years ago, endoscopy began with a candle and tin tube [1–3]. It was the development of the Hopkin's Rod-Lens systems in 1966, however, that began the evolution toward current video systems. The first simultaneous visualization of the abdominal cavity by all members of the operating team was accomplished through the attachment of a computer chip television camera to a laparoscope in 1986. This set the stage for the development of modern laparoscopy.

Laparoscopes

Today, laparoscopic procedures are performed using a descendant of the original Hopkin's Rod-Lens system. Most surgeons utilize a dedicated viewing laparoscope using a 0°, 30°, or 45° angle lens. Ten millimeter remains the most commonly used laparoscope size, although 5-mm scopes and smaller microendoscopes are available (Figure 1-2).

The authors prefer to use a 30° laparoscope when performing most advanced procedures allowing for manipulation of the angle of view and broadening the visual field accessible through a single port. This ability makes potentially dangerous maneuvers, such as retroesophageal dissection during Nissen fundoplication, much safer when performed under direct visualization. Laparoscopic suturing can be more readily performed using an angled lens system because the laparoscope can be manipulated in a manner that limits obstruction during needle placement. The proper use of an angled lens laparoscope does, however, require slightly more dexterity and experience when compared with a 0° scope.

Light Source

A high-intensity light source is essential for adequate illumination of the abdominal or thoracic cavity. Fiberoptic transmission of light from source to laparoscope to operative field can be accomplished with a negligible loss of intensity using modern systems. The clarity of the video image depends on the quality of light transmission. Meticulous maintenance of the fiberoptic light cable including replacement when fibers are damaged is essential for safe operation.

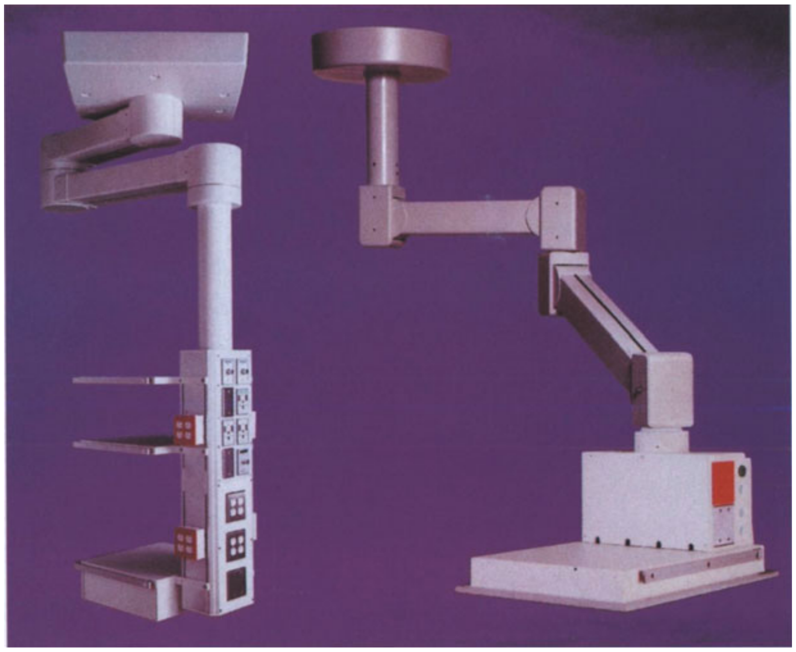


FIGURE 1-1.
Photograph of the Heraeus arm (Hanauport Universal Ceiling Camera; Heraeus Surgical, Milpitas, CA; with permission).

Despite separation of the light source from the fiberoptic cable by a heat shield, the intensity of the light may be transmitted as heat at the end of the laparoscope. Care must be taken to prevent thermal injury that may occur when the exposed end of a fiberoptic cable or laparoscope comes in contact with objects or personnel within the operative field.

Video Camera

The camera is the optical/electronic interface that attaches to the laparoscope. The camera and laparoscope are linked to a microprocessor that receives and transmits the image. One-chip cameras (450 horizontal lines per inch of resolution) provide adequate visualization for most laparoscopic operations. Three-chip cameras (700 horizontal lines per inch) are considered optimal, however, for advanced laparoscopic procedures and provide markedly improved resolution.

Video Monitors

High-resolution video monitors enable the accurate reproduction of images produced by the fiberoptic light source and video camera. The monitor should match the camera in quality, as the resolution is a product of the least accurate element.

Most monitoring systems are connected to a video cassette recorder or a photographic printer. Hard topics of laparoscopic images provide surgical documentation as well as a valuable record of the gross pathology encounters. A great deal of controversy remains regarding the filming of procedures and the creation of permanent documentation, however. Many surgeons are reluctant to record these procedures due to the potential legal implications should an intraoperative complication occur. Currently, there is no legal mandate that procedures must be recorded or that, if recorded, the tape must be included as part of the medical record.

Three Dimensional and High Definition Television

Three-dimensional (3-D) laparoscopic systems have been developed in an attempt to provide depth perception as an adjunct to traditional two-dimensional images. The loss of depth perception seems to be most apparent when attempting to perform precise maneuvers such as suturing. The initial 3-D systems were an advance in concept, yet a regression in image quality. Most systems provided a central "hot spot" (area of high light intensity) surrounded by a darker periphery. The resolution of the image is currently more comparable to a one-chip than a three-chip system. In addition, all members of the operating team must wear specially designed goggles that polarize the image in conjunction with the video image. Recent advances markedly improve image quality and ease of use (Figure 1-3).

These 3-D systems are currently used on a selective basis in specialized centers but have not gained wide acceptance. Three-dimensional technology is considered to be an intermediate step between the currently used three-chip systems and the future use of high definition television (HDTV). HDTV provides an image with outstanding resolution and a sense of depth perception. The currently produced HDTV systems are cost prohibitive, sometimes only available at seven to ten times the price of three-chip systems. The future acceptance of HDTV at a consumer level is likely to make these systems more affordable, however.

Equipment

Insufflation

Visualization of the peritoneal cavity requires distension or retraction of the abdominal wall, creating an operative field for instrumentation and manipulation. Although an adequate cavity may be achieved by mechanical retraction of the abdominal wall ("gasless laparoscopy"), creation of a pneu-

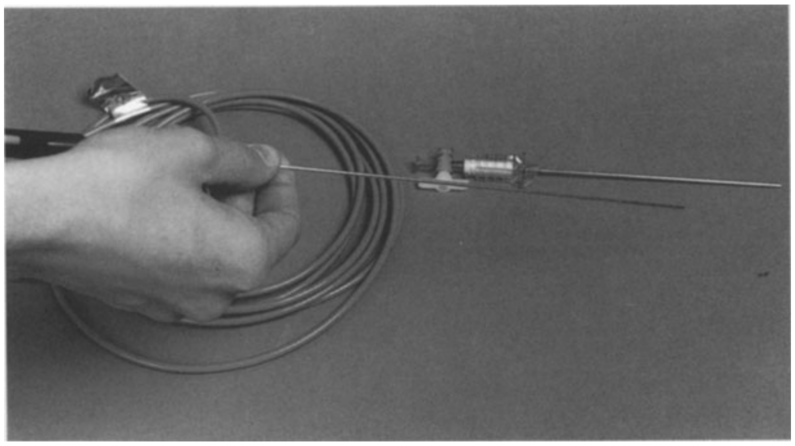


FIGURE 1-2.
Photograph of a microendoscope (Pixie™ scope; Origin Medsystems, Menlo Park, CA).

FIGURE 1-3.
Photograph of the 3-D Deep Vision viewing system. (*From* Automated Medical Products Corporation, New York, NY; with permission.)

moperitoneum by insufflation of gas has been traditionally used to establish the operative field. The development of an automatic insufflation device that provides continuous flow of gas as well as intra-abdominal pressure regulation was developed by Dr. Kurt Semm almost three decades ago and is the most popular system currently in use.

Various gases have been used for insufflation including air, oxygen, nitrogen, nitrous oxide, helium, argon, and carbon dioxide. Carbon dioxide is currently the most popular gas for insufflation due to its characteristics of suppression of combustion, high solubility, availability, and low cost. Carbon dioxide has the disadvantage of absorption from the peritoneum with the theoretical potential for metabolic acidosis. Patients with impaired pulmonary function may experience unacceptable levels of carbon dioxide retention during laparoscopic procedures.

Insufflators are designed to deliver carbon dioxide through a regulator at variable flow rates and constant cavity pressures. The optimal intra-abdominal pressure maintained in the adult human during laparoscopic surgery is 12 to 15 mm Hg. Excessive pressure within the peritoneal cavity may lead to hemodynamic instability secondary to venous compression and should prompt immediate release of the pneumoperitoneum and consideration of conversion to an open procedure. Early models of insufflators delivered up to 3 L/min, while the second-generation insufflators were capable of 8 to 10 L/min delivery. More recently designed "high-flow" systems can operate at a rate of 15 to 16 L/min, which allows for the maintenance of adequate pneumoperitoneum even in the face of continuous gas leaks from trocar sites. It is imperative that the insufflator is equipped with a working pop-off valve and alarm to avoid excessive abdominal distension.

The entire operating room team should be familiar with the controls and gauges of the insufflator. The pressure and flow rate should be observed during the initial insufflation of the peritoneal cavity and periodically checked thereafter. A high flow rate and low initial pressure (less than 5 mm Hg) should be evident if the Hasson cannula is properly positioned. Initial readings of elevated pressure and low flow rates are indicative of an improperly positioned trocar, a closed valve, kinked insufflation tubing, or inadequate anesthesia causing a Valsalva reaction. Abnormal initial pressures should prompt the immediate cessation of gas flow in order to prevent infusion of gas into the extraperitoneal or intravascular space. Optimal abdominal pressures in unusual settings, such as pregnancy, have not been established. The role of laparoscopy in the pregnant patient is controversial, although anecdotal successes in small numbers of women have been reported.

Insufflation Needles

Most insufflation needles are based on the design of Veress, in which a spring-loaded, blunt-tipped obturator is advanced past a sharp needle tip as it enters the abdominal cavity. The spring-loaded system has the advantage of covering the exposed sharp edge of the needle immediately after penetration. Insufflation needles are available in reusable and disposable styles. A significant advantage of the disposable needle is that the tip is always sharp, standardizing the amount of force that is required for insertion.

Initially, the technique for placing the Veress needle involved elevating the abdominal wall with towel clips and inserting the needle into the abdominal cavity with considerable force.

The authors prefer an open or Hasson technique in the vast majority of patients (Figures 1-4 to 1-9). Although studies have demonstrated complication rates from both the open and closed techniques to be similar, the types of complications may be markedly different. While injury to the bowel may occur with the Hasson technique, great vessel perforation is unlikely. Most life threatening and fatal complications of laparoscopic procedures have occurred by aberrant Veress needle or initial trocar placement, resulting in an air embolus or major vascular injury that is not immediately controlled.

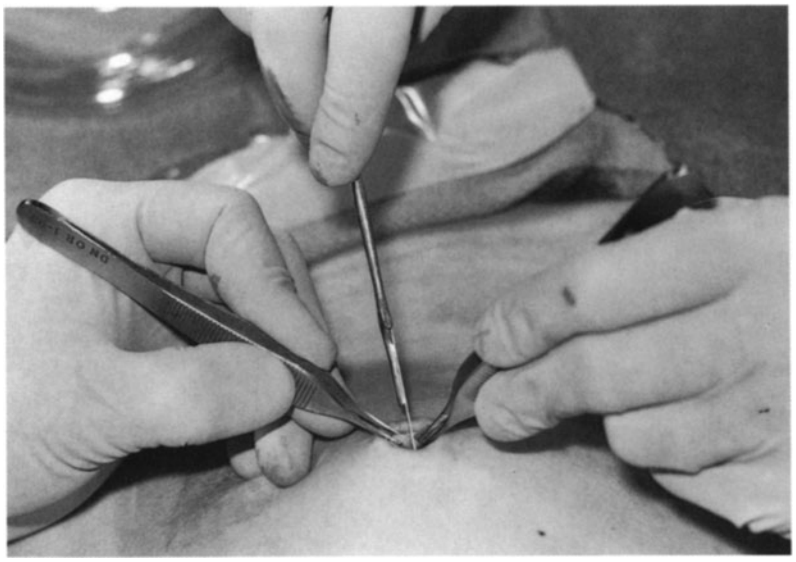


FIGURE 1-4.

Hasson trocar technique. A 10-mm vertical skin incision is made within the umbilicus. The deepest point within the umbilicus serves as the center of the incision.

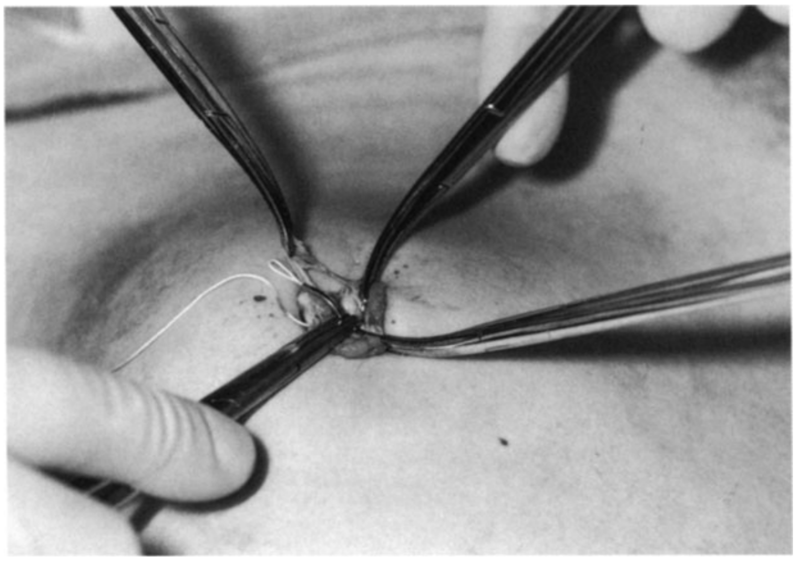


FIGURE 1-5.

The tissues are grasped between clamps, elevated, and divided until the peritoneum is entered. A stay suture is placed through the fascia on each side of the incision.

Trocars

Trocar/cannula systems allow for insertion of instruments and the laparoscope. They are available in disposable and reusable styles. Much emphasis has been placed on trocar safety and most single-use trocars now have safety shields or retractable tips. These safety devices have reduced the number of trocar-related complications but do not totally eliminate the occurrence of catastrophic events.

The placement of secondary trocars (trocars other than those housing the laparoscope) should virtually always occur without complications as secondary trocars are placed under direct laparoscopic visualization. The peritoneal surface should be examined for the presence of the epigastric vessels underneath the proposed site of trocar placement. Additionally, the abdominal wall may be transilluminated to identify and avoid superficial veins. Trocar tips must be sharp and their placement should be performed smoothly. The requirement of excessive force to place a trocar indicates that an improper technique is being used. Excessive resistance should cause the surgeon to examine the skin incision for adequacy and to check the trocar to be certain that it is properly loaded in a way that allows the sharp tip to be exposed. Placement of secondary trocars should be done using a "J-maneuver." This technique involves placing the trocar under direct visualization at a 90° angle to the abdominal wall. The trocar is advanced until the trocar tip penetrates the peritoneum. The hand controlling the trocar is then lowered so that the tip of the trocar is elevated and the cannula is advanced in a direction parallel to the peritoneal surface of the abdominal wall. Adherence to this technique can be expected to minimize visceral or retroperitoneal injury.

Optimal spacing and positioning of the cannulae is important for the successful completion of laparoscopic

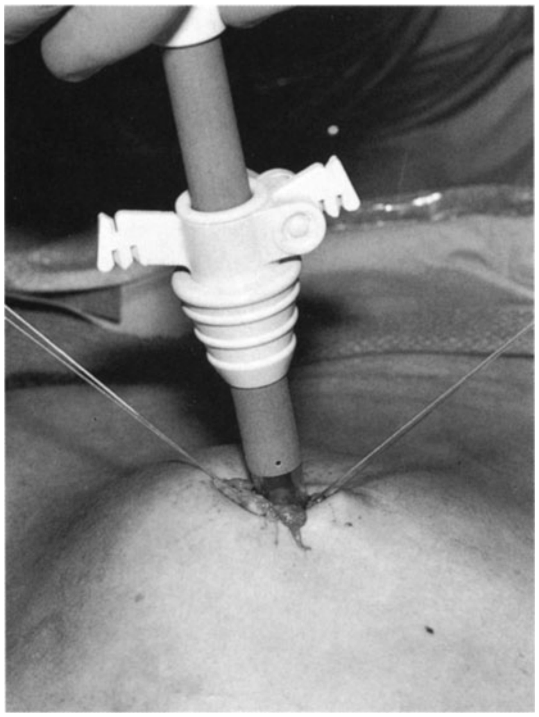


FIGURE 1-6.
The stay sutures are elevated as the Hasson cannula is inserted into the abdomen.

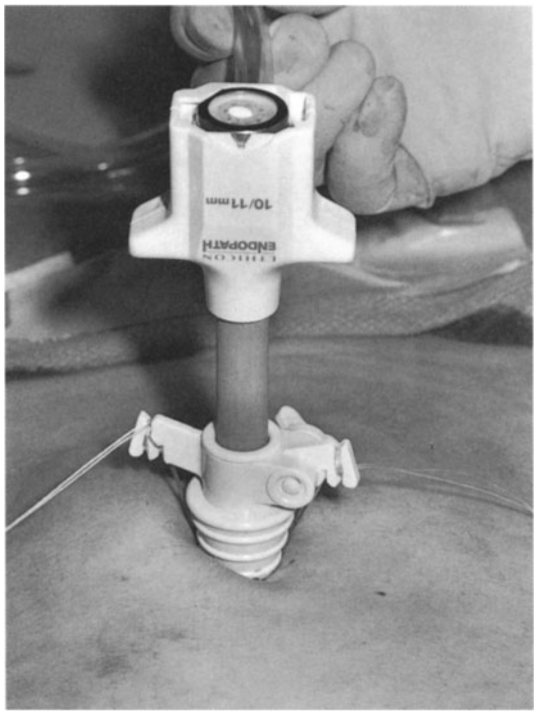


FIGURE 1-7.
The stay sutures are used to secure the cannula to the fascia. The insufflator tubing is attached to the cannula.

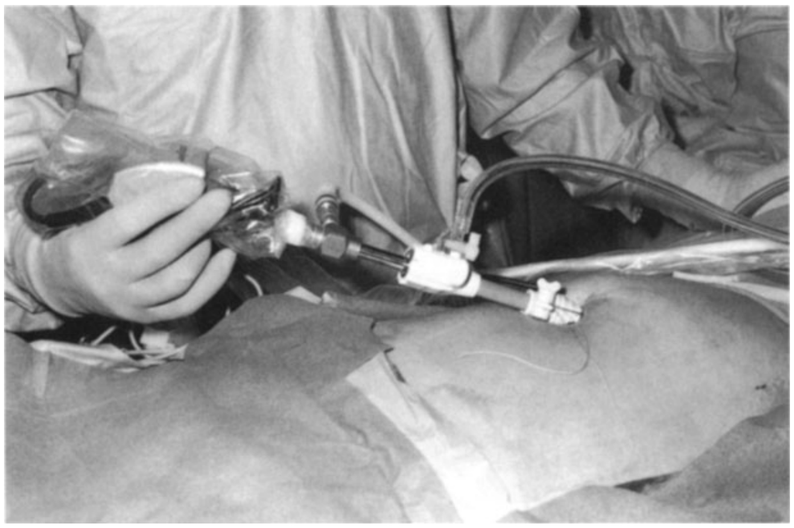


FIGURE 1-8.
The laparoscope is inserted and a 360° evaluation of the peritoneal cavity is performed.

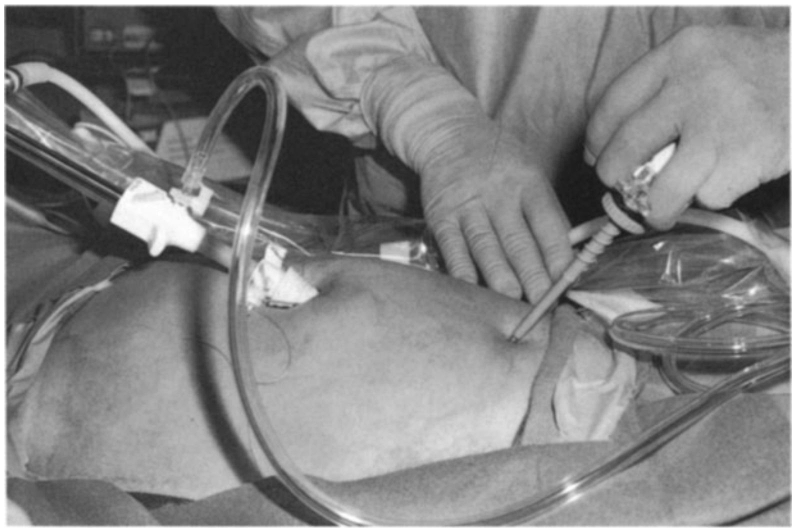


FIGURE 1-9.
A secondary trocar/cannula is inserted under laparoscopic visualization.

procedures. Cannulae should be spaced 7 to 10 cm apart (or one hand's breadth apart). Trocars should be triangulated away from yet directed toward the target organ. This allows the surgeon to work using two hands along the same axis as the laparoscope. One should avoid trocar placement that will require the surgeon or assistant to work directly against the visual axis of the laparoscope.

Irrigation/Aspiration

A wide variety of irrigation systems are currently available, ranging from manually pumped systems to pressurized irrigation systems that provide a high flow irrigation and aspiration. High flow systems are essential for advanced laparoscopic procedures where one needs to rapidly clear blood that is obscuring the field. Flow rates are dependent on several factors such as the pressure placed on the bag of fluid, the resistance within the tubing, and the diameter of the irrigation/aspiration wand. High flow insufflation devices (15 to 16 L/min) should be in place when utilizing an advanced irrigation/aspiration system because the suction will deflate the pneumoperitoneum rapidly.

Several systems include fluid warmers to maintain homeostatic patient temperatures. Other recent advances in irrigation/aspiration device design include the ability to place instrumentation such as cautery, graspers, and scissors through the suction irrigation port.

It is important that bleeding be rapidly controlled during laparoscopic procedures. A small amount of blood within the peritoneal cavity can absorb a great deal of light, thus making visualization suboptimal. This blood can also obscure tissue planes. The authors use 8000 units of heparin in each bag of irrigation in an attempt to prevent pooled blood from clotting. This dose of heparin within the peritoneal cavity does not cause systemic anticoagulation. Additionally, changing the position of the operating table allows one to collect pooled fluids and to assess the color of the irrigant for the presence of ongoing hemorrhage.

Instruments

Forceps

A variety of instruments used to grasp tissue are available, many of which have been designed to mimic standard surgical instrumentation. Graspers can be divided into those that are atraumatic or those that contain teeth on the tissue handling surface (Figure 1-10). The authors prefer to utilize atraumatic graspers in virtually all circumstances with the exception of the removal of a specimen from the abdominal cavity.

Endoscopic scissors are also produced with a variety of tips. The most commonly used scissors are those with curved tips analogous to Metzenbaum scissors (Figure 1-11). Other types of scissors have been designed for specific purposes such as hook scissors or micro-scissors for use on the cystic duct (Figure 1-12). Most endoscopic scissors may

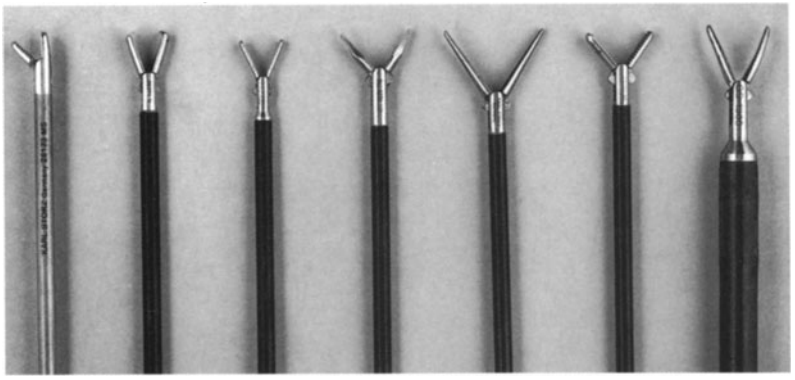


FIGURE 1-10.
Photograph of graspers, atraumatic and those that contain teeth.

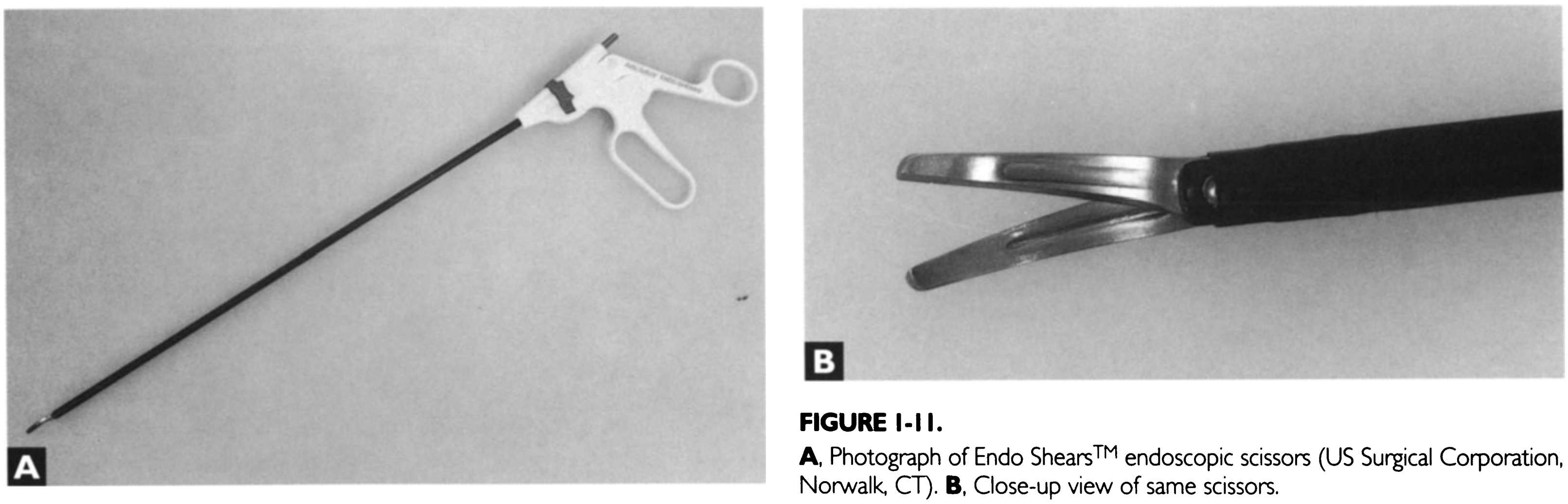


FIGURE 1-11.
A, Photograph of Endo Shears™ endoscopic scissors (US Surgical Corporation, Norwalk, CT). **B**, Close-up view of same scissors.

be attached to the electrosurgical unit for simultaneous cutting and cautery.

Several types of instrumentation have been developed that are unique to endoscopic surgery. The endoscopic hook cautery is frequently used to divide the peritoneal attachments between the gallbladder and the liver (Figure 1-13). As in open procedures, exposure is crucial for the safe performance of an operation. Endoscopic retractors such as the Endo Retract™ (US Surgical, Norwalk, CT) have been designed with a variety of shapes and sizes (Figure 1-14). The endoscopic knot pusher is essential for the placement of extracorporeal tied sutures (Figure 1-15). Single-use laparoscopic sutures are available with an attached knot pusher (Figure 1-16). The Endo Stitch™ (US Surgical,

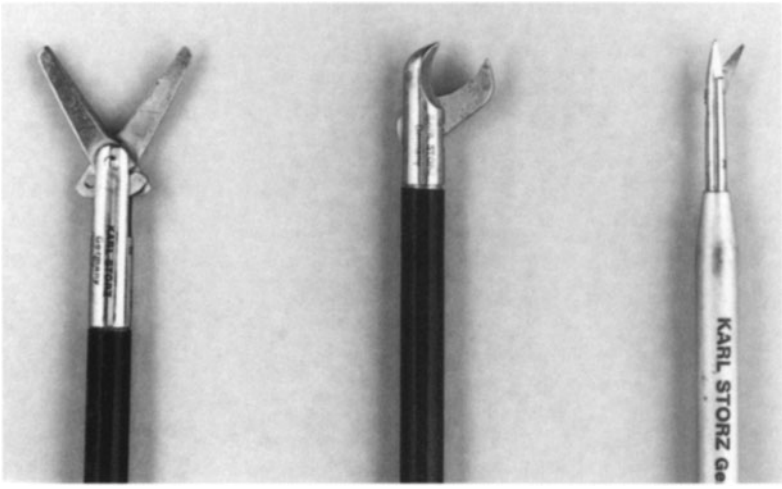
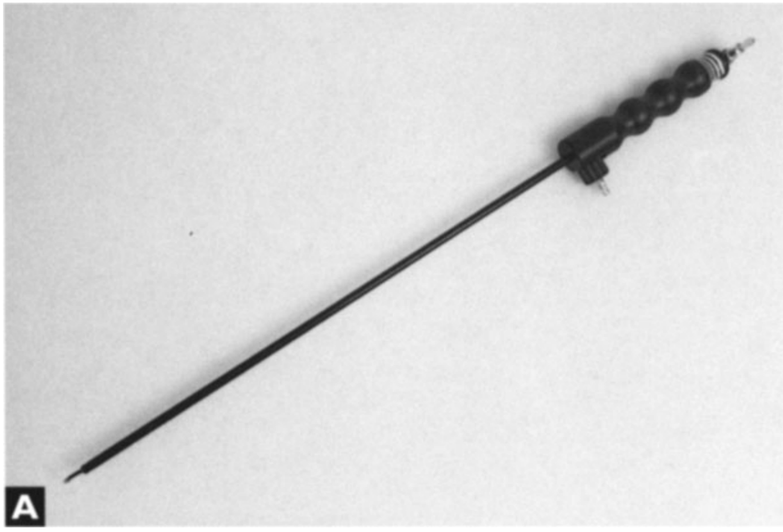


FIGURE 1-12.
Photograph of three types of endoscopic scissors showing the variety of tips.



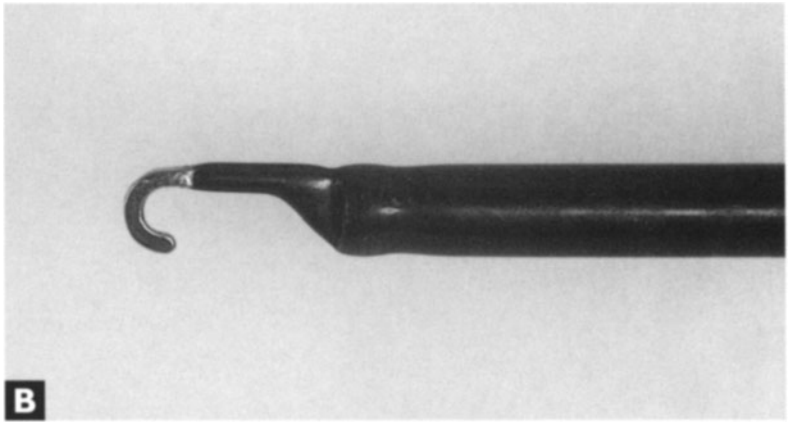
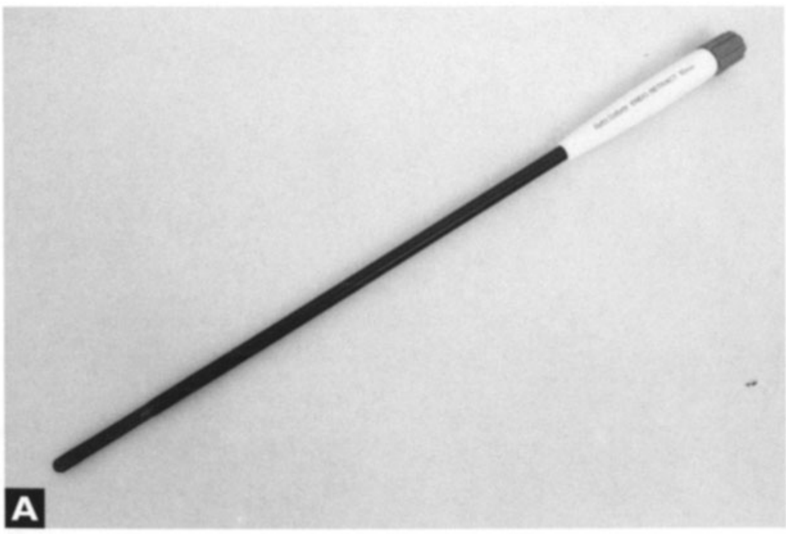


FIGURE 1-13.
A, Photograph of an endoscopic hook cautery. **B**, Close-up view of the hook cautery.



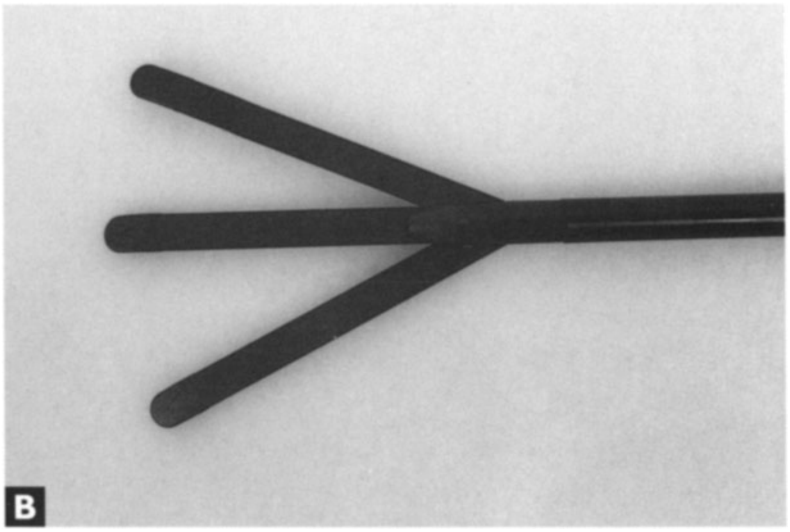


FIGURE 1-14.
A, Photograph of the Endo Retract™ endoscopic retractor (US Surgical Corporation, Norwalk, CT). **B**, Close-up view of the same retractor.

Norwalk, CT) represents a significant innovation in laparoscopic instrumentation. This device greatly facilitates laparoscopic suturing (Figure 1-17). Conventional sutures may be used for endoscopic purposes when placed using an endoscopic needle driver (Figure 1-18).

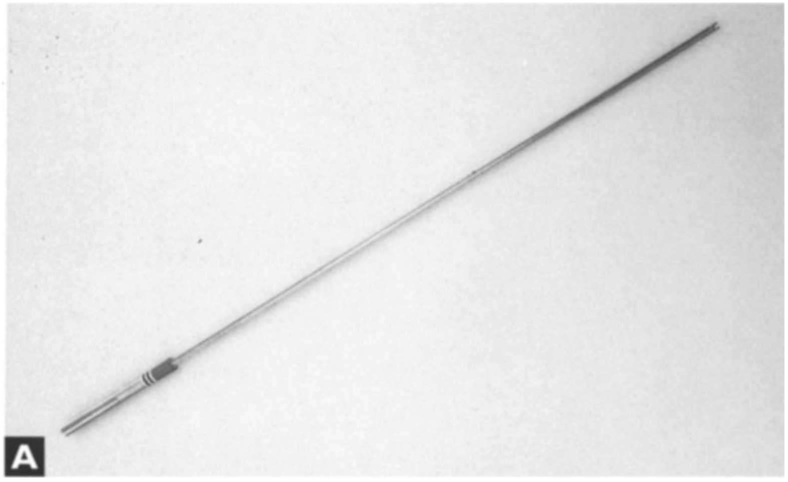
Endoscopic stapling devices are expensive instruments that facilitate the performance of laparoscopic procedures in a time-efficient manner. The endoscopic hernia stapler is considered essential by most laparoscopic surgeons for the placement of mesh during an endoscopic hernia repair (Figure 1-19). The endoscopic clip applier is one of the most frequently used laparoscopic instruments. This device plays a significant role in the rapid acceptance of laparoscopic cholecystectomy due to the ease with which the surgeon can control the cystic duct and vessels with surgical clips. Endoscopic stapling devices such as the Endo GIA and Endo TA (US Surgical, Norwalk, CT) are applied to tissues and used in a manner analogous to their conventional counterparts (Figure 1-20). Endoscopic atraumatic bowel clamps are used by surgeons wishing to perform anastomosis via laparoscopic techniques (Figure 1-21).

Training and Credentialling

Laparoscopic surgery requires a knowledge base and specific skills in addition to one's general surgical training. Laparoscopic procedures should be performed only by those capable of performing the same procedures in an open manner. However, technical expertise in conventional operations does not translate into technical competency in laparoscopic procedures. An increasing effort is currently underway to integrate laparoscopic surgery as an essential component of residency training. However, there remains a tremendous need for the training of practicing surgeons in these techniques, as well as the ongoing need for the introduction of evolving techniques and technology.

There currently exists no nationally accepted standards for the credentialling of surgeons in laparoscopic surgery. The Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) has published recommendations for the training and credentialling of surgeons in laparoscopic surgery. However, the medical/legal burden of credentialling surgeons rests at the level of the individual hospital.

The essential components of training in order to meet credentialling standards for most institutions include the atten-



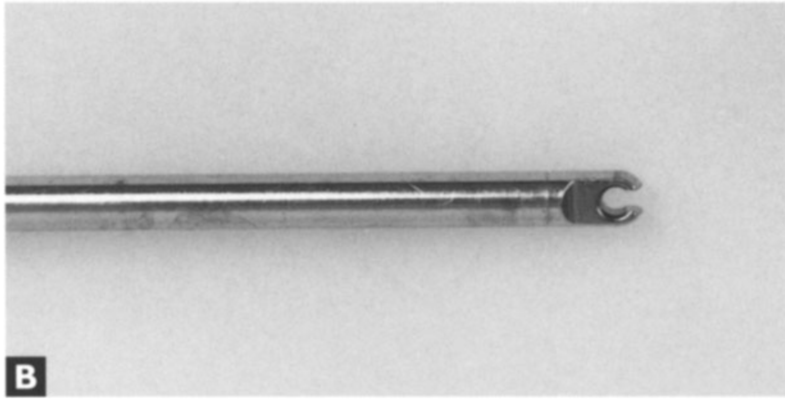


FIGURE 1-15.
A, Photograph of an endoscopic knot pusher. **B**, Close-up view of knot pusher.

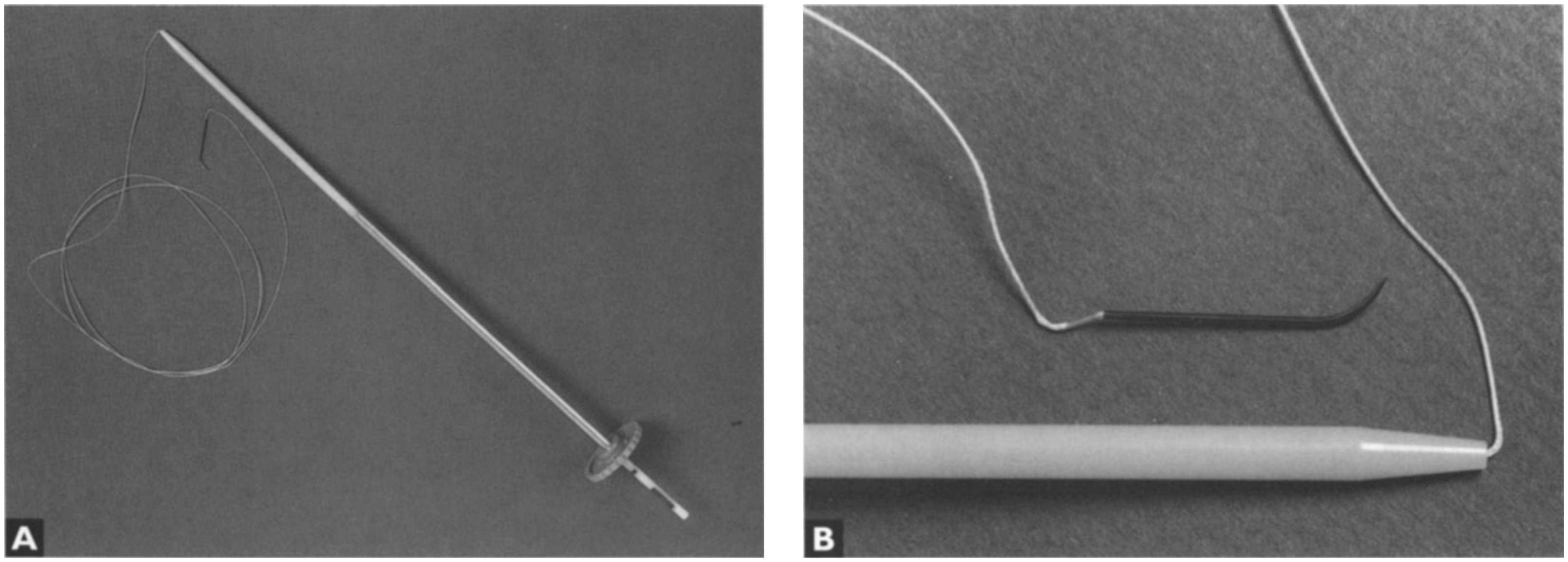


FIGURE 1-16.
A, Photograph of a single-use laparoscopic suture with an attached knot pusher (US Surgical Corp., Norwalk, CT).
B, Close-up view of suture and pusher.

dance by the surgeon at a laparoscopic training course that includes didactics and hands-on laboratory training. The surgeon must participate as an observer or as an assistant in a specified number of cases. The surgeon must then perform a specified number of cases in the presence of a preceptor, an individual previously credentialled for this same procedure who serves as a teacher or mentor. The surgeon must then perform a specified number of cases in the presence of and be approved by a proctor. A proctor is an unbiased individual who observes the surgeon performing laparoscopic procedures without intervening or instructing during the operation. The proctor then makes a recommendation to the hospital regarding the surgeon's competency to perform this type of operation. The final stage of credentialling is the review and approval by the hospital credentialling committee. The number of cases required at each stage varies greatly between institutions. SAGES will provide guidelines for training and credentialling of surgeons in laparoscopic surgery upon request; their address is as follows: Suite 3000, 2716 Ocean Park Boulevard, Santa Monica, California, 90405.

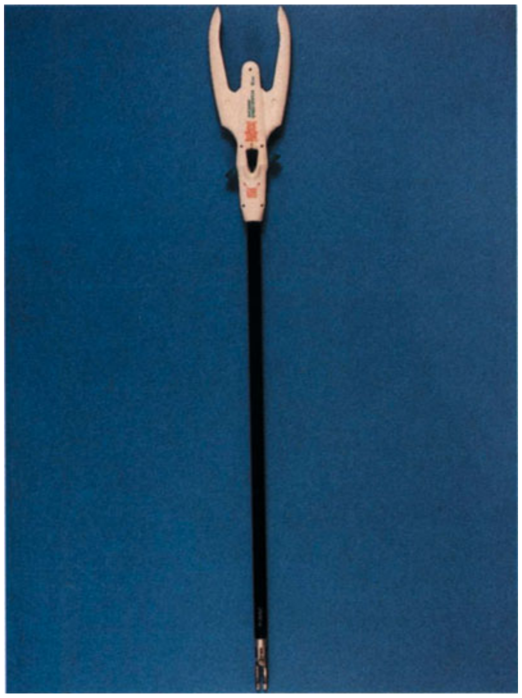


FIGURE 1-17.
Photograph of the Endo Stitch™ (US Surgical Corporation, Norwalk, CT) device for laparoscopic suturing.

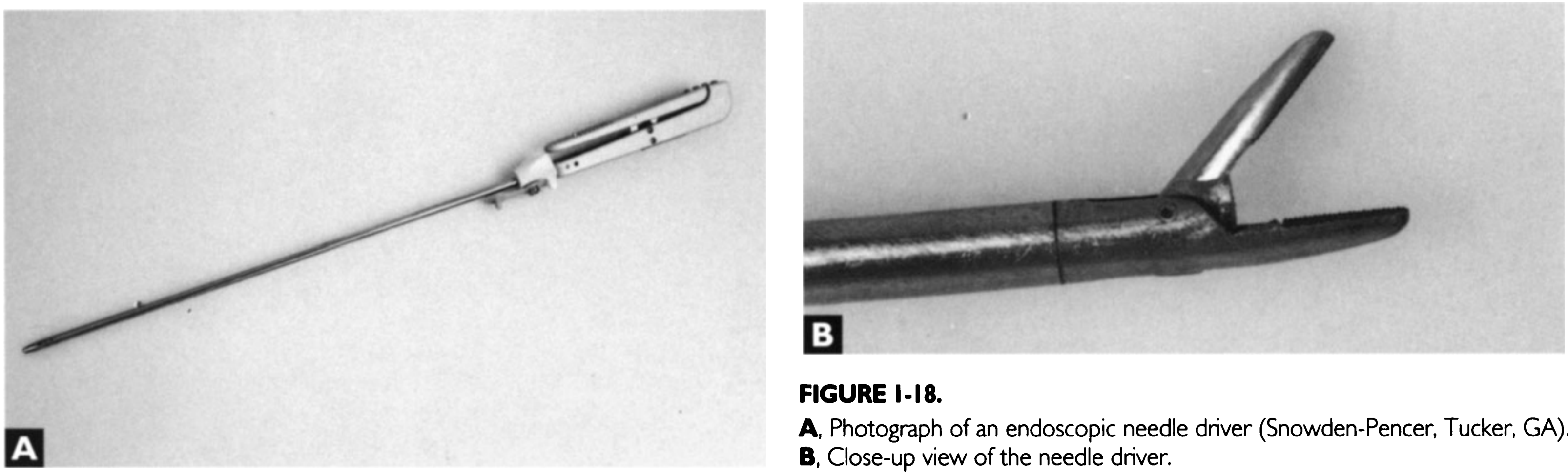


FIGURE 1-18.
A, Photograph of an endoscopic needle driver (Snowden-Pencer, Tucker, GA). **B**, Close-up view of the needle driver.

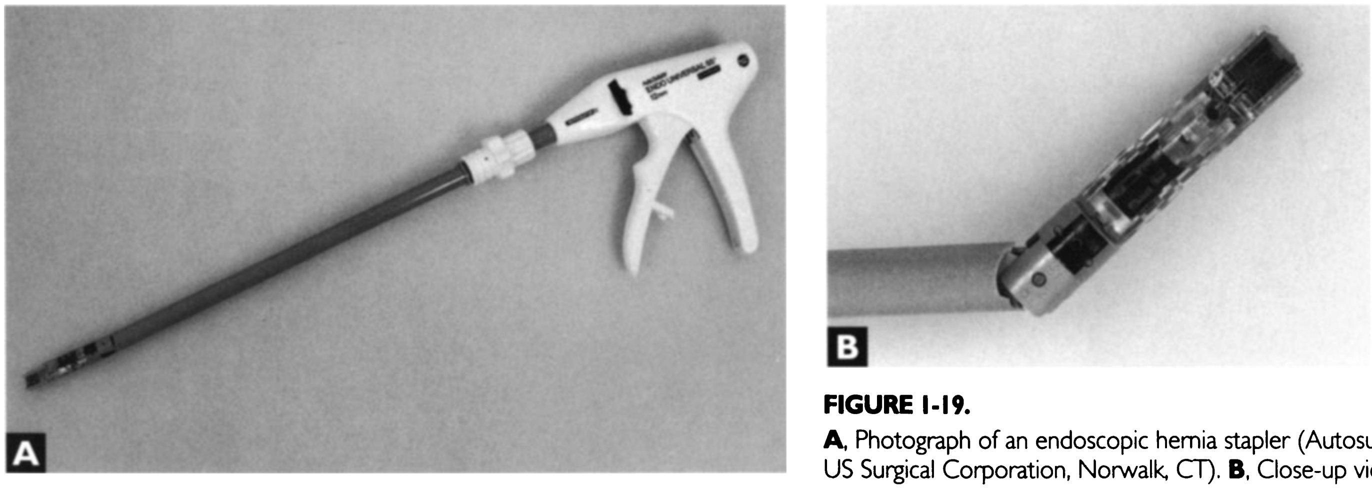
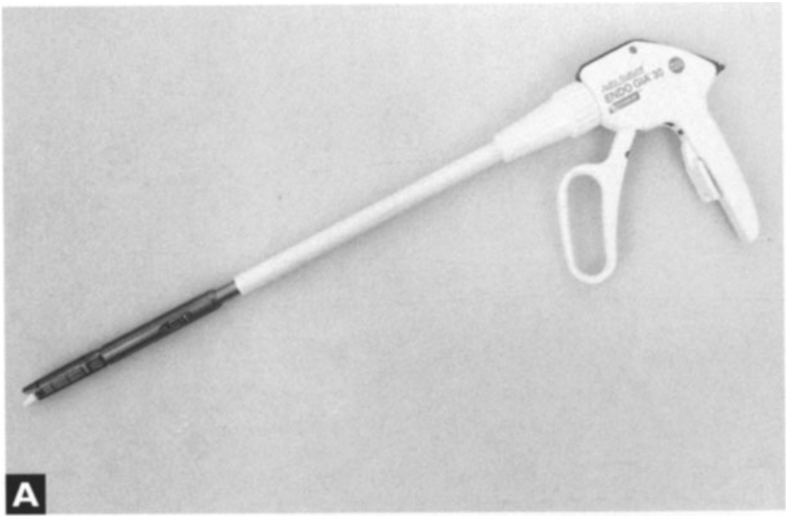


FIGURE 1-19.
A, Photograph of an endoscopic hernia stapler (Autosuture Universal 65™; US Surgical Corporation, Norwalk, CT). **B**, Close-up view of the stapler.



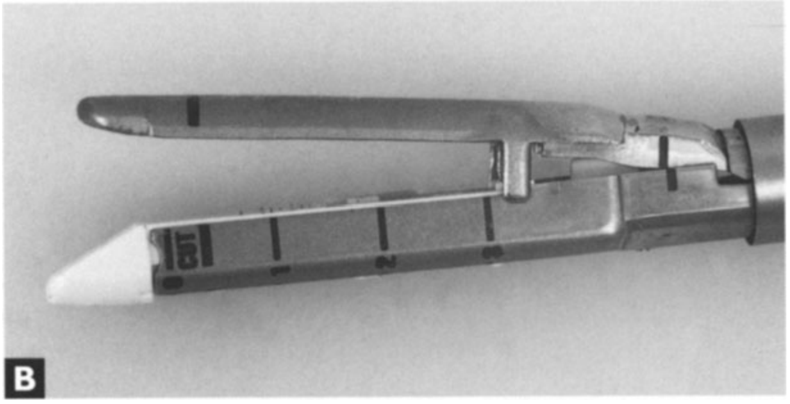
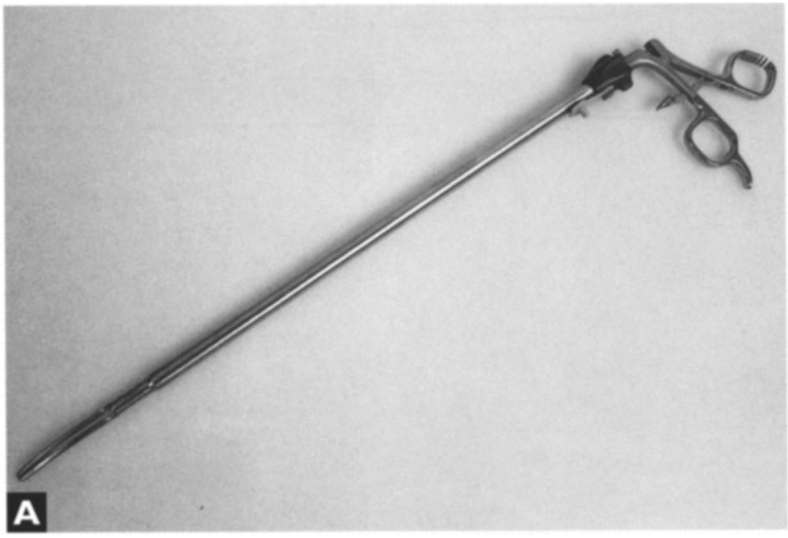


FIGURE 1-20.
A, Photograph of the Autosuture Endo GIA 30™ endoscopic stapler (US Surgical Corporation, Norwalk, CT). **B**, Close-up view of the stapler.



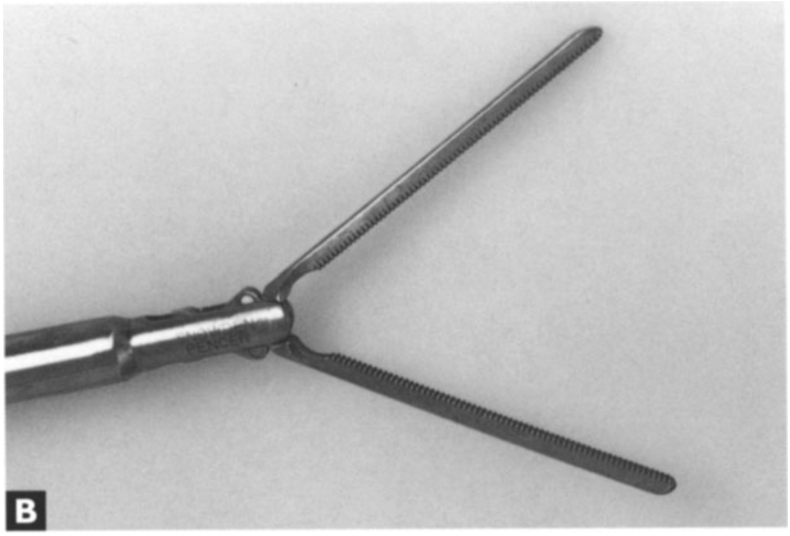


FIGURE 1-21.
A, Photograph of an endoscopic bowel clamp (Snowden Pencer, Tucker, GA). **B**, Close-up view of the clamp.

References

1. Berci G: History of endoscopy. In *Endoscopy.* Edited by Berci G. New York: Appleton-Century-Crofts; 1976:xix–xxiii.
2. Knyrim K, Seidlitz H, Vakil N, Classes M: Perspectives in "electronic endoscopy" past, present, and future of fibers and CCDs in medical endoscopes. *Endoscopy* 1990, 22(suppl 1):2–8.
3. Hunter JG, Sackier JM, eds.: *Minimally Invasive Surgery.* New York: McGraw-Hill, Inc.; 1993.

CHAPTER
2

Laparoscopic Antireflux Procedures

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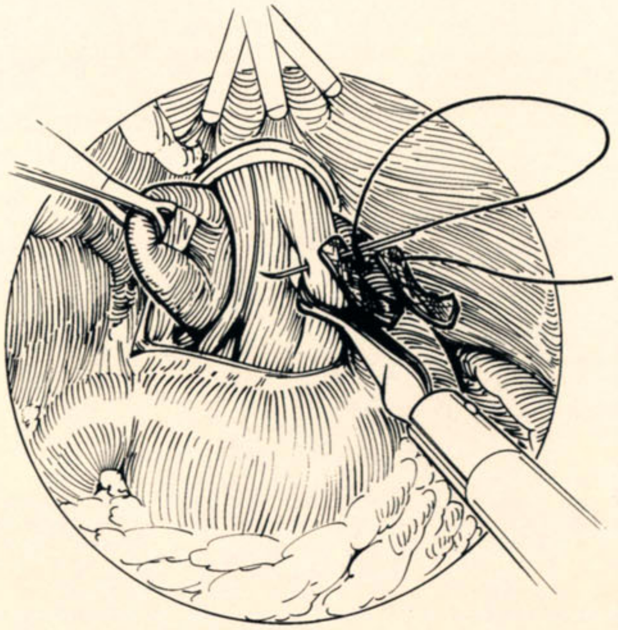
Theodore N. Pappas



The term *gastroesophageal reflux disease* (GERD) has been introduced to represent a wide spectrum of damage to the oropharynx, larynx, respiratory tissue, and esophagus clinically recognized by heartburn.

In 1951, Allison [1] coined the term *reflux esophagitis.* He also described the relationship of hiatal hernia and reflux esophagitis. In 1956, Rudolph Nissen introduced the fundoplication as a simple operative correction of reflux esophagitis [2]. The operation was performed over a large esophageal bougie through a left subcostal incision or a lower left thoracotomy (Figures 2-1 through 2-3.) Nissen's technique was to mobilize the abdominal segment of the esophagus and the lesser curvature of the stomach by division of the gastrohepatic ligament. Almost at the same time as Nissen's introduction of an antireflux procedure, the Belsey Mark IV and Hill gastropexy were described (Figures 2-4 through 2-8). The Belsey Mark IV repair is performed through a left sixth interspace thoracotomy to create a 240° fundic wrap [3]. The technical objectives of the Hill procedure [4] involve utilization of the anterior and posterior phrenoesophageal bundles to anchor the gastroesophageal junction posteriorly to the preaortic fascia and the median arcuate ligament (posterior gastropexy). In 1963, Toupet [5] modified the Nissen fundoplication such that he created a posterior 270° fundic wrap (Figure 2-9).

In 1991, Geagea [6] carried out the first Nissen fundoplication using a solely laparoscopic technique in a 43-year-old woman with severe reflux esophagitis. The important part of the operation was the creation of the 360° fundus wrap by laparoscopic technique. Seromuscular gastric silk sutures were used to secure the wrap. The vagi nerves were preserved and ordinarily included with the fundic wrap.

Bittner and coworkers [7] reported a patient series who underwent the Nissen fundoplication with the innovative technique and under laparoscopic guidance for GERD. This technique essentially mimicked the traditional open Nissen procedure, and a success rate of greater than 90% was achieved.

Nissen fundoplication under laparoscopic guidance offers an alternative form of surgical therapy for patients with GERD. The laparoscopic technique avoids many of the disadvantages of the traditional approach such as a large abdominal incision, associated postoperative discomfort, and prolonged recovery periods.

Anatomy

The esophagus comprises the cervical, thoracic, and abdominal segments. The point of origin corresponds to the caudal border of the cricoid cartilage and the lower margin of the cricopharyngeus muscle at the level of the sixth cervical vertebral body. The esophagus extends downward through the superior and posterior mediastina of the thorax. It passes through the esophageal hiatus of

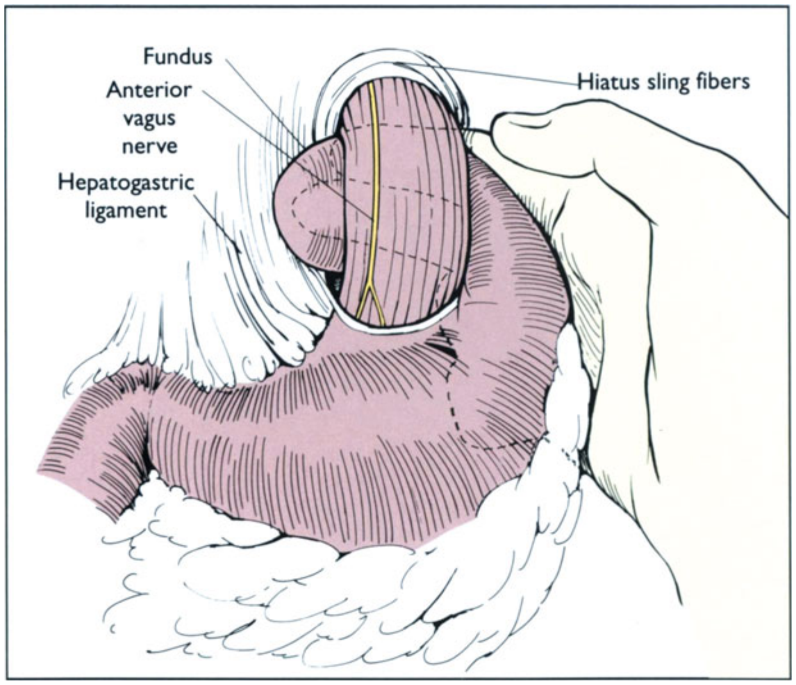


FIGURE 2-1.
Technique of Nissen fundoplication. Through a left subcostal laparotomy or a lower thoracotomy, the lower esophagus and upper portion of the stomach have been mobilized. The anterior fundic wall is brought around the esophagus. The short gastric vessels are not usually divided.

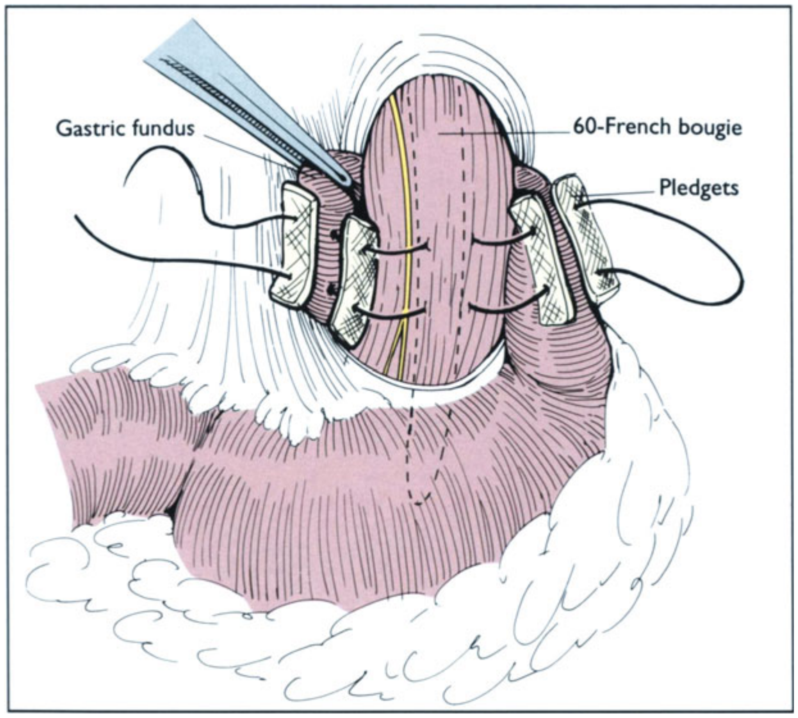


FIGURE 2-2.
Construction of the Nissen fundoplication. A number 60-French bougie is passed across the gastroesophageal junction. Seromuscular heavy nonabsorbable sutures are used to approximate the adjacent layers of gastric fundus and incorporating the anterior wall of the esophagus. Pledgets at each tissue interface, buttressed with a horizontal mattress suture, hold the wrap. Interrupted sutures can also be used for the construction.

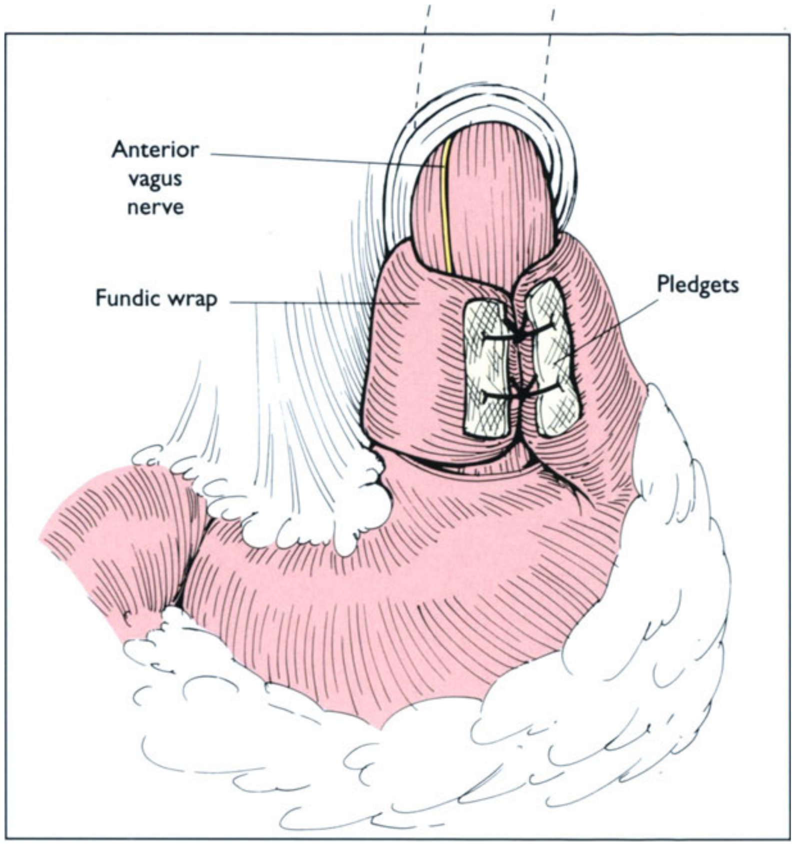


FIGURE 2-3.
Completed 360° Nissen fundoplication. Fundoplication should be 2 cm in length and loose enough that one finger can easily be inserted between the plication and the esophagus with a bougie in place ("floppy Nissen"). Anterior and posterior vagus nerves are included in the wrap. Two interrupted heavy silk sutures are in place to stabilize the fundoplication.

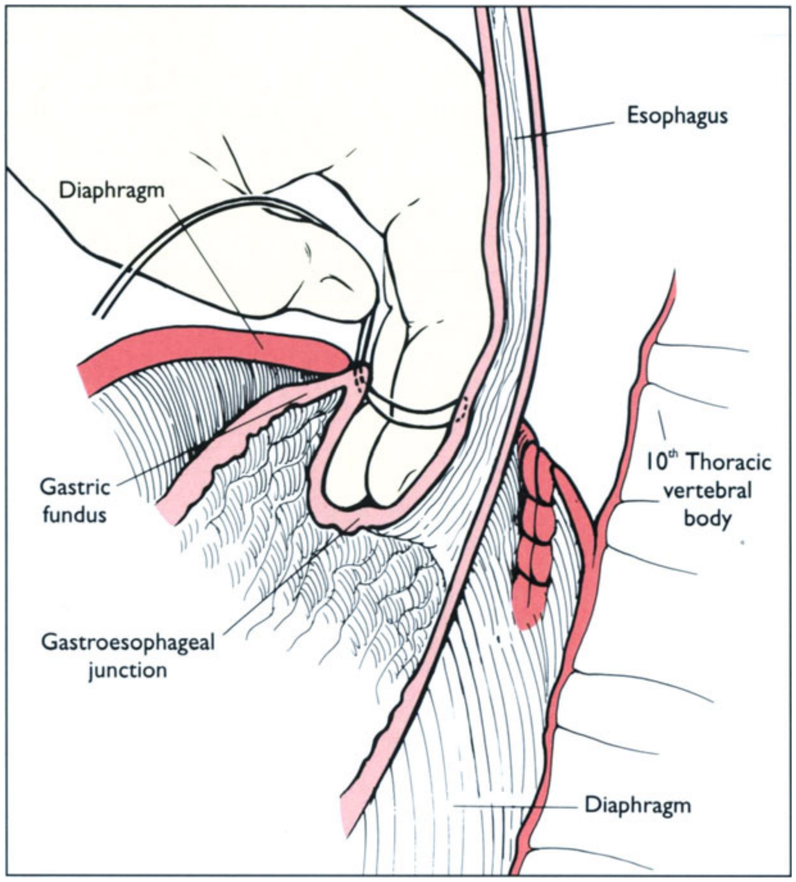


FIGURE 2-4.
Belsey Mark IV operation. Through a left sixth interspace posterolateral thoracotomy, the lower part of the esophagus and the hiatus are exposed. The esophagus is completely mobilized to the level of the lung root and the cardia. The upper part of the stomach is mobilized and brought through the hiatus into the left chest. The sutures in the crus posteriorly have been placed and tied to close the hiatus. The construction of a 240° partial fundoplication is started by placing the first row of three mattress sutures between the fundus of the stomach and esophagus, 2 cm above the gastroesophageal junction.

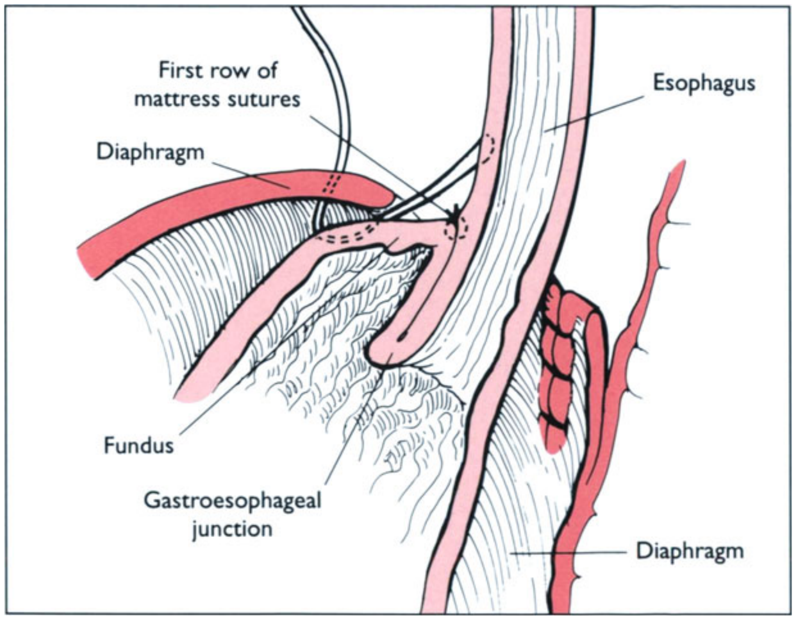


FIGURE 2-5.
Belsey Mark IV operation. After completion of the first row of mattress sutures, a second row of three mattress sutures is placed through the diaphragm, fundus, and esophagus. In this illustration, the first suture is in place.

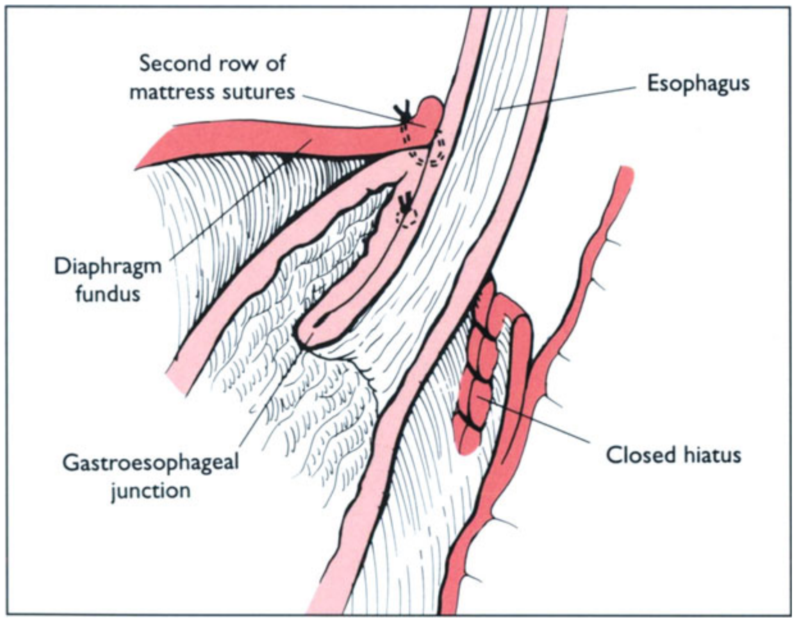


FIGURE 2-6.
Completed Belsey Mark IV operation. Sagittal section of repair. The second row of mattress sutures joining diaphragm, stomach, and esophagus are tied after the reconstruction has been placed beneath the diaphragm.

the diaphragm to join the cardia of the stomach about the level of the tenth thoracic vertebra. The accompanying structures on its course through the hiatus are the anterior and posterior vagal trunks (Figure 2-10). In its short abdominal portion (25 to 30 cm in length), the esophagus lies upon the diaphragm with the esophageal impression of the left lobe of the liver applied to its anterior aspect. The length of the intra-abdominal segment in the normal state averages 1.5 to 2 cm.

The lower esophagus segment is subdivided into the supradiaphragmatic portion, inferior esophageal constriction, vestibule, and cardia. This segment is supplied

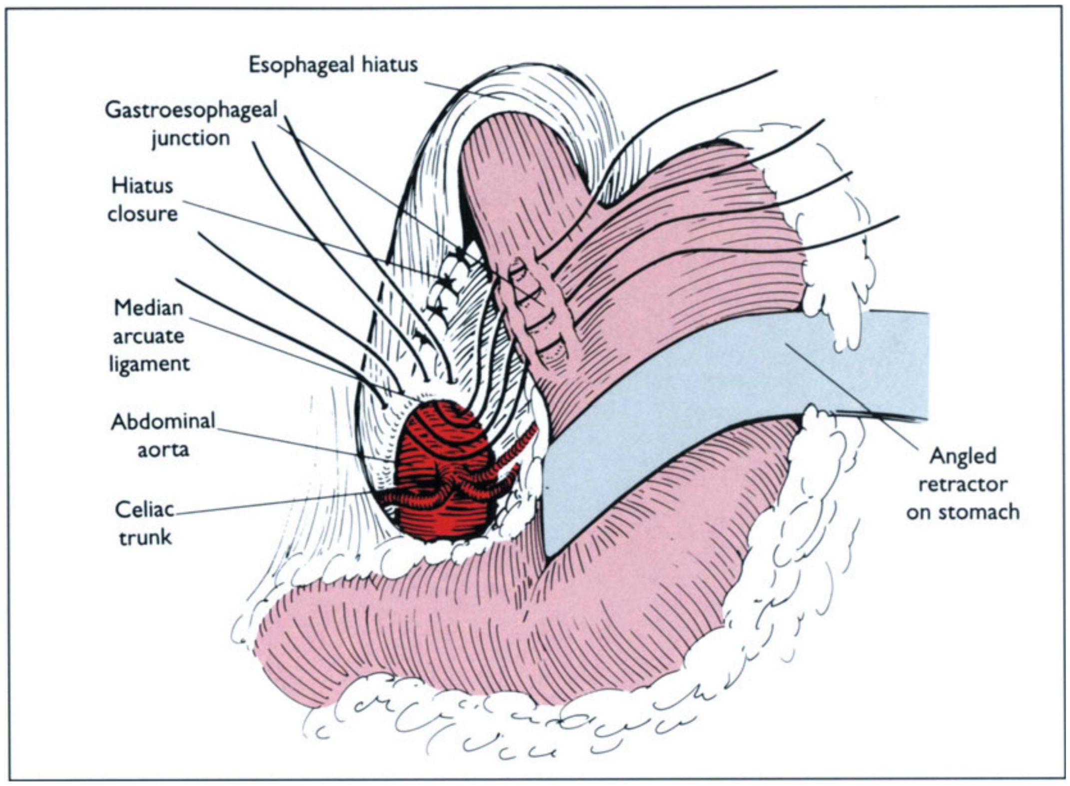


FIGURE 2-7.
Median arcuate ligament repair or Hill procedure. The initial dissection should clearly define the median arcuate ligament and the celiac axis. Crural approximation and hiatus closure is performed first after mobilization of the distal esophagus. Interrupted sutures anchor the gastroesophageal junction posteriorly to its primary attachment, the preaortic fascia (posterior gastropexy). The gastropexy reduces the esophageal circumference and bunches tissue into its lumen. The procedure has to be done under manometric control.

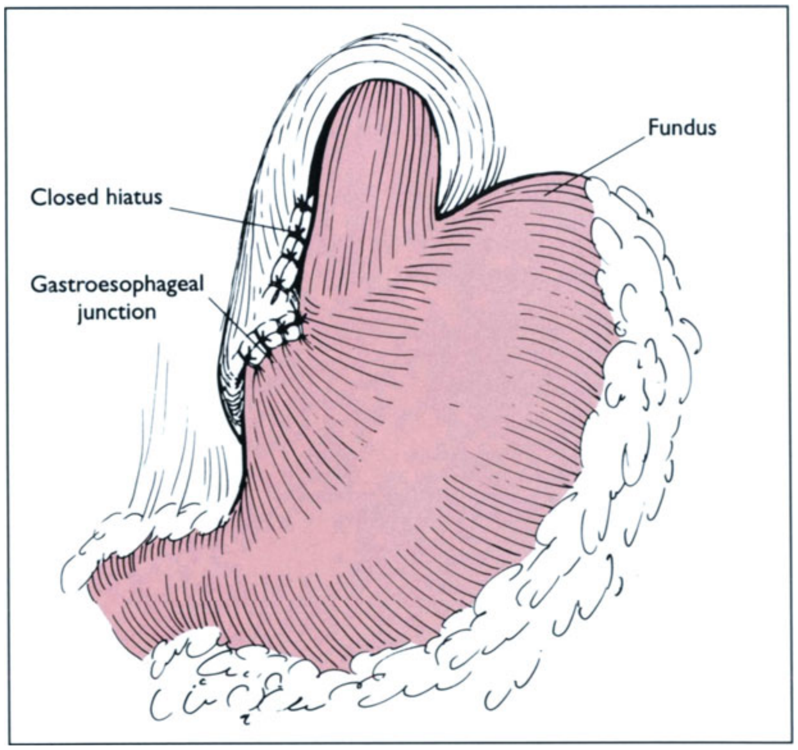


FIGURE 2-8.
Completion of the Hill procedure (posterior gastropexy). The gastroesophageal junction is attached to the median arcuate ligament. The principle of the Hill repair is plication of the lower esophagus and maintenance of an intra-abdominal length of the esophagus.

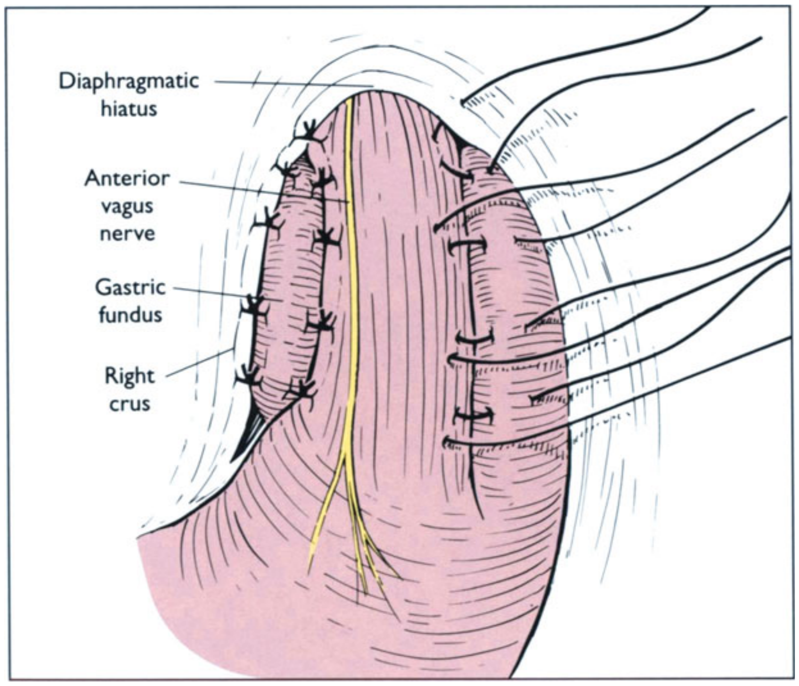


FIGURE 2-9.
The technique of the 270° Toupet fundoplication. The wrap is fixed to the crura posteriorly and anchored with seromuscular interrupted sutures anteriorly to the esophagus.

by an ascending branch of the left gastric artery. Venous drainage of that segment enters the coronary vein and paracaridal venous plexus below the diaphragm. Preganglionic fibers of the vagus nerve synapse with ganglion cells in the myenteric plexus of the esophagus. Sympathetic innervation occurs from the thoracic ganglia.

The anatomy and physiology of the gastroesophageal junction and of the esophageal hiatus is essential to the understanding of reflux mechanisms and antireflux procedures. The muscle fibers surrounding the esophagus and creating the hiatus are mainly from the right crus of the diaphragm (Figure 2-10). In addition, several layers that separate the thoracic and the abdominal cavity support the esophageal hiatus. The most important structure is the phrenoesophageal membrane, a condensation of endoabdominal and endothoracic fascia (Figure 2-11). This membrane anchors the esophagus within the hiatus. In most individuals this membrane inserts 3.3 cm above the junction of the tubular esophagus with the stomach. Part of the problem of defining the gastroesophageal junction is the fact that the internal junction does not coincide with the external junction. Gahagan [8] describes this region as follows: "the external junction the termination of the tube, the esophagus and the beginning of a pouch, the stomach lies 1 cm below the internal junction, the mucosal boundary."

Pathophysiology, Presentation, and Differential Diagnosis

It is now recognized that although there is no anatomical lower esophageal sphincter in humans, a physiologic sphincter mechanism exists and extends over the terminal 1 to 4 cm of the esophagus. Manometrically, this specialized segment represents a zone of high pressure referred to as the lower esophageal sphincter (LES). In the resting state, the LES is contracted and its mean pressure is 13 mm of mercury. The overall length of the LES is 3.6 cm on average, 2 cm as the intra-abdominal portion and the remainder in the thoracic cavity. The control of gastroesophageal reflux is achieved by the following mechanisms: intrinsic muscle tone of the LES, intra-abdominal esophageal segment, abrupt opening of the narrowing swallowing tube into dilated gastric pouch (La Place law), and normal gastric emptying. The functional state of the LES determines the development of GERD. Patients with an LES pressure of less than 5 mm of mercury or an abdominal portion smaller than 1 cm present with GERD in 90% of cases [9].

Hiebert and Belsey's [10] observations clearly showed that pathologic reflux and hiatal hernia were separate entities. Approximately 80% of patients with GERD have a radiographically demonstrable axial hernia. When radiographic maneuvers are applied to diagnose a hiatal hernia, approximately only 5% of such individuals have

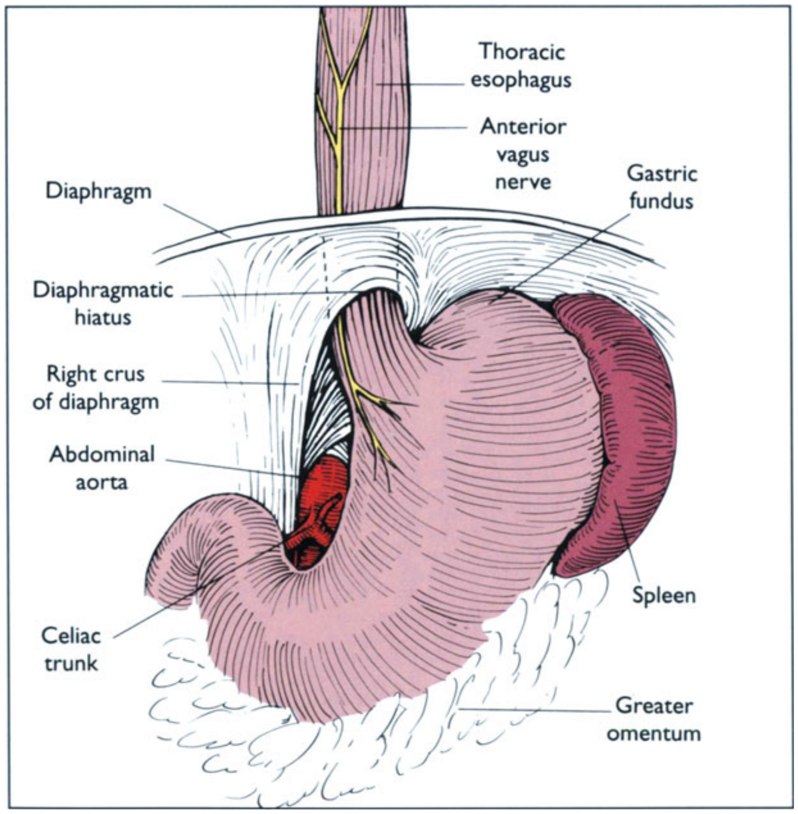


FIGURE 2-10.
Anatomy of the diaphragmatic hiatus and the abdominal segment of the esophagus. The diaphragmatic hiatus is a sling of muscle fibers that arises from the right crus of the diaphragm in the majority of individuals.

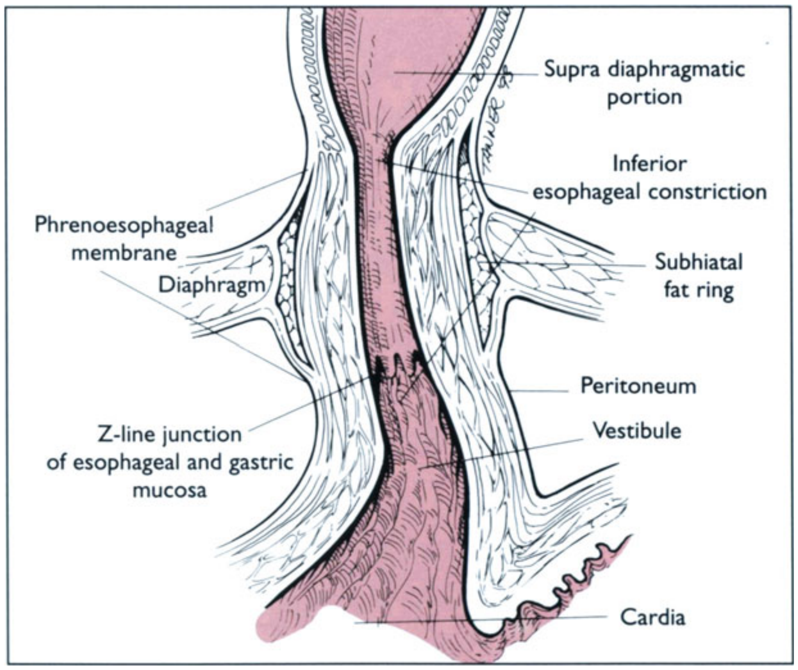


FIGURE 2-11.
Anatomy of the lower esophagus and the esophagogastric junction. The precise location of the gastroesophageal junction is difficult to define since the internal junction, the mucosal boundary (Z-line), does not coincide with the external junction.

pathologic gastroesophageal reflux. Presumably, this is because the phrenoesophageal membrane insertion still leaves an adequate segment of distal esophagus exposed to abdominal pressure. Reflux is prevented when there is a 10-cm water column abdominothoracic pressure difference [11].

Although delayed gastric emptying has a strong correlation with severe reflux and esophagitis, it is not known whether the gastric emptying delay proceeds the pathologic reflux or whether esophageal inflammation from reflux esophagitis causes vagal nerve dysfunction and inhibits gastric emptying [12].

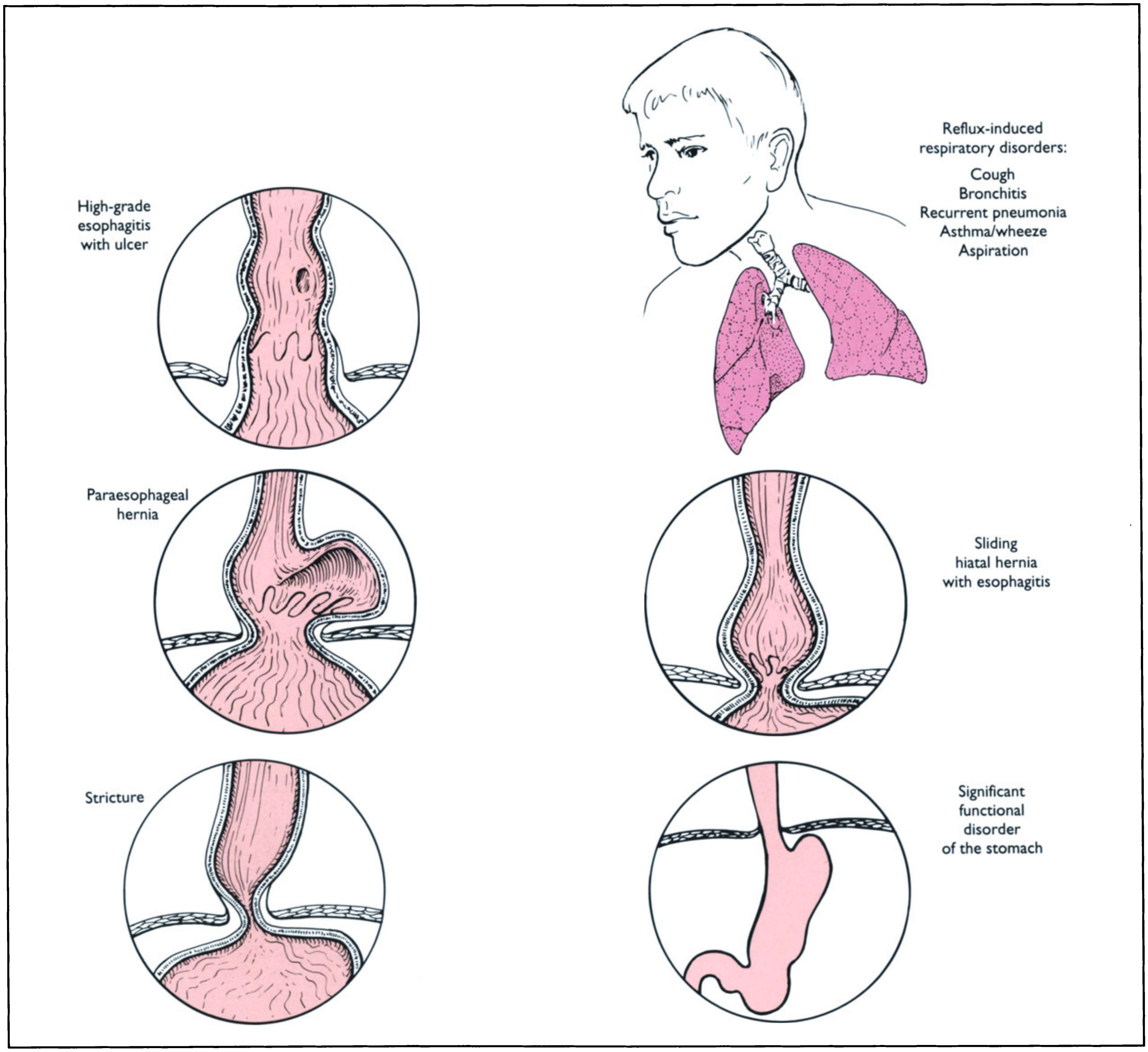


FIGURE 2-12.
Diagrammatic representation of the manifestations of gastroesophageal reflux disease and indications for surgery.

Twenty-four–hour intraesophageal pH monitoring documents that normal individuals have physiological reflux after meals. Seven percent experience heartburn every day and 36% of healthy individuals experience heartburn once a month. Pathologic degrees of reflux are diagnosed when reflux becomes prolonged or occurs throughout the day or at night. Esophagitis as a complication of reflux develops when gastric acid or pancreaticobiliary secretions reach the esophagus with increased frequency and a failure of protective esophageal mechanisms occurs. An important aspect in the protection against the noxious effects of gastroesophageal reflux is coordinated peristaltic clearing and secondary peristalsis of the esophagus that is triggered by distention or irritation of the mucosa of the distal esophagus. When abnormal reflux occurs, the damage to the esophageal mucosa may range from none to the development of a severe peptic stricture (Figure 2-12). The degree of damage to the esophagus is graded as I (erythema of the mucosa without ulcerations), II (ulcerations), III (chronic ulcerations with fibrosis), and IV (stricture) [13]. Table 2-1 summarizes the symptoms and complications in patients who present with symptomatic GERD. The most common differential diagnoses, such as cholelithiasis, peptic ulcer disease, gastritis, esophageal motor disease, and angina pectoris are demonstrated in Figure 2-13.

Table 2-1. Symptoms and complications in patients with symptomatic gastroesophageal reflux disease*

Symptoms or complications	*n*, %
Heartburn	85
Dysphagia	37
Stricture	19
Regurgitation	23
Nausea or vomiting	21
Cough	47
Bronchitis	35
Pneumonitis	16
Asthma or wheeze	16
Hemoptysis	13
Aspiration	8

*This table demonstrates the incidence and clinical features of reflux disease drawn from reports of 2178 patients [20,21]. Heartburn, dysphagia, and regurgitation are the classic esophageal symptoms. The complications of reflux disease are high-grade esophagitis, stricture, and Barrett's esophagus.

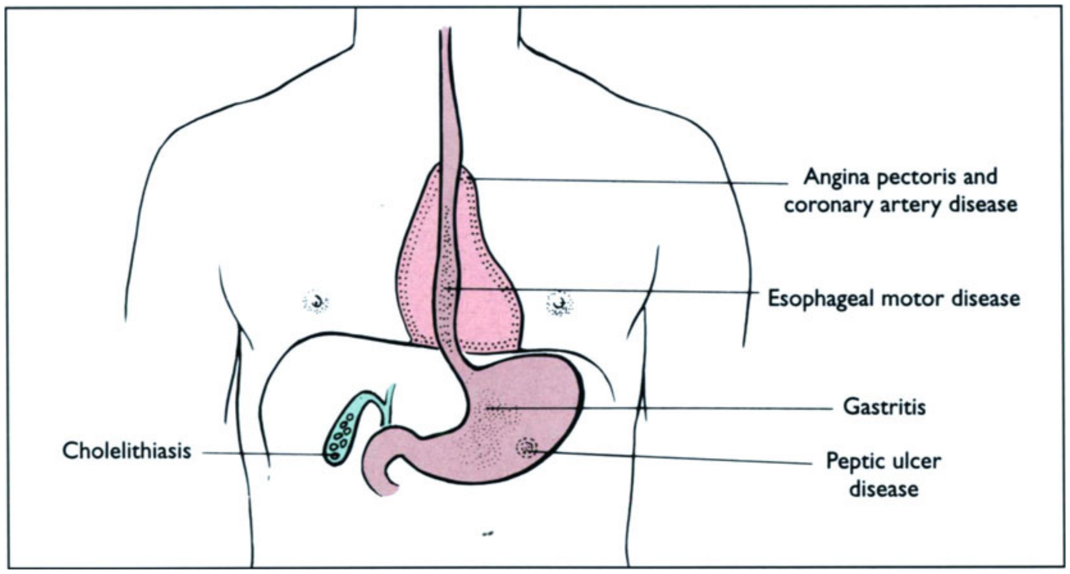


FIGURE 2-13.
This diagram demonstrates the most important alternative diagnoses in patients with gastroesophageal reflux disease.

Diagnostic studies to define GERD and to evaluate patients for laparoscopic Nissen fundoplication include manometery of the esophagus, 24-hour pH monitoring, and esophagogastroduodenoscopy with biopsies (Figure 2-14). A mechanical sphincter defect is defined by a resting pressure less than 6 mm Hg or less than 2 cm in length [14].

The indications for laparoscopic Nissen fundoplication are identical to the open antireflux procedures. Primary indications for surgery are medical management failure, need for long-term omeprazole treatment, or complications of GERD like high-grade esophagitis, stricture, or Barrett's esophagus (Figures 2-12 and 2-15).

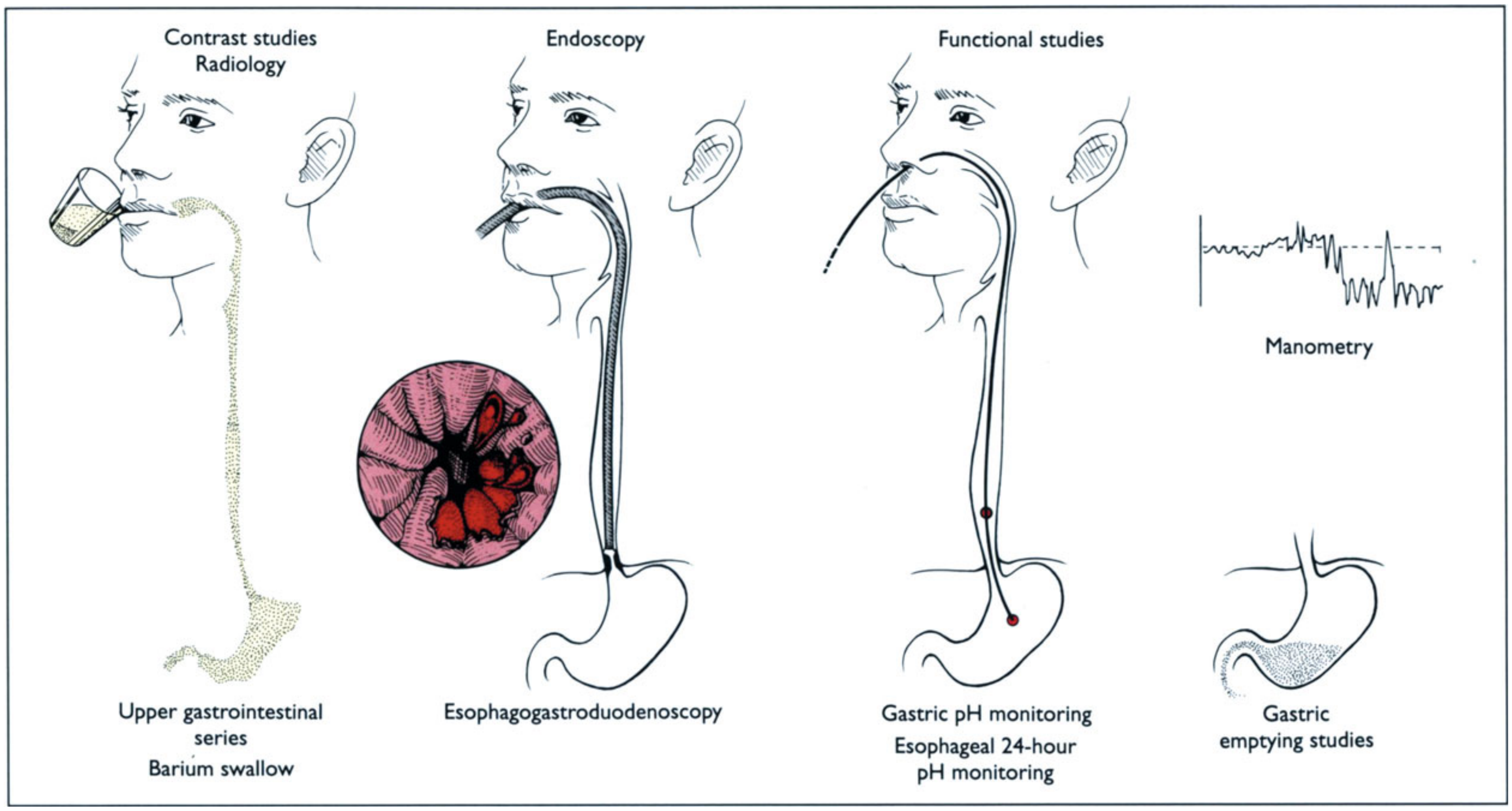


FIGURE 2-14.
Diagnostic studies in patients with gastroesophageal reflux disease.

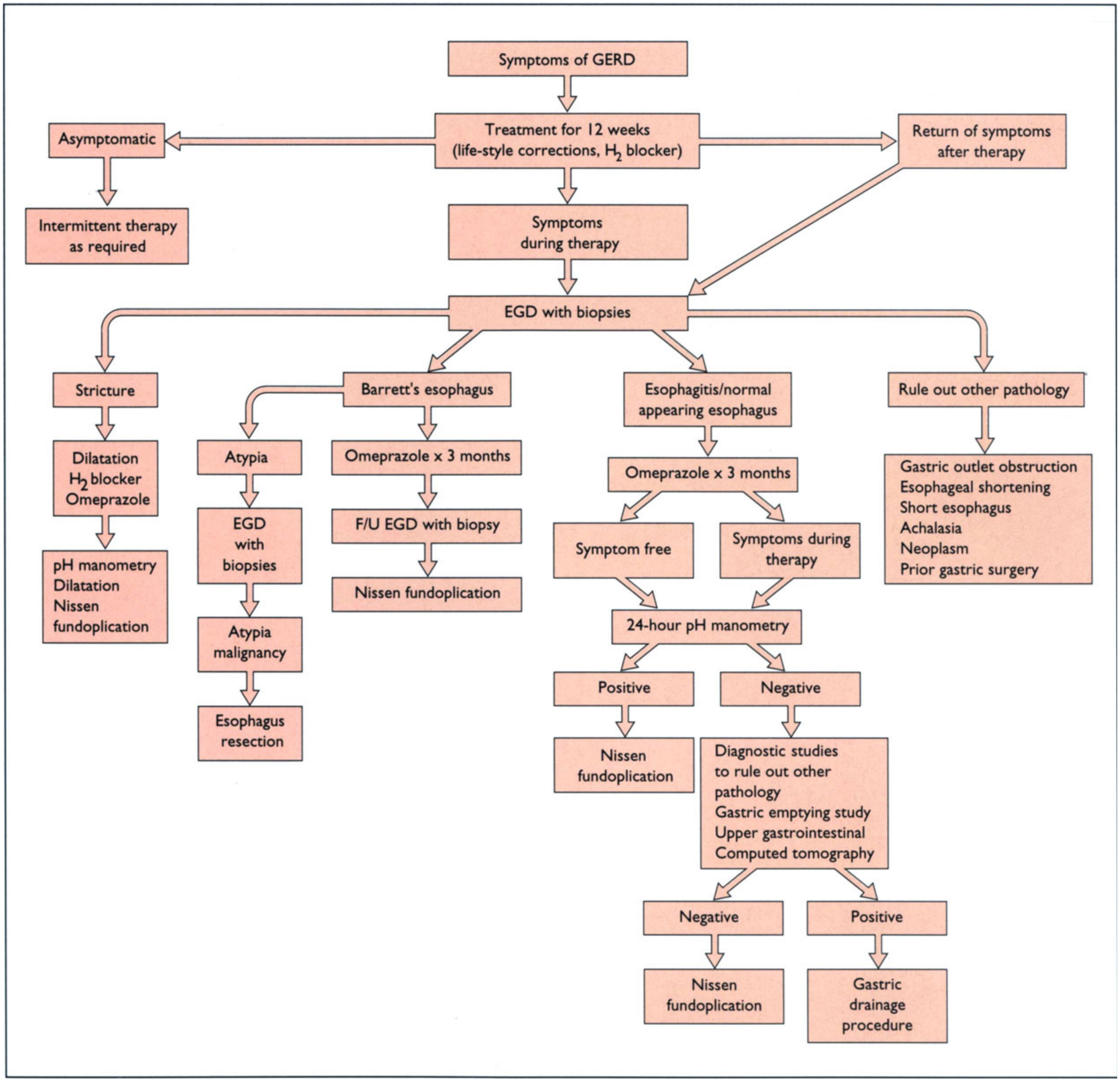


FIGURE 2-15.

Algorithm for the approach to patients with gastroesophageal reflux disease. Patients who initially present with dysphagia in their symptom complex should undergo upper endoscopy immediately to evaluate the obstructive cause. Every patient who is considered for Nissen fundoplication should undergo 24-hour pH study and manometry to exclude esophageal motility disorder. Diabetic patients should also be studied by gastric emptying studies to evaluate the gastric motility. EGD—esophagogastroduodenoscopy; F/U—follow-up; pH—24 hour pH study; R/O—rule out.

Surgical Technique

The Nissen fundoplication, which is done laparoscopically, is identical to the one via the open technique (Figures 2-16 to 2-21). For the laparoscopic construction of the fundoplication, pledgets can be used between the esophagus and stomach as described by DeMeester and coworkers [5] in 1986. A "floppy Nissen" wrap of approximately 2 to 3 cm is created over a 58- to 60-French bougie to parallel the open technique as close as possible (Figures 2-22 to 2-28; Figures 2-29 and 2-30 illustrate an alternative procedure). The short gastric vessels are not ligated or divided for the mobilization of the gastric fundus. Crural repair or approximation is not undertaken. Anterior and posterior vagus nerves are included in the wrap. The Hasson cannula is used in all patients with a history of previous abdominal surgery.

Set-up

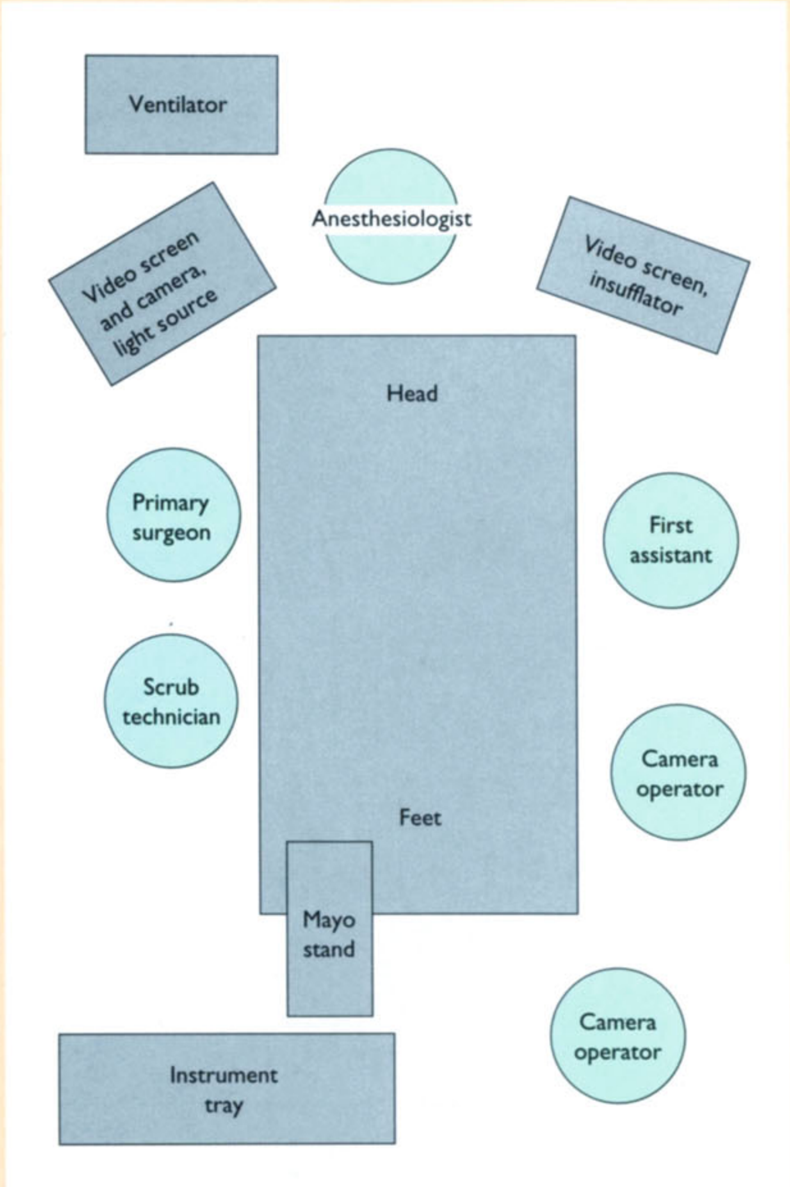


FIGURE 2-16.

Operative set-up for laparoscopic Nissen fundoplication. Foley and nasogastric catheters are placed after induction of general anesthesia. The patient is then placed in the 30° Trendelenburg position with the arms tucked at the sides. A pneumoperitoneum is established with a Veress needle inserted into the peritoneal cavity through a 1-cm infraumbilical incision. In patients with previous abdominal surgery the open technique is used and an approximately 2.5-cm incision made for the introduction of the Hasson cannula. A 10-mm sheath is used for the insertion of the video camera.

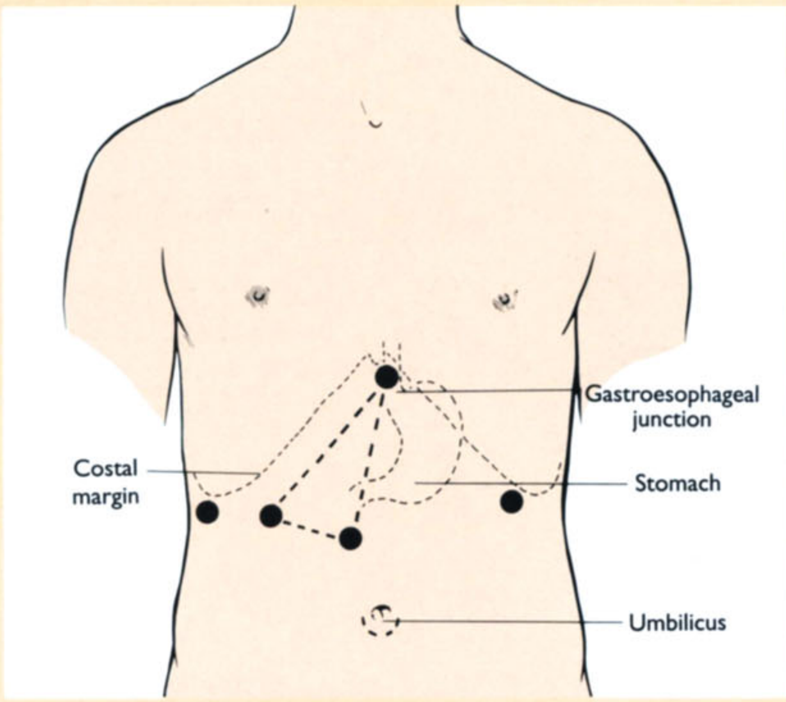


FIGURE 2-17.

Trocar placement for laparoscopic Nissen fundoplication. The pneumoperitoneum is maintained at 15 mm Hg. In patients with a large abdomen or a long distance between umbilicus and xiphoid process, a supraumbilical incision is made for the insertion of the video camera. Five more trocars are introduced under visual control. A 10-mm trocar in the left upper quadrant is necessary for placement of an endoscopic Babcock clamp. A 10-mm trocar is placed at the upper midline for a fan retractor. A trocar is placed in the far right lateral aspect of the costal margin for placement of a second endoscopic Babcock clamp. The *triangle* describes the trocar placement for the surgeon operating two handed at the base of the triangle. The trocars should be placed as high as possible to allow them to reach the hiatus. The apex of the triangle faces the gastroesophageal junction.

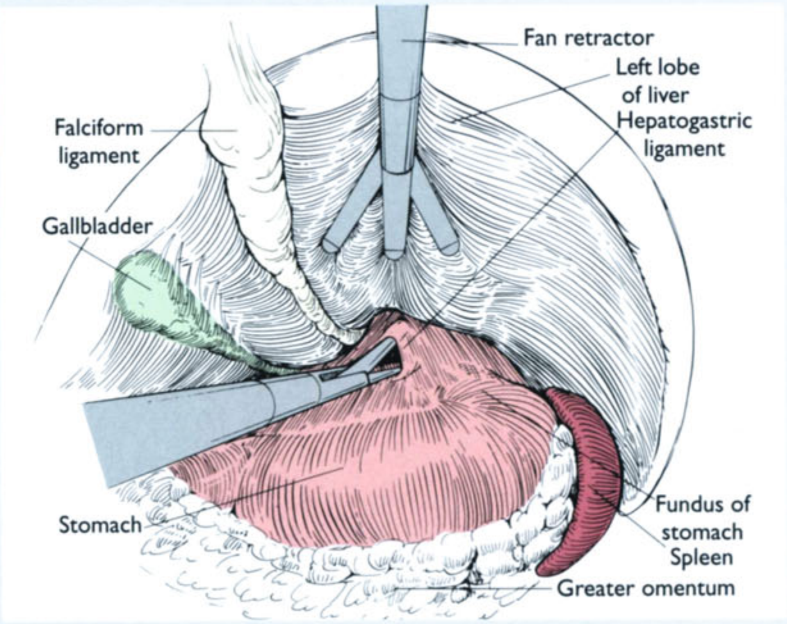


FIGURE 2-18.
This illustration demonstrates the view as seen from the 10-mm trocar at the umbilicus. The fan retractor elevates the left lobe of the liver. The hepatogastric ligament is sharply dissected for the mobilization of the gastroesophageal junction.

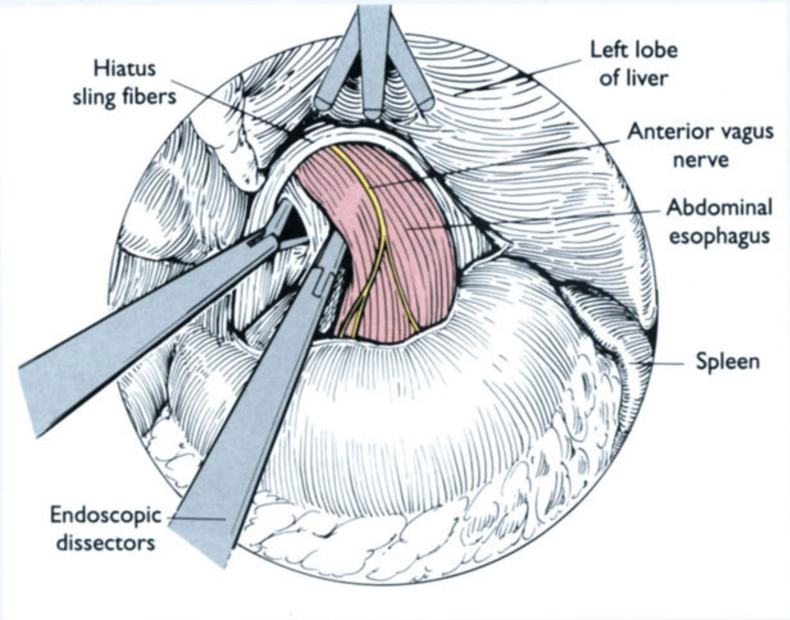


FIGURE 2-19.
The hepatogastric ligament is opened. The right crus of the diaphragm is then mobilized from the gastroesophageal junction. Care is taken to accurately distinguish the crus from the esophagus. Moving the nasogastric tube in the esophagus while the gastroesophageal junction is viewed helps to define the anatomy.

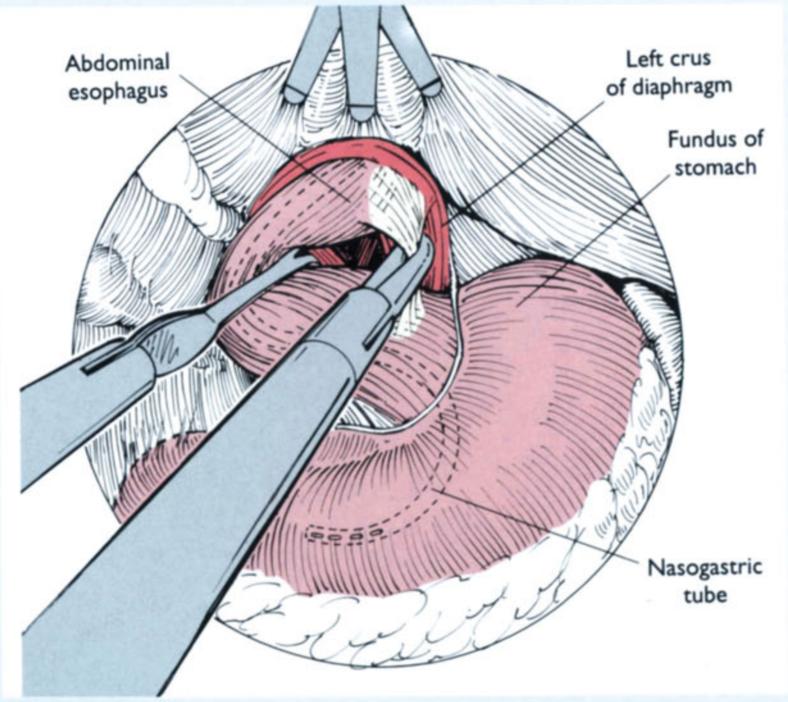


FIGURE 2-20.
With the esophagus retracted to the patient's right, the left diaphragmatic crus is dissected, and the space between this side of the esophagus and crura is opened bluntly. With the esophagus retracted upward, the retroesophageal space is dissected under direct vision. Care is taken not to enter the pleural space.

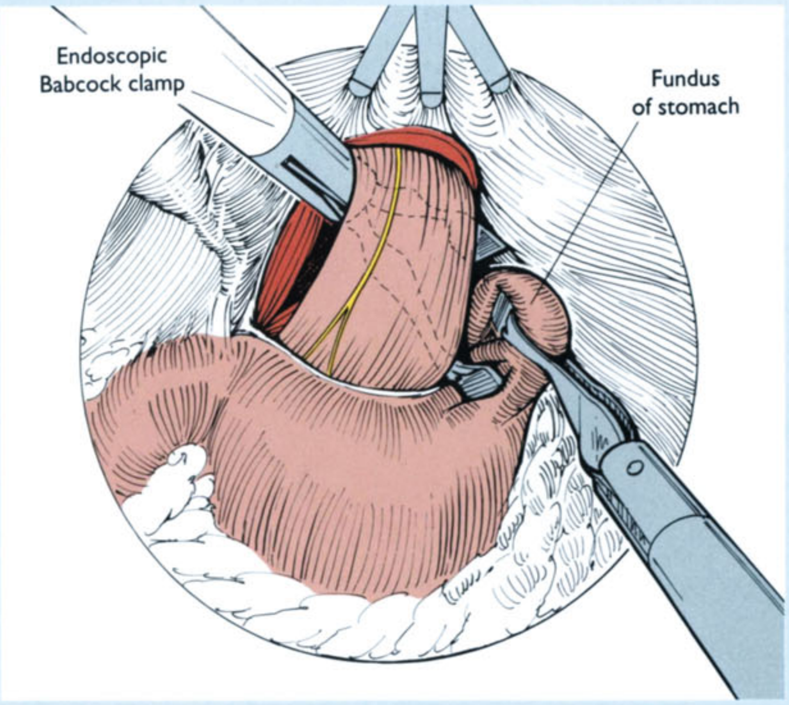


FIGURE 2-21.
An endoscopic Babcock clamp is placed from the most lateral right trocar and is passed behind the gastroesophageal junction. The placement of instruments in this area is done under direct vision. The fundus of the stomach is grasped with a second Babcock clamp from the left side and passed behind the gastroesophageal junction. The nasogastric tube is replaced with a 58- or 60-French bougie.

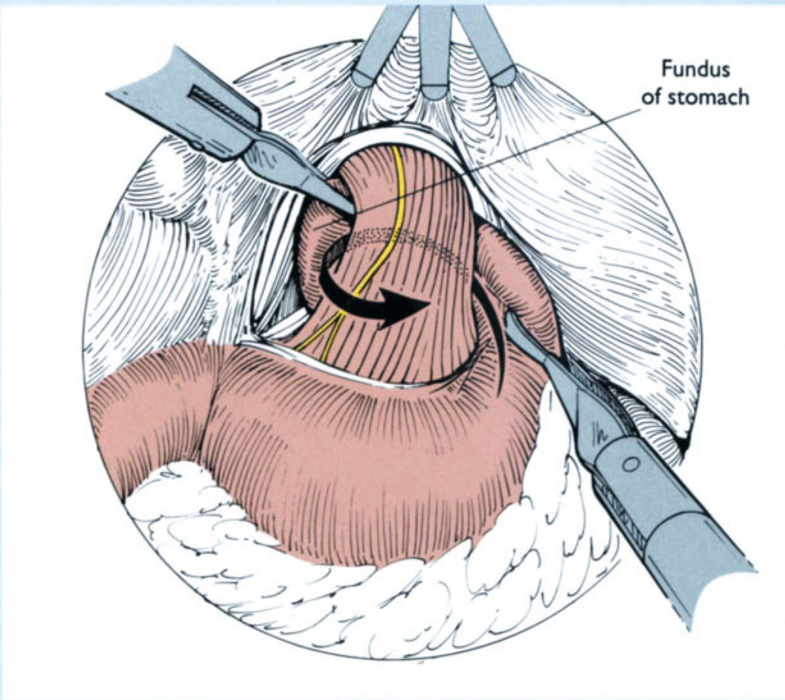


FIGURE 2-22.
The right endoscopic Babcock clamp is gently pulling the fundus of the stomach across the back of the gastroesophageal junction. With the same segment of stomach that was being passed around the back of the esophagus, the 360° wrap is created.

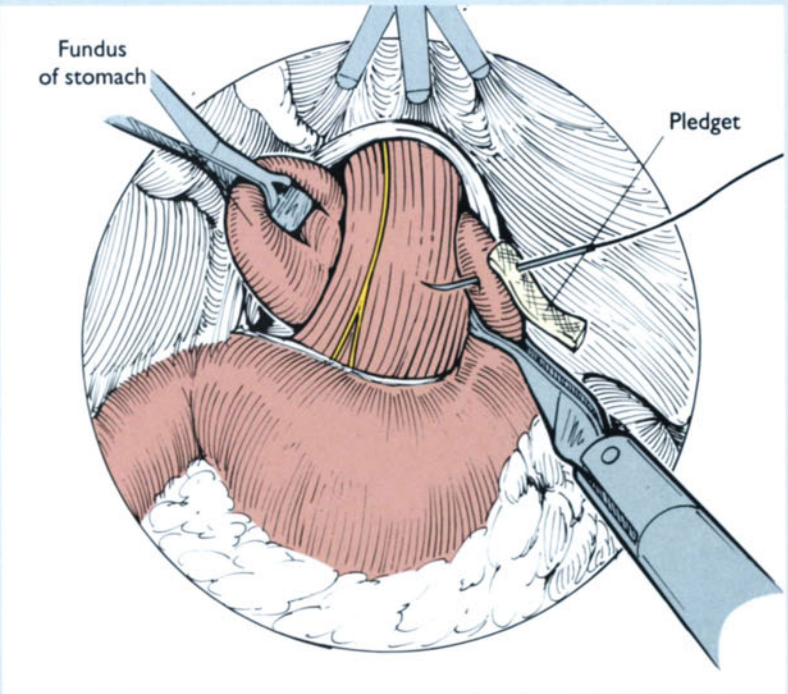


FIGURE 2-23.
Pledgets are then passed into the abdomen. Pledgets are used at each interface of stomach and esophagus to support a zero nonabsorbable suture. The anterior and posterior vagus nerves are included in the wrap.

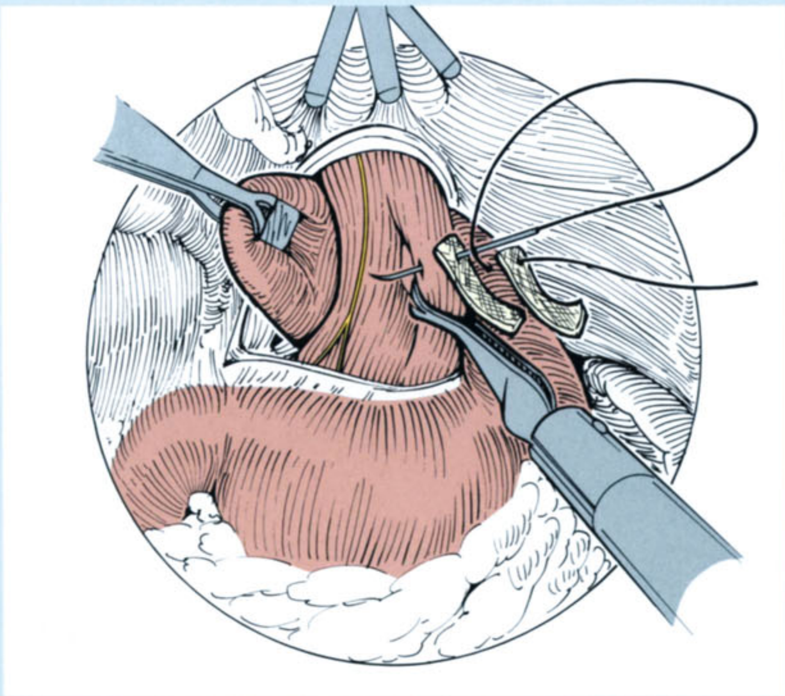


FIGURE 2-24.
Four pledgets are used. At first the superior suture is placed, usually from the left side to the right side. Seromuscular stitches are performed.

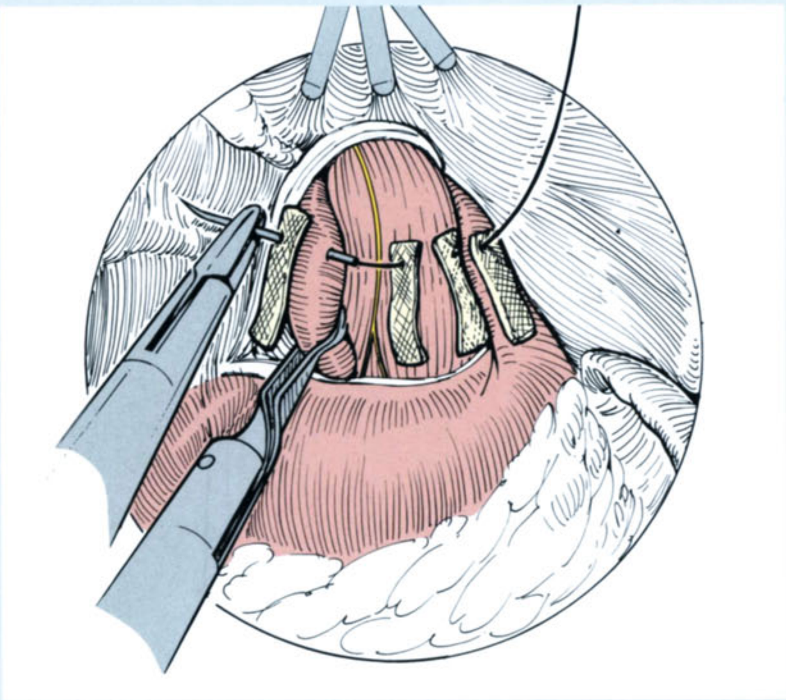


FIGURE 2-25.
The suture is passed from the left side through pledget, stomach, pledget, esophagus, pledget, stomach, and pledget.

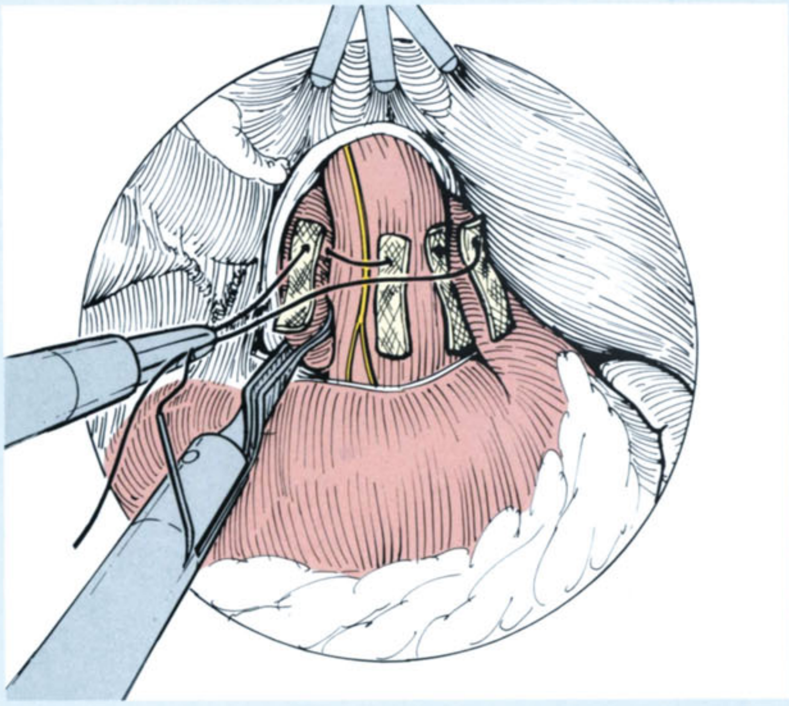


FIGURE 2-26.
The suture is then brought out through the same 10-mm trocar through which it was introduced. An extracorporal knot is tied, which is introduced into the peritoneal cavity and slid down with a pusher bar.

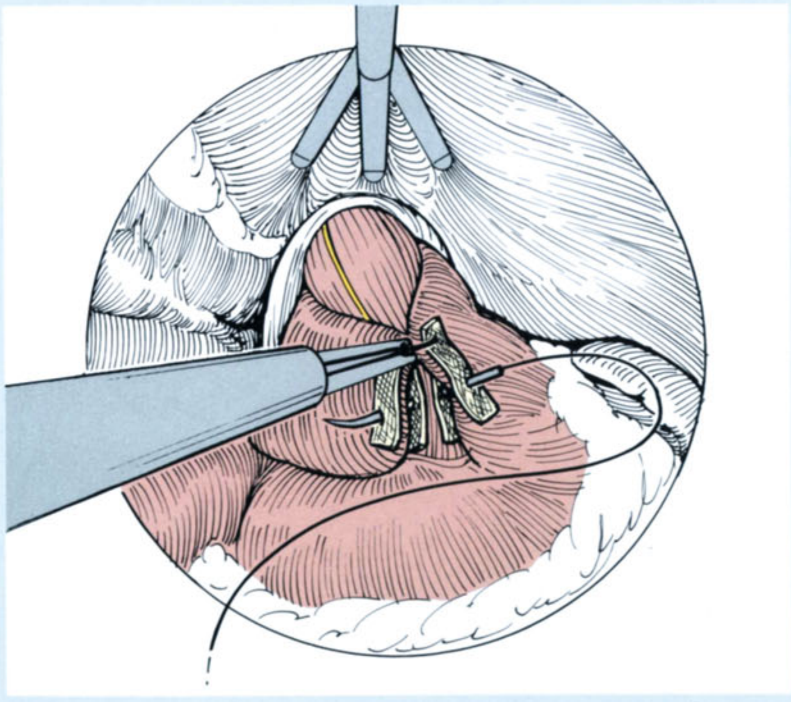


FIGURE 2-27.
A second suture is placed inferior to the previous one, approximately 1 to 1.5 cm apart, using an identical technique.

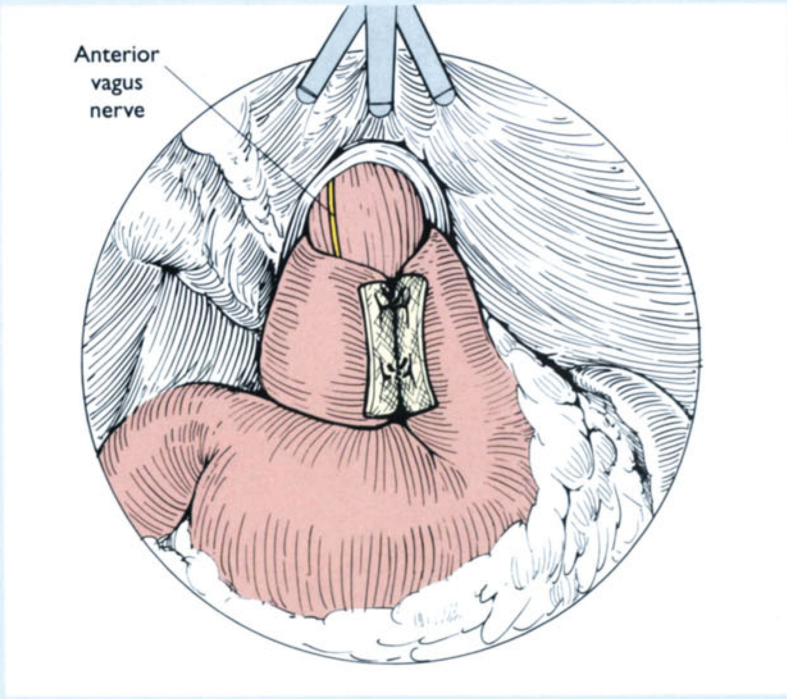


FIGURE 2-28.
The complete 360° wrap is demonstrated. The length of the wrap is approximately 2 cm, and as demonstrated above, created over a large bougie to create a loose "floppy Nissen." Trocars are then removed, the pneumoperitoneum released, the incisions closed with interrupted number 1 polyglactin sutures, and incision dressings are applied.

Alternative Set-up

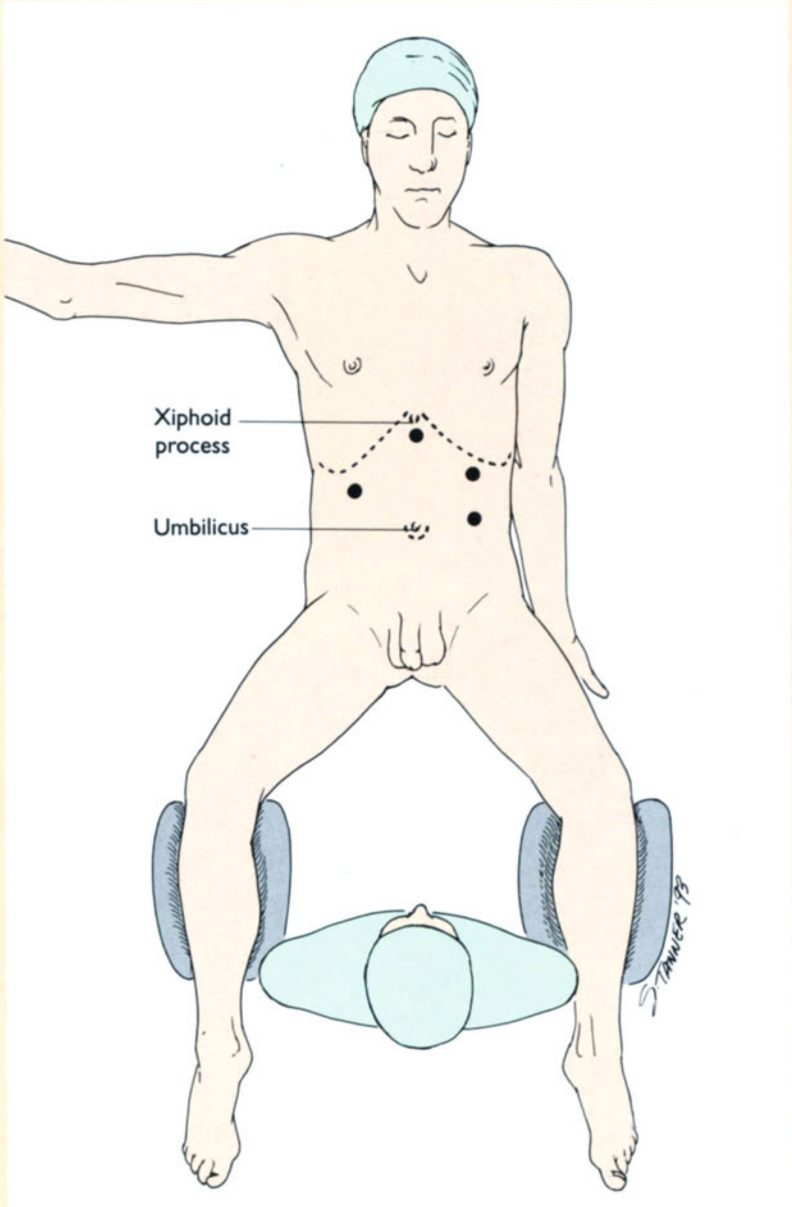


FIGURE 2-29.
Alternative set-up. The surgeon is positioned between the legs of the patient. The patient is in lithotomy and reverse (20° to 30°). Trendelenburg position. Five trocars are placed high in the epigastrium. The video camera is introduced through the left upper quadrant trocar.

Alternative Procedure

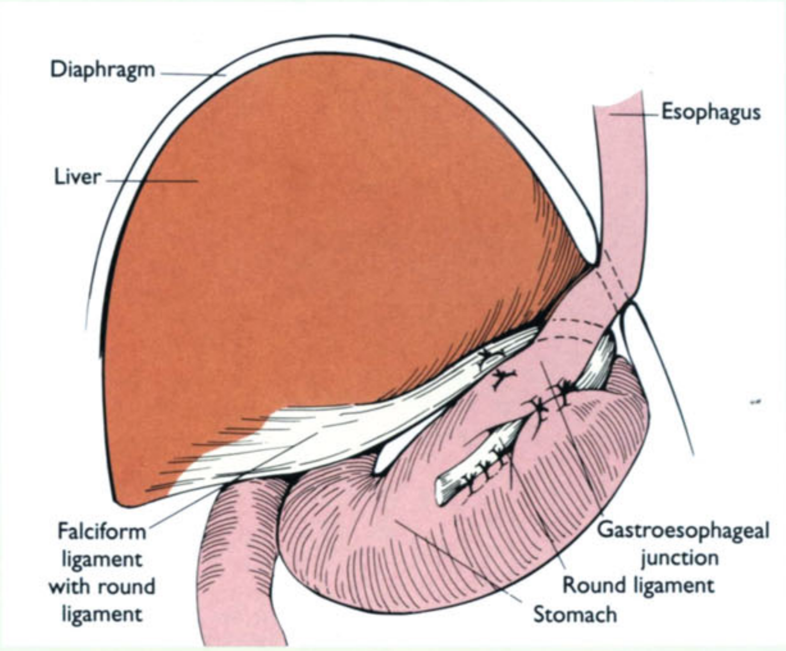


FIGURE 2-30.
Alternative laparoscopic antireflux procedure: laparoscopic ligamentum teres (round ligament) cardiopexy. The procedure consists of three sequential parts: mobilization of the teres ligament with preservation of its blood supply, mobilization of the abdominal esophagus, and cardiopexy with the teres ligament sling [17].

Results

Dallemagne and coworkers [16] reported on the first series of 12 patients who underwent laparoscopic Nissen fundoplication. Three of the 12 patients required conversion to open laparotomy for equipment failure or bleeding encountered during dissection of the short gastric vessels. The remaining nine patients reported complete relief of symptoms. Laparoscopic reduction, crural repair, and fundoplication of a large hiatal hernia was performed by Cuschieri and coworkers [18] in eight patients. Crural repair and fundoplication was done by continuous suture technique. The average operating time was 3 hours. The postoperative complications were cervical emphysema (three patients), left pneumothorax (one patient), and transient dysphagia (one patient). All had no symptoms and absence of acid reflux 3 months postoperatively.

Bittner and coworkers [7] in 1993 laparoscopically explored 35 patients for Nissen fundoplication. There was a 0% mortality rate and the total hospital morbidity rate was 25.7% (nine of 35 patients). Five patients required conversion to open Nissen fundoplication, three due to hemodynamic instability secondary to presumed pneumothorax, a transverse colotomy in one patient, and a distal esophageal perforation in another patient. The total surgical time of laparoscopic Nissen fundoplication was 109 minutes on average. The majority of the patients were discharged on postoperative day 2 or 3. Three patients developed severe dysphagia due to a tight wrap, whereby two patients required dilatation for resolution of their symptoms, and the other patient's symptoms resolved spontaneously. Overall, 26 of the 30 patients who underwent the laparoscopic Nissen fundoplication (87%) described the outcome of the operation as "excellent" and "good." All patients returned to baseline activities and full employment within 14 days after the operation. The clinical assessment and satisfaction scores of the 30 patients who successfully underwent laparoscopic Nissen fundoplication are shown in Table 2-2.

In conclusion, laparascopic Nissen fundoplication can be performed safely and is an effective antireflux procedure. It has the same good results as standard Nissen fundoplication. The best results are obtained in carefully selected patients who present predominantly with regurgitation and heartburn. As in many other laparoscopic procedures, a shorter hospital stay and an earlier return to baseline activities is recognized. Total costs are less compared with the standard technique due to a decreased when hospital stay and an earlier return to work [19].

Table 2-2. Clinical assessment of operative results*

Assessment	%
Mortality	0
Conversion to open	14
Complications	13
Reflux control	96
Severe dysphagia	10
Moderate dysphagia	24
Inability to belch	50
Pulmonary improvement	50
Overall results	
Excellent	67
Good	20
Fair	0
Poor	13

*In-hospital, 30-day, and follow-up outcome (3–6 months) of the 35 patients with symptomatic gastroesophageal reflux disease who were explored laparoscopically for Nissen Fundoplication. Total surgical time of laparoscopic Nissen fundoplication was 109 minutes on average. The majority of the patients were discharged home after the operation on postoperative day 3.

References

1. Allison PR: Reflux esophagitis, sliding hiatal hernia and the anatomy of repair. *Surg Gynecol Obstet* 1951, 92:419–431.
2. Nissen R: Eine einfache Operation zur Beeinflussung der Refluxoesophagitis. *Schweiz Med Wochenschr* 1956, 86:590–592.
3. Baue AE, Belsey RHR: The treatment of sliding hiatus hernia and reflux esophagitis by the Mark IV technique. *Surgery* 1967, 62:396–406.
4. Hill LD: An effective operation for hiatal hernia: an eight year appraisal. *Ann Surg* 1967, 166:681–692.
5. Toupet AM: Technique d'oesophago-gastroplastic avec phreno-gastropexie appliquee dans le cure radicale des hernies hiatales et comme complement de l'operation de Heller dans les cardiospasmes. *Academie de Chirurgie* 1963, 89:394–399.
6. Geagea T: Laparoscopic Nissen's fundal plication is feasible. *Can J Surg* 1991, 34:313.
7. Bittner HB, Meyers WC, Brazer SR, Pappas TN: Laparoscopic Nissen fundoplication: operative results and short-term follow-up. *Am J Surg* 1994, in press.
8. Gahagan T: The function of the musculature of the esophagus and stomach in the esophagogastric sphincter mechanism. *Surg Gynecol Obstet* 1962, 114:293–303.
9. Stein HJ, DeMeester TR: Who benefits from antireflux surgery. *World J Surg* 1992, 16:313–319.
10. Hiebert CA, Belsey RHR: Incompetency of the gastric cardia without radiologic evidence of hiatal hernia. *J Thoracic Cardiovasc* 1961, 42:352–362.
11. DeMeester TR, Wernly JA, Bryant GH, Little AG, Skinner DB: Clinical and in vitro analysis of determinants of gastroesophageal competence. *Am J Surg* 1979, 137:39–46.
12. Skinner DB: Pathophysiology of gastroesophageal reflux. *Ann Surg* 1985, 202:546–556.
13. Ismail-Beigi F, Horton PF, Pope CE II: Histologic consequences of gastroesophageal reflux in man. *Gastroenterology* 1970, 58:163–170.
14. Stein HJ, Barlow AP, DeMeester TR, Hinder RA: Complications of gastroesophageal reflux disease: role of the lower esophageal sphinchter, esophageal acid and acid/alkaline exposure, and duodenogastric reflux. *Ann Surg* 1992, 216:35–43.
15. DeMeester TR, Bonavina L, Albertucci M: Nissen fundoplication for gastroesophageal reflux disease: evaluation of primary repair in 100 consecutive patients. *Ann Surg* 1986, 204:9–20.
16. Dallemagne B, Weerts JM, Jehaes C, Markiewicz, Lombard R: Laparoscopic Nissen fundoplication: preliminary report. *Surg Laparosc Endosc* 1991, 3:138–143.
17. Nathanson LK, Shimi S, Cuschieri A: Laparoscopic ligamentum teres (round ligament) cardiopexy. *Br J Surg* 1991, 78:947–951.
18. Cuschieri A, Shimi S, Nathanson LK: Laparoscopic reduction, crural repair, and fundoplication of large hiatal hernia. *Am J Surg* 1992, 163:425–430.
19. Schmidt CM, Brazer SR, Cowper PL, Bittner HB, Pappas TN: Laparoscopic versus conventional Nissen fundoplication: a cost-effective analysis. (In press.)
20. Urschel HC, Paulson DL: Gastroesophageal reflux and hiatal hernia: complications and therapy. *J Thorac Cardiovasc Surg* 1967, 53:21–32.
21. Skinner DB, Belsey RHR: Surgical management of esophageal reflux and hiatal hernia: long-term results with 1030 patients. *J Thorac Cardiovasc Surg* 1967, 53:33–50.

CHAPTER 3

Laparoscopic Vagotomy

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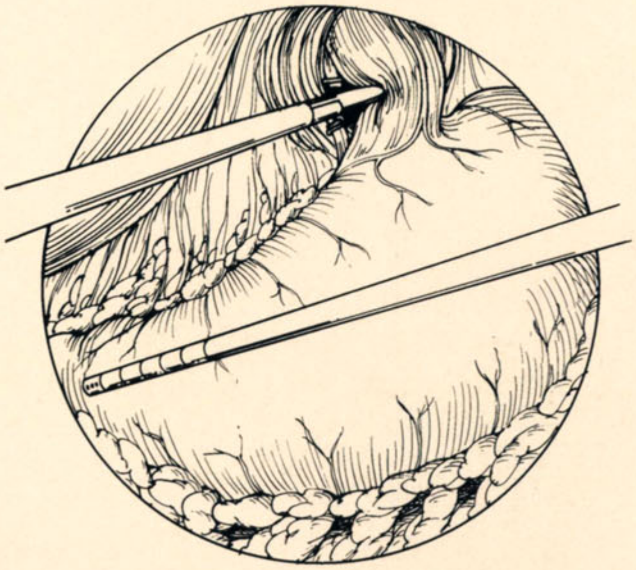
Theodore N. Pappas



Peptic ulcer disease is primarily an affliction of the 20th century, although it was first identified in 1799 [1]. As the disease became widespread in the early to mid 1900s, antiulcer operations were developed and refined. Truncal vagotomy was introduced by Dragstedt and Owens in 1943 [2], and when paired with a drainage procedure, quickly superseded more extensive operations to become the mainstay of surgical therapy for peptic ulcer disease (Table 3-1). This and other procedures (Figure 3-1) soon made up a large proportion of elective abdominal surgery.

Table 3-1. Major events in the history of peptic ulcer disease

Year	Study	Event
167 BC	Cheng [8]	Described the first evidence of ulcer disease in a Chinese man who died of a perforated ulcer
1688	Lenepneau [9]	First described duodenal ulcer
1793	Baillie [10]	Established gastric ulcer as a disease entity
1881	Wölfler [11]	First successful pylorectomy (for cancer of the distal stomach)
1881	Rydygier [12]	First gastric resection for peptic ulceration
1881	Fronmüller [13]	First performed gastric resection with gastroenterostomy
1885	von Hacker [14]	First performed pyloroplasty
1890	Pavlov [15]	Description of the physiologic effects of vagotomy
1922	Wertheimer [16] and Latarjet [17]	First selective vagotomy in a human subject
1943	Dragstedt and Owens [2]	Reintroduced truncal vagotomy for widespread clinical use
1956	Weinberg and coworkers [18]	Popular modification of Heineke-Mikulicz pyloroplasty
1957	Griffith and Harkins [19]	Highly selective vagotomy introduced
1977		H_2 blockers available for clinical use
1989	Dubois [20]	First laparoscopic vagotomy in humans
1991		Omeprazole available for short-term therapy of active duodenal ulcer

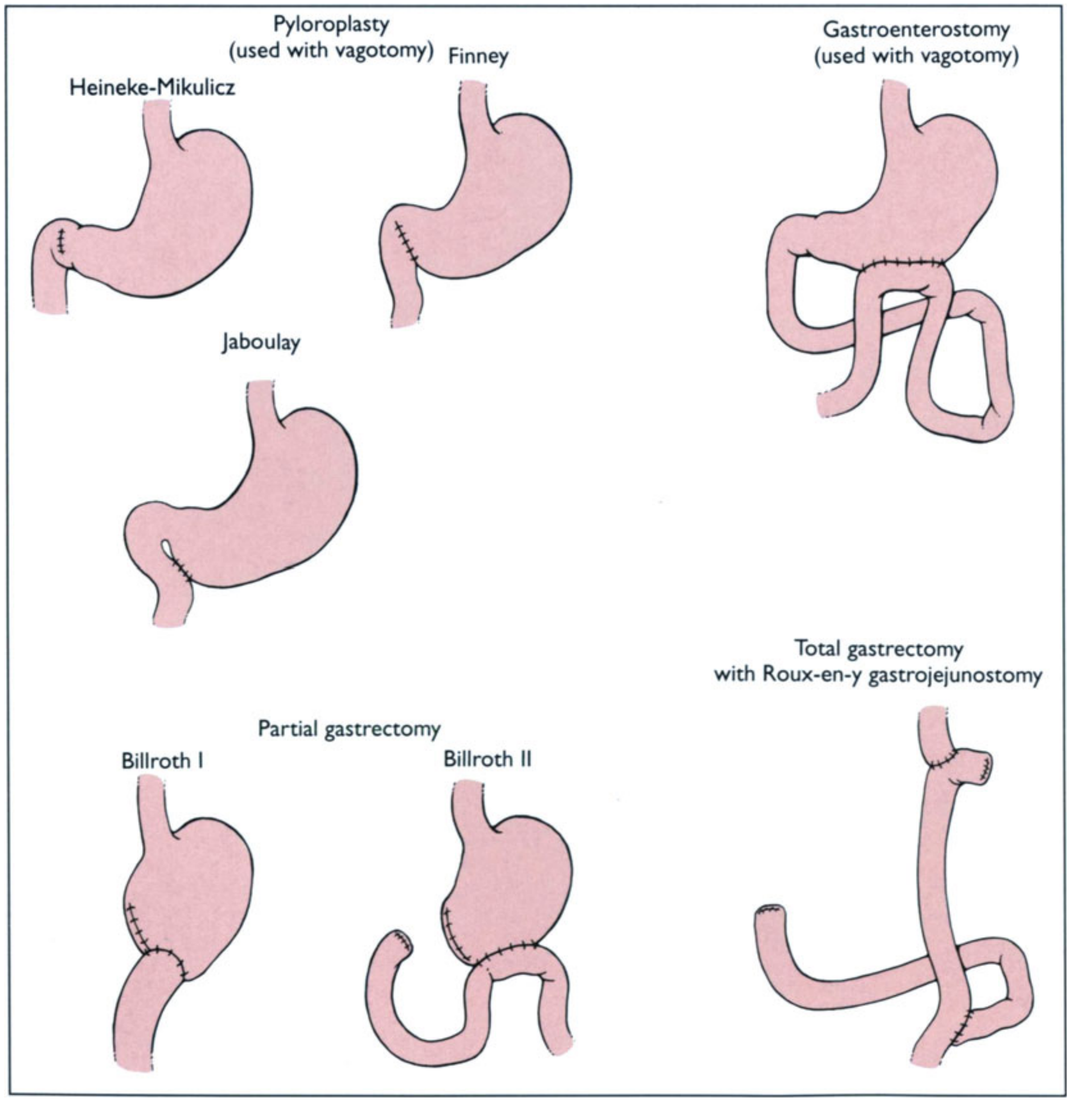


FIGURE 3-1.
Other procedures comprising a large portion of elective abdominal surgery, some used with vagotomy.

Over the past few decades, however, the discovery of effective medical therapy coupled with the decreasing incidence of peptic ulceration has had a profound effect on the management of peptic ulcer disease. Indications for surgery are now largely composed of ulcer complications such as bleeding, perforation, and obstruction (Figure 3-2). Elective surgery is confined to patients with intractable ulcer pain and noncompliance with medical therapy. The high cost of lifetime medical therapy is becoming another important consideration in the management of ulcer diathesis.

Laparoscopic vagotomy is a recent innovation, one of the newest in a growing armamentarium of laparoscopic procedures. Preceding laparoscopic operations have been singularly well tolerated and are now widely available due to patient demand and quality instrumentation. For these reasons, techniques for laparoscopic vagotomy present viable options for the active younger patient with resistant peptic ulcer disease. They may also serve the growing proportion of older patients requiring surgical management of ulcer disease.

Anatomy

The right and left vagus nerves provide parasympathetic input to the stomach and the remaining gastrointestinal tract (Figure 3-3). Closely approximating the outer wall of the esophagus near the diaphragmatic hiatus, the right

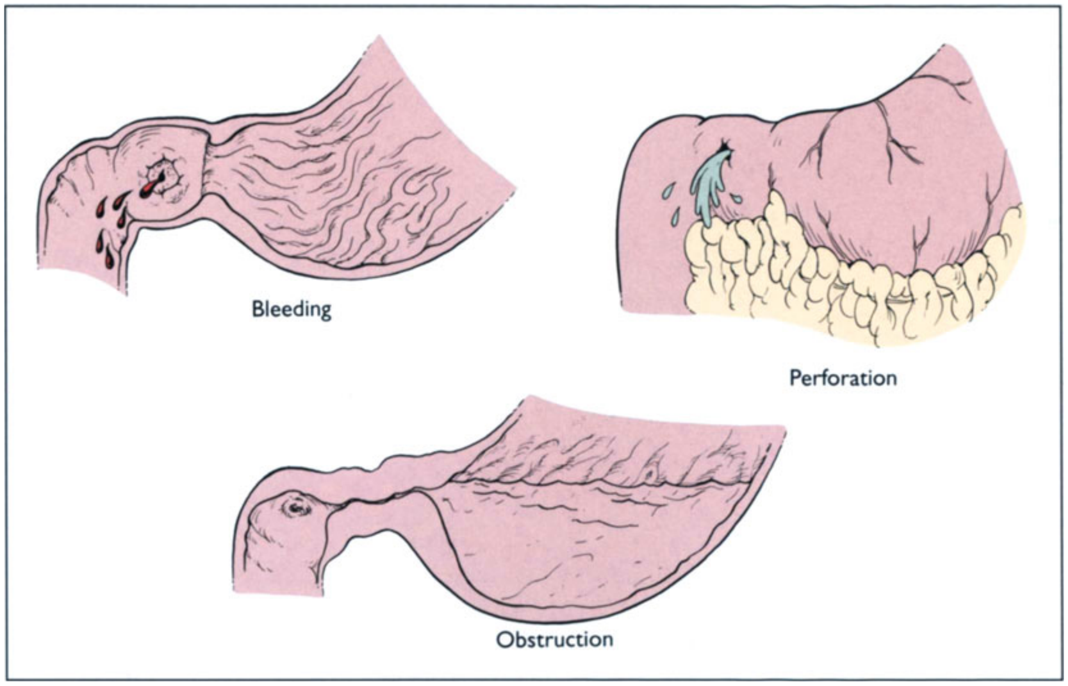


FIGURE 3-2.
Indications for surgical intervention in peptic ulcer disease.

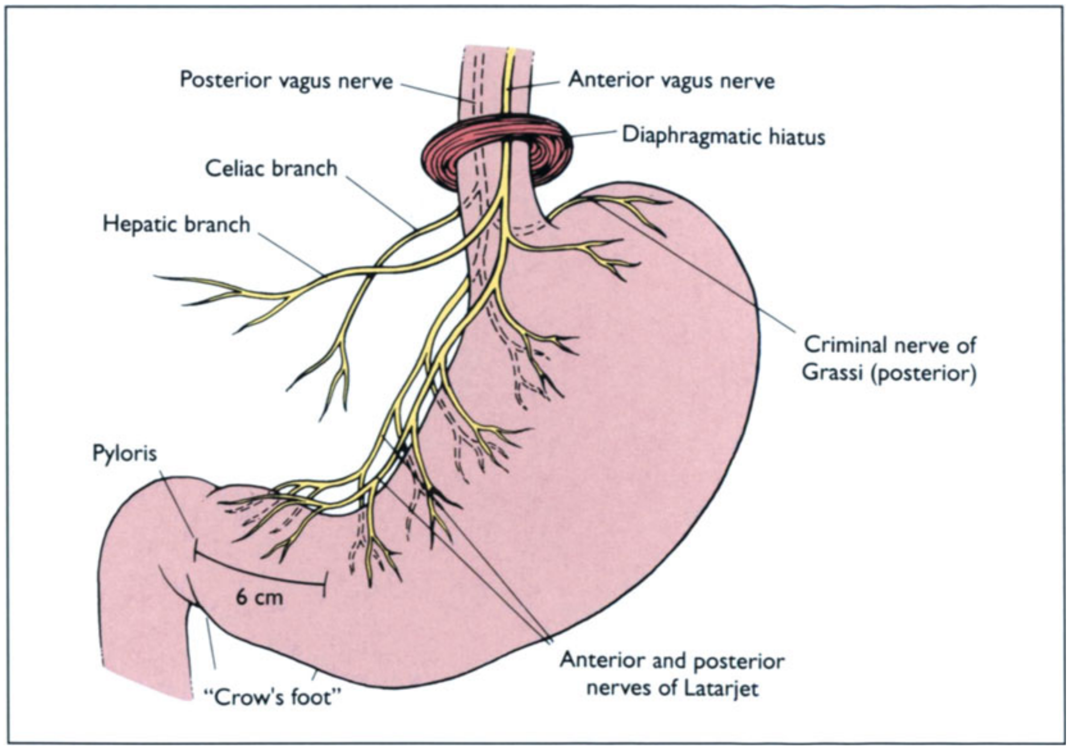


FIGURE 3-3.
Anatomy showing the right and left vagus nerves providing parasympathetic input to the stomach, liver, and celiac plexus.

and left trunks follow the direction of embryonic foregut rotation. Accordingly, the right vagus rotates to a posterior position while the left vagus curves anteriorly. Before reaching the gastroesophageal junction, the posterior trunk bifurcates, sending a branch to the celiac plexus. The anterior trunk also splits, forming a division that supplies the liver. The posterior and anterior gastric branches (nerves of Latarjet) then follow the lesser gastric curvature, where smaller branches enter the gastric wall. The primary nerves terminate in a "crow's foot," which innervates the pylorus and approximately 6 cm of distal stomach. Here, the vagus primarily affects gastric emptying.

Pathophysiology, Presentation, and Differential Diagnosis

The exact pathophysiologic mechanism of peptic ulcer formation is unknown, although there are a number of closely associated factors (Figure 3-4). The normal physiology of gastric acid secretion is illustrated in Figure 3-5. Production of gastric acid by the parietal cell is affected by acetylcholine, histamine, and gastrin. Increased gastric acid and pepsin secretion are often present in patients with peptic ulcer disease. The markedly high acid levels are thought to be due to abnormal proliferation of oxyntic glands [3]. It has become evident, however, that impairment of mucosal resistance may be just as important [4].

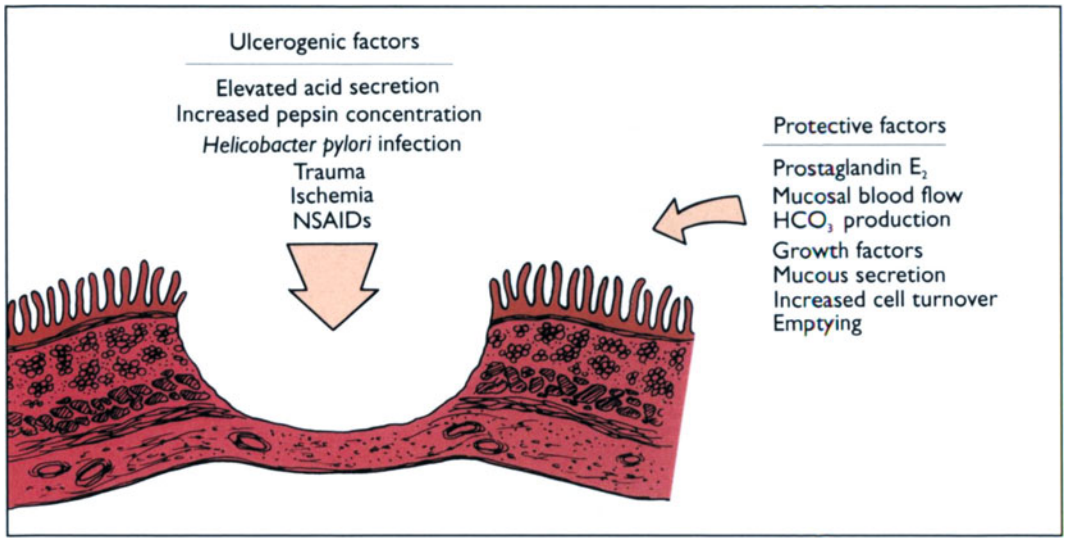


FIGURE 3-4.
Pathogenesis of peptic ulcer formation. NSAID—nonsteroidal anti-inflammatory drug.

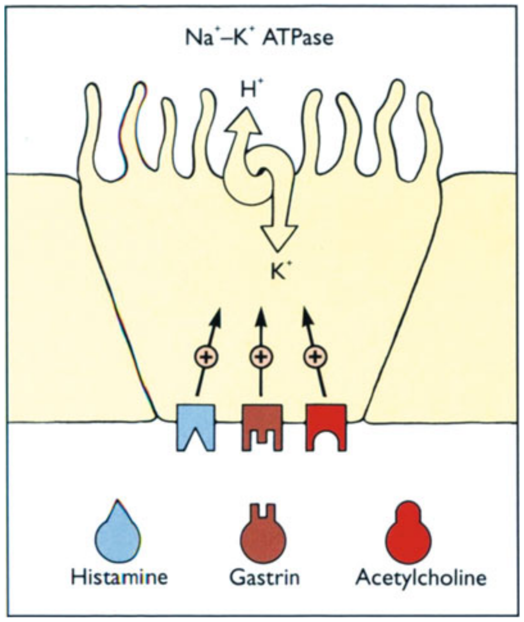


FIGURE 3-5.
Normal physiology of gastric acid secretion. Three separate pathways, mediated by histamine, gastrin, and acetylcholine, stimulate the parietal cell Na^+-K^+ ATPase to produce gastric acid

Alterations in blood flow, growth factor concentrations, bicarbonate production, mucus secretion, and prostaglandin synthesis can all damage the mucosal barrier. Nonsteroidal anti-inflammatory drugs (NSAIDs) may compromise mucosal defenses by inhibiting the synthesis of protective prostaglandins [5]. Table 3-2 outlines pharmacologic and other agents that are associated with peptic ulcer formation. The subject of recent investigation, the gram-negative bacterium *Helicobacter pylori*, initiates an inflammatory gastritis and is implicated in the pathogenesis of peptic ulcers [6]. Other factors including altered gastric motility, genetic disposition, glucocorticoid use, cigarette smoking, and psychologic stress have undetermined roles in the pathogenesis of peptic ulcer disease [7]. In addition, interactions among ulcerogenic factors are highly complex and may vary between individuals.

Peptic ulcer disease commonly presents with pain, often described as a burning, gnawing, aching, or even hungry sensation. Pain will occur 1 to 3 hours after meals and may awaken the patient at night. Food and antacids will bring relief to many patients, thus encouraging the practice of "feeding the ulcer." However, the classic pattern of epigastric pain relieved by meals or antacids may not always be present. Also, some patients without pain have upper gastrointestinal endoscopy or radiologic contrast studies that reveal persistent ulceration of the duodenal bulb. Currently, candidates for laparoscopic vagotomy are patients with persistent pain or documented ulceration refractory to medical therapy. These conditions may be due either to severe ulcer diathesis or noncompliance with medication.

The differential diagnosis for chronic epigastric pain in lieu of proven peptic ulcer disease includes gastric ulceration, gastritis, Zollinger-Ellison syndrome, pancreatitis, carcinoma of the stomach or pancreas, esophageal disease, symptomatic cholelithiasis, chronic cholecystitis, abdominal wall disorders, and angina from myocardial ischemia or pericarditis. Many other conditions cause abdominal symptoms that can mimic ulcer disease or its complications (Table 3-3).

Table 3-2. Ulcerogenic drugs and other associated factors

Ulcerogenic drugs		Other associated factors
NSAIDs:		Chronic gastritis
Diclofenac	Meclofenamic acid	Cigarette smoking
Etodolac	Nabumetone	Coffee
Fenoprofen	Naproxen	Ethanol
Flurbiprofen	Phenylbutazone	Glucocorticoids
Ibuprofen	Piroxicam	Lewis phenotype
Indomethacin	Sulindac	Male sex
Ketoprofen	Tenoxicam	Psychologic stress
Ketorolac	Tolmetin	Prior localized radiation therapy

NSAIDs—nonsteroidal anti-inflammatory drugs.

Table 3-3. Differential diagnosis of peptic ulcer disease

Upper gastrointestinal tract	Other intra-abdominal	Other
Esophagitis	Colonic carcinoma	Pneumonia
Gastric ulcer	Benign colonic diseases	Pleuritic pain
Gastritis	Mesenteric ischemia	Pulmonary embolus
Zollinger-Ellison syndrome	Infarction of liver or spleen	Costochondritis
Carcinoma of the stomach, pancreas, or esophagus	Bowel obstruction	Myocardial ischemia
Pancreatitis	Meckel's diverticulitis	Pericarditis
Gallbladder disease		Sickle cell crisis
		Abdominal wall disorders
		Renal pain
		Factitious abdominal pain

Surgical Technique

Figures 3-6 through 3-27 depict the surgical technique for laparoscopic vagotomy.

Set-up

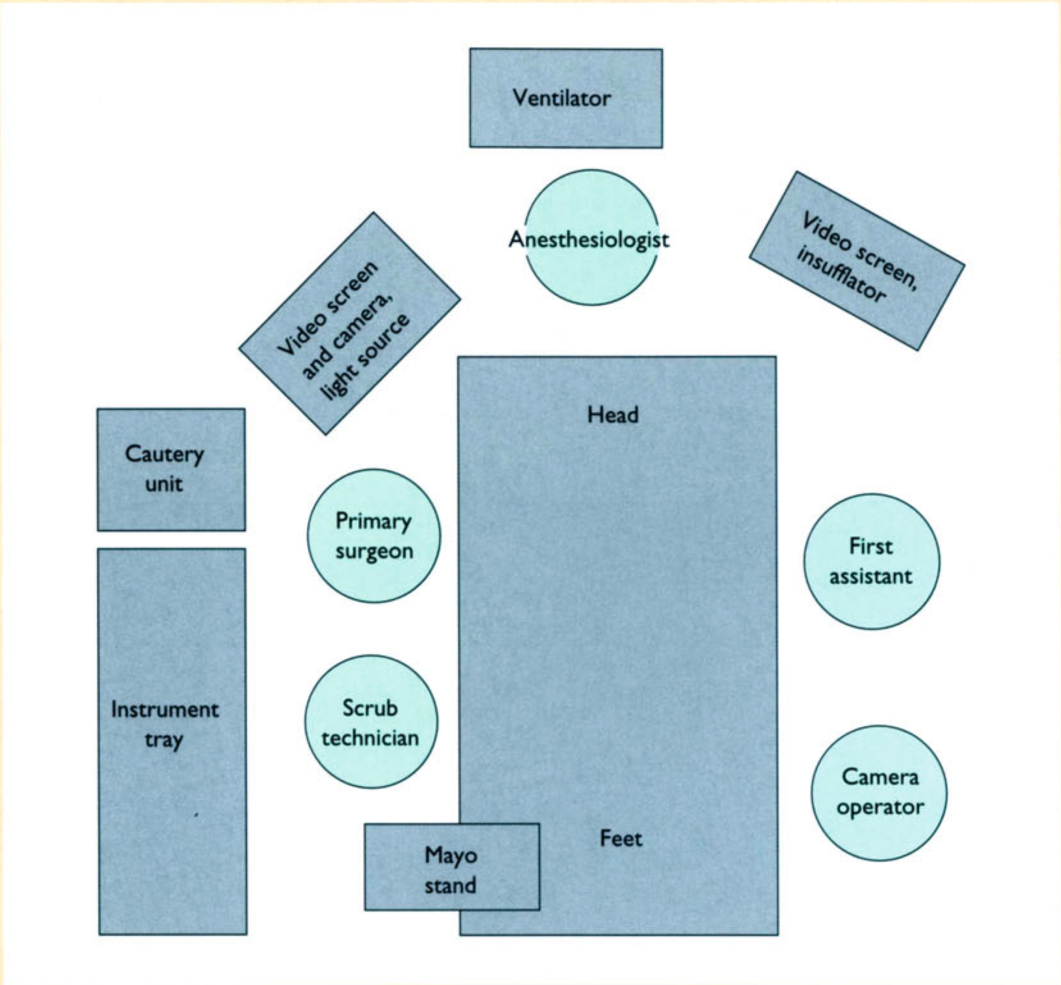


FIGURE 3-6.
Operative set-up for laparoscopic vagotomy. Antibiotics are administered at the time of induction of general anesthesia. Foley and nasogastric catheters are placed. The abdomen is prepared in the usual fashion.

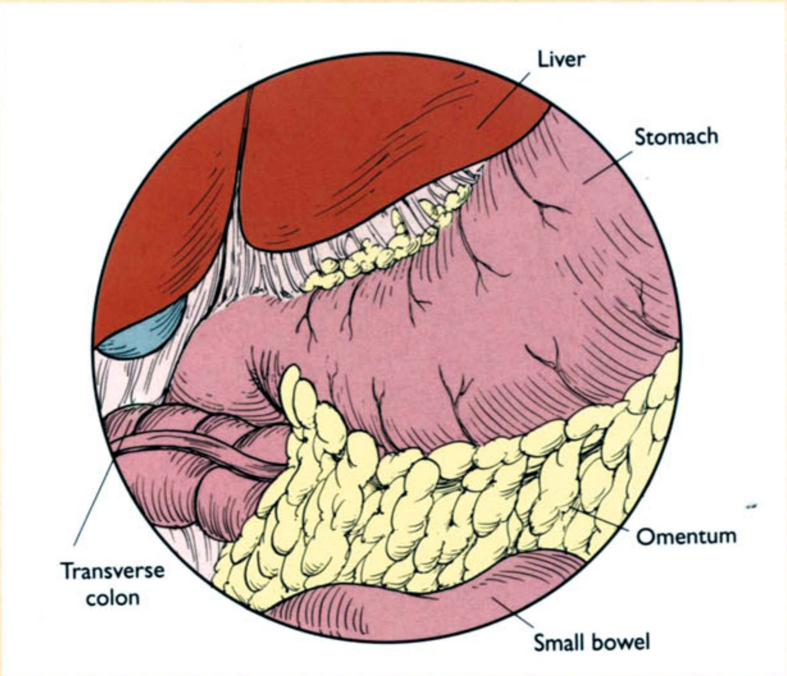


FIGURE 3-7.
The patient is first placed in the Trendelenburg position. A Veress needle or Hasson trocar is used to enter the peritoneal cavity for carbon dioxide insufflation to 12 to 15 mm Hg. The laparoscope is inserted through the 10-mm sheath placed above or below the umbilicus and the abdominal contents are examined. In individuals with long abdomens, a better view of the hiatus is obtained with supraumbilical camera placement. The patient is then placed in reversed Trendelenburg position and the liver, gallbladder, small bowel, omentum, and stomach are identified.

Set-up

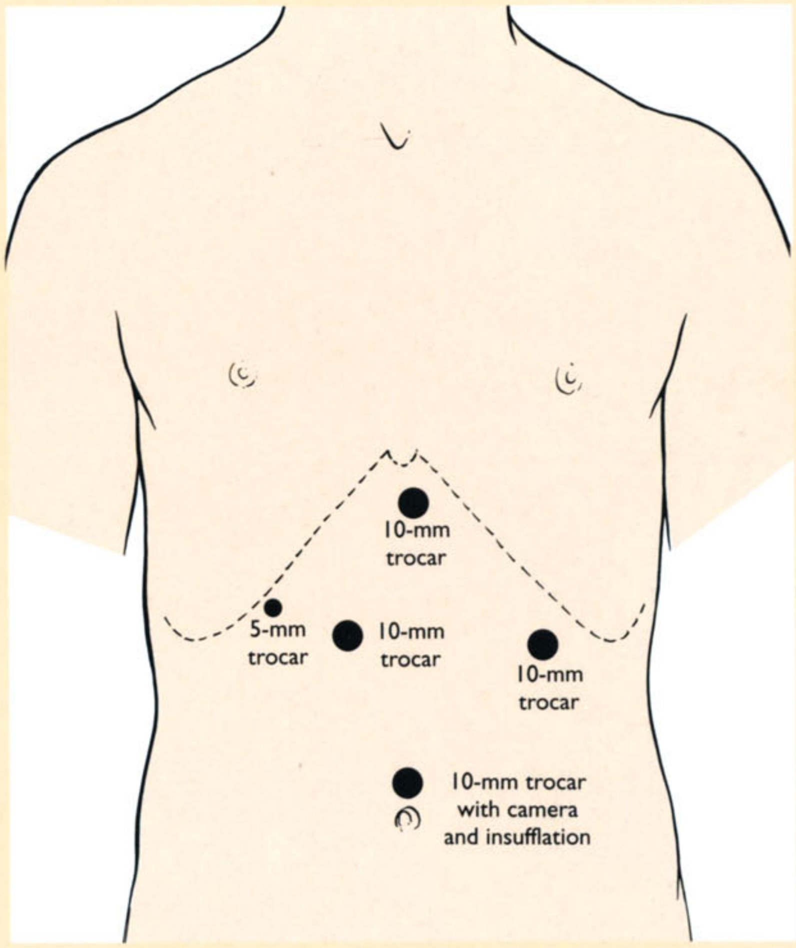


FIGURE 3-8.

Four additional trocars are placed in the upper abdomen under direct laparoscopic vision. A 10-mm trocar is placed in the upper midline near the xyphoid process and to the left of the falciform ligament. Through it, a retracting instrument is introduced for holding the liver away from the hiatus. The surgeon operates from two ports, a 5-mm and 10-mm port placed a few centimeters to the right of the midline. The first assistant operates from the left side through a 10-mm trocar placed in the left midclavicular line near the costal margin.

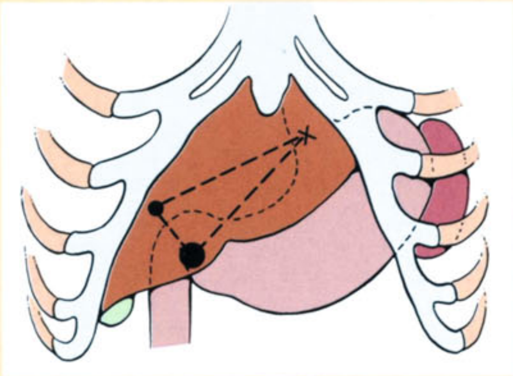


FIGURE 3-9.

This diagram demonstrates the position of the primary surgeon's operating trocars. The 5- and 10-mm ports are located at the basal corners of an isosceles triangle. This hiatus represents the apex of the triangle. This set-up allows the surgeon to use both hands simultaneously.

Procedure

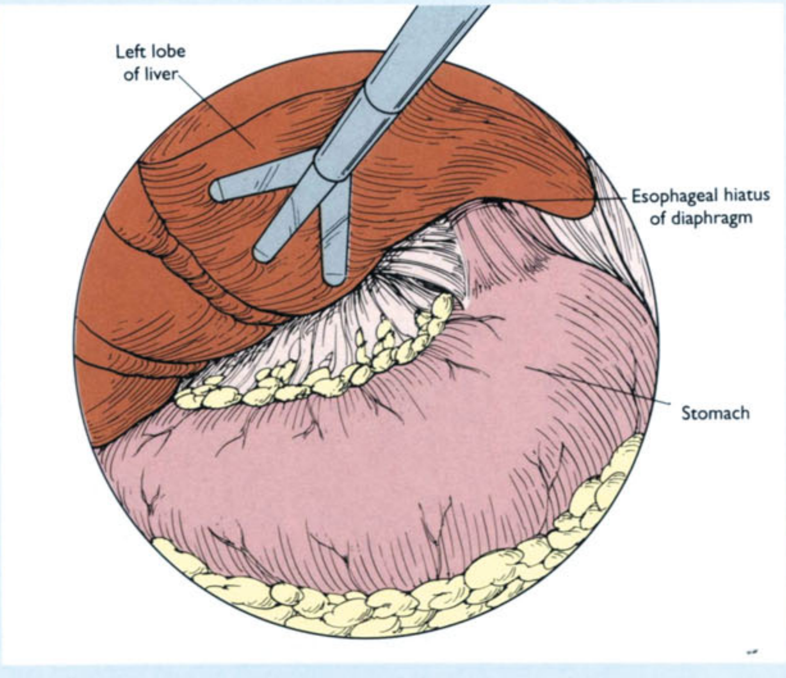


FIGURE 3-10.

The internal anatomy of the hiatal area is shown. A fan retractor is used to hold the left lobe of the liver away from the gastroesophageal junction. The assistant may use an endoscopic Babcock to pull the stomach inferiorly.

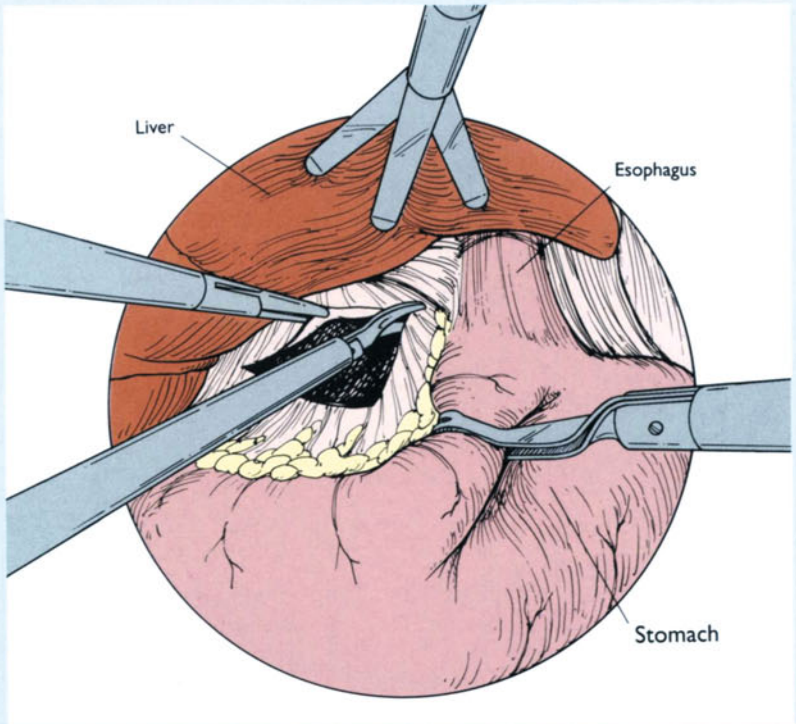


FIGURE 3-11.

Exposure of the hiatus. Endoscopic scissors or a small blunt grasper with electrocautery is used by the surgeon to divide the lesser omentum. The edges are retracted away, exposing the diaphragmatic hiatus.

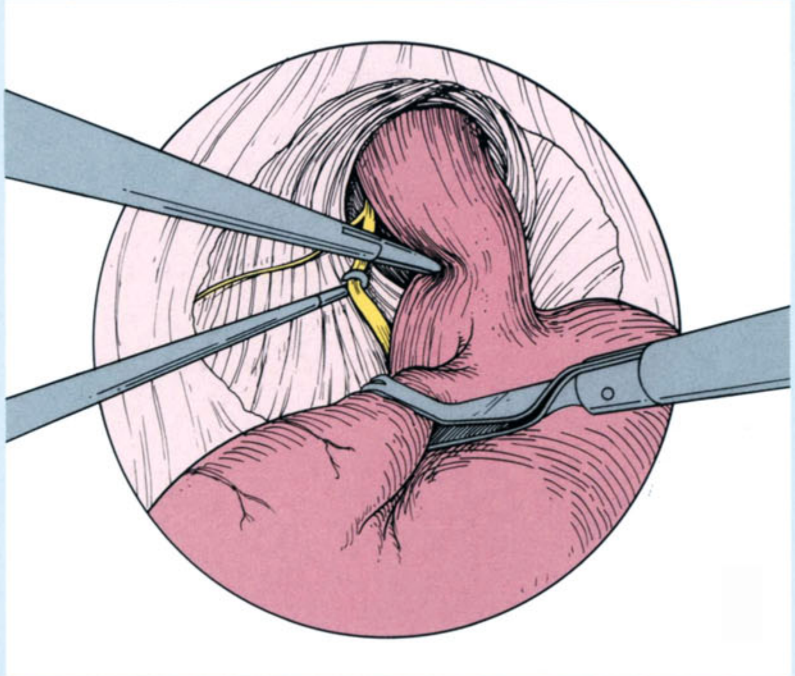


FIGURE 3-12.
Exposure of the posterior vagus is illustrated. After creation of a plane between the right crus of the diaphragm and the esophagus, the surgeon retracts the esophagus to the left with a blunt dissector. The posterior vagus is identified on the posterior surface of the esophagus at the inferior border of the hiatus. With the hook dissector in the other hand, the surgeon dissects and lifts the nerve away from surrounding structures.

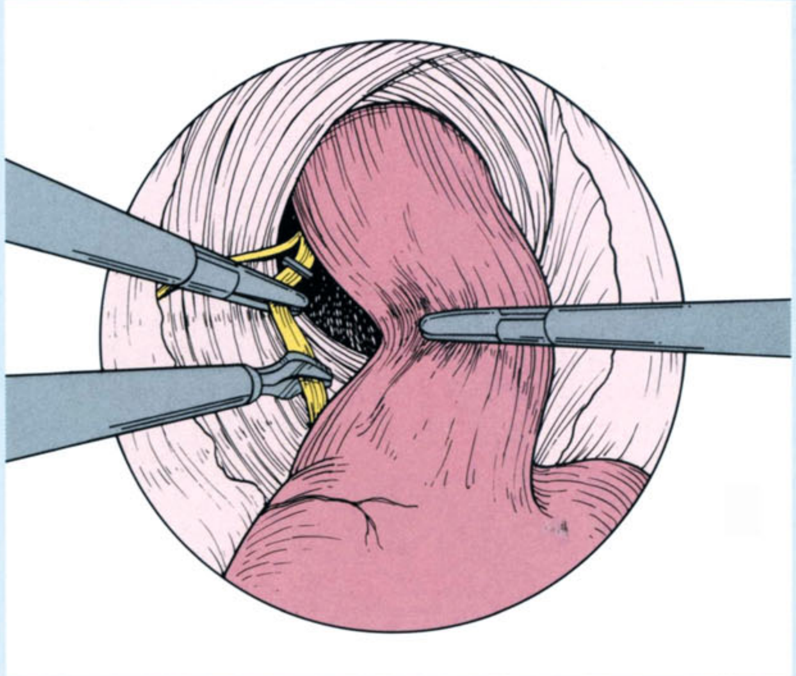


FIGURE 3-13.
The posterior vagus is grasped with endoscopic forceps and clipped superiorly and inferiorly with endoscopic clips. It should be clipped as high as possible in the hiatus to ensure division of the criminal nerve of Grassi.

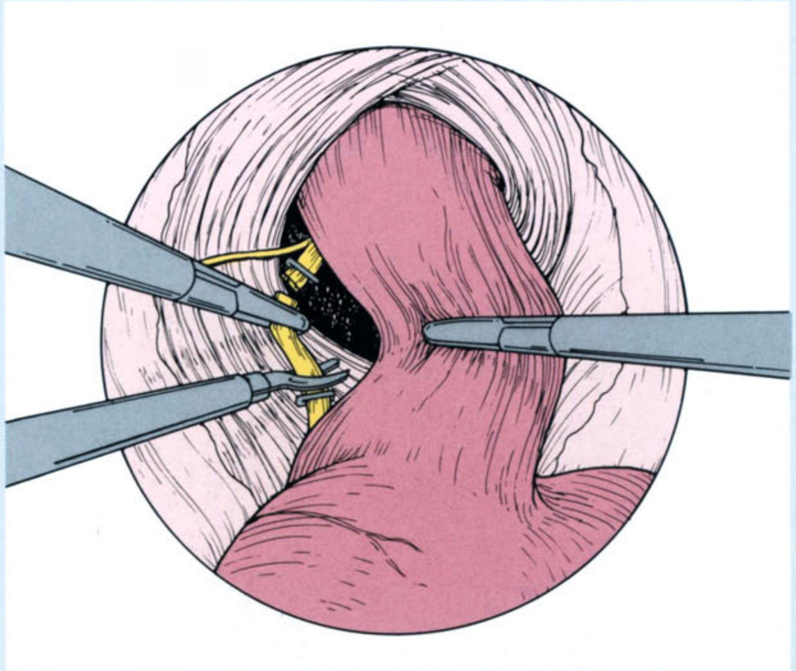


FIGURE 3-14.
Endoscopic scissors are used to remove the section between clips for pathologic confirmation. Before proceeding, the posterior esophagus is examined for any remaining vagal fibers.

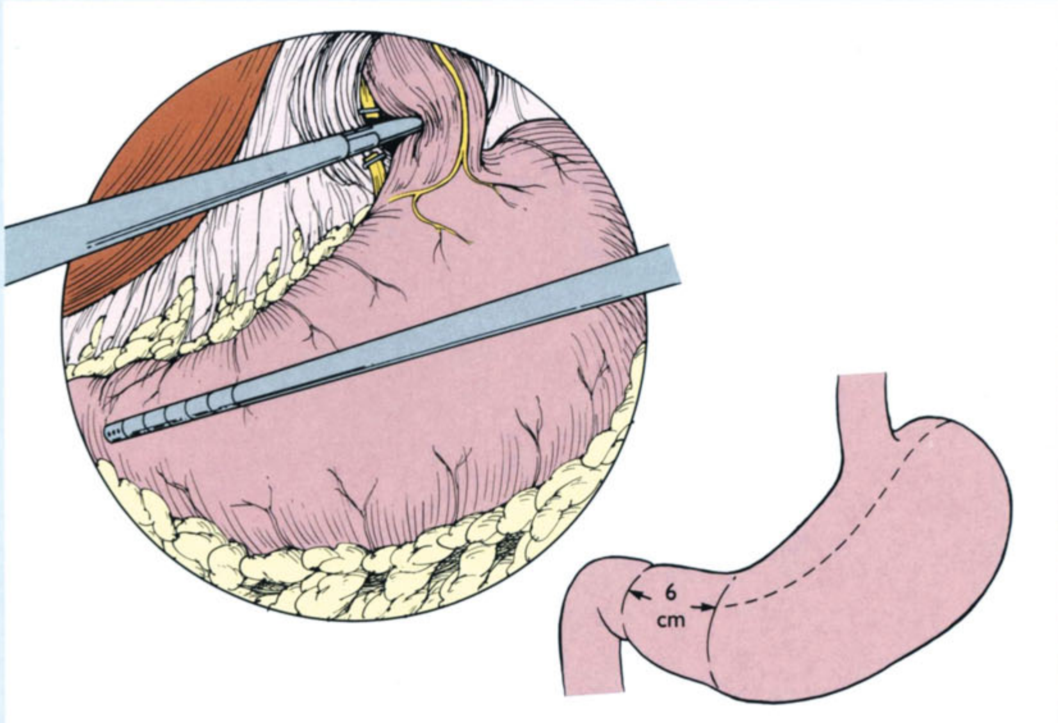


FIGURE 3-15.

Following posterior truncal vagotomy, anterior highly selective vagotomy is performed. Dissection of the branches of the anterior nerve of Latarjet is begun 6 cm from the pylorus, sparing the "crow's foot" innervation to the pylorus. This distance may be measured by placing 1-cm markings on an endoscopic suction/irrigation device prior to insertion into the abdomen. The 6-cm distance may then be measured and superficially marked on the stomach wall with the electrocautery.

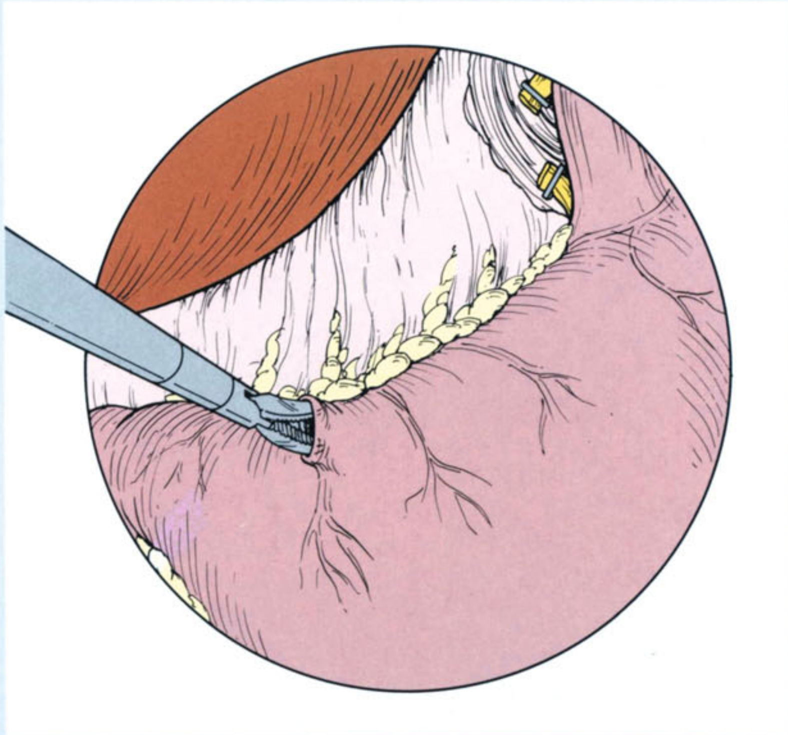


FIGURE 3-16.

Dissection of the anterior vagal branches is illustrated. The alligator forceps are used to dissect and isolate each anterior neurovascular bundle along the lesser curvature as shown. Dissection is limited to areas on the stomach wall. Special care is taken to include the anterior fibers at the base of the esophagus.

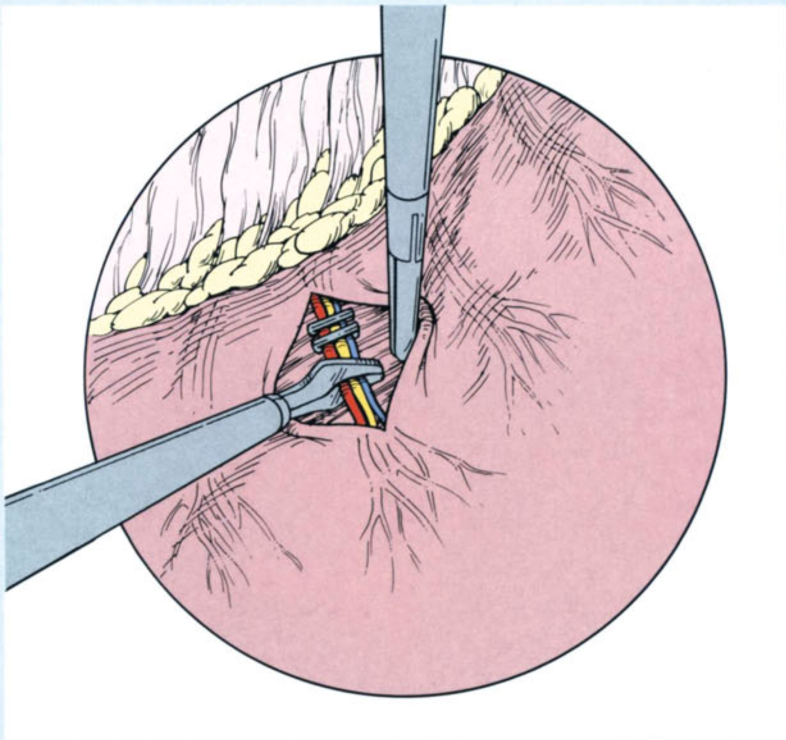


FIGURE 3-17.

Each neurovascular bundle along the line of dissection is doubly clipped. (A total of four clips are placed in each bundle.)

Procedure

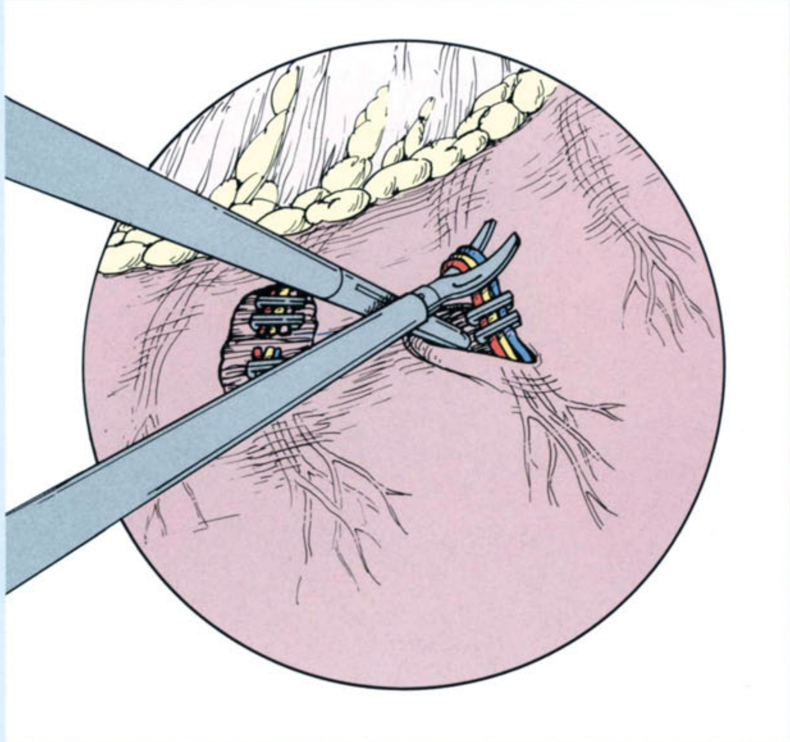


FIGURE 3-18.
Nerve branch, artery, and vein are sharply divided between clips.

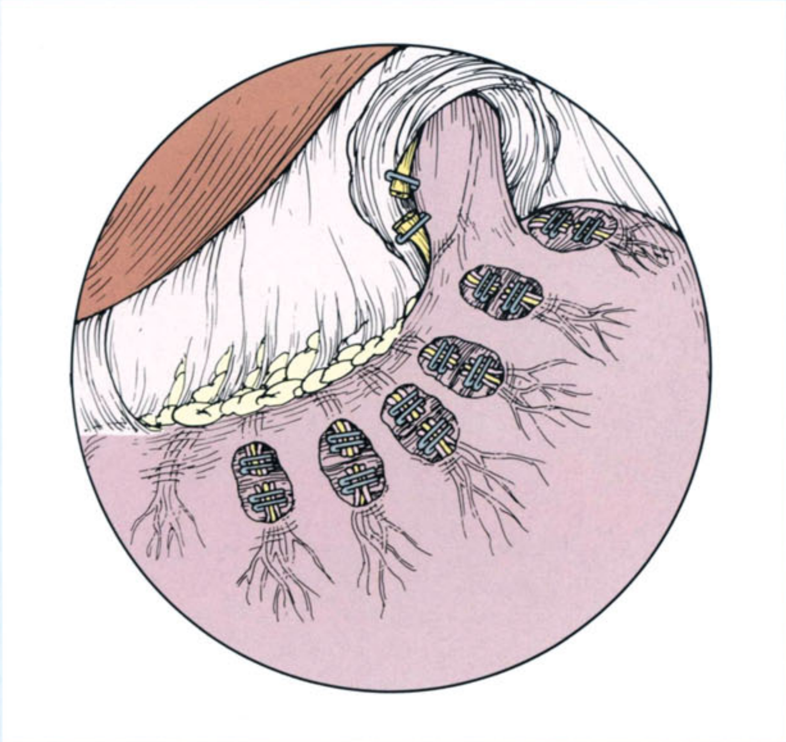


FIGURE 3-19.
The completed posterior truncal vagotomy and anterior highly selective vagotomy are illustrated.

Alternative Procedure

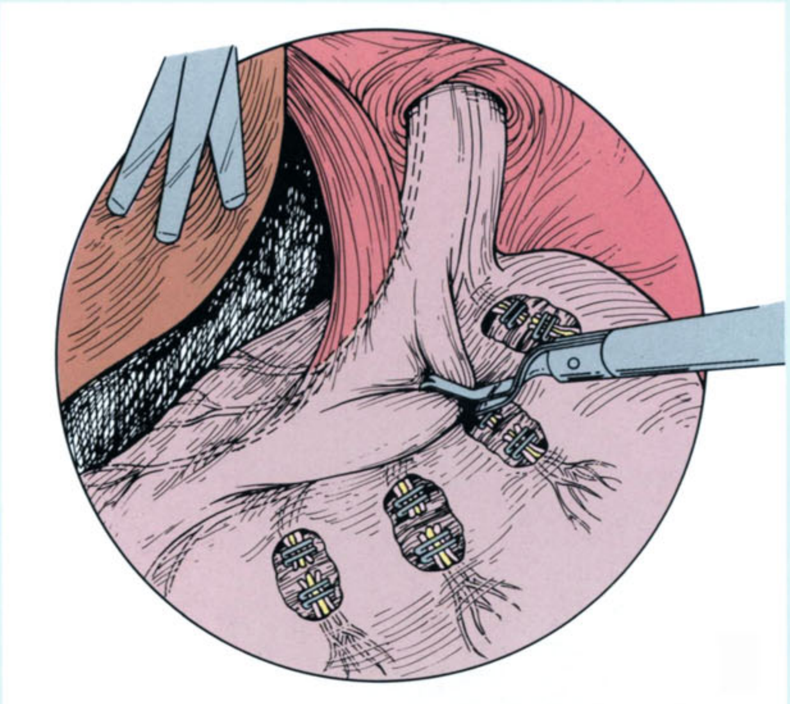


FIGURE 3-20.
When technically feasible, anterior and posterior highly selective vagotomy is a desirable alternative to posterior truncal vagotomy and anterior highly selective vagotomy. Retraction of the lesser curvature by the assistant gives the surgeon access to the posterior wall of the stomach.

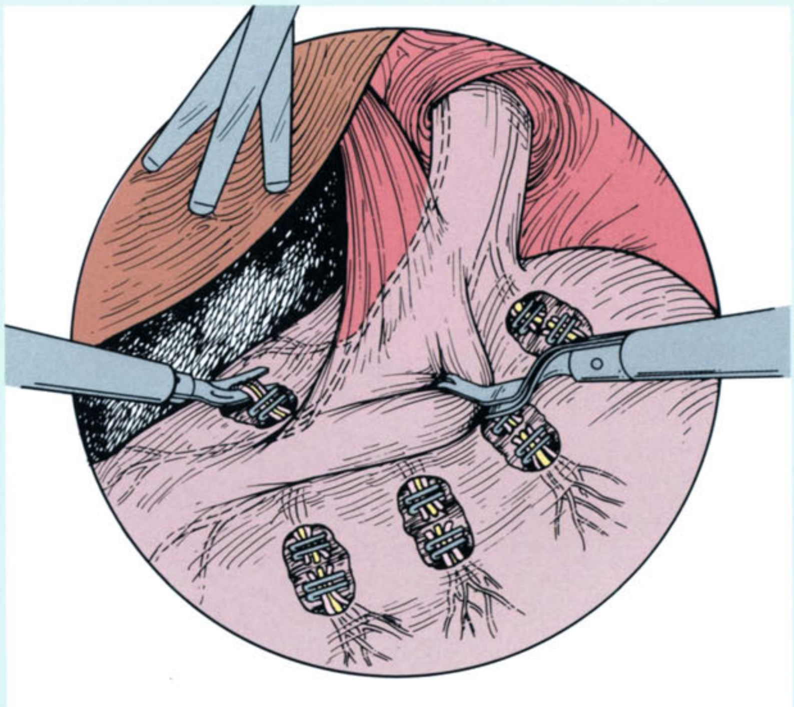


FIGURE 3-21.
As with the anterior highly selective vagotomy, dissection is initiated 6 cm from the pylorus. Nerve branch, artery, and vein are isolated, clipped, and divided.

Alternative Procedure

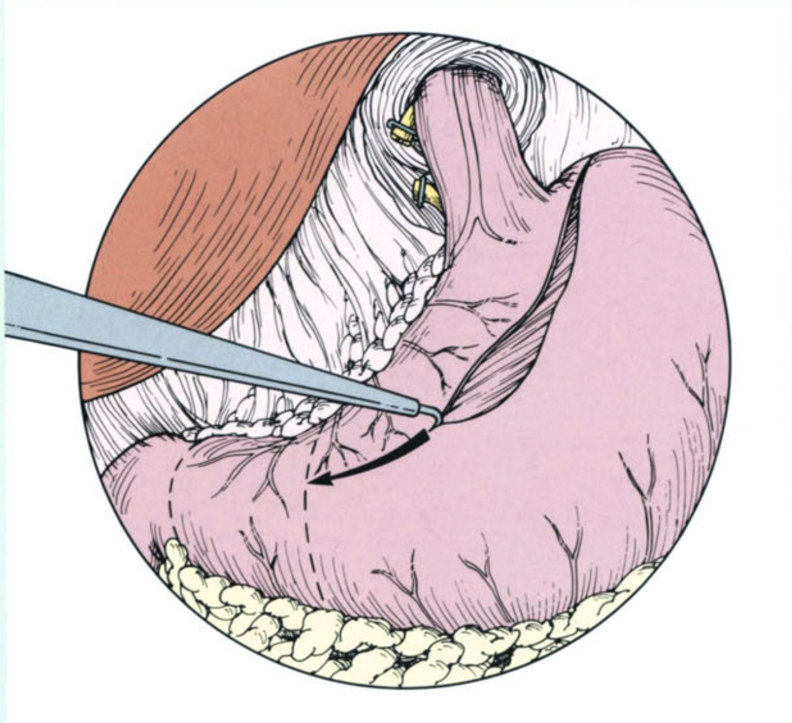


FIGURE 3-22.
Anterior lesser curvature seromyotomy is an alternative to anterior highly selective vagotomy. A hook electrocautery dissector or laser probe is used to perform a seromyotomy 1.5 cm from the lesser curvature, beginning at the gastroesophageal junction and ending 6 cm from the pylorus. Close range direct laparoscopic vision is required.

FIGURE 3-23.
Homeostasis is facilitated by oversewing using running suture technique or by application of fibrin glue or other procoagulant materials. Intragastric methylene blue dye confirms the absence of perforation.

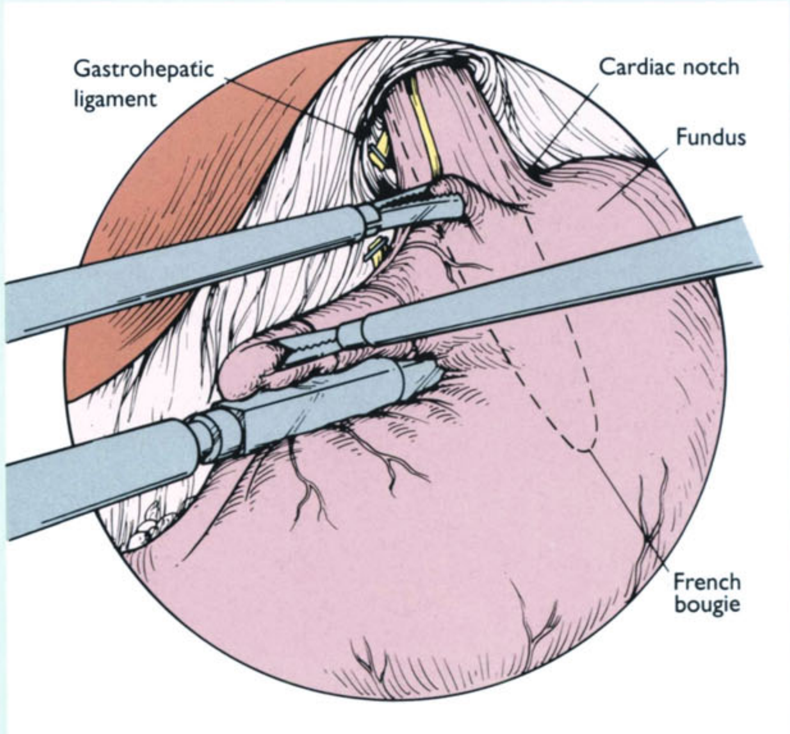


FIGURE 3-24.
Anterior highly selective vagotomy may alternatively be performed with a stapling device. After insertion of a bougie dilator through the gastroesophageal junction, the endoscopic stapling device is placed across a double full thickness of the anterior gastric wall.

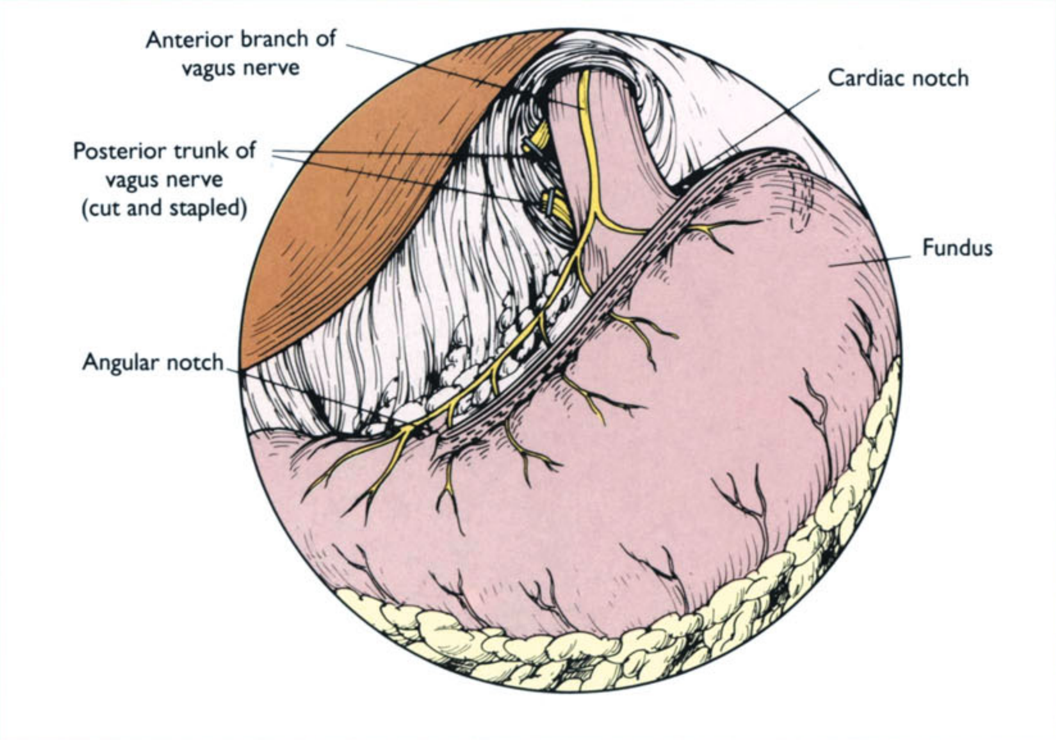


FIGURE 3-25.
Serial end-to-end stapling along the lesser curvature is used to complete the procedure.

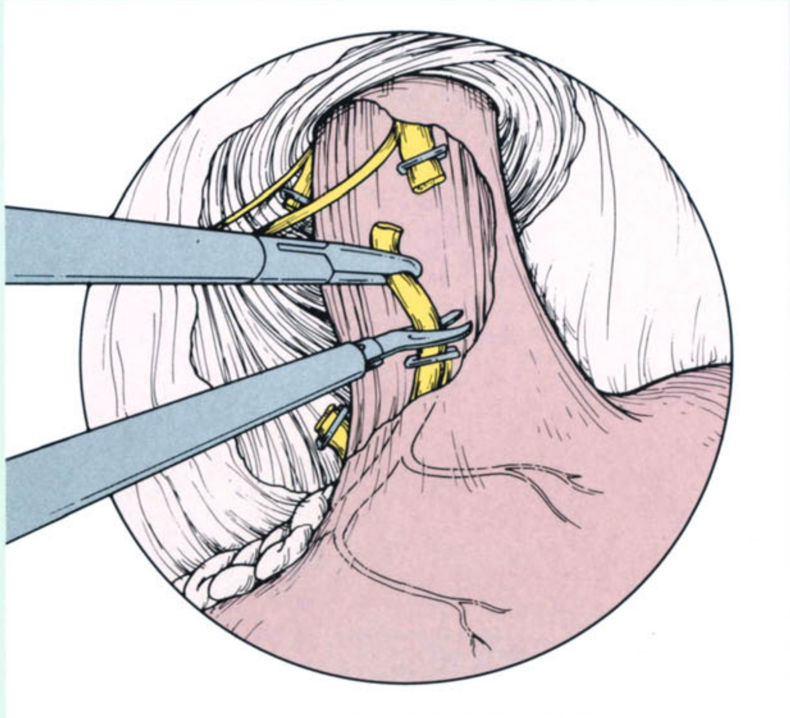


FIGURE 3-26.
Anterior and posterior truncal vagotomy with drainage is preferred for patients with obstruction. The anterior vagal trunk is dissected, clipped superiorly and inferiorly, and the interposing segment is removed for histologic section. The posterior truncal vagotomy is performed as previously described.

Summary of Procedures

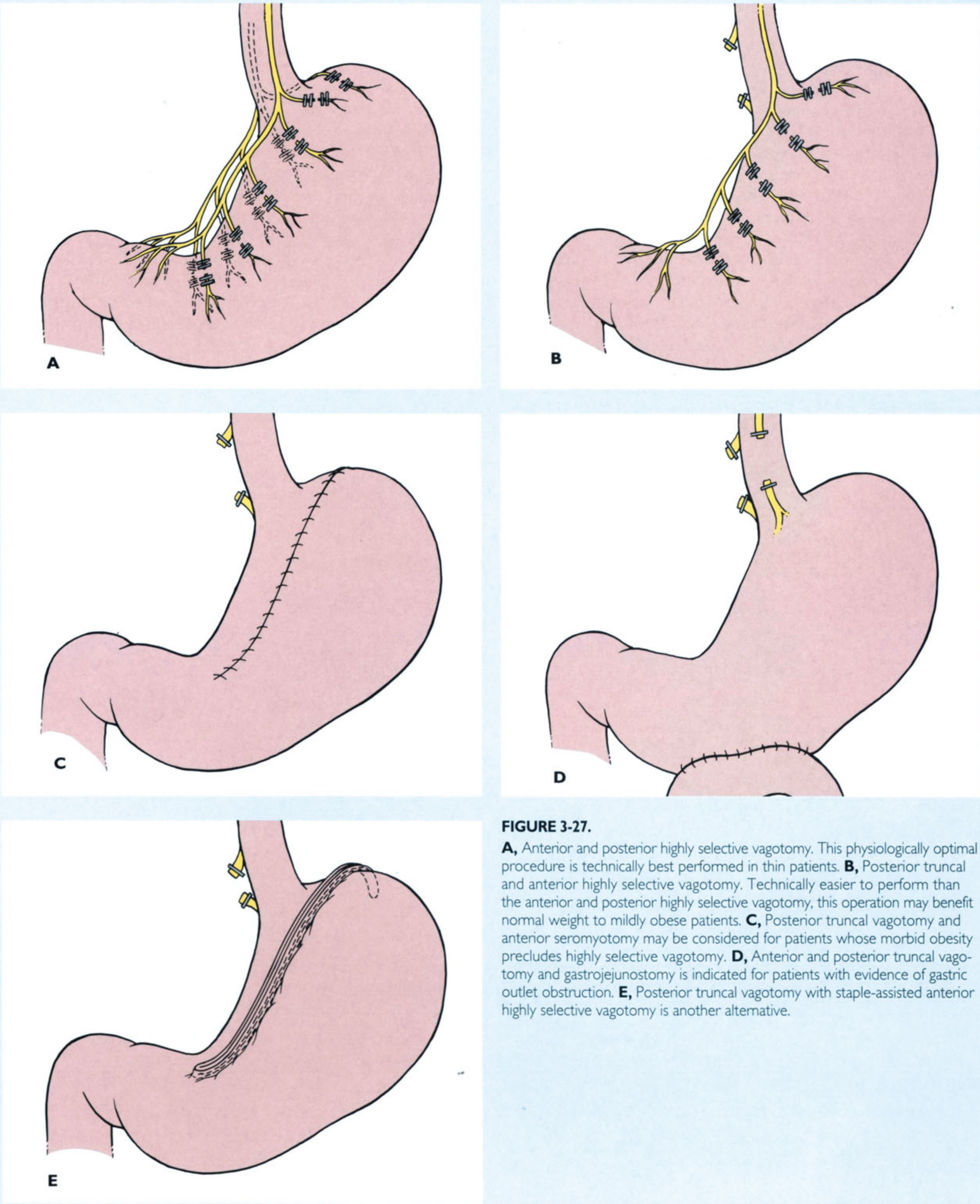


FIGURE 3-27.

A, Anterior and posterior highly selective vagotomy. This physiologically optimal procedure is technically best performed in thin patients. **B,** Posterior truncal and anterior highly selective vagotomy. Technically easier to perform than the anterior and posterior highly selective vagotomy, this operation may benefit normal weight to mildly obese patients. **C,** Posterior truncal vagotomy and anterior seromyotomy may be considered for patients whose morbid obesity precludes highly selective vagotomy. **D,** Anterior and posterior truncal vagotomy and gastrojejunostomy is indicated for patients with evidence of gastric outlet obstruction. **E,** Posterior truncal vagotomy with staple-assisted anterior highly selective vagotomy is another alternative.

Results

At present, there are few reported cases of laparoscopic vagotomy. Table 3-4 outlines series and case reports to date with short-term results. There have been no reported operative mortalities and few operative morbidities. In all cases, the procedure was well tolerated and associated with a brief in-hospital postoperative recovery.

Currently, highly selective vagotomy is the traditional operation of choice for uncomplicated intractable peptic ulcer disease. Compared with other procedures, it is associated with a lower incidence of side effects such as dumping syndrome. Ulceration recurs in up to 30% of patients but is usually amenable to medical therapy. Truncal vagotomy and antrectomy have much lower recurrence rates; however, the incidence of diarrhea and dumping is high. Table 3-5 summarizes the results of traditional modes of surgery for peptic ulcer disease. Refinement of the laparoscopic alternative for highly selective vagotomy may increase the use of this operation for intractable ulcers.

Despite early optimistic reports, the different techniques of laparoscopic vagotomy and the relative indications proposed have yet to be refined. Comparative studies of laparoscopic vagotomy with traditional medical and surgical therapies, especially highly selective vagotomy, will aid in defining the role of this newly evolving technique. Finally, as a relatively advanced laparoscopic procedure, guidelines for practice and training in laparoscopic vagotomy are advised but not established.

In summary, laparoscopic vagotomy is a new and promising adjunct to more established therapy for peptic ulcer disease. With careful patient selection, the procedure is technically feasible for experienced laparoscopic surgeons. Although the potential benefits are significant, comparisons of cost, safety, and efficacy have yet to be completed.

Table 3-4. Reported laparoscopic vagotomy cases

Study	Year	Total, *n*	PTAHS	PTASM	TBDP	Thor	TGJ	T	Decrease in acid secretion	Postoperative in-hospital days	Complete ulcer healing	Complications
Kum and Goh [21]	1992	12	6	2	3	—	—	—	12	4	NR	1†
Bailey and coworkers [22]	1991	1*	1	—	—	—	1	—	NR	2	1	0
Mouiel and Katkhouda [23]	1993	36	—	34	2	—	—	—	36	3–5	33	4‡
Laws and coworkers [24]	1992	4	—	—	—	4	—	—	NR	1–3	NR	0
Chisholm and coworkers [25]	1992	1	—	—	—	1	—	—	NR	3	1	0
Murphy and McDermott [26]	1991	4	—	—	—	—	—	4	NR	NR	NR	0
Nottle [27]	1991	1	1	—	—	—	—	—	NR	3	1	0

*Performed with laparoscopic cholecystectomy.
†Poor gastric emptying requiring endoscopic dilatation.
‡Two cases of delayed gastric emptying, one case of severe reflux, and one case of recurrent duodenal spasm.
NR—not reported.
PTAHS—posterior truncal and anterior highly selective vagotomy.
PTASM—posterior truncal vagotomy and anterior lesser curvature seromyotomy.
T—truncal vagotomy without drainage.
TBDP—truncal vagotomy with balloon dilatation of the pylorus.
TGJ—truncal vagotomy and gastrojejunostomy.
Thor—thoracoscopic vagotomy.

Table 3-5. Results of conventional operations for peptic ulcer disease

Procedure	Mortality rate, %	Recurrence rate, %	Morbidity rate, %
Highly selective vagotomy	0.1–0.3	5–30	5
Truncal vagotomy and antrectomy	0.6–1.8	< 2	10–40
Truncal vagotomy and pyloroplasty	0.5–1.4	10–15	11–25

References

1. Wilbur DL: The history of disease of the stomach and duodenum with reference also to etiology. In *The Stomach and Duodenum*. Edited by Eusterman GB, Balfour DL. Philadelphia: W.B. Saunders; 1935.
2. Dragstedt LR, Owens RM, Jr: Supradiaphragmatic section of vagus nerves in treatment of duodenal ulcer. *Proc Soc Exp Biol Med* 1943, 53:152–154.
3. Mulholland MW, Debas HT: Chronic duodenal and gastric ulcer. *Surg Clin North Am* 1987, 67:489.
4. Szabo S: Gastroduodenal mucosal injury—acute and chronic: pathways, mediators, and mechanisms. *J Clin Gastroenterol* 1991, 13(suppl):S1–S8.
5. Selling JA, Hogan DL, Aly A, *et al.*: Indomethacin inhibits duodenal mucosal bicarbonate secretion and endogenous prostaglandin E_2 output in human subjects. *Ann Intern Med* 1987, 106:368–371.
6. Hentschel E, Brandstäatter G, Dragosics B, *et al.*: Effect of ranitidine and amoxicillin plus metronidazole on the eradication of *Helicobacter pylori* and the recurrence of duodenal ulcer. *N Engl J Med* 1993, 328:308–312.
7. Mertz HR, Walsh JH: Peptic ulcer pathophysiology. *Med Clin North Am* 1991, 75:799–814.
8. Cheng TO: Glimpses of the past from the recently unearthed ancient corpses in China. *Ann Intern Med* 1984, 101:714–715.
9. Lenepneau I: Cas de perforation der duodenum de lien d'une ancienne cicatrice de cet intestina. *Gaz Hop* 1838, 35:137.
10. Baillie M: The morbid anatomy of some of the most important parts of the human body. Edited by Johnson J, Nicol G. London; 1793.
11. Wölfler A: Resection of the cancerous pylorus performed by Professor Billroth. Edited by Absolon KB, Absolon M. *Rev Surg* 1968, 25:381.
12. Rydygier LV: Die erste magenusektion für geschwür. *Berl Klin Wochensch* 1882, 19:32.
13. Fronmüller R: *Operation der Pylorus Stenose (Erlandgen Dessertation).* Fürth: Schröder; 1886.
14. von Hacker V: Zur casuistik und statistik der magenresektionen und gastroenterotomieen. *Arch Klin Chir* 1885, 32:616.
15. Pavlov IP, Schumova-Simanovskaja E: Innervation der magendrüsen beim hunde. *Zentralbl Physiol* 1889, 3:113.
16. Wertheimer P, ed. *L'Innervation et L'éenervation Gastriques: Etude Anatomique, ÈExperimentale et Clinique.* Lyon: Imprimérie-Express; 1922.
17. Latarjet A: Résection des nerfs de l'estomac. *Bull Acad Natl Med (Paris)* 1922, 87:681.
18. Weinberg JA, Stempien SJ, Movius HJ, *et al.*: Vagotomy and pyloroplasty in treatment of duodenal ulcer. *Am J Surg* 1956, 92:202–207.
19. Griffith CA, Harkins HN: Partial gastric vagotomy: an experimental study. *Gastroenterology* 1957, 32:96.
20. Dubois F: Laparoscopic vagotomy. Edited by Cuschieri A, Buess G, Périssat J. *Operative Manual of Endoscopic Surgery.* Berlin: Springer-Verlag; 1992.
21. Kum CK, Goh P: Laparoscopic vagotomy: a new tool in the management of duodenal ulcer disease [letter]. *Br J Surg* 1992, 79(9):977.
22. Bailey RW, Flowers JL, Graham SM, *et al.*: Combined laparoscopic cholecystectomy and selective vagotomy. *Surg Laparosc Endosc* 1991, 1(1):45–49.
23. Mouiel J, Katkhouda N: Laparoscopic vagotomy for chronic duodenal ulcer disease. *World J Surg* 1993, 17:34–39.
24. Laws HL, Naughton MJ, McKernan BJ: Thoracoscopic vagectomy for recurrent peptic ulcer disease. *Surg Laparosc Endosc* 1992, 2(1):24–28.
25. Chisholm EM, Chung SCS, Sunderland GT, *et al.*: Thoracoscopic vagotomy: a new use for the laparoscope. *Br J Surg* 1992, 79:254.
26. Murphy JJ, McDermott EWM: Laparoscopic truncal vagotomy without drainage for the treatment of chronic duodenal ulcer. *Irish Med J* 1991/1992, 84(4):125–126.
27. Nottle PD: Laparoscopic vagotomy for chronic duodenal ulcer. *Med J Aust* 1991, 155(9):648.

CHAPTER 4

Laparoscopic Gastrostomy and Jejunostomy

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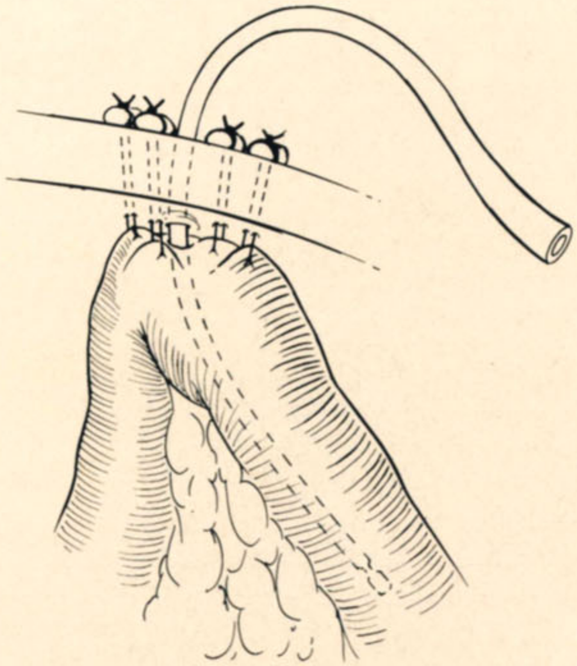
John P. Grant



The provision of access for prolonged feeding modalities in the debilitated patient remains a significant clinical challenge. It is important to minimize morbidity and cost while enhancing quality of life. While oral feeding is optimal, the presence of an altered mental status of dysphagia often requires that artificial access be established into either the stomach or jejunum. If such an access can be placed, enteral feeding has been shown to be effective, inexpensive, and relatively simple to care for in the hospital, nursing care facility, or home.

The history of enteral feeding, summarized in Table 4-1, dates back to William Beaumont's well-documented observations regarding his patient, Alexis St. Martin, who developed a gastrocutaneous fistula after being wounded with a musket. Beaumont introduced a variety of substances through the fistula and documented some basic properties of gastric physiology. The first to propose creation of a gastrostomy as a therapeutic procedure was Egeberg, a Norwegian, who thought feeding via gastrostomy would prolong the survival of patients with esophageal carcinoma [1]. Although Egeberg considered a gastrostomy, there is no record of him actually performing one. The first to perform a surgical gastrostomy was Sedillot [2] of Strasbourg, placing three gastrostomies over a 9-year period. All three patients succumbed to peritonitis in this pre-Listerian era [2]. In 1858, Busch [3] reported intrajejunal supplementation through a jejunal fistula in a female patient gored in the abdomen by a bull. This patient reportedly gained 19 pounds over a 21-week period.

With improvement in antisepsis and operative technique, Surmay [4] constructed a successful jejunostomy for feeding purposes in 1878. Subsequently, many investigators published variations of both gastrostomies and jejunostomies including Witzel [5], Maydl [6], Stamm [7], and Janeway [8,9]. By the beginning of the 20th century, access for enteral nutrition was fairly well developed. Unfortunately, feeding access procedures did not achieve popularity due to frequent complications. During the period between 1920 and 1933, Barber [10] reported 20 cases of jejunostomy tube placement for enteral supplementation at Bellevue Hospital. He used the "method of Witzel" most frequently, introducing an 18- to 25-French catheter approximately 20 to 30 centimeters from the ligament of Treitz. Ten of these patients died less than 2 weeks postoperatively from complications related to the tube. Due to the tube-related complications, he proposed disposing of the tube entirely, leaving a jejunostomy stoma on the abdominal wall through which nutrients are introduced [10].

Table 4-1. Historical milestones in the development of enteral feeding access

Year	Investigator	Commentary
1833	Beaumont	Classic observations reported concerning Alexis St. Martin's gastric fistula
1837	Egeberg	First to propose the construction of a gastrostomy for nutritional supplementation
1846	Sédillot	Conceptualized and performed first surgical gastrostomy
1858	Busch	First report of direct enteral feeding (via jejunal fistula)
1878	Surmay	First surgical jejunostomy created for enteral feeding
1891	Witzel	Described serosal imbrication over a catheter as applied to gastrostomy tube placement
1892	Maydl	Described technique of continent jejunostomy
1894	Stamm	Classic description of gastrostomy tube placement
1895	Eiselberg [16]	First to perform a "Witzel" feeding jejunostomy
1896	Fontan	Reported construction of a continent gastrostomy
1905	Hofmeister [17]	First description of "Stamm" jejunostomy
1913	Janeway	Constructed a continent seromuscular tube gastrostomy
1926	Heyd [18]	First reported adjuvant jejunostomy
1954	McDonald	First needle catheter jejunostomy performed
1981	Gauderer and Ponsky	First report of percutaneous endoscopic gastrostomy tube placement
1990	O'Regan and Scarrow [19]	Initial report of laparoscopic jejunostomy
1991	Edelman and coworkers [20]	First report describing laparoscopic gastrostomy

The next significant advancement occurred in 1954 when McDonald [11] introduced the needle catheter jejunostomy as an adjunct to gastric surgery. This technique proved to be a relatively safe access for short-term enteral feeding complementing major abdominal procedures. Complications were quoted to be less than 2%. Limitations of this procedure included catheter dislodgement and obstruction. Commercial kits for this technique became available in 1973 [12], and needle catheter jejunostomy became a popular route of short-term, postoperative enteral feeding.

Patients requiring a long-term feeding access continued to require laparotomy for gastrostomy or jejunostomy tube placement, until Gauderer, Ponsky, and Izant [13] reported on a new method for gastrostomy tube placement, percutaneous endoscopic gastrostomy (PEG), in 1980. This technique was revolutionary as it did not require general anesthesia or a laparotomy. The percutaneous endoscopic gastrostomy has since become the method of choice for long-term feeding access with reported major complications of 2.8% and minor complications of 6.0% [14]. If jejunal access was required, a feeding tube could be advanced through the gastrostomy tube. Unfortunately, patients with obstructing esophageal lesions are not candidates for the percutaneous endoscopic gastrostomy. Fluoroscopically placed percutaneous gastrostomy and gastrojejunostomy tubes have been developed by radiologists as an alternative to laparotomy, but the small tube size limits this technique to a select group of patients [15]. With the advent of laparoscopic surgery in the late 1980s, placement of gastrostomy and jejunostomy tubes by this methodology now offers an ideal alternative when a PEG cannot or should not be done.

Anatomy

The stomach is the largest dilatation of the foregut which comes to lie in the left upper quadrant anteriorly. It is generally divided into five regions: the cardia, fundus, corpus, antrum, and pylorus. The proximal margin of the stomach is the functional lower esophageal sphincter, whereas the anatomic pyloric sphincter separates the stomach from the duodenum. The small intestine extends from the pylorus to the cecum and consists of the duodenum (20 cm), jejunum (100 to 110 cm), and ileum (150 to 160 cm). The proximal margin of the jejunum is at the ligament of Treitz.

There are several issues to consider when choosing an anatomic site for long-term feeding access. Indications for instituting long-term enteral feedings are summarized in Table 4-2. Since the stomach serves as a reservoir for masticated food, dilutes hypertonic fluids, provides a predigestive role in the initial breakdown of gastric contents, and regulates efflux of food into the proximal duodenum, gastric feeding is advantageous relative to jejunal feeding. Gastrostomy tube placement allows bolus feeding, is more economical since it usually requires less equipment, and allows for easy and safe administration of nearly all required medications. The jejunal route should only be considered for long-term feeding in the presence of gastroparesis, in patients with small gastric remnants, and when there is a risk of aspiration, although aspiration with jejunostomy tube feedings has also been reported [21]. When jejunal feeding is indicated, steady infusion using an infusion pump is preferable over bolus feeding to prevent diarrhea secondary to "dumping" that occurs when hyperosmolar, carbohydrate-rich formulas are administered too rapidly into the small bowel. Feedings can usually be done cyclically over 12 to 14 hours per day. Great care must be exercised when medications are given directly into the jejunum to prevent clogging of the tube, to avoid diarrhea from hyperosmolality, and to assure absorption of the drug. Complications of enteral feeding are summarized in Table 4-3.

Table 4-2. Indications for enteral feeding
Dysfunctional swallow/recurrent aspiration
Head and neck neoplasia
Benign and malignant esophageal obstruction
Severe facial trauma
Nutritional supplementation (anorexia)
Gastroparesis
Altered mental status

Table 4-3. Complications of enteral feeding
Aspiration
Diarrhea/cramps/bloating
Tube occlusion/dislodgement/leakage
Wound infection
Perforated viscus

Surgical Technique

Laparoscopic placement of a gastrostomy or jejunostomy tube is usually performed under general anesthesia. As the abdominal insufflation need only be 8 to 10 mm Hg, use of local anesthesia with intravenous sedation is acceptable in selected patients. Patients are placed supine on the operating table, and positioning the table in reverse Trendelenburg is helpful. The open Hasson technique for placement of the initial infraumbilical trocar should be used liberally in patients with a history of prior abdominal surgery to avoid inadvertent perforation of adjacent viscera or major vascular structures. The remaining technical aspects of the procedure are summarized in the figures below.

Figures 4-1 through 4-4 depict the relevant anatomy and operative set-up for laparoscopic jejunostomy or gastrostomy.

Set-up

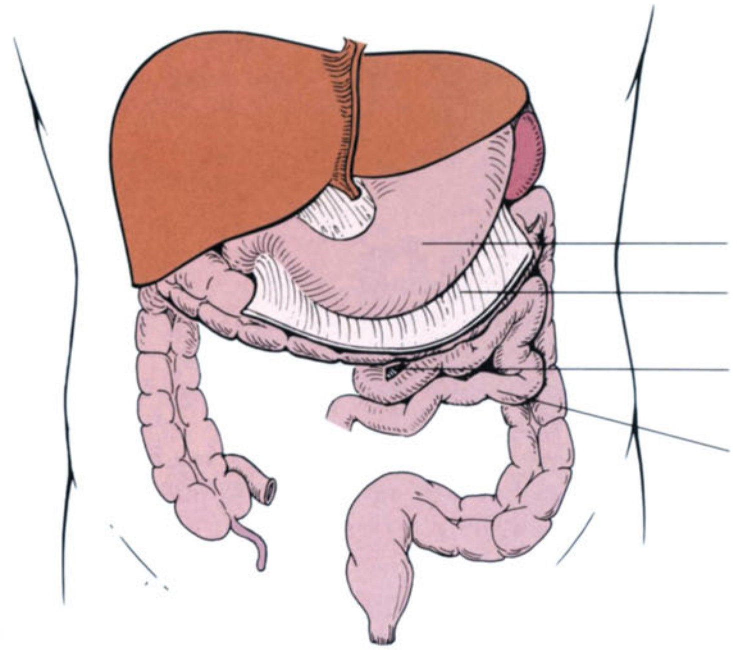


FIGURE 4-1.

Anatomy relevant to laparoscopic jejunostomy or gastrostomy tube placement. Identification of the ligament of Treitz for J-tube placement is essential, and the antrum adjacent to the pylorus should be avoided for G-tube placement.

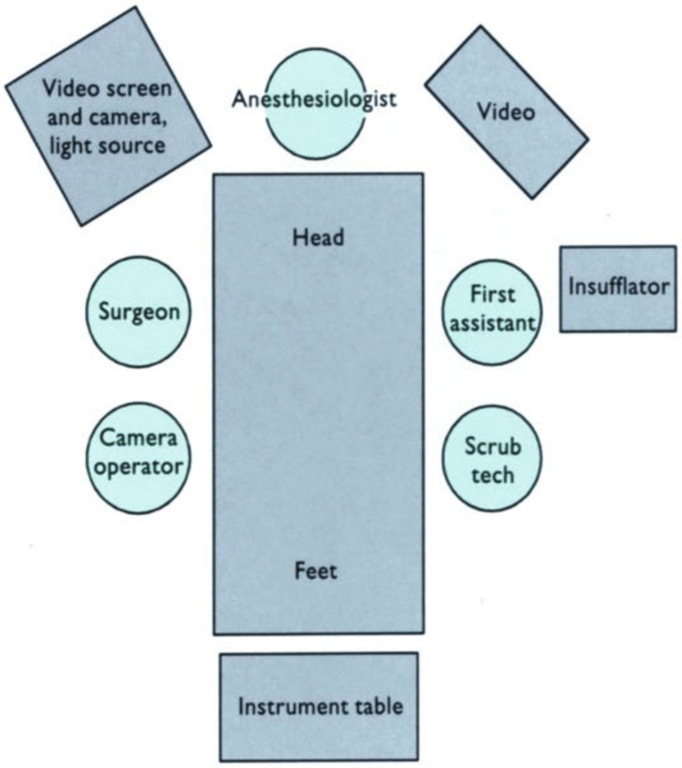


FIGURE 4-2.

Operative set-up for laparoscopic feeding tube placement. Foley and nasogastric catheters are routinely placed prior to initial trocar placement. Video monitors are oriented directly across from the surgeon and first assistant as illustrated.

Set-up

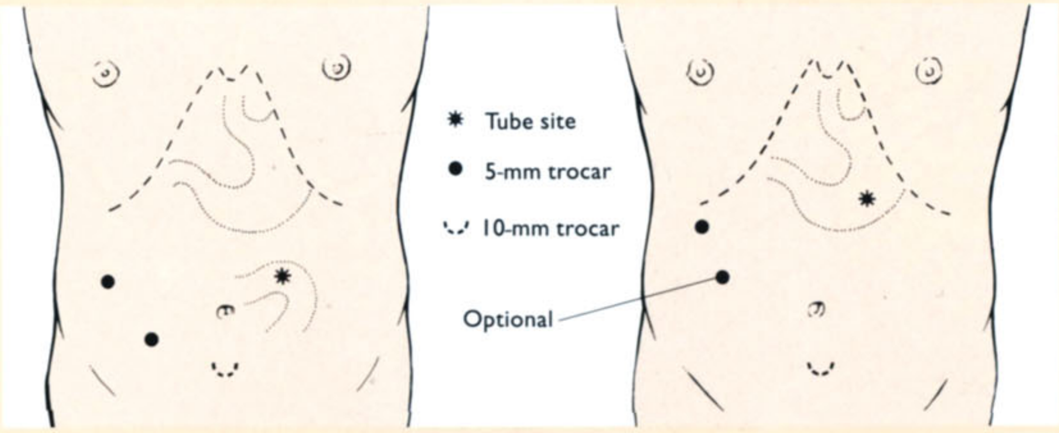


FIGURE 4-3.

Trocar positioning for jejunostomy (*left*) and gastrostomy (*right*) tube placement. Initially, the patient is placed in the Trendelenburg position, a 10-mm port is placed infraumbilically using an open Hasson technique, the abdomen is insufflated to 10 mm Hg, and exploratory laparoscopy is performed with adhesiolysis as necessary. One or two additional 5-mm ports are then placed under direct vision in the labeled positions.

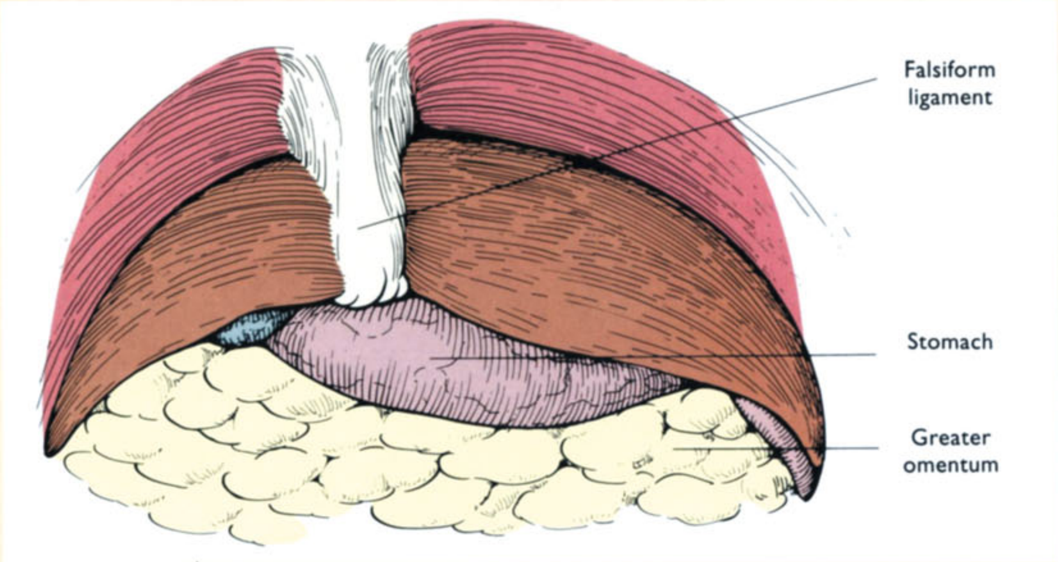


FIGURE 4-4.

After insertion of the laparoscope, the inferior aspect of the stomach, greater omentum, gastrocolic ligament, and transverse colon are visualized. The anterior wall of the stomach is easily accessible with retraction inferiorly by the first assistant. Access to the proximal small bowel requires cephalad-anterior retraction of the greater omentum and transverse colon.

Figures 4-5 through 4-16 depict the surgical technique for laparoscopic jejunostomy.

Procedure

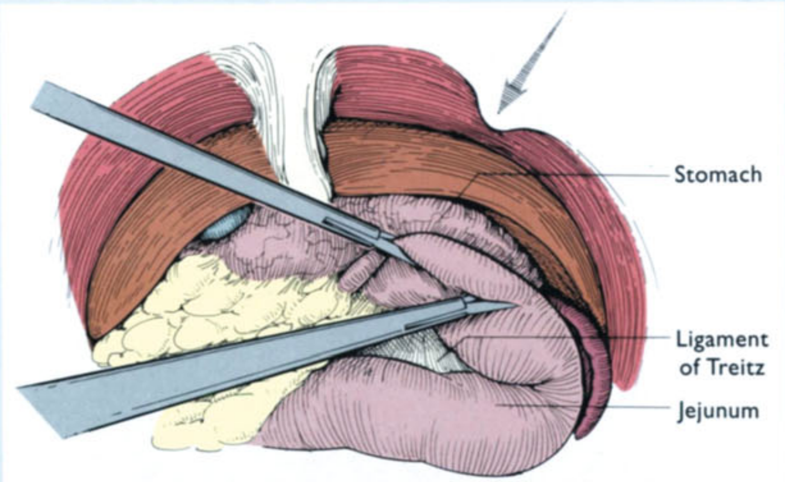


FIGURE 4-5.

Laparoscopic J-tube placement is initiated by running the bowel proximally to locate the ligament of Treitz. Positioning the patient in the reverse Trendelenburg position will facilitate this step. The site for tube placement is generally 10 to 20 cm from the ligament of Treitz. The loop of jejunum should approximate to the anterior abdominal wall in a tension-free manner. Extrinsic compression of the anterior abdominal wall in the left upper quadrant by the first assistant (*arrow*) is helpful in selecting the site for the tube tract.

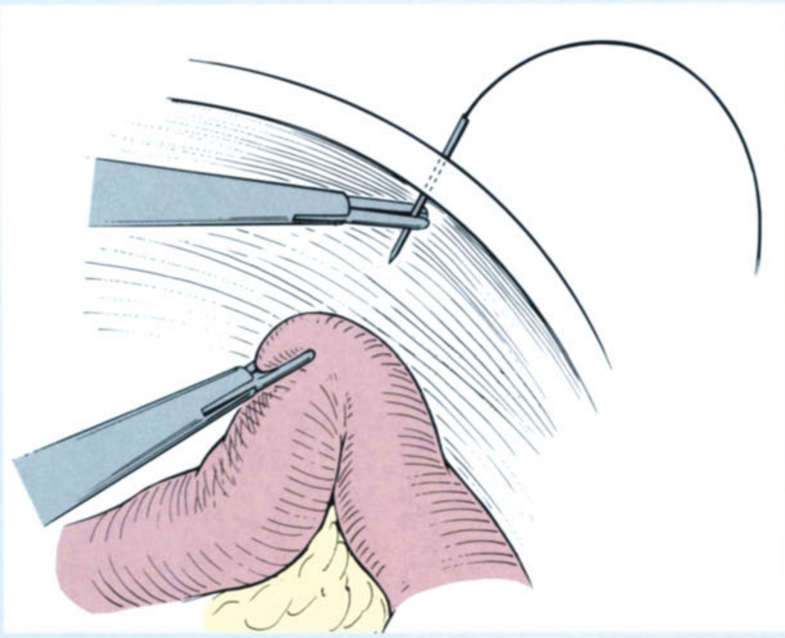


FIGURE 4-6.

Once the jejunostomy site is determined, the loop is held adjacent to the abdominal wall and a 3-0 silk on a Keith needle is placed transabdominally.

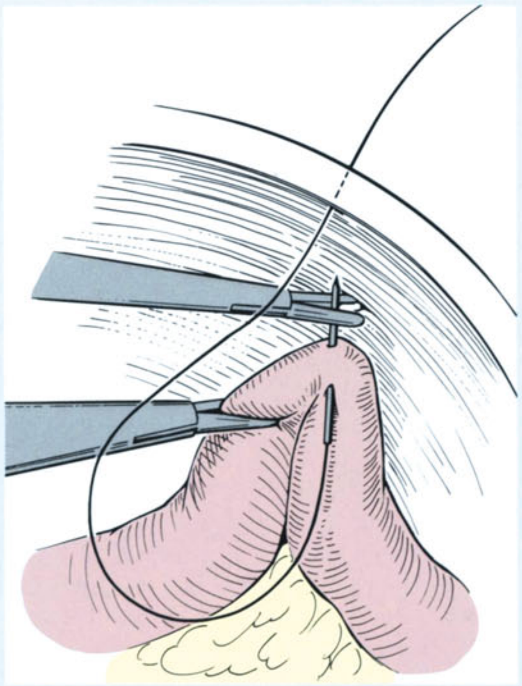


FIGURE 4-7.
This suture is mattressed through the seromuscular layers of the jejunal loop, and brought back through the abdominal wall.

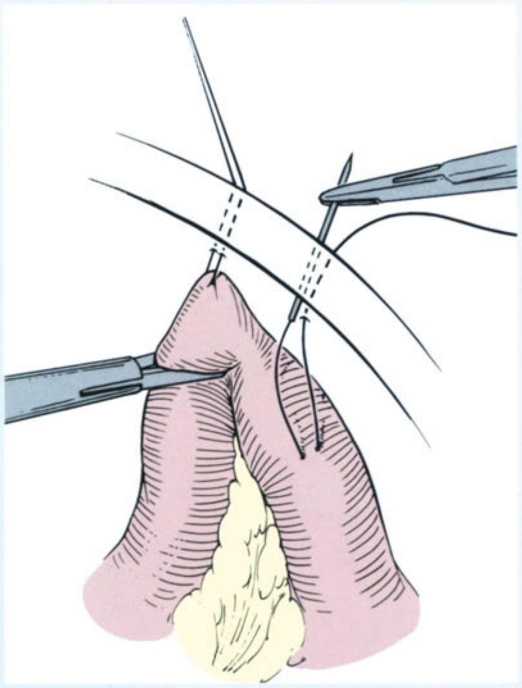


FIGURE 4-8.
A second seromuscular suture is placed in a similar manner. The tails of these sutures are temporally tagged with Crile hemostats.

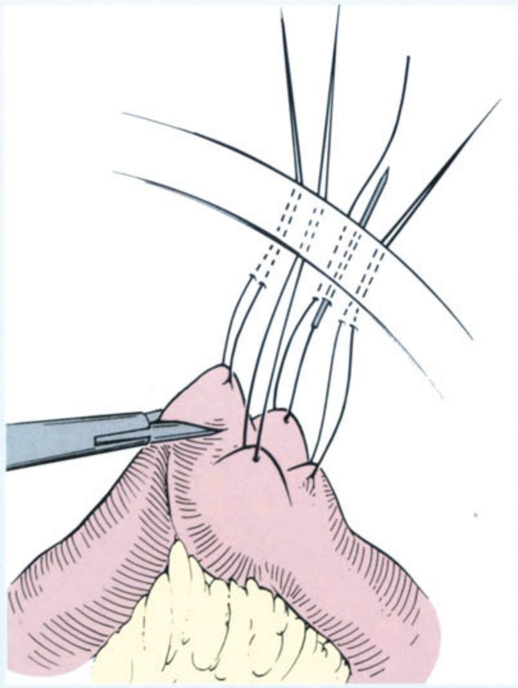


FIGURE 4-9.
The third and fourth seromuscular sutures are placed square to the others.

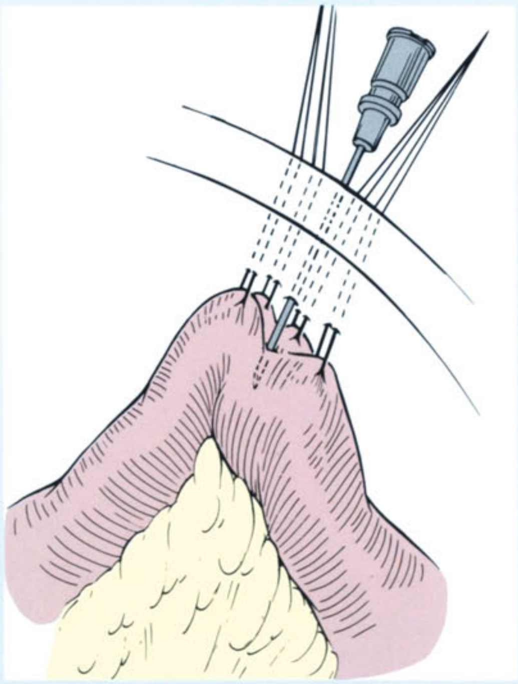


FIGURE 4-10.
A 16-G needle from an introducer kit is placed through the abdominal wall into the lumen of the jejunal loop within the boundaries of the seromuscular sutures.

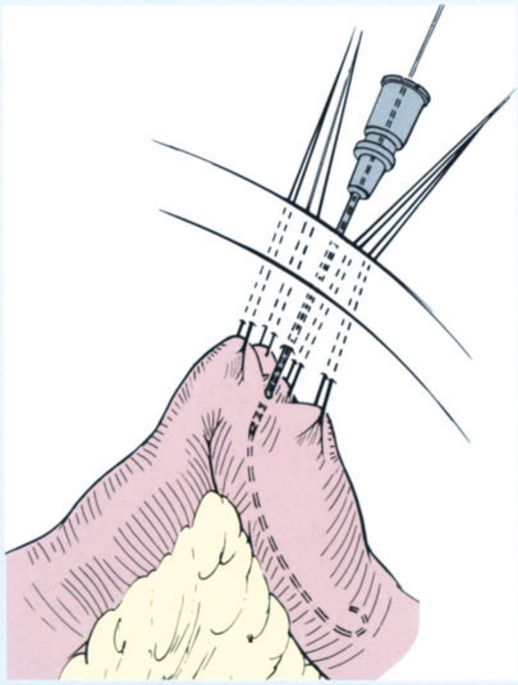


FIGURE 4-11.
A guidewire is then passed through the needle (Seldinger technique) and directed into the distal bowel for a distance of 10 to 15 cm.

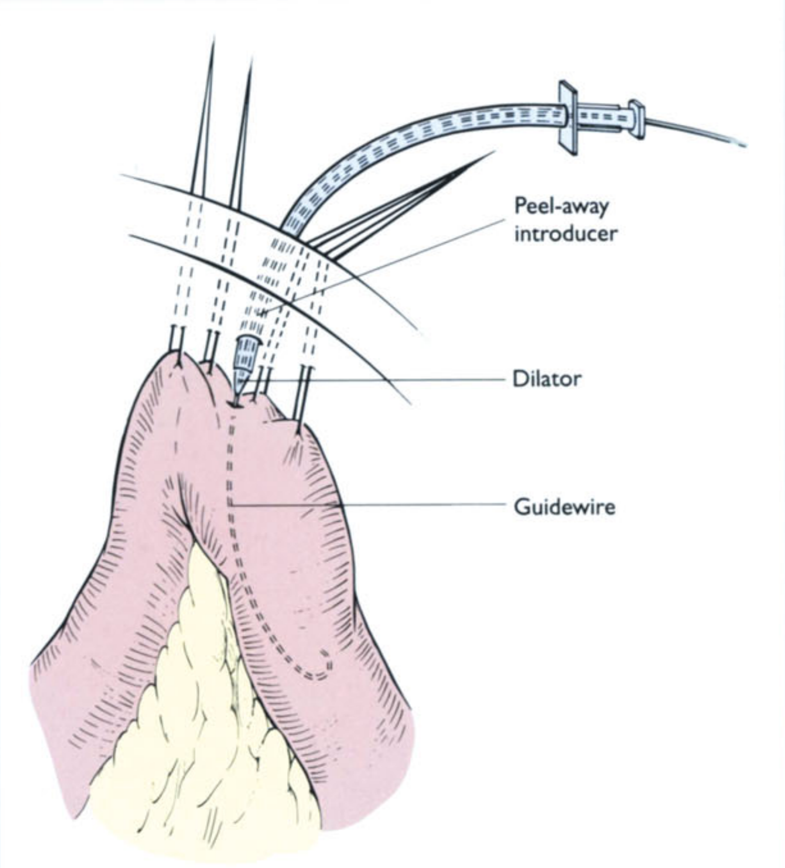


FIGURE 4-12.
A 14-French dilator and peel-away introducer are placed over the guidewire and passed distally into the small bowel over the wire under direct vision. The jejunal loop may require traction by an assistant to facilitate this step.

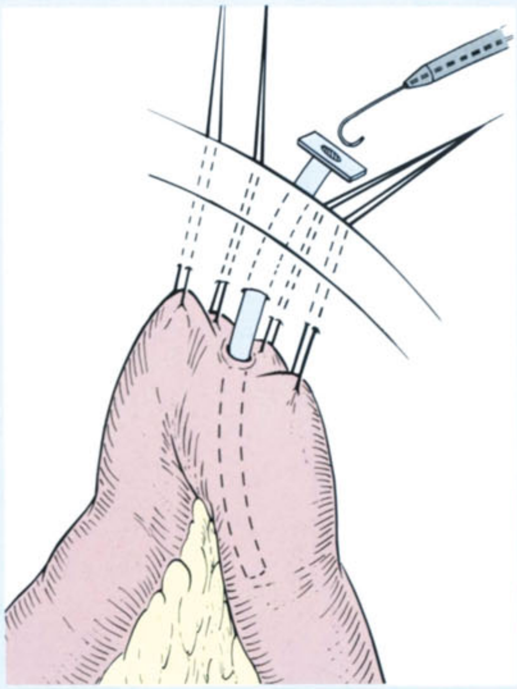


FIGURE 4-13.
The guidewire and dilator are removed leaving the peel-away introducer in place for subsequent jejunostomy tube placement.

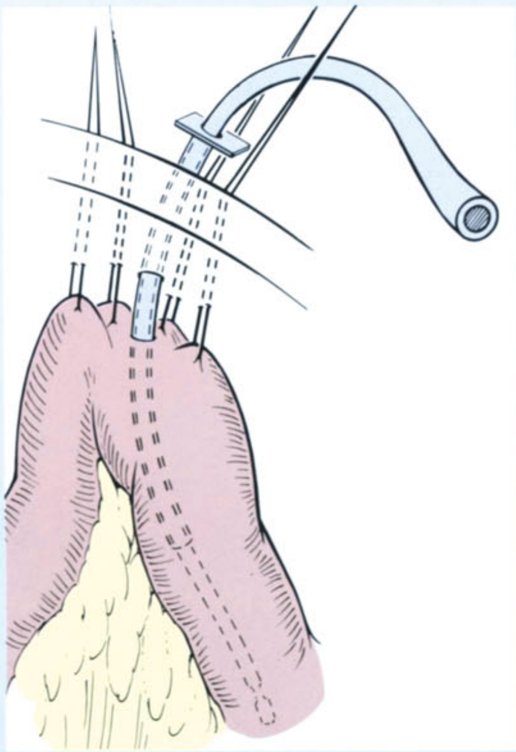


FIGURE 4-14.
A 12-French rubber Robinson catheter is passed through the peel-away introducer into the distal limb of the jejunostomy.

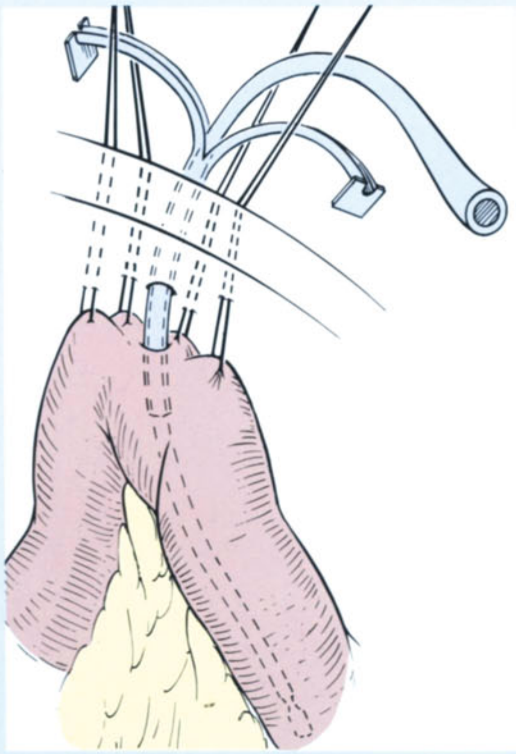


FIGURE 4-15.
The peel-away introducer is split and discarded leaving the jejunostomy tube correctly positioned.

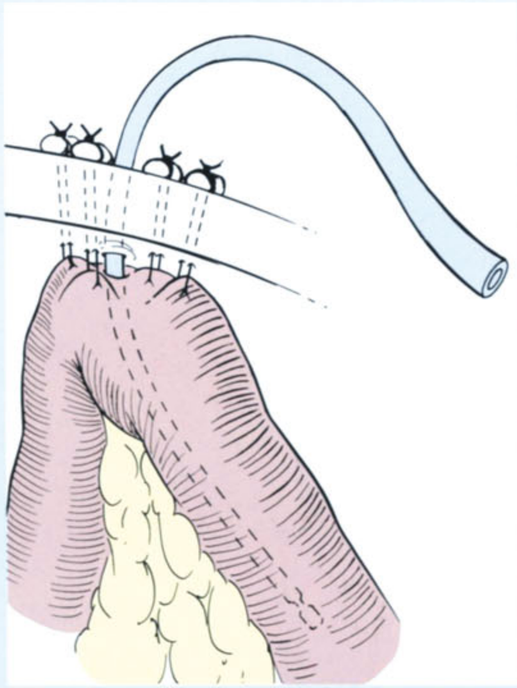


FIGURE 4-16.
The jejunal loop is approximated to the abdominal wall by the seromuscular sutures, and these sutures are secured over rubber bolsters at the skin level. An additional 3-0 nylon suture is placed to secure the jejunostomy tube to the skin.

Figures 4-17 through 4-25 depict the alternative method employing a commercial T-fastener kit.

Alternative Procedure

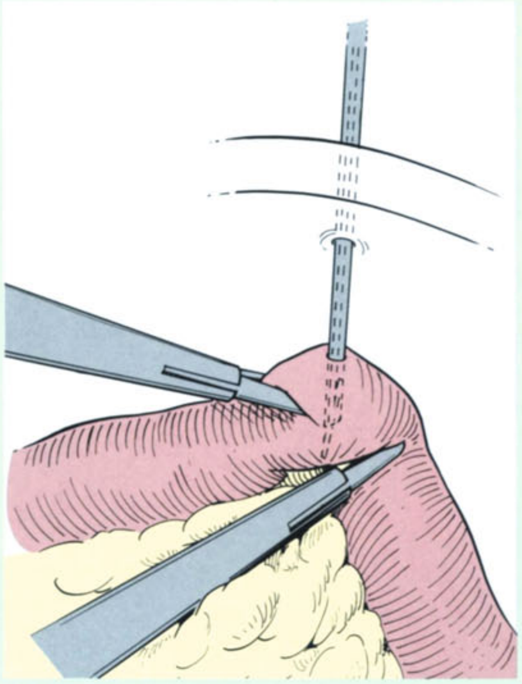


FIGURE 4-17.
After locating a suitable site for tube placement as above, a T-fastener applier is introduced through the abdominal wall into the bowel lumen and fired.

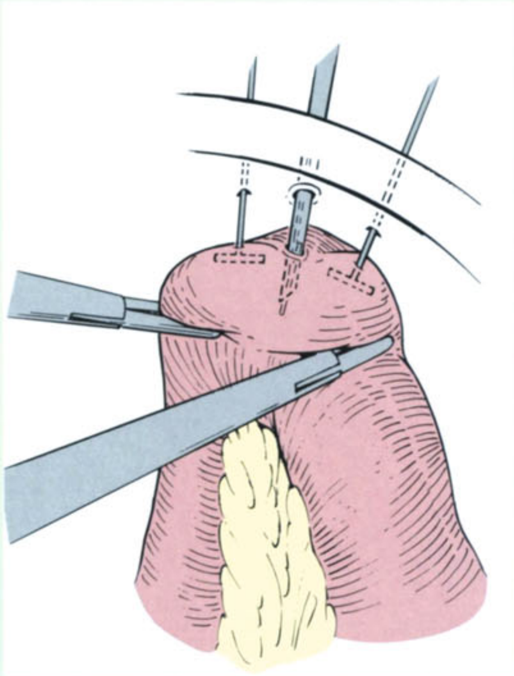


FIGURE 4-18.
The remaining T-fasteners are placed in a similar manner forming a square through which the jejunostomy tube will be placed.

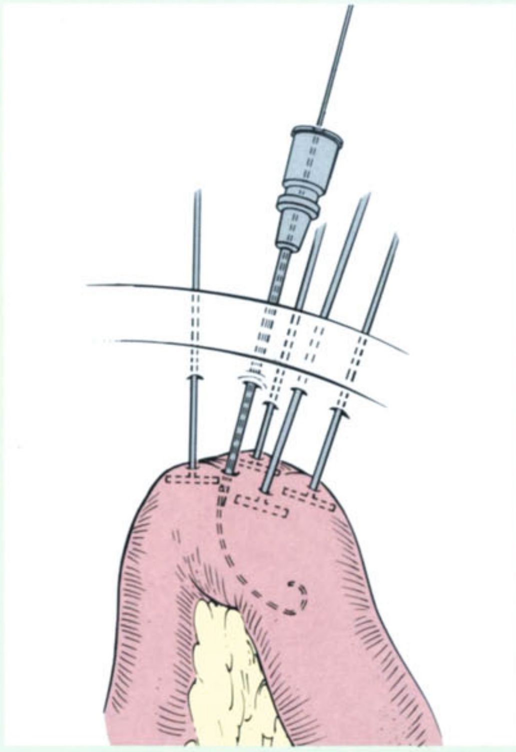


FIGURE 4-19.
A 16-G needle from an introducer kit is placed through the abdominal wall into the lumen of the jejunal loop within the boundaries of the T-fasteners, and a guidewire is passed distally through this needle.

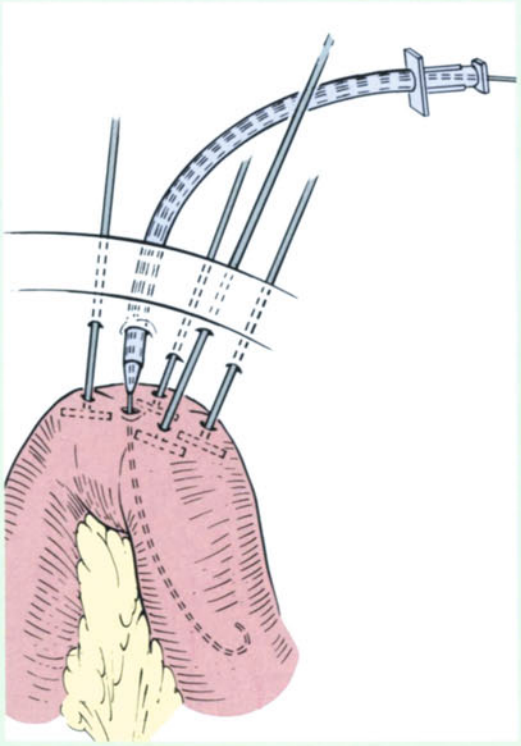


FIGURE 4-20.
Placement of a dilator and peel-away introducer over the guidewire follows, as above.

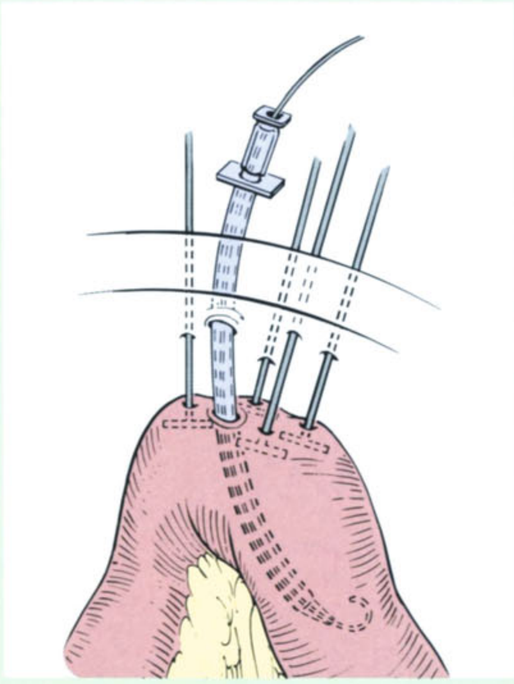


FIGURE 4-21.
Continued placement of a dilator and peel-away introducer.

Alternative Procedure

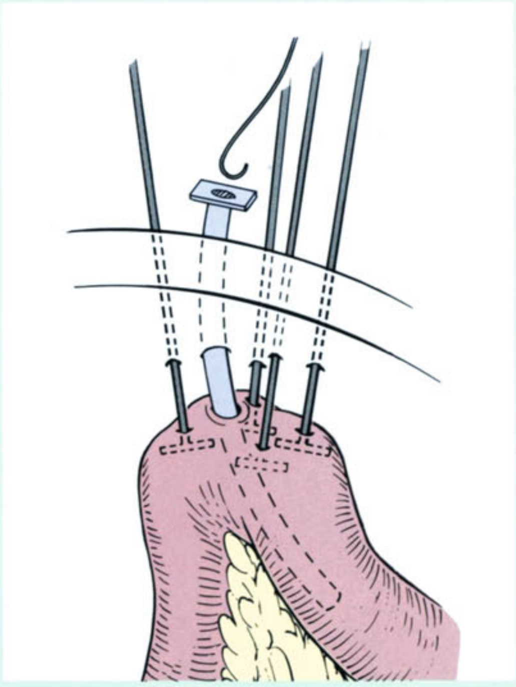


FIGURE 4-22.
The guidewire and dilator are withdrawn leaving the peel-away introducer in place for jejunostomy tube placement.

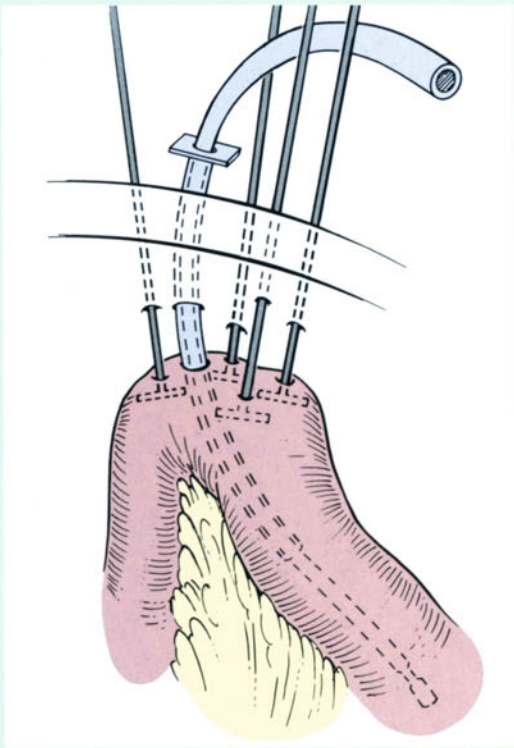


FIGURE 4-23.
A 12-French red rubber Robinson catheter is passed through the peel-away introducer into the distal limb of the jejunostomy.

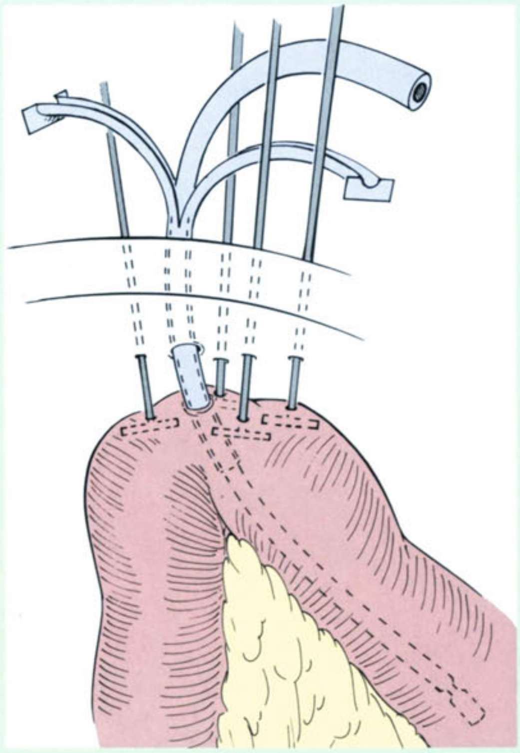


FIGURE 4-24.
The peel-away introducer is split and discarded leaving the jejunostomy tube correctly positioned.

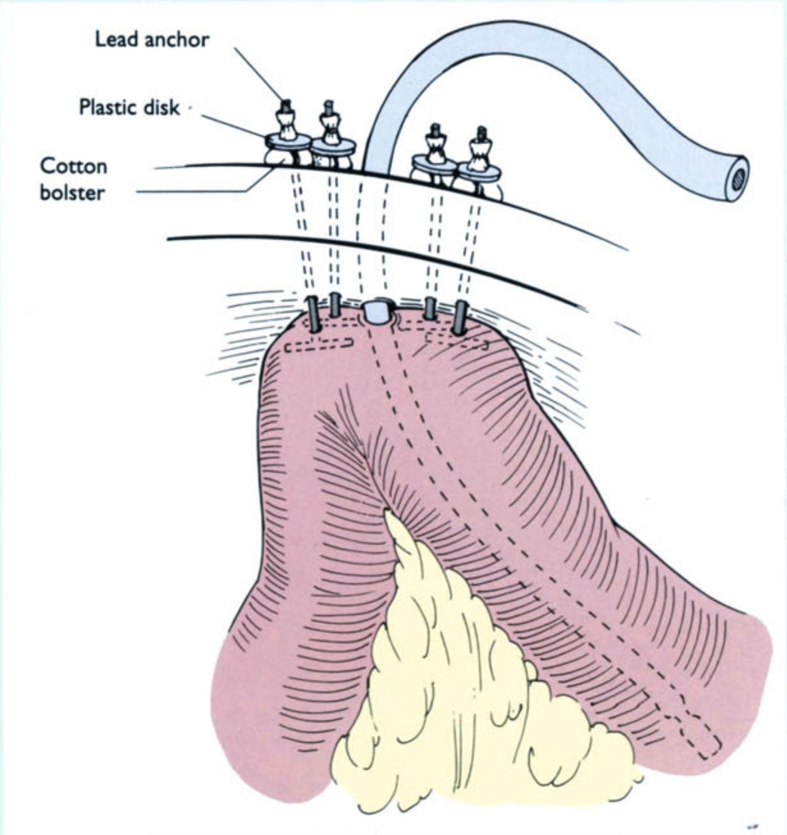


FIGURE 4-25.
The jejunal loop is approximated to the abdominal wall by placing lead anchors over plastic disks and cotton bolsters on the T-fasteners, following which the lead anchors are crimped. The extra length of the T-fasteners is cut back to the lead anchors. An additional 3-0 nylon suture is placed to secure the jejunostomy tube to the skin.

Figures 4-26 through 4-32 depict the surgical technique for laparoscopic gastrostomy.

Procedure

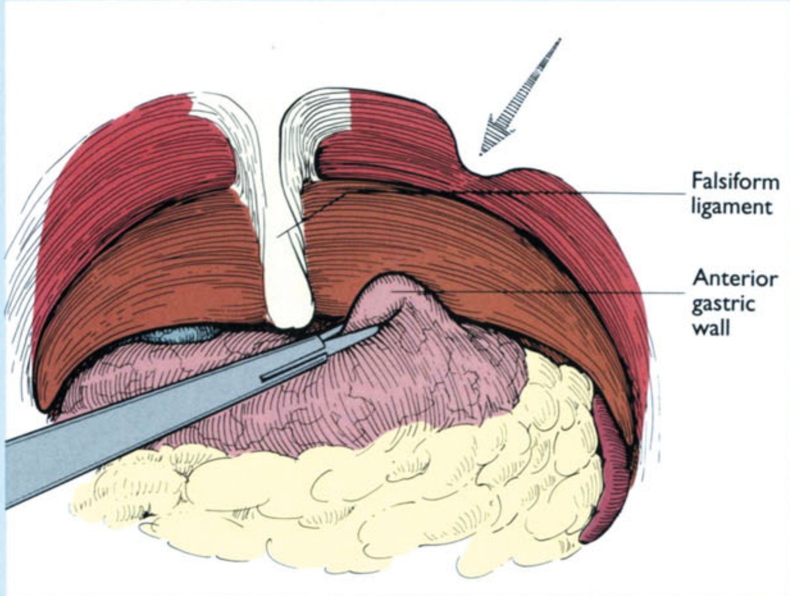


FIGURE 4-26.
Following initial laparoscopic exploration, air is insufflated into the stomach, if possible, to slightly distend it. A convenient area of the anterior gastric wall is chosen as the gastrostomy site and held in place with a grasper. A suitable skin exit site is located with the aid of blunt digital palpation (*arrow*) such that the gastrostomy site will not be under tension.

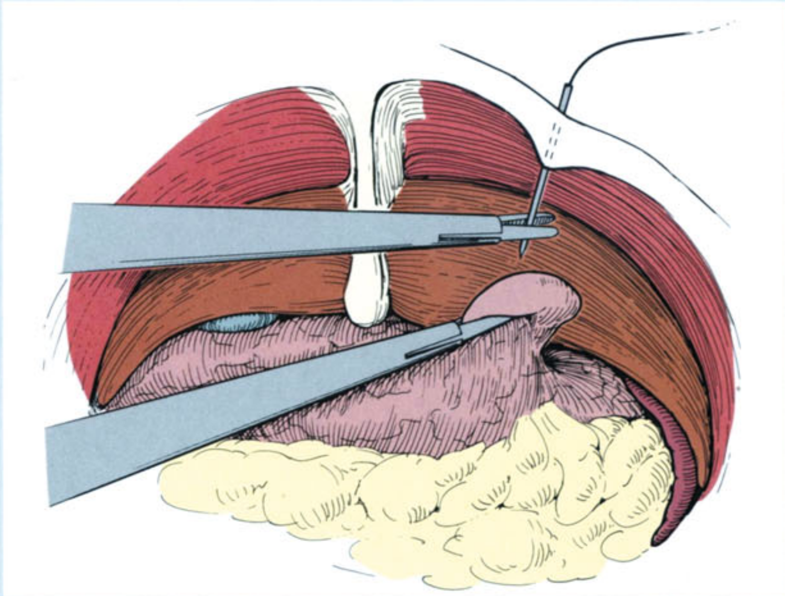


FIGURE 4-27.
Once the gastrostomy site is determined, a 3-0 silk suture on a Keith needle is placed transabdominally adjacent to the predetermined stoma site at the skin level. This suture is mattressed through the seromuscular layers of the gastric wall and brought back through the abdominal wall in a similar manner as the jejunostomy seromuscular sutures described previously.

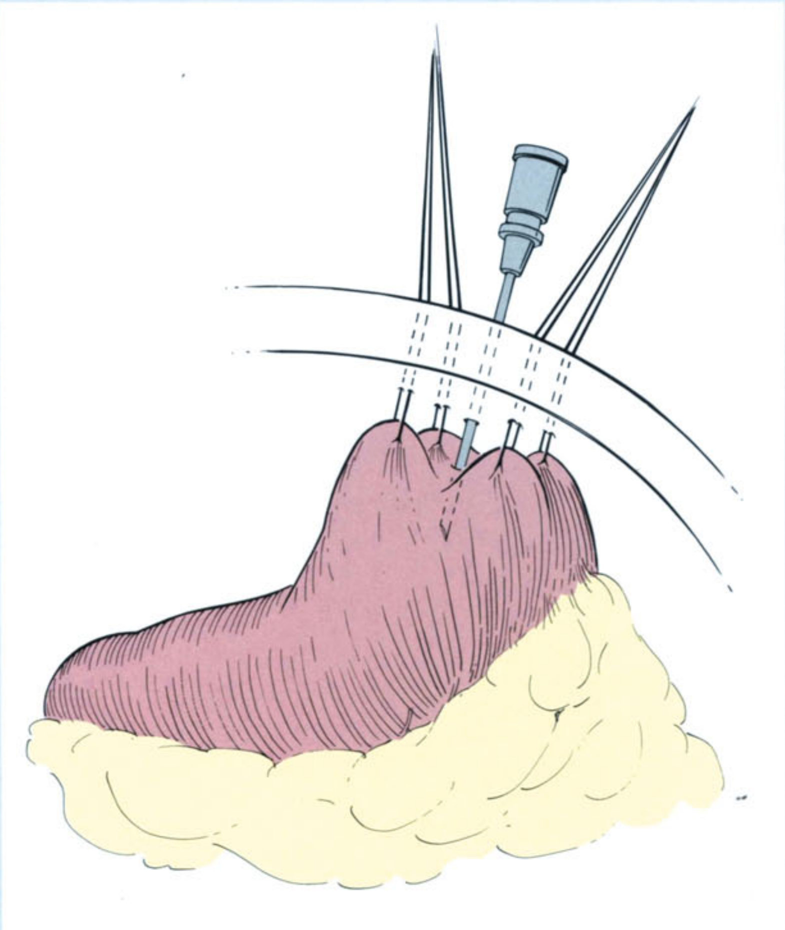


FIGURE 4-28.
A total of four gastric seromuscular sutures are placed oriented square to each other, and a 16-G needle from an introducer kit is placed into the gastric lumen.

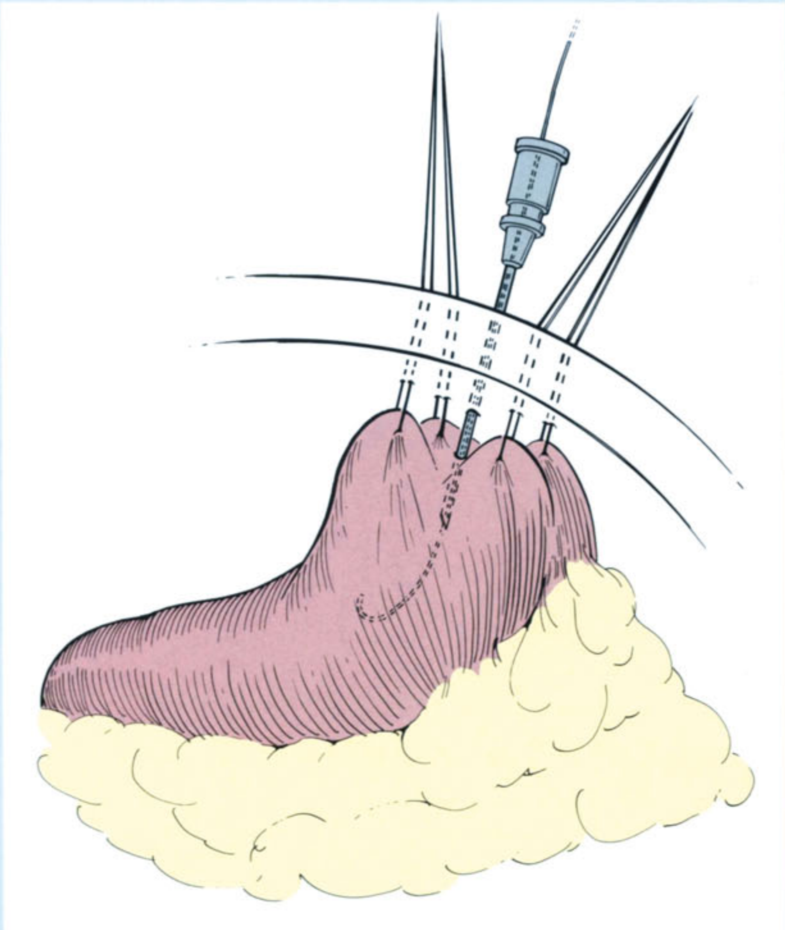


FIGURE 4-29.
A guidewire is placed through this needle into the gastric lumen, and the needle is withdrawn over the guidewire.

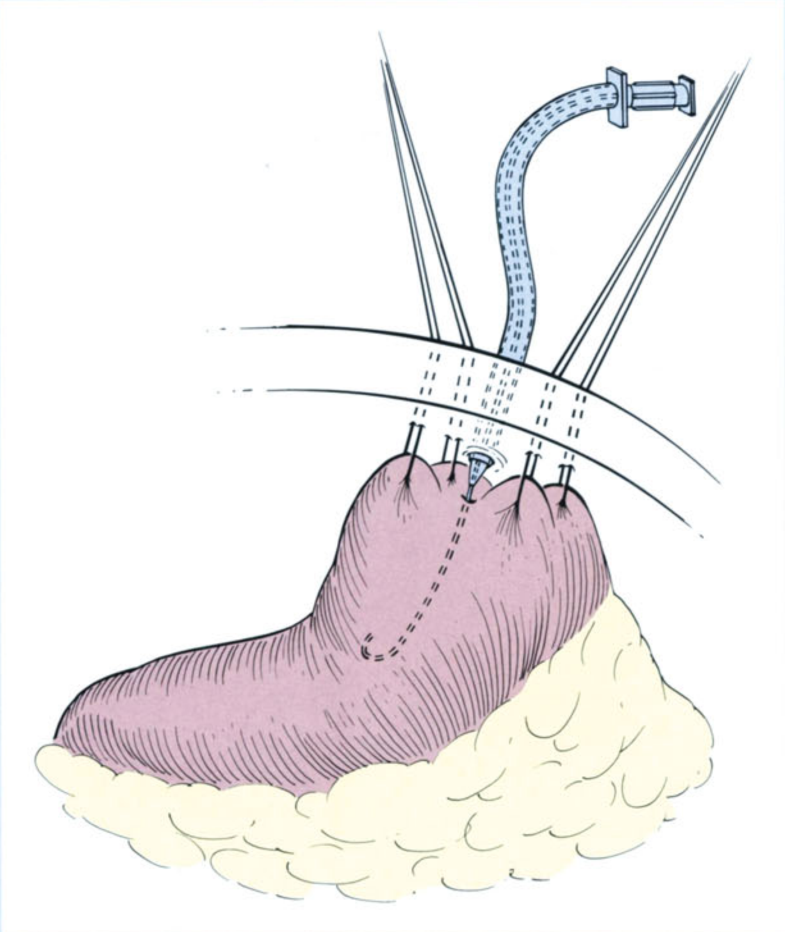


FIGURE 4-30.
An 18-French dilator and peel-away introducer are then placed over the guidewire into the gastric lumen dilating the tract to allow for subsequent tube placement. It may be necessary to incise the skin adjacent to the guidewire to facilitate placement.

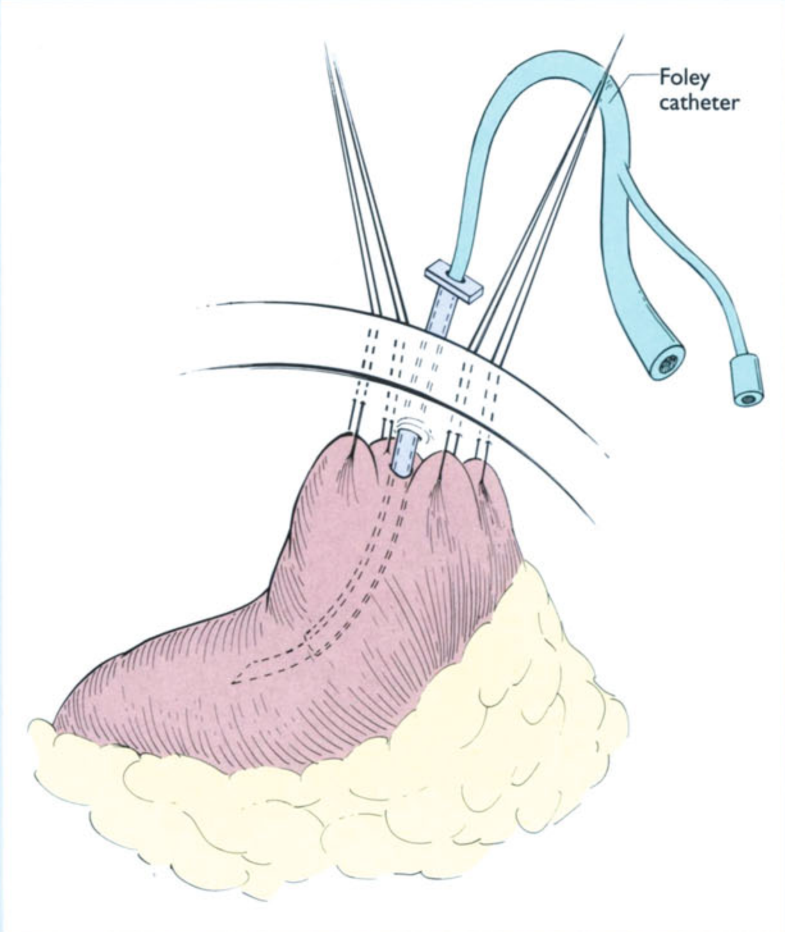


FIGURE 4-31.
A 16-French Foley urologic catheter is placed through the dilator into the gastric lumen.

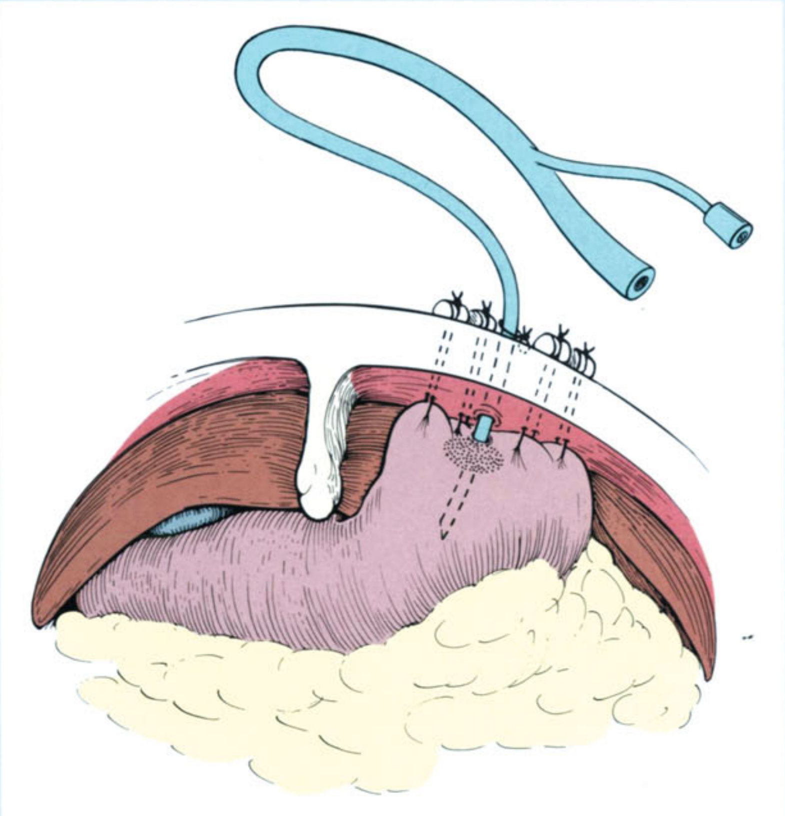


FIGURE 4-32.
The catheter balloon is inflated and the serosa is approximated to the abdominal wall by placing traction on the previously placed sutures and Foley catheter. The sutures are secured over cotton bolsters at the skin level. An additional 3-0 nylon suture is placed to secure the gastrostomy tube to the skin.

Figures 4-33 through 4-37 depict the alternative T-fastener method.

Alternative Procedure

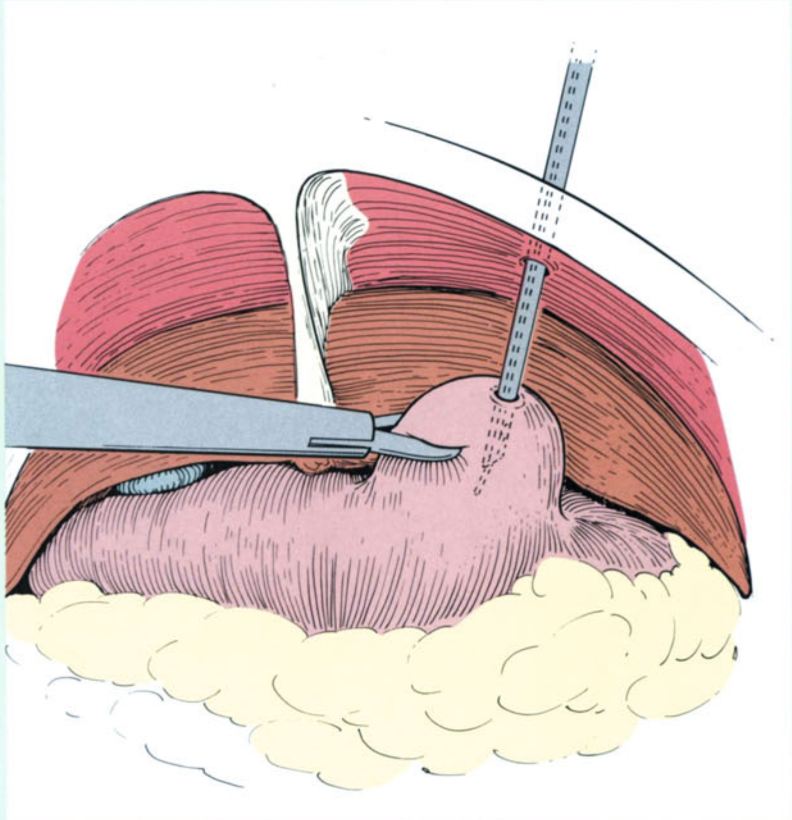


FIGURE 4-33.

After locating a suitable site for tube placement as above and insufflating air into the stomach if possible, a T-fastener applier is introduced through the abdominal wall into the gastric lumen and fired. The antrum adjacent to the pylorus should be avoided to decrease the incidence of both distal tube migration and gastric outlet obstruction.

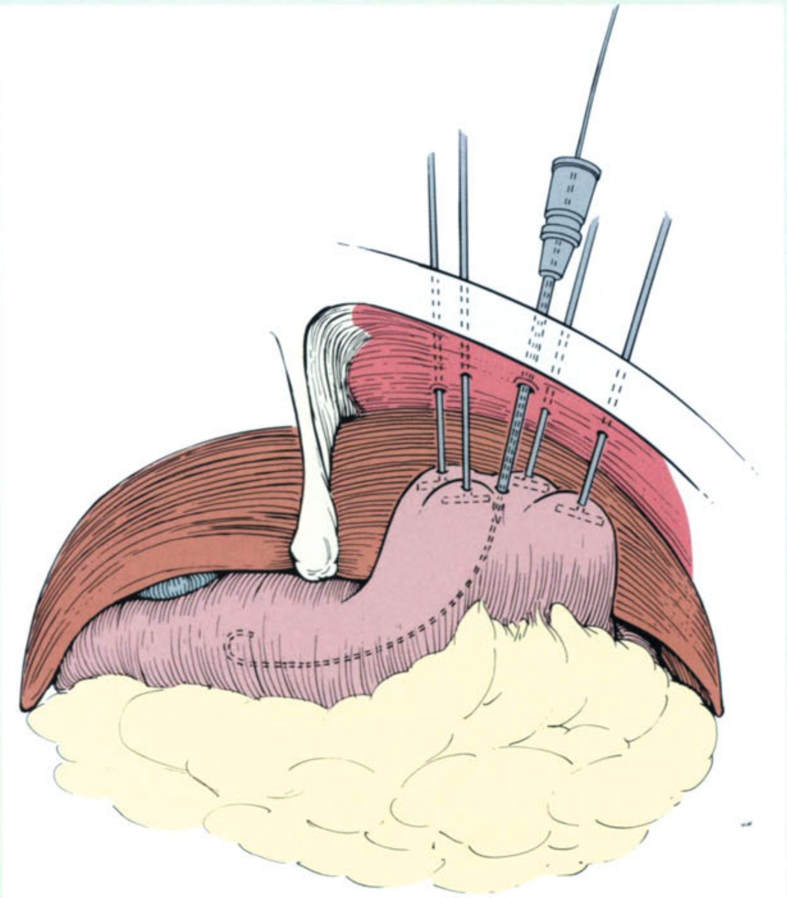


FIGURE 4-34.

The remaining T-fasteners are placed in a similar manner forming a square through which the gastrostomy tube will be placed. A 16-G needle from a Hickman introducer kit is placed through the abdominal wall into the gastric lumen within the boundaries of the T-fasteners, and a guidewire is passed distally through this needle.

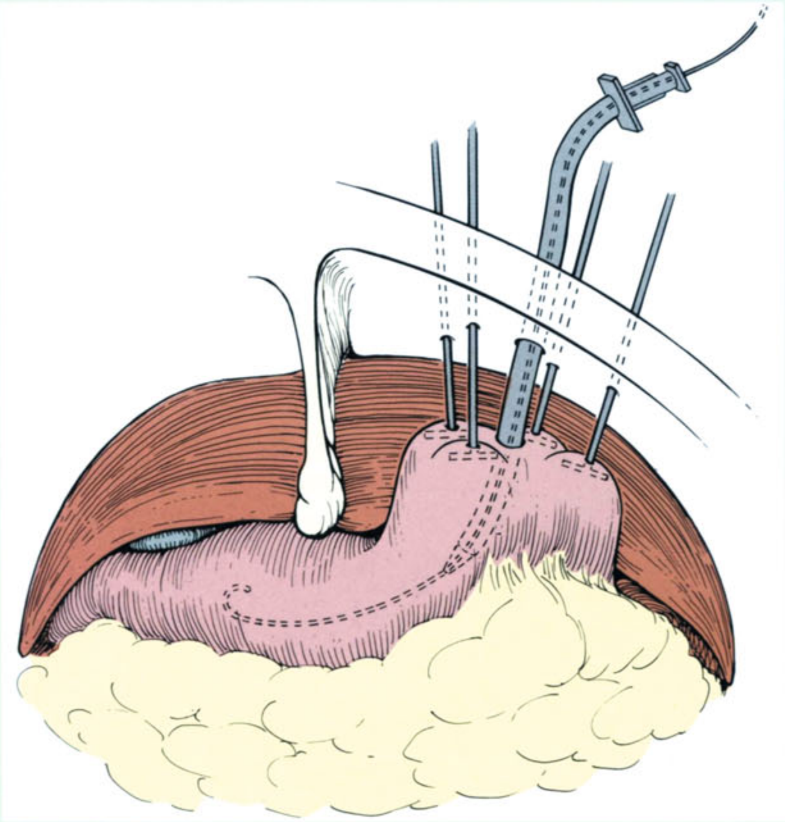


FIGURE 4-35.

The needle is withdrawn over the guidewire, and placement of a dilator and peel-away introducer follows, as above.

Alternative Procedure

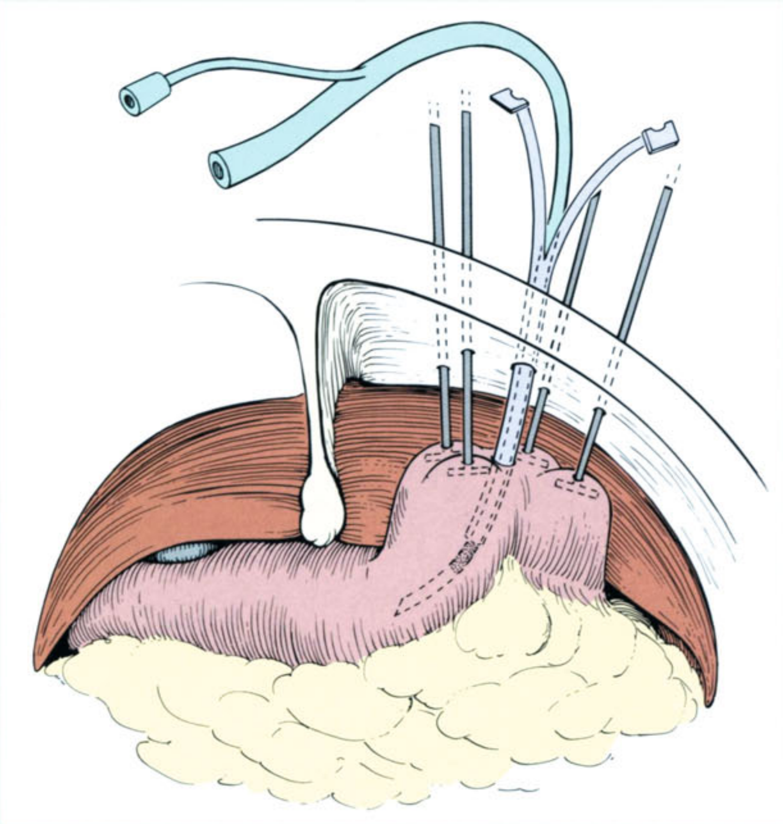


FIGURE 4-36.
The guidewire and dilator are withdrawn, and a 16-French Foley catheter is passed through the peel-away introducer into the gastric lumen. The Foley balloon is inflated with 10 mL of saline, and the peel-away introducer is split and discarded leaving the gastrostomy tube correctly positioned.

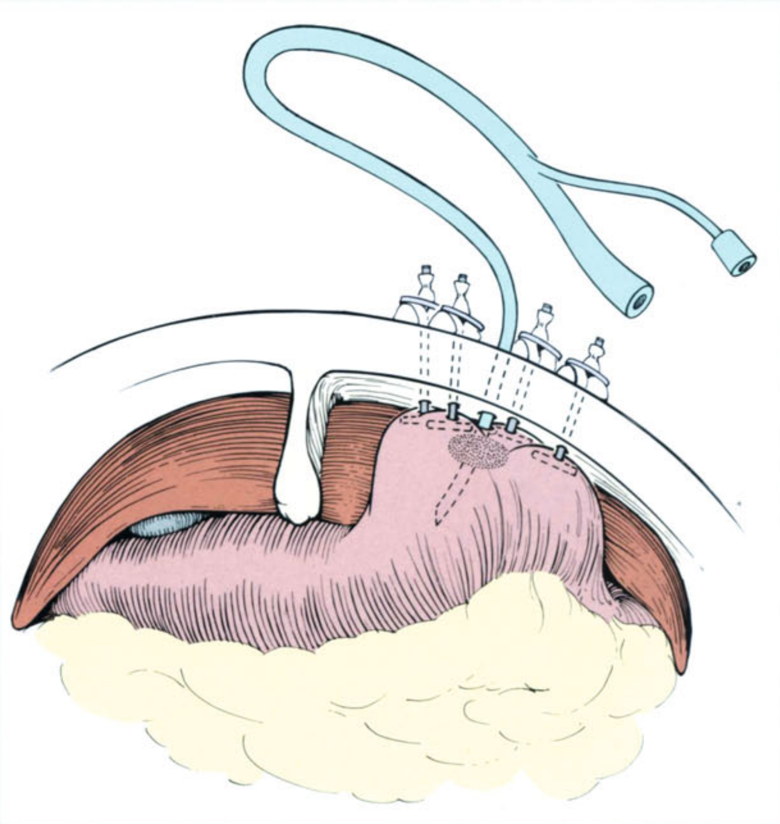


FIGURE 4-37.
The gastric serosa is approximated to the abdominal wall by placing lead anchors over plastic disks and cotton bolsters on the T-fasteners, following which the lead anchors are crimped. The extra length of the T-fasteners is cut back to the lead anchors. An additional 3-0 nylon suture is placed to secure the gastrostomy tube to the skin.

Results

At the time of this writing, results of laparoscopically placed feeding tubes are limited to anecdotal case reports. In our experience, there has been a minimal learning curve as tube placement does not require additional laparoscopic skills. This is particularly true when T-fasteners are used. In general, the patients requiring long-term enteral feeding have a limited life expectancy, and the least invasive procedures to provide these patients with a reasonable quality of life is the goal of therapy. When percutaneous endoscopic feeding tubes cannot be placed, laparoscopic feeding tube placement is a very satisfactory alternative. For both gastrostomy and jejunostomy tubes, we have been able to initiate enteral feeding 24 hours after placement. There is minimal postoperative discomfort, and the small trocar incisions have been well tolerated.

In summary, the current techniques for placing these tubes are described based on the instrumentation available at the time of publication. Further technical refinements are anticipated with the continued development of endoscopic surgery as new instruments are introduced.

References

1. Egeberg CA: Om behandlingen af impenetrable strictura i madroret. *Norsk mag f laegevidensk*, 1841, 2:97.
2. Sedillot MC: Oservation de gastrostomie. *Gaz d hop* 1853, 26:160–161.
3. Busch W: Beitrag zur physiology der verdauungsorgane. *Virchow Arch* 1858, 14:140.
4. Surmay M: De l'enterostomie. *Bull Gen Ther* 1878, 94:445–455.
5. Witzel O: Zur technik der magenfistelanlegung. *Zentralbl Chir* 1891, 18:601–604.
6. Maydl K: Ueber eine neue methode zur ausfuhrung der jejunostomie und gastroenterostomie. *Wien Med Wochenschr* 1892, 42:740–743.
7. Stamm M: Gastrostomy by a new method. *Med News* 1894, 65:324–326.
8. Janeway HH: Eine neue gastrostomie methode. *Munchen Med Wochenschr* 1913, 60:1705.
9. Janeway HH: The relation of gastrostomy to inoperable carcinoma of the esophagus. *JAMA* 1913, 61:93.
10. Barber WH: Jejunostomy. *Ann Surg* 1993 97:553–576.
11. McDonald HA: Intrajejunal drip in gastric surgery. *Lancet* 1954, 1:1007.
12. Delany HM, Carnevale NJ, Garvey JW: Jejunostomy by a needle catheter. *Surgery* 1973, 73:786–790.
13. Gauderer MWL, Ponsky JL, Izant RJ: Gastrostomy without laparotomy: a percutaneous endoscopic technique. *J Pediatr Surg* 1980, 15(6):872–875.
14. Grant JP: Percutaneous endoscopic gastrostomy. *Ann Surg* 1993, 217:168–174.
15. Ho C-S, Yee ACN, McPherson R: Complications of surgical and percutaneous nonendoscopic gastrostomy: review of 233 patients. *Gastroenterology* 1988, 95:1206–1210.
16. Eiselberg AF: Ueber ausschaltung inoperable pylorus-stricturen nebst bemerkungen über die jejunostomie. *Arch Klin Chir* 1895, 50:919–939.
17. Hofmeister F: Verhandl D Naturf. *Aerzte* 1905, 77:95.
18. Heyd CG: Jejunostomy. *Am J Surg* 1926, 1:188–192.
19. O'Regan PJ, Scarrow GD: Laparoscopic jejunostomy. *Endoscopy* 1990, 22:39–40.
20. Edelman D, Unger S, Russin D: Laparoscopic gastrostomy. *Surg Laparoendosc* 1991, 1(4):251–253.
21. DiSario JA, Foutch PG, Sanowski RA: Poor results with percutaneous endoscopic jejunostomy. *Gastrointest Endosc* 1990, 36(3):257–260.

CHAPTER 5

Laparoscopic Gastrojejunostomy

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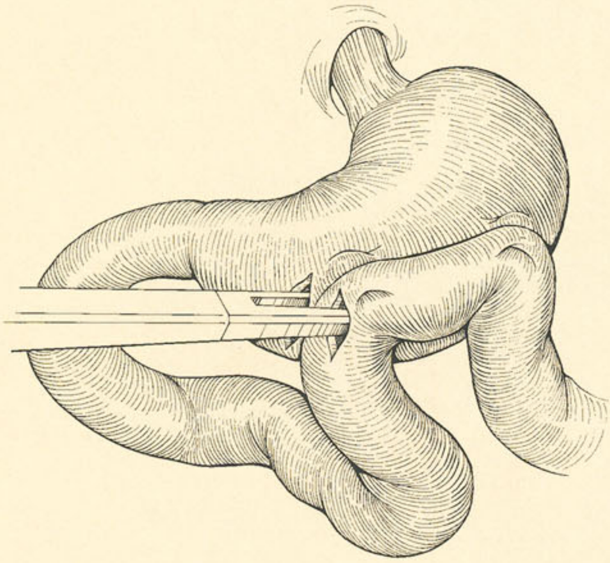
Theodore N. Pappas



Gastrojejunostomy is the term used to describe anastomosis of the stomach to the jejunum. This operation is usually used in combination with other procedures in the treatment of a variety of surgical conditions ranging from peptic ulcer disease to pancreatic carcinoma [1–3]. The first gastrojejunostomy was performed in 1881 by Anton Wölfler for the treatment of pyloric obstruction in a patient with carcinoma (Figure 5-1) [4,5]. In 1883, Curvoisier modified Wölfler's technique by placing the gastrojejunostomy on the posterior aspect of the stomach instead of the anterior wall [6]. Despite the fundamental contributions of these individuals to the development of the gastrojejunostomy, the surgeon most often associated with this procedure is Theodor Billroth. In 1885, while operating on a patient with gastric outlet obstruction secondary to a pyloric tumor, Billroth performed a gastric resection and then restored gastrointestinal tract continuity with a side-to-side gastrojejunostomy [7]. This procedure is now referred to as the Billroth II. Billroth I, on the other hand, involves end-to-end anastomosis of the stomach to the duodenum following distal gastric resection.

Sporadic reports of laparoscopic gastrojejunostomy have appeared in the literature over the past couple of years; however, it is difficult to determine when the first procedure was performed. In 1992, Brune and Schönleben reported their results of laparoscopic gastrojejunostomy in two patients with gastric outlet obstruction due to carcinoma of the pancreatic head [8]. Goh and coworkers [9] performed a laparoscopic subtotal gastrectomy with Billroth II reconstruction for the treatment of chronic gastric ulcer in an elderly patient. As has been demonstrated with laparoscopic cholecystectomy and appendectomy, advocates of laparoscopic gastrojejunostomy have maintained that benefits such as decreased postoperative discomfort and shorter hospitalizations warrant wider application of this technique. Although it has not been extensively studied,

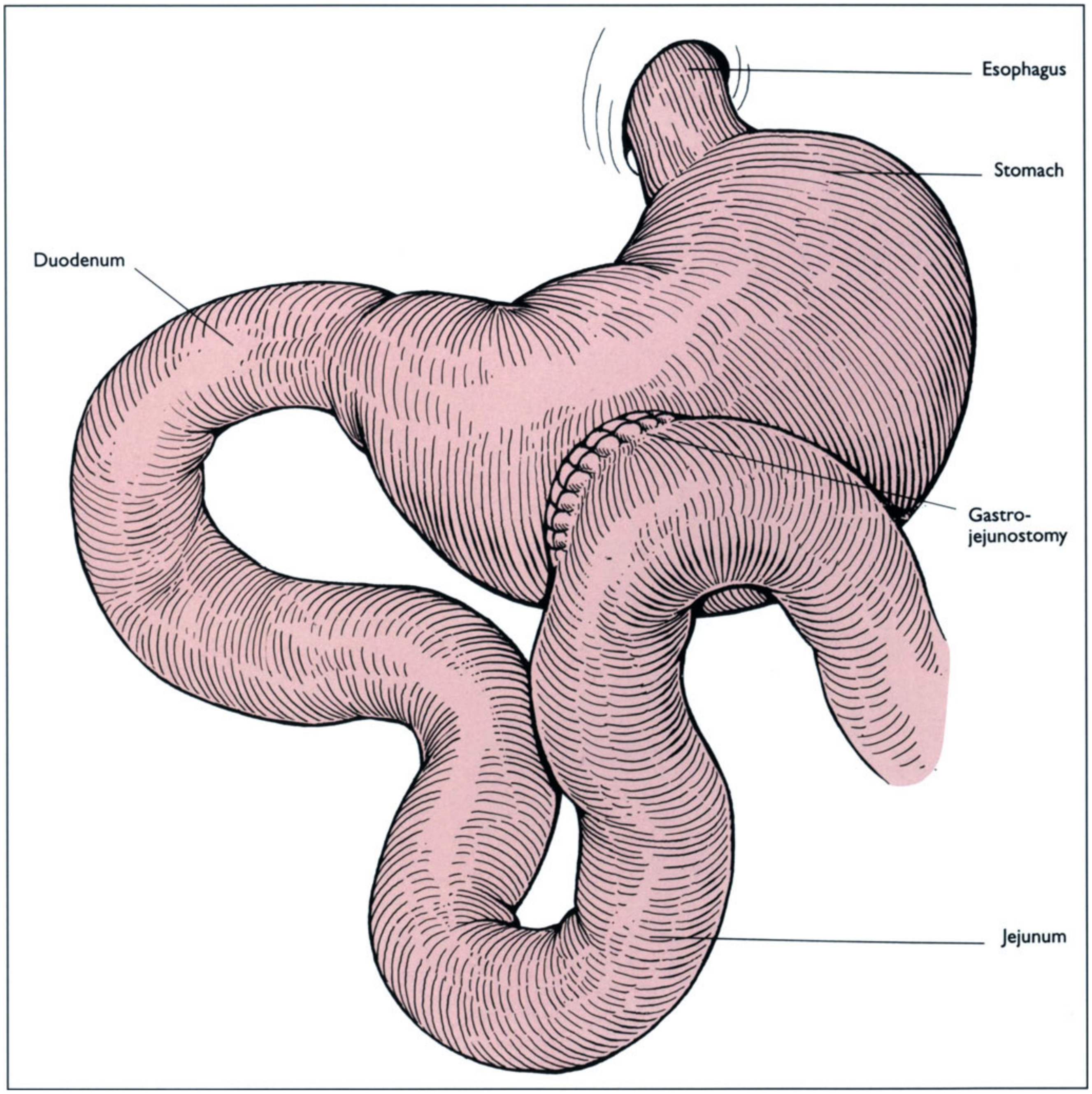


FIGURE 5-1.
This figure depicts the first gastrojejunostomy performed by Wölfler in 1881. This procedure simply involves anastomosis of the stomach to the jejunum so that proximal obstruction of the gastrointestinal tract may be bypassed.

surgeons have reported more rapid return of bowel function as measured by bowel sounds, flatus, and bowel movements following laparoscopic intestinal surgery compared with open procedures. This certainly argues in favor of employing laparoscopy to perform gastrojejunostomy in patients undergoing palliative procedures, thereby minimizing the duration of hospitalization.

Improvements in preoperative patient preparation, anesthetic management, and postoperative care have led to decreased operative morbidity and mortality in patients undergoing open gastrojejunostomy. Nonetheless, it is difficult to state an overall operative morbidity and mortality for open gastrojejunostomy because of the variety of disorders, both benign and malignant, that are treated with this procedure. For example, operative mortality can range from less than 1% to 40%, depending on the preoperative state of health of the patient [1–3]. Although it is unlikely that laparoscopic gastrojejunostomy will result in improved patient mortality when compared with the open procedure, it will conceivably become the method of choice in specific clinical situations. For example, a patient with duodenal and/or biliary obstruction secondary to an inoperative tumor located in the head of the pancreas may be a candidate for laparoscopic double bypass (gastrojejunostomy and cholecystojejunostomy).

Anatomy

Disease processes that require formation of a gastrojejunostomy usually involve organs in the region of the stomach and jejunum; therefore, an understanding of the regional anatomy is essential. The stomach and jejunum are intraperitoneal components of the upper gastrointestinal tract that are separated by the duodenum. Anatomically, the stomach is divided into five regions: cardia, fundus, corpus, antrum, and pylorus (Figure 5-2). These areas aid the surgeon in planning and executing gastric resections; however, with the exception of the pylorus, they do not correspond to functional regions. The stomach receives its blood supply via an extensive network of blood vessels. The major vessels include the left and right gastric arteries that supply the lesser curvature, the left and right gastroepiploic arteries that supply the greater curvature, the short gastric arteries that supply the fundus, and the gastroduodenal artery that supplies the pyloric region (Figure 5-3). Venous drainage of the stomach is parallel to the arterial system. The parasympathetic nervous system is responsible for both gastric motility and acid secretion and innervates the stomach via the vagus nerves.

The duodenum is a retroperitoneal portion of the upper gastrointestinal tract that begins immediately distal to the pylorus and extends to the ligament of Treitz. It assumes a characteristic C loop configuration *in situ* and is divided into four segments: first portion (superior or bulb), second portion (descending), third portion (transverse), and fourth portion (ascending). The head of the pancreas is situated within the C loop of the duodenum, and the confluence of the common bile and pancreatic ducts enters the intestinal tract in the second portion of the duodenum (Figure 5-4).

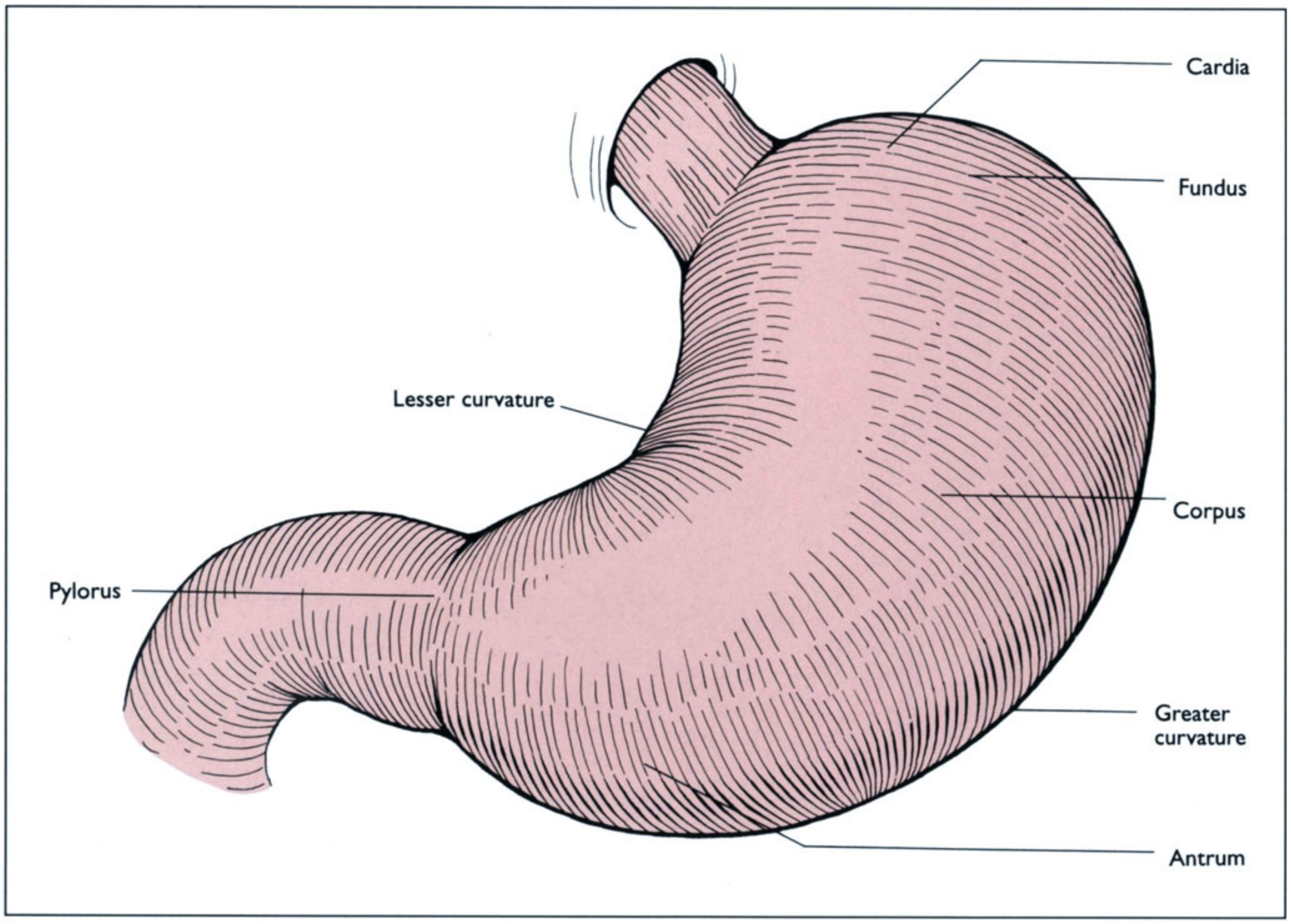


FIGURE 5-2.
The five regions of the stomach: cardia, fundus, corpus, antrum, and pylorus. The greater and lesser curvatures are also demonstrated.

The ligament of Treitz is the anatomic landmark that denotes the end of the duodenum and the beginning of the jejunum. Although there is no structure to indicate the terminus of the jejunum, it is generally accepted that it spans two fifths of the distance from the ligament of Treitz to the ileocecal valve. The jejunum receives its blood supply via mesenteric vessels that originate from the superior mesenteric artery. The primary function of the jejunum is the absorption of nutrients generated by the digestive actions of the stomach, duodenum, pancreatic secretory products, and bile. Gastrojejunostomy is a feasible option because in most instances proximal gastrointestinal tract orientation, although redirected, is fairly well preserved.

The transverse colon deserves special mention in this section because of its proximity to the stomach and jejunum (Figure 5-5). One method of classifying a gastrojejunostomy is by its relation to the transverse colon. An antecolic gastrojejunostomy is situated anterior to the transverse colon and involves anastomosis of the jejunum to the anterior gastric wall. Conversely, the jejunum is anastomosed to the posterior gastric wall in a retrocolic gastrojejunostomy. The retrocolic approach requires the surgeon to traverse the transverse mesocolon in order to perform the anastomosis. Although retrocolic gastrojejunostomy provides better drainage of the stomach due to its location in the dependent portion of the stomach, it would be a challenging procedure to perform laparoscopically.

Pathophysiology, Presentation, and Differential Diagnosis

Treatment regimens of a number of clinical conditions involve the surgical formation of a gastrojejunostomy. A detailed discussion of each of these is beyond the scope of this chapter; however, two disease processes for which gastrojejunostomy is indicated have been selected for discussion: unresectable pancreatic cancer and peptic ulcer disease.

Pancreatic Adenocarcinoma

Adenocarcinoma of the pancreas is presently the fifth leading cause of cancer death in the United States [3,10]. Although no definite risk factors have been identified, ciga-

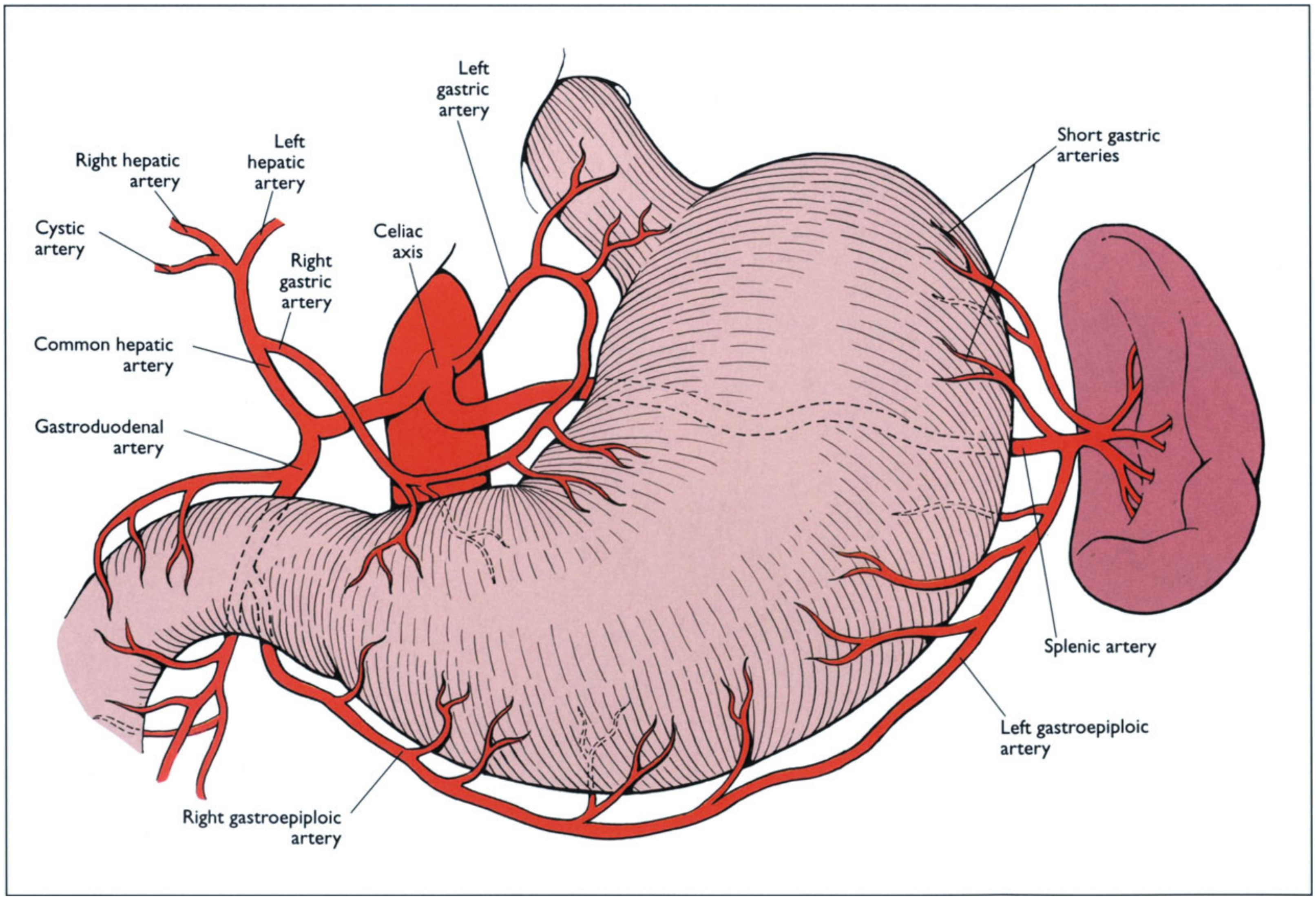


FIGURE 5-3.

The stomach is an extremely well-vascularized organ. The majority of arterial blood is supplied by four vessels: the right and left gastric arteries and the right and left gastroepiploic arteries. Simultaneous ligation of any three of these vessels usually does not affect gastric viability. The short gastric arteries also contribute to the stomach's blood supply.

rette smoking, alcohol abuse, and diabetes mellitus have been implicated [11]. There also appears to be an association between previous gastric surgery and an increased incidence of pancreatic neoplasia that is thought to be related to duodenogastric reflux [12,14]. The prognosis for pancreatic cancer remains dismal, with an overall 5-year survival that approaches 1% [15]. Once the diagnosis is confirmed, only 10% to 25% of patients are candidates for curative resection [3,16]. Despite seemingly "complete" surgical extirpation, only 5% of these patients are alive after 5 years [3]. The poor survival statistics associated with pancreatic cancer are at least threefold: the biology of the disease, the virtual absence of symptoms until the tumor has spread to contiguous structures or metastasized, and the failure of standard pancreaticoduodenectomy to eliminate unrecognized gross and microscopic disease. At present, adjuvant therapy is in the developmental stages and has not had a significant effect on survival.

Signs and symptoms of pancreatic adenocarcinoma are dependent on the location of the primary tumor. Approximately 65% occur in the head of the gland, whereas the body and tail are affected in only 15% and 10% of patients, respectively [3]. The remaining pancreatic carcinomas are diffuse in nature. Patients with tumors of the pancreatic head usually present earlier in the course of their disease due to the proximity of vital structures. For example, jaundice due to compression of the extrahepatic biliary tree is evident on presentation in 87% of patients with tumors in the pancreatic head but only 13% of those with body or tail tumors [17]. Signs and symptoms that are not associated with the site of the primary tumor include weight loss (92%–100%), pain (72%–87%), and nausea and vomiting (37%–45%) [17]. Serum laboratory studies that are usually associated with pancreatic carcinoma include elevated conjugated bilirubin and alkaline phosphatase levels. The diagnosis is frequently made on the basis of clinical presentation; however, confirmation with computed tomography is usually necessary and often provides the surgeon with a noninvasive indication of resectability.

Although there are reports of unresected pancreatic cancer patients surviving for 5 years or more, most surgeons believe complete resection offers the only chance for cure. The Whipple procedure is most widely used and involves removal of the head of the pancreas and the duodenum (pancreaticoduodenectomy) [18]. As has already been stated, however, the vast majority of patients are not candidates for curative surgical resection. The largest role for surgery in this disease process is for the palliative treatment

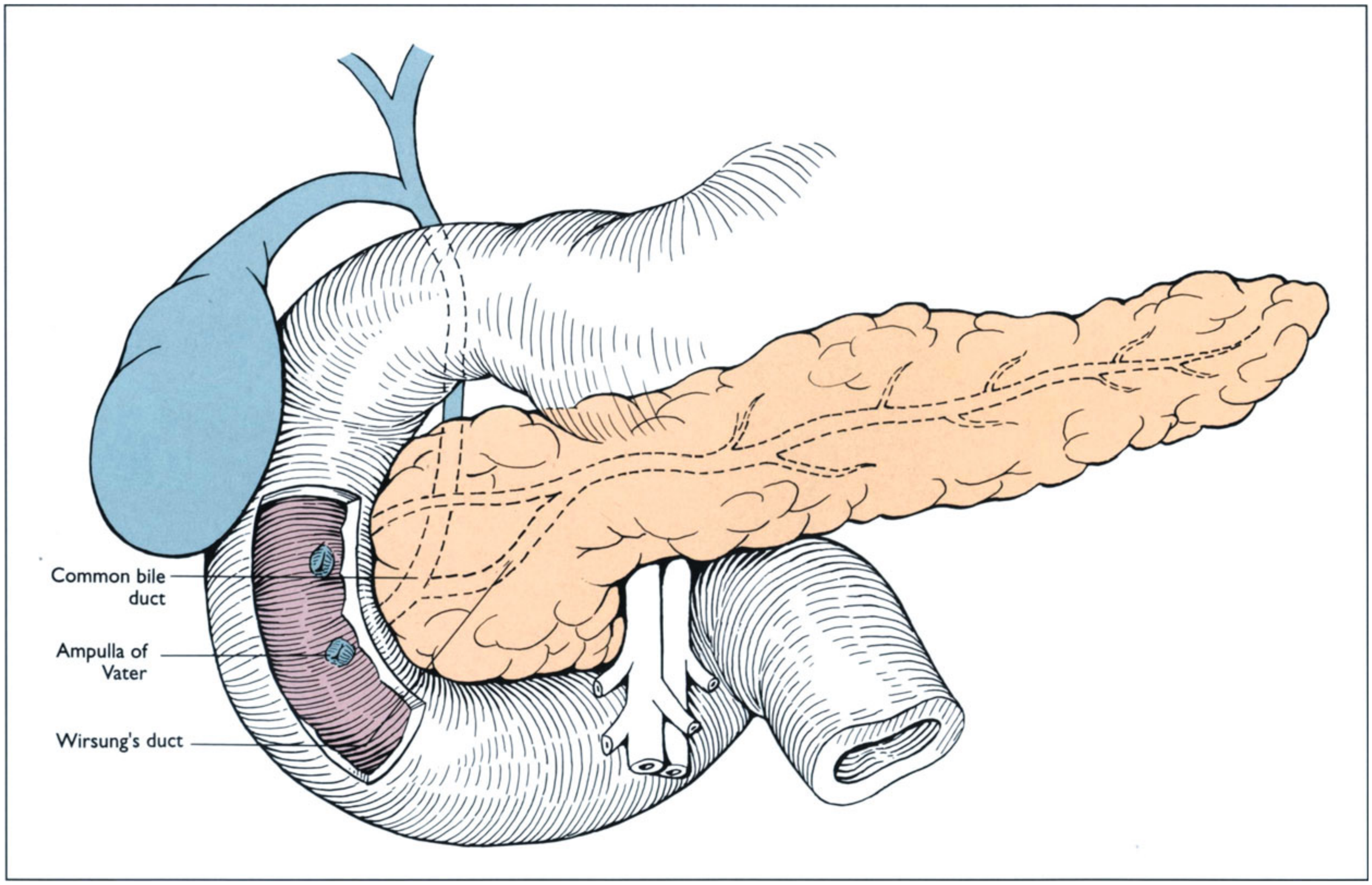


FIGURE 5-4.

The duodenal C loop contains the head of the pancreas. Although ductal anatomy varies among individuals, the common bile duct usually merges with the major pancreatic duct (Wirsung's duct), prior to entering the duodenum in the second segment. This diagram depicts the proximity of the pancreas to both the duodenum and common bile duct, thus making it easy to envision extrinsic compression of either of these structures by a tumor in the head of the pancreas.

of symptoms, most notably jaundice and nausea and vomiting [19,23]. These symptoms are secondary to compression of the extrahepatic biliary tree and duodenum, respectively. Jaundice associated with pancreatic cancer should be treated if it is symptomatic (*ie*, significant hepatic dysfunction or pruritus due to biliary stasis). Percutaneous, endoscopic, and surgical techniques are currently employed [24]. Surgical prophylactic biliary bypass is routinely performed if a patient is found to have unresectable disease at laparotomy and is usually accomplished by cholecystojejunostomy (*see* Chapter 10). Vomiting associated with duodenal obstruction is customarily treated by bypassing the obstruction with a gastrojejunostomy. There is some debate in the literature as to the necessity of performing prophylactic gastrojejunostomy in patients undergoing surgical biliary diversion without evidence of duodenal obstruction [19,22]. Approximately 20% of patients treated for biliary obstruction eventually develop duodenal obstruction in the course of the disease [3].

In the treatment of pancreatic disease, laparoscopic surgery will impact most significantly on the *palliative* treatment of pancreatic cancer. Treatment options are now available to clinicians so that the quality of life of these patients is maximized. These include laparoscopic gastrojejunostomy in conjunction with laparoscopic cholecystojejunostomy. Laparoscopic procedures are associated with decreased hospital stay and hastened recovery, thus enabling these terminally-ill patients to spend quality time at home. Although laparoscopic gastrojejunostomy usually relieves duodenal obstruction in patients with pancreatic cancer, the majority of patients with biliary obstruction are not candidates for laparoscopic cholecystojejunostomy. Drainage of bile via a cholecystojejunostomy is usually inadequate if a pancreatic mass compresses the common bile duct within 1 centimeter of the junction of the common hepatic and cystic ducts (PB Cotton, Personal communication).

Peptic Ulcer Disease

Peptic ulcer disease remains a major public health concern despite the wide application of endoscopy and effective anti-ulcer agents such as histamine type 2 (H-2) receptor antagonists (ranitidine, cimetidine) and proton pump

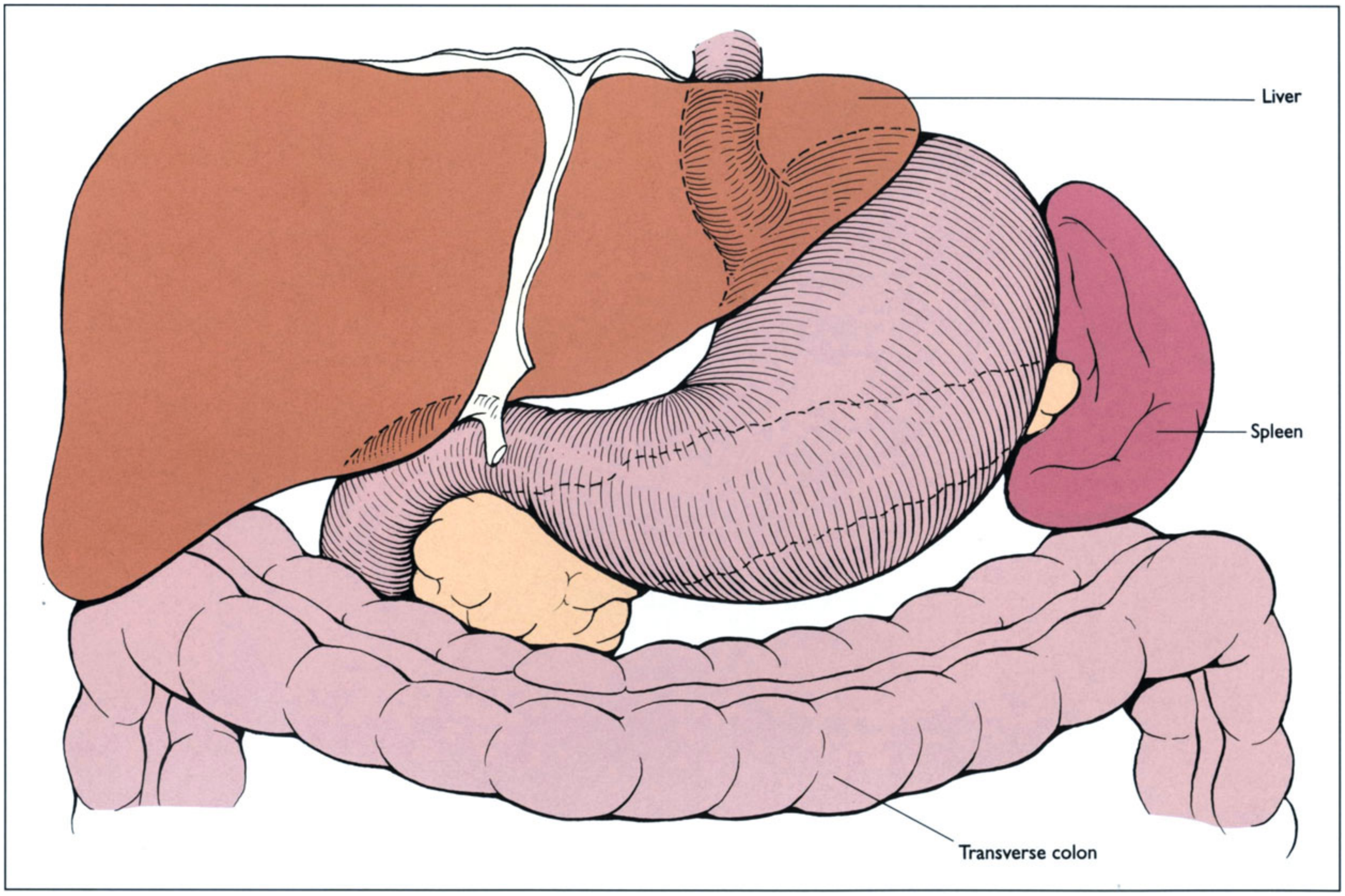


FIGURE 5-5.

The transverse colon overlies the region where a gastrojejunostomy is performed. An antecolic gastrojejunostomy is placed anterior to the transverse colon and involves the anterior wall of the stomach. A retrocolic gastrojejunostomy is placed through the transverse mesocolon and anastomosed to the posterior gastric wall.

blockers (omeprazole). The most common indications for hospitalization in order of incidence are hemorrhage, intensive treatment of uncomplicated peptic ulcer, and perforation [25]. A medical regimen is most often employed in the routine management of peptic ulcer disease; however, surgical therapy is frequently necessary to treat complications of the disease.

A detailed discussion of gastrointestinal physiology is beyond the scope of this chapter; however, a few concepts deserve mention. The pathogenesis of peptic ulcer disease consists of multiple factors including an increase in the ability to secrete gastric acid and pepsin and a decrease in the appropriate mucosal defense mechanisms. The primary functions of the stomach are to mix ingested food with gastric secretions so that the digestion can occur and to propel gastric contents to the small intestine. Important digestive components produced by the stomach include hydrochloric acid and pepsin. Regulation of gastric acid secretion requires a complex interaction of the central nervous system, the gastrointestinal tract, and a variety of hormones and peptides. Ingestion of food stimulates the release of gastrin, which in turn stimulates the release of hydrochloric acid. When gastric pH decreases below 5, pepsin is released from the zymogen pepsinogen, and protein digestion is then initiated [26].

There are several protective mechanisms that act to prevent stomach and proximal small intestinal damage from the actions of gastric acid and pepsin. Mucus is secreted by cells located within the gastric epithelial layer and serves as a physical barrier that separates the gastric mucosa from the acidic contents of the stomach. Bicarbonate is also secreted by gastric epithelial cells and maintains a neutral pH at the level of the mucosal cells despite the presence of acidic gastric contents above the layer mucus [1]. Several mechanisms are involved in the inhibition of gastric acid secretion. One of the most significant is the negative feedback loop initiated by the fall in gastric pH associated with the digestion of food in the stomach. The result is an inhibition of gastrin release which, in turn, eliminates a substantial stimulus of gastric acid secretion [26].

The first portion of the duodenum is the site most frequently affected by peptic ulcer disease, whereas the pyloric channel, prepylorus, distal gastric body, and distal segments of the duodenum are less often involved [1,2]. As has been previously stated, the etiology of peptic ulcer disease is multifactorial. An association between gastric acid hypersecretion and peptic ulcer disease has been demonstrated [1,2,27]. In fact, when compared with healthy individuals, patients with duodenal ulcers tend to have increased basal acid levels, greater acid release in response to meals, and increased acid response to intravenous histamine challenge [2]. Other factors theorized to be associated with peptic ulcer disease include cigarette smoking, nonsteroidal antiinflammatory agent use, and intestinal *Helicobacter pylori* infection [1,2].

The symptom that provokes peptic ulcer patients to seek medical attention most often is pain. It is usually located in the epigastric area and is episodic in nature. The character of the pain varies between patients and can range from a dull ache to a stabbing sensation. It is usually relieved by ingesting food or antacids. Physical examination of patients with *uncomplicated* peptic ulcer disease is usually unremarkable, and routine laboratory studies generally do not reveal any abnormalities. Endoscopic and radiologic evaluations are invaluable components of the diagnostic process. Uncomplicated cases are usually treated with H-2 blockers or other oral agents with excellent results.

The use of surgical therapy in the treatment of peptic ulcer disease is reserved for complications of the disease. These include unresponsiveness to medical therapy, obstruction, perforation, and hemorrhage. Laparoscopic surgery will likely be used in the treatment of intractable ulcer disease and ulcers producing gastrointestinal tract obstruction. Perforation and massive hemorrhage are surgical emergencies that are most effectively treated by exploratory laparotomy; therefore, these complications will not be discussed further.

Ulcers that are refractory to medical therapy are considered intractable. Characteristics of intractability include the following: ulcers that persist for at least 3 months despite medical therapy, recurrence within 1 year of healing despite maintenance therapy, and recurrent or persistent ulcer disease without significant remissions [28]. It is generally accepted that surgical procedures for intractability should be simple so that operative mortality is minimized [2]. The operative goal is to reduce the acid secreting ability of the stomach. Procedures that are effective in accomplishing this objective include truncal vagotomy/pyloroplasty and truncal vagotomy/antrectomy. Either of these procedures can be performed laparoscopically; however, vagotomy/antrectomy is pertinent to this discussion because the gastrointestinal tract may be reconstructed with a Billroth II anastomosis. Vagotomy/antrectomy is particularly effective because vagotomy reduces cholinergic stimulation of gastric acid secretion and antrectomy removes gastrin-producing cells.

Occasionally, peptic ulcers of the pyloric channel produce such significant inflammation and edema that gastric outflow tract obstruction occurs. In the acute stages of this syndrome, bowel rest, nasogastric suctioning, intravenous hydration, and intravenous H-2 blockers are indicated. Conservative therapy usually results in resolution of the obstruction. Scarring of the pylorus may result in chronic obstruction and even malnutrition. In the case of malnutrition, the therapeutic measures used for acute obstruction should be augmented with intravenous hyperalimentation. If obstruction persists despite aggressive supportive therapy, surgery is indicated. Adequate operative intervention includes a procedure that effectively addresses peptic ulcer disease and eliminates the obstruction. Laparoscopic truncal vagotomy and antrectomy with a Billroth II reconstruction is one option.

Surgical Technique

Reports of laparoscopic gastrojejunostomy are beginning to appear in the literature [8,9]. At present there is no uniform method of performing the operation. Figures 5-6 through 5-15 outline two techniques of laparoscopic gastrojejunostomy that may be used in the treatment of a variety of conditions such as those described above.

Set-up

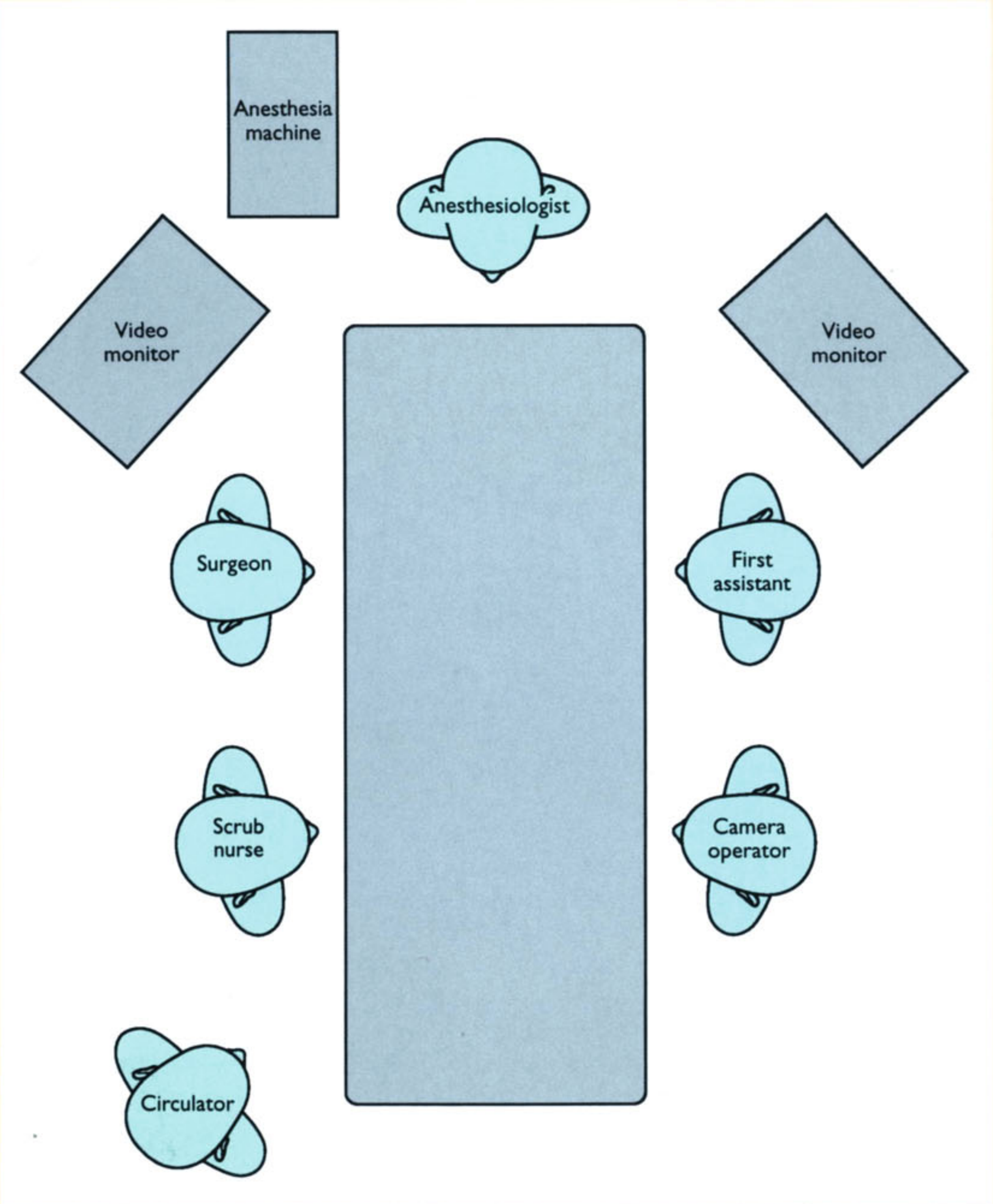


FIGURE 5-6.
Proper performance of laparoscopic procedures requires adequate preoperative planning so that each member of the operating team knows his or her function. Proper positioning of personnel and equipment is essential if the procedures are to be performed efficiently. This diagram depicts the location of each operating team member and major equipment. The surgeon and scrub nurse are to the right of the patient and the first assistant and camera operator are to the patient's left. Note that video monitors are placed on both sides of the operating table so that all members of the operating team have an unobstructed view of the operation.

Set-up

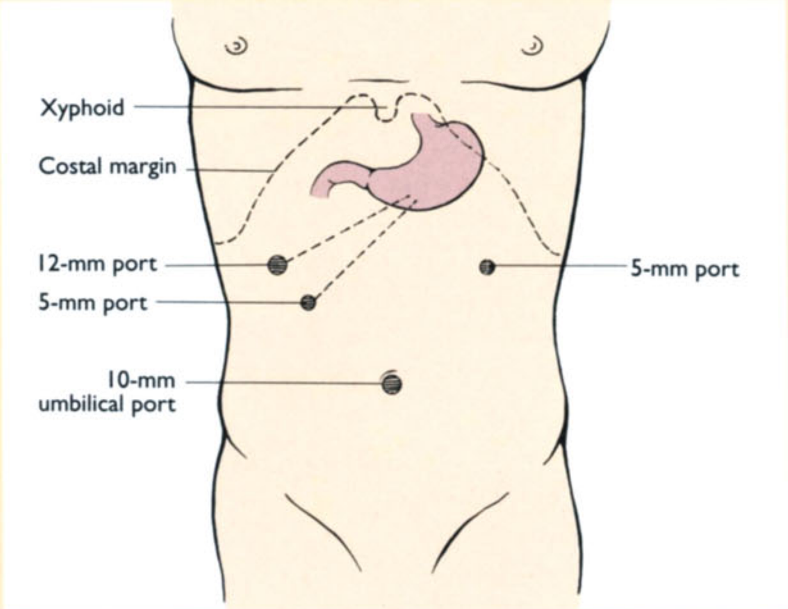


FIGURE 5-7.

An effective scheme for laparoscopic gastrojejunostomy trocar placement is depicted in this figure. A nasogastric tube and Foley catheter are placed after general anesthesia is induced so as to minimize the chance of stomach and bladder injury during trocar placement. The camera port is 10 mm and may be placed supra-, intra-, or infraumbilically. This port is placed using either the Hasson (open) method or the percutaneous (Veress needle) approach. The peritoneal cavity is insufflated with CO_2, and the camera is inserted when the peritoneal pressure is 15 mm Hg. Exploratory laparoscopy is then performed. Some surgeons elect to use exploratory laparoscopy prior to anticipated Whipple procedures. Laparoscopy permits biopsy of peritoneal implants or hepatic metastases not seen on computed tomography (CT) scan that may prove unresectability of disease. If a Whipple procedure is not indicated, laparoscopic gastrojejunostomy may then be performed. After adequate exploration of the peritoneal cavity is completed, the remaining trocars are placed under direct vision. Twelve-mm and 5-mm ports are placed in the right upper quadrant in such a manner that they form an isosceles triangle with the anticipated area of gastrojejunostomy serving as the vertex. A second 5-mm port is placed in the left upper quadrant for the first assistant.

Procedure

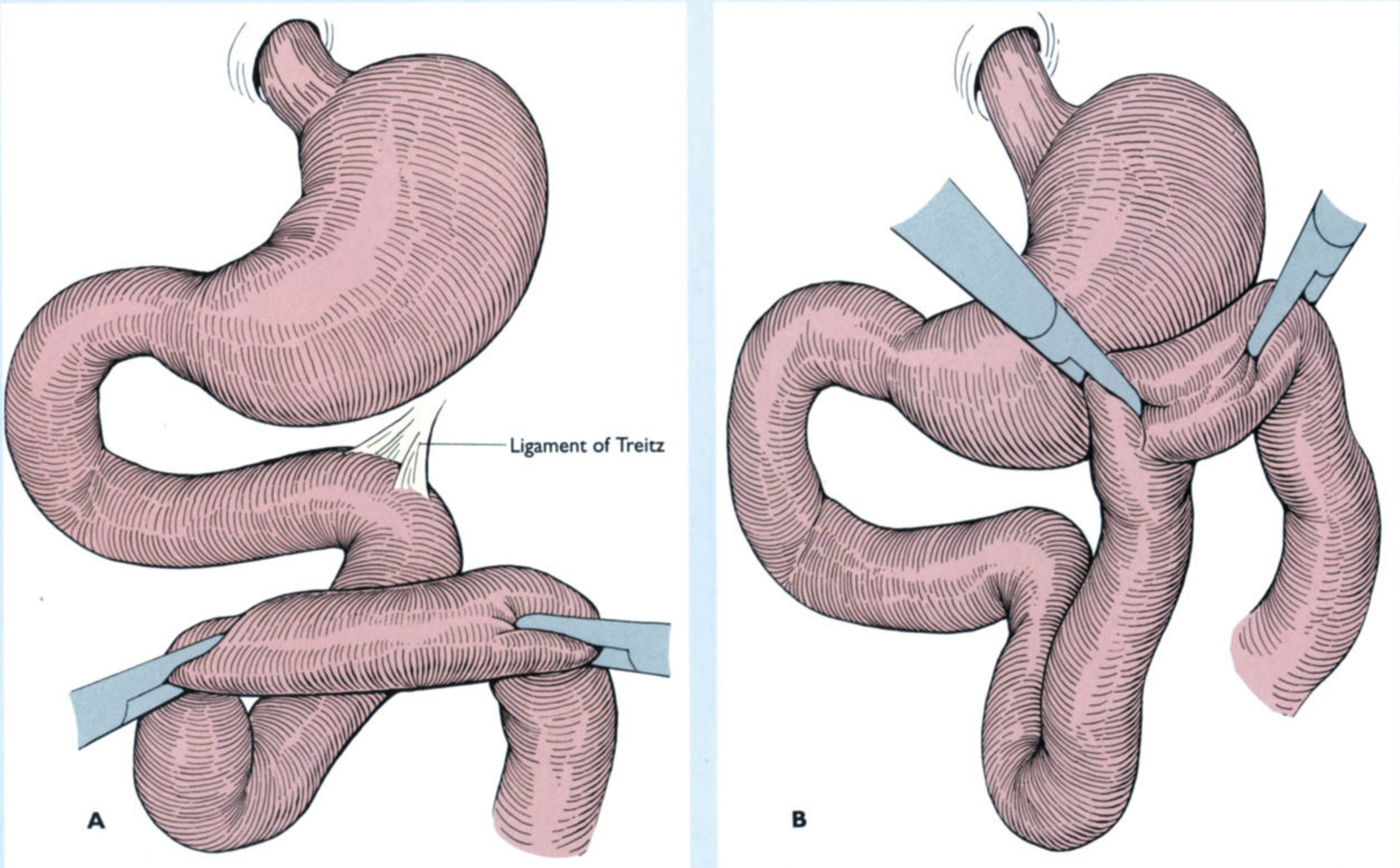


FIGURE 5-8.

A, Locate the ligament of Treitz and proceed distally along the jejunum until an adequate segment can be mobilized to the anterior surface of the stomach without tension. **B**, Care must be taken to properly orient the jejunum so that the mesentery is not twisted.

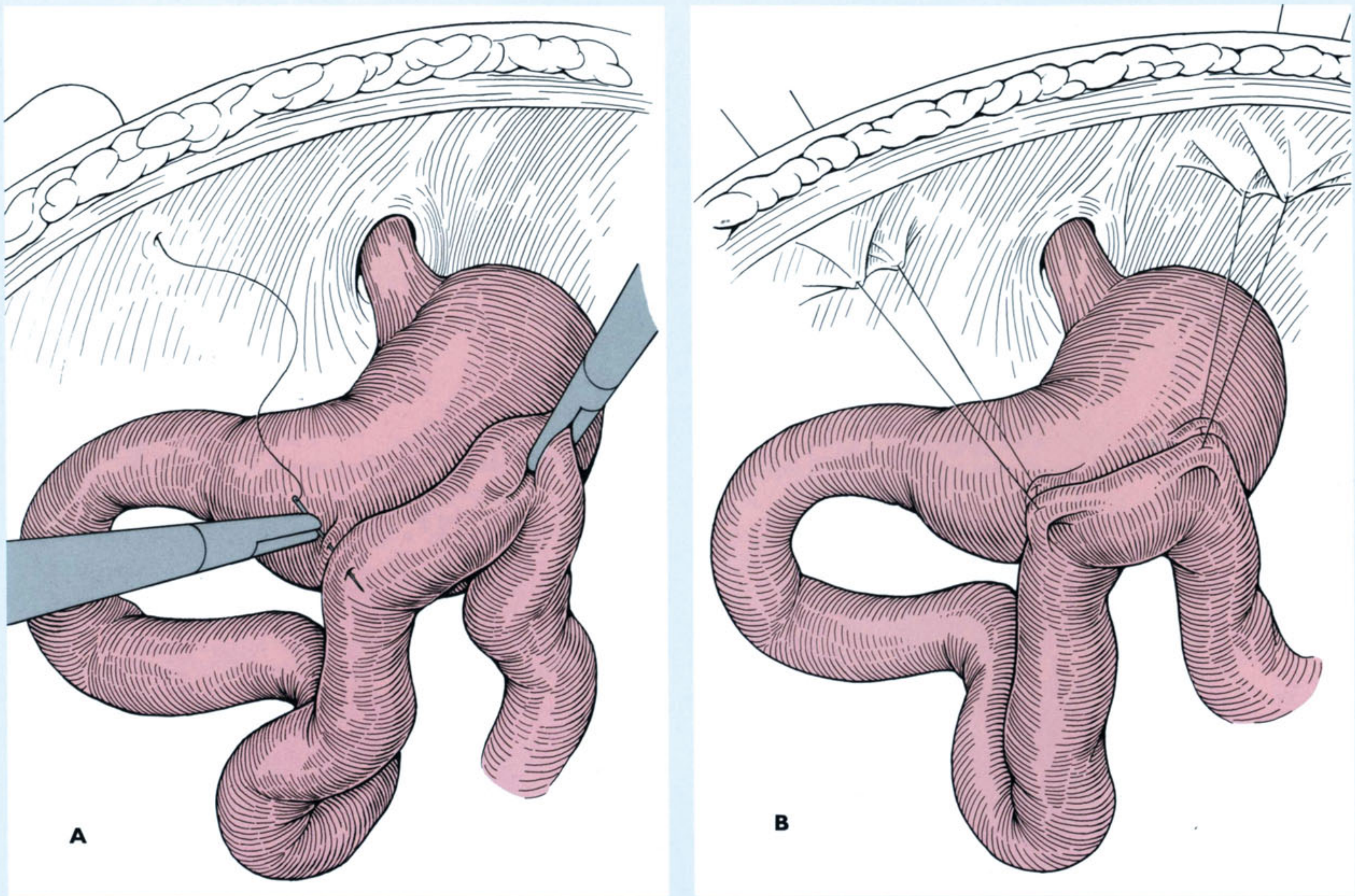


FIGURE 5-9.

A, After selecting a segment of jejunum for anastomosis, the orientation of jejunum and stomach is maintained by silk sutures that are passed through the abdominal wall with straight needles under direct vision. The straight needle is grasped with an endoscopic grasper or needle driver, passed through the seromuscular layers of the stomach and jejunum, and then driven out of the peritoneal cavity through the abdominal wall. **B**, These tagging sutures should be placed at least 6 cm apart so that a generous gastrojejunostomy is formed. Appropriate pressure is then applied to these sutures so that the stomach and jejunum are tented and the boundaries of the gastrojejunostomy are delineated.

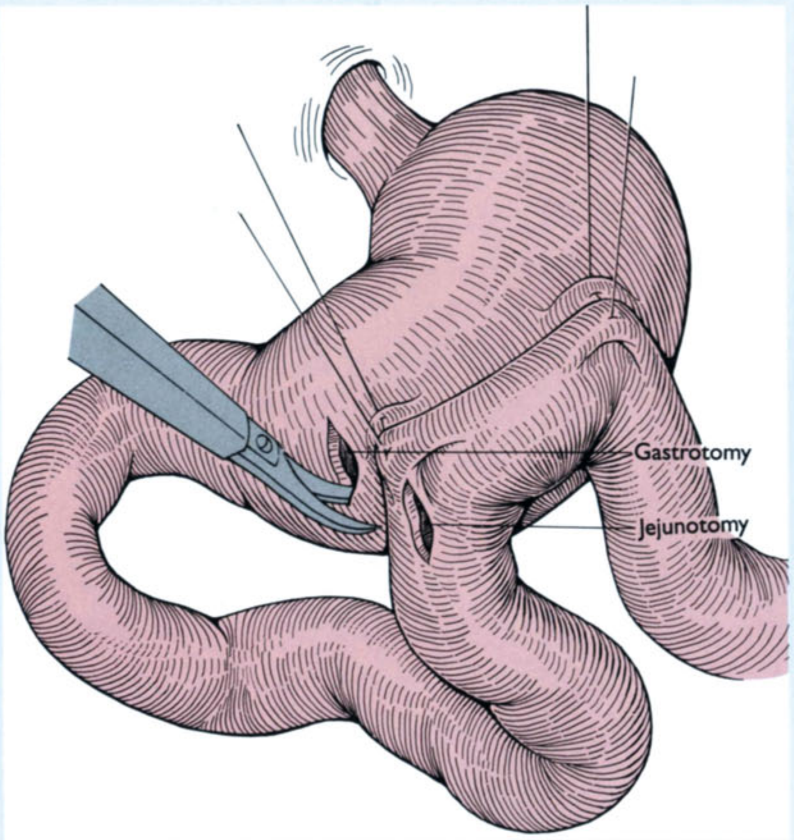


FIGURE 5-10.
Electrocautery is used to make a gastrotomy and a jejunotomy just large enough to accommodate the limbs of the endoscopic stapling device.

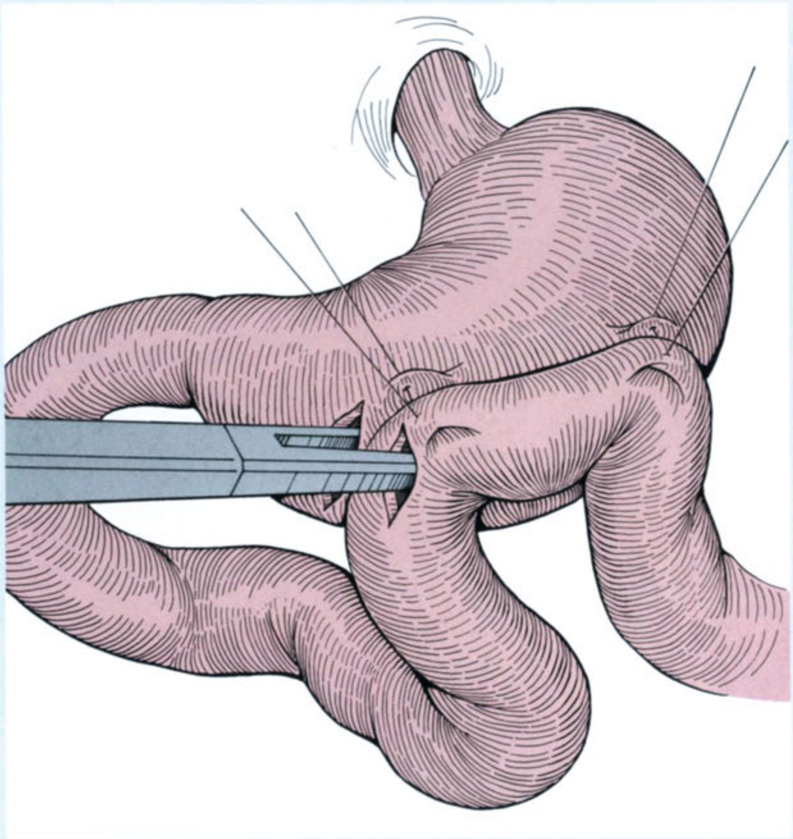


FIGURE 5-11.
A 30-mm endoscopic stapler is passed through the 12-mm port and one limb is fed through the gastrotomy and the other through the jejunotomy. The device is fired two or three times to make an anastomosis 60 to 90 mm in length. The endoscopic stapler is probably superior to staples used for open procedures because it places six rows of staples instead of four.

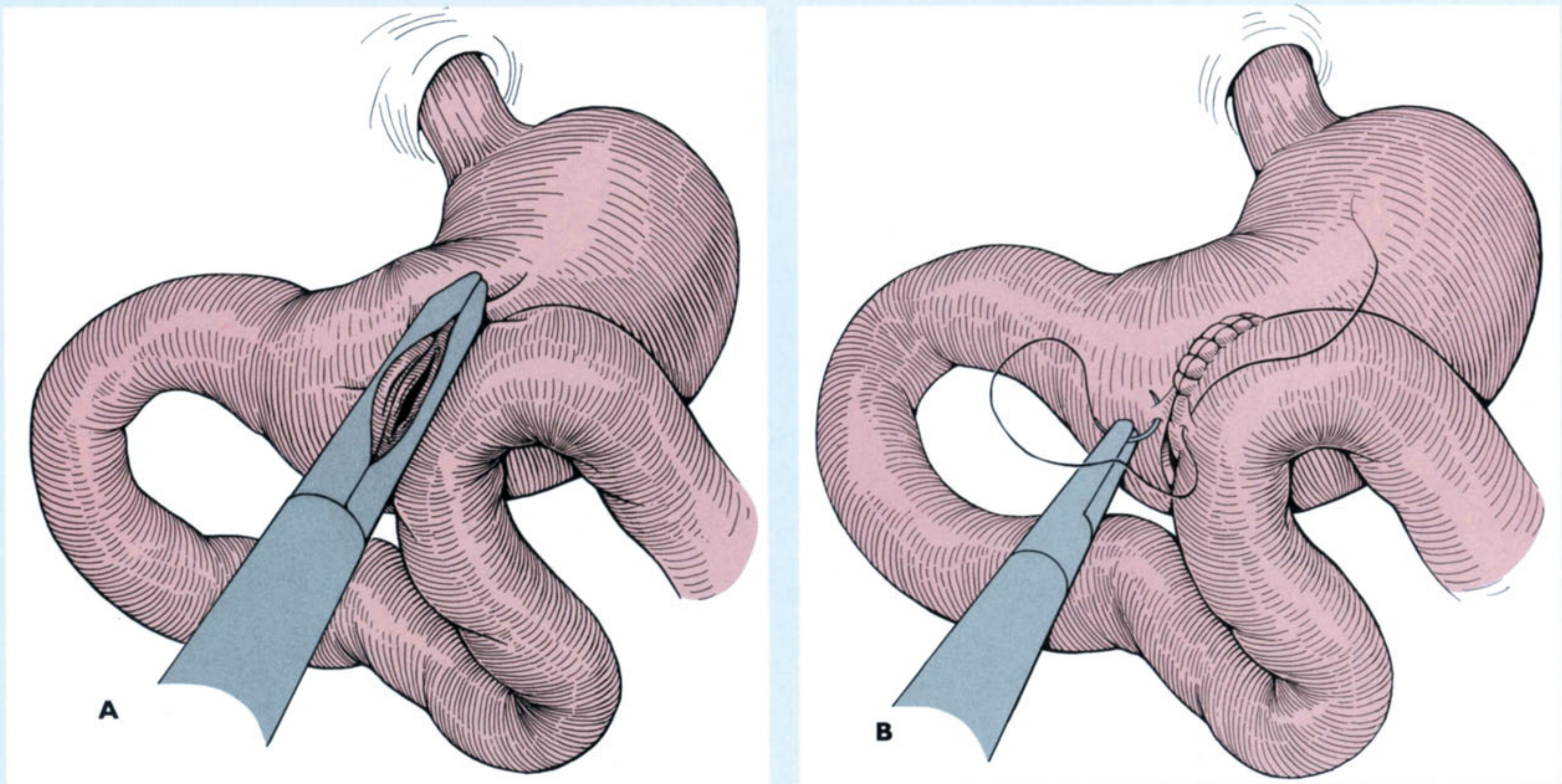


FIGURE 5-12.
The enterotomy that remains may be closed with either an endoscopic stapler (*panel A*) or silk sutures (*panel B*).

Alternative Procedure

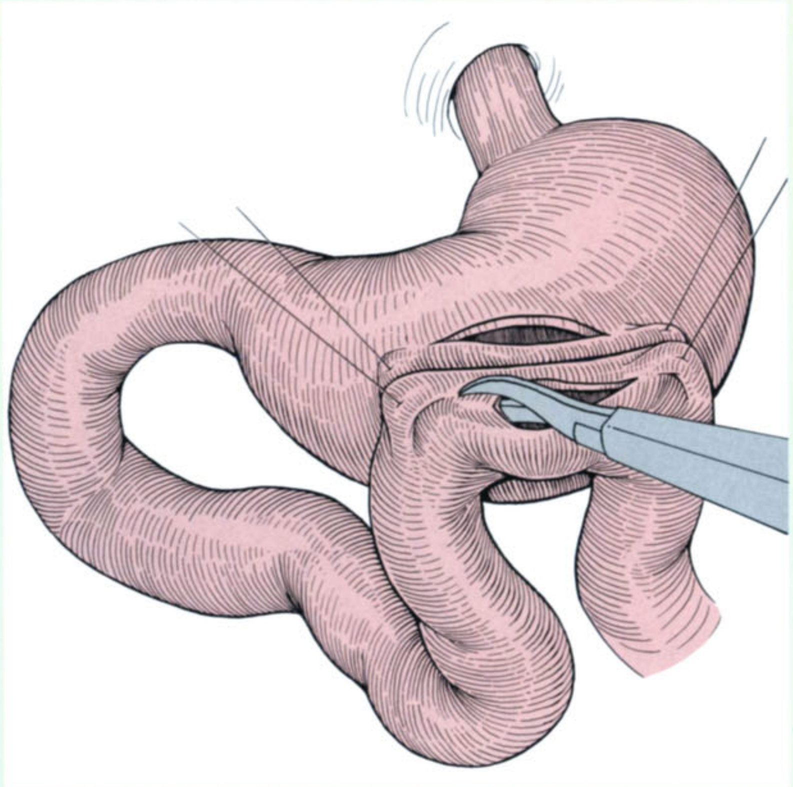


FIGURE 5-13.
An alternate method for laparoscopic gastrojejunostomy is a sewn anastomosis. Tenting of the stomach and jejunum is performed with straight needles as outlined in Figure 5-9. A long gastrotomy and corresponding jejunotomy are made between the tagging sutures.

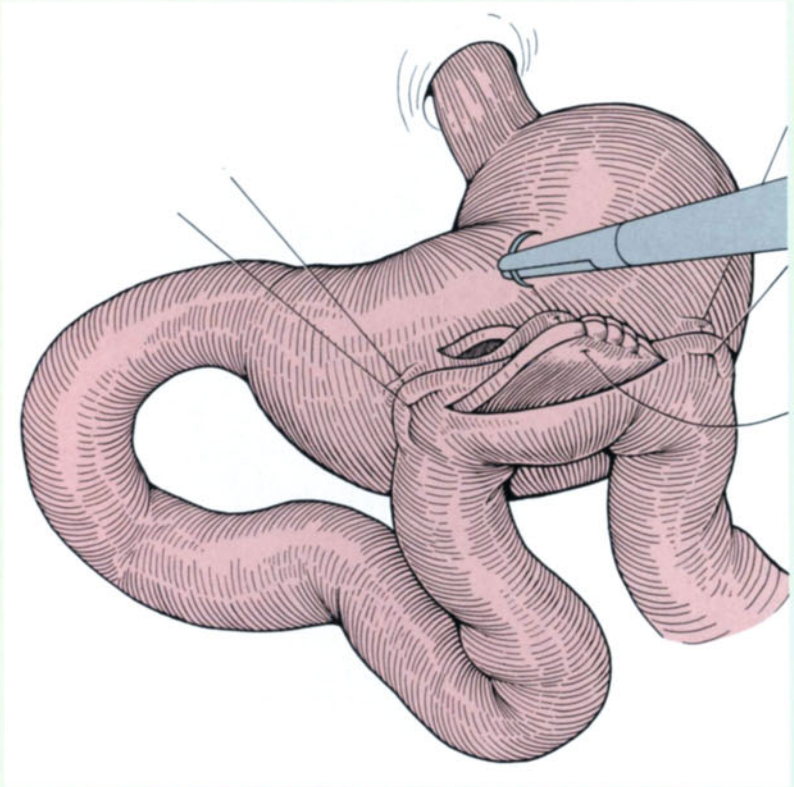


FIGURE 5-14.
Full-thickness, interrupted sutures are placed along the posterior wall of the anastomosis. Intra- or extracorporeal knot-tying techniques may be used.

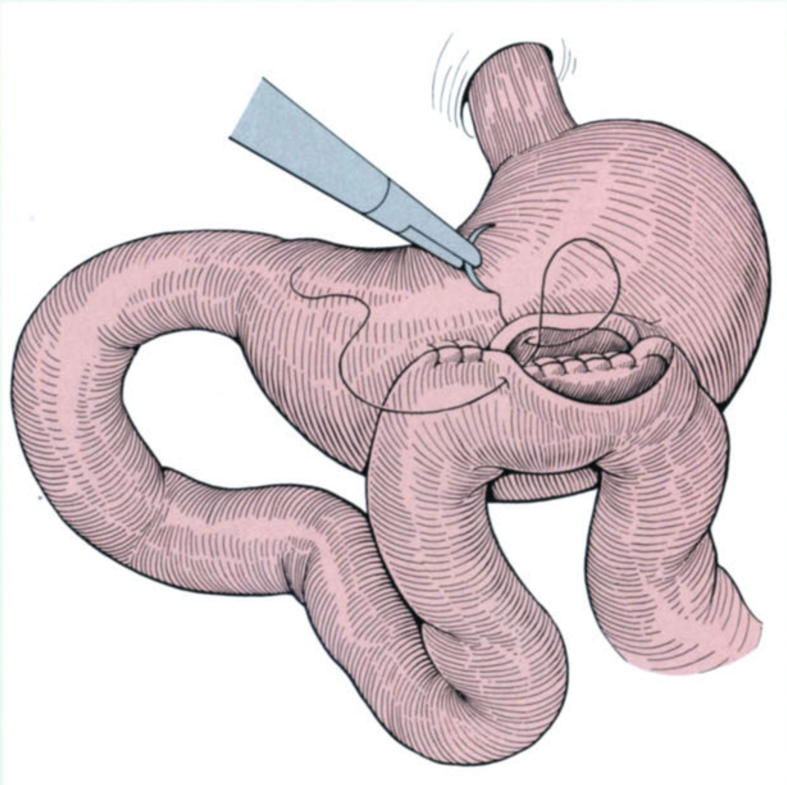


FIGURE 5-15.
The anastomosis is completed by placing interrupted sutures along the anterior edge of the anastomosis.

Postoperative Management

The nasogastric tube should be left in place in the early postoperative period to protect the anastomosis from gastric dilatation. It may be removed with evidence of intestinal function (bowel sound, flatus, bowel movement) and then a clear liquid diet may be initiated and advanced as tolerated. Pain following laparoscopic gastrojejunostomy is usually limited; therefore, multiple doses of intravenous or intramuscular narcotics are not necessary.

Results

Experience in laparoscopic gastrojejunostomy remains limited; therefore, it would be premature to judge early results and compare it with the open technique. Based on preliminary reports, it is clear that this technique can be performed safely and does produce a functional anastomosis.

Conclusions

As laparoscopic surgeons become more skilled, the indications for laparoscopic surgery will continue to expand. It has been demonstrated at a number of medical centers that it is feasible to perform laparoscopic gastrojejunostomy. Whether this procedure provides any tangible advantages to the open technique remains to be documented. The following clinical scenario may demonstrate its utility: a 70-year-old patient with duodenal obstruction secondary to unresectable adenocarcinoma of the pancreas. Uncomplicated open gastrojejunostomy would require up to 7 days of hospitalization and 6 weeks of recuperation. Laparoscopic gastrojejunostomy would require 3 to 4 days of hospitalization and less than 2 weeks of recuperation. A patient with a lifespan of a few months would certainly benefit from the laparoscopic approach.

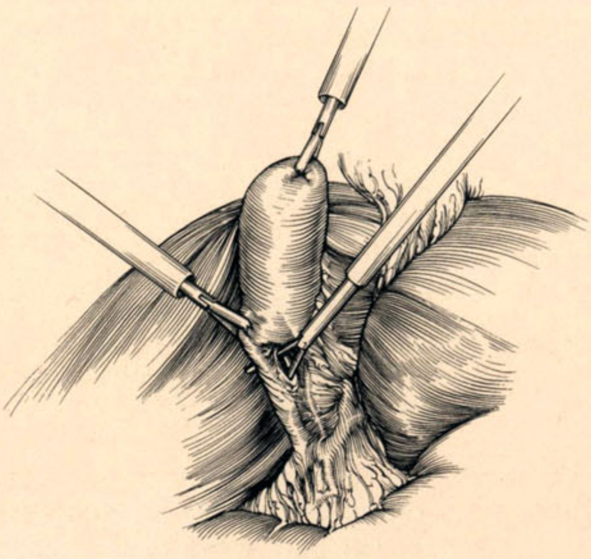
References

1. Mulholland MW: Duodenal ulcer. In *Surgery: Scientific Principles and Practice.* Edited by Greenfield LJ, Mulholland MW, Oldham KT, Zelenock GB. Philadelphia: J.B. Lippincott Company; 1993:674–689.
2. Kauffman GL, Conter RL: Stress ulcer and gastric ulcer. In *Surgery: Scientific Principles and Practice.* Edited by Greenfield LJ, Mulholland MW, Oldham KT, Zelenock GB. Philadelphia: J.B. Lippincott Company; 1993:689–702.
3. Bell RH: Neoplasms of the exocrine pancreas. In *Surgery: Scientific Principles and Practice.* Edited by Greenfield LJ, Mulholland MW, Oldham KT, Zelenock GB. Philadelphia: J.B. Lippincott Company; 1993:816–833.
4. Thompson JC: The stomach and duodenum. In *Textbook of Surgery: The Biological Basis of Modern Surgical Practice.* Edited by Sabiston DC. Philadelphia: W.B. Saunders Company; 1986:810–853.
5. Tanner NC: The surgical treatment of peptic ulcer. *Br J Surg* 1964, 51:5–23.
6. Arends TW, Nahrwold DL: Gastric resection and reconstruction. In *Shackelford's Surgery of the Alimentary Tract.* Edited by Zuidema GD. Philadelphia: W.B. Saunders Company; 1991:149–172.
7. Maingot R: The Billroth II operations. In *Abdominal Operations.* Edited by Maingot R. New York: Appleton-Century-Crofts; 1980:385–419.
8. Brune IB, Schönleben K: Laparoskopische seit-zu-seit-gasto-jejunostomie. *Chirurg* 1992, 63:577–580.
9. Goh P, Tekant Y, Kum CK, *et al.*: Totally intra-abdominal laparoscopic Billroth II gastrectomy. *Surg Endosc* 1992, 6:160.
10. Yeo CJ, Cameron JL: The pancreas. In *Textbook of Surgery: The Biological Basis of Modern Surgical Practice.* Edited by Sabiston DC. Philadelphia: W.B. Saunders Company; 1991:1076–1107.
11. Morgan RGH, Wormsley KG: Progress report: cancer of the pancreas. *Gut* 1977, 18:580–596.
12. Watanapa P, Flaks B, Oztas H, *et al.*: Duodenogastric reflux enhances growth and carcinogenesis in the rat pancreas. *Br J Surg* 1992, 79:791–794.
13. Taylor PR, Dowling RH, Palmer TJ, *et al.*: Induction of pancreatic tumours by longterm duodenogastric reflux. *Gut* 1989, 30:1596–1600.
14. DiMagno EP, Shorter RG, Taylor WF, Go VLW: Relationships between pancreaticobiliary ductal anatomy and pancreatic ductal and parenchymal histology. *Cancer* 1982, 49:361–368.
15. Gudjonsson B: Cancer of the pancreas: 50 years of surgery. *Cancer* 1987, 60:2284–2303.
16. Livingston EH, Welton ML, Reber HA: Surgical treatment of pancreatic cancer: the United States experience. *Int J Pancreatol* 1991, 9:153–157.
17. Howard JM, Jordan GL: Cancer of the pancreas. *Curr Probl Cancer* 1977, 2:5–52.
18. Whipple AO, Parsons WB, Mullins CR: Treatment of carcinoma of the ampulla of Vater. *Ann Surg* 1935, 102:763–779.
19. Lillemoe KD, Sauter PK, Pitt HA, *et al.*: Current status of surgical palliation of periampullary carcinoma. *Surg Gynecol Obstet* 1993, 176:1–10.
20. Pretre R, Huber O, Robert J, *et al.*: Results of surgical palliation for cancer of the head of the pancreas and periampullary region. *Br J Surg* 1992, 79:795–798.
21. Singh SM, Longmire WP, Reber HA: Surgical palliation for pancreatic cancer. *Ann Surg* 1990, 212:132–139.
22. Potts JR, Broughan TA, Hermann RE: Palliative operations for pancreatic carcinoma. *Am J Surg* 1990, 159:72–78.
23. Singh SM, Reber HA: Surgical palliation for pancreatic cancer. *Surg Clin North Am* 1989, 69:599–611.
24. Cotton PB: Nonsurgical palliation of jaundice in pancreatic cancer. *Surg Clin North Am* 1989, 69:613–627.
25. Kurata JH, Corboy ED: Current peptic ulcer time trends: an epidemiological profile. *J Clin Gastroenterol* 1988, 10:259–268.
26. Johnson LR: Gastric secretion. In *Gastrointestinal Physiology.* Edited by Johnson LR. St. Louis: The C.V. Mosby Company; 1985:63–82.
27. Thompson JC: The stomach and duodenum. In *Textbook of Surgery: The Biological Basis of Modern Surgical Practice.* Edited by Sabiston DC. Philadelphia: W.B. Saunders Company; 1991:756–787.
28. Piper DW: The refractory ulcer. *World J Surg* 1987, 11:268–273.

CHAPTER 6

Basic Techniques of Laparoscopic Cholecystectomy

Christopher R. Watters



Although gallstones were first described in the fifth century by the Greek physician Alexander Trallianus, therapy for gallstone disease was delayed until 1867 when John Stough Bobbs performed the first cholecystotomy with removal of gallstones in the case of a 32-year-old woman with hydrops of the gallbladder [1]. This was followed in 1882 by the first cholecystectomy by Langenbuch in Berlin. His patient was discharged from the hospital 7 weeks following the new procedure. During the first half of the 20th century, the most significant advances in the field pertained primarily to improved diagnosis. The surgical treatment of gallbladder disease remained largely unchanged until the introduction of laparoscopic techniques for cholecystectomy. With some debate in the literature on who deserves credit for this advancement, several investigators are listed in Table 6-1.

Anatomy

The gallbladder is from 7 to 10 cm in length, with a maximal width of 2.5 to 3 cm at the fundus, and a typical volume of approximately 30 cc, although in marked distension the gallbladder can contain as much as 300 cc. It is bound to the gallbladder fossa between the right and left hepatic lobes on the undersurface of the liver. The attachment can vary from an intrahepatic location to a true mesentery. Blood supply comes via the cystic artery that arises from the right hepatic artery in 95% of cases, but it can occasionally be derived from the left hepatic, common hepatic, gastroduodenal, or superior mesenteric arteries. Double cystic arteries are found in 8% and accessory cystic arteries in 12% of patients.

The cystic duct is from 2.5 to 4 cm in length. It passes very close to the free right margin of the gastrohepatic ligament, usually joining the main hepatic duct at an acute angle. Within it are a number of spiral folds known as the valves of Heister that can make catheter passage difficult in intraoperative cholangiography. Occasionally, the cystic duct can take a longer course posterior to the main hepatic duct and empty into it posteriorly.

Pathophysiology, Presentation, and Differential Diagnosis

Cholecystectomy is indicated for the treatment of symptomatic gallstone disease, acalculous cholecystitis, and, in very specific instances (*eg*, porcelain gallbladder or immunosuppression), asymptomatic patients. Occasionally it may be indicated with documented biliary dyskinesia or "crystal disease."

Chronic cholecystitis is characterized by recurrent bouts of right upper quadrant or epigastric pain that usually follows meals and can radiate through to the back. Frequently, the pain is accompanied by nausea, vomiting, and a feeling of abdominal fullness or bloating. Attacks typically last from 30 minutes to 24 hours. The discomfort of chronic cholecystitis is believed to represent biliary colic and not inflammation. A complex of symptoms that does not include pain is unlikely due to chronic cholecystitis even if gallstones are demonstrated.

Acute cholecystitis is characterized by acute bacterial inflammation of the gallbladder, usually resulting from cystic duct obstruction secondary to calculous (95% of

Table 6-1. Milestones in the diagnosis and treatment of gallbladder disease

Year	Investigator	Location	Procedure
1867	John Stough Bobbs	USA	First cholecystostomy
1882	Carl Langenbuch	Berlin	First cholecystectomy
1890	Ludwig Courvoisier	Basel	First choledocholithotomy
1924	Evarts Graham and Warren Cole	USA	First cholecystogram in humans
1953	Eric Yuhl	USA	First cholescintigram
1987	Phillipe Mouret	France	First laparoscopic cholecystectomy
1988	Eddie Reddick and Douglas Olsen	USA	First laparoscopic cholecystectomy in USA

Table 6-2. Differential diagnosis of cholecystitis

Acute appendicitis	Fitz-Hugh-Curtis syndrome
Duodenal ulcer	Pyelonephritis
Gastric ulcer	Gastroesophageal reflux
Acute pancreatitis	Radicular pain
Hepatitis	Coronary artery disease
Right heart failure	

Table 6-3. Advantages and disadvantages of the laparoscopic versus open approach

Advantages	Disadvantages
Smaller incisions	Equipment requirements
Less pain	More difficult to control bleeding
Rapid return to full activity	Possibly increased incidence of bile duct injury
Briefer hospital stay	Difficult to explore common bile duct
Decreased total cost	Restricted application due to adhesions and inflammation
Fewer pulmonary effects	

cases). Persistent pain and tenderness in the right upper quadrant are present in almost every case. Nausea and vomiting occur in two thirds of patients and are thought to be secondary to the rapid rise in gallbladder pressure. Fever is present in 80% of patients. Signs of peritoneal irritation, such as Murphy's sign, become more common as the disease progresses. The white blood cell count is elevated in 85% of cases. Common processes mimicking acute cholecystitis are summarized in Table 6-2.

Although the laparoscopic approach to cholecystectomy has significantly decreased the recovery time, it should not be viewed as expanding the indications for cholecystectomy. The first decision is whether or not a cholecystectomy is indicated and the second decision is whether a laparoscopic or open approach is more appropriate. Although there are many advantages to the laparoscopic approach (Table 6-3), there are still patients in whom an open cholecystectomy is indicated.

Surgical Technique

Figures 6-1 through 6-12 depict the surgical technique for laparoscopic cholecystectomy.

Set-up

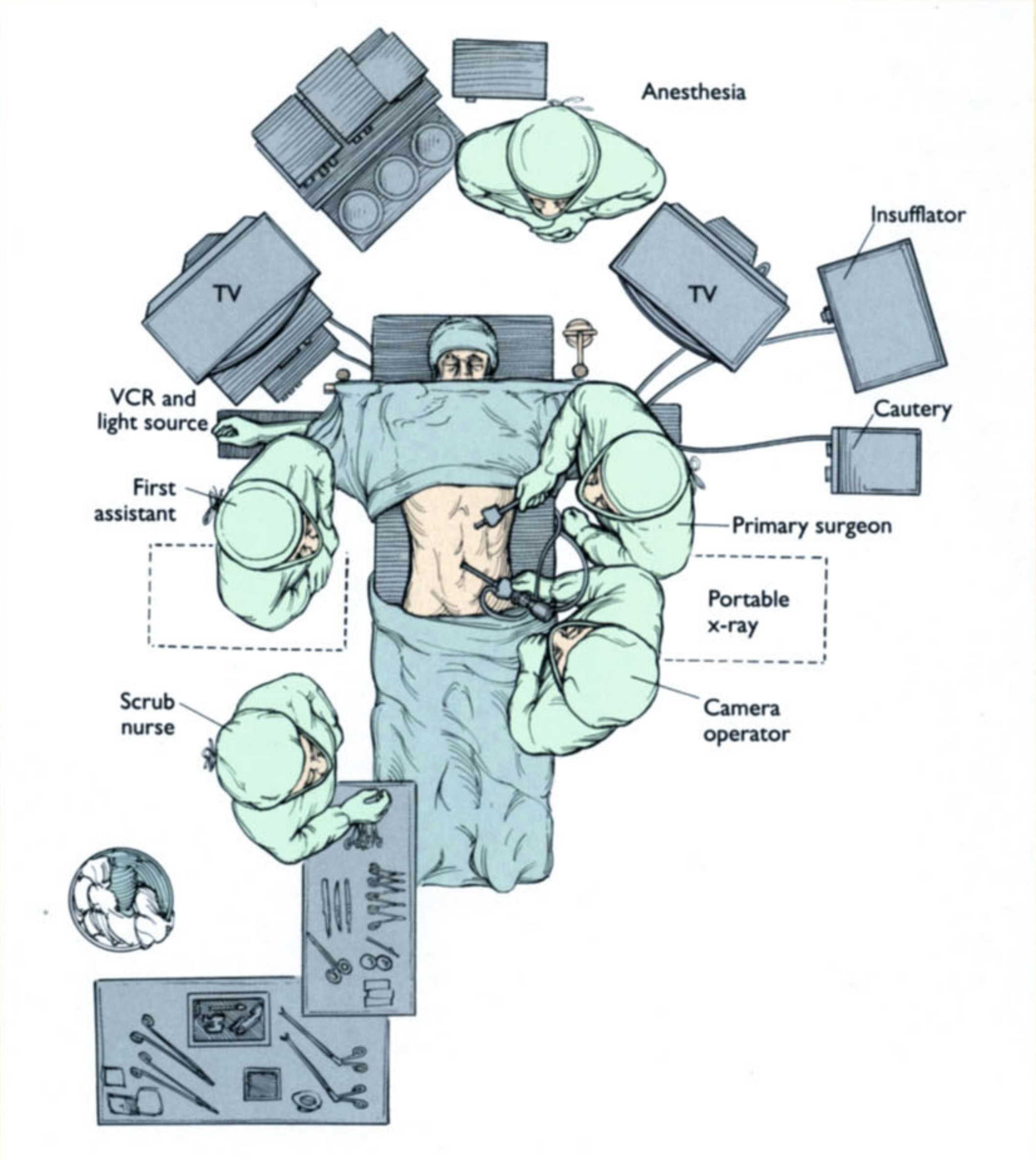


FIGURE 6-1. Operative set-up for laparoscopic cholecystectomy. The use of a separate camera operator is optional as many surgeons prefer to operate the camera with the left hand and use the right hand for instrument manipulation. A preoperative dose of antibiotic, usually a first-generation cephalosporin, is administered prior to induction. Foley and nasogastric catheters are placed after induction of general anesthesia.

Set-up

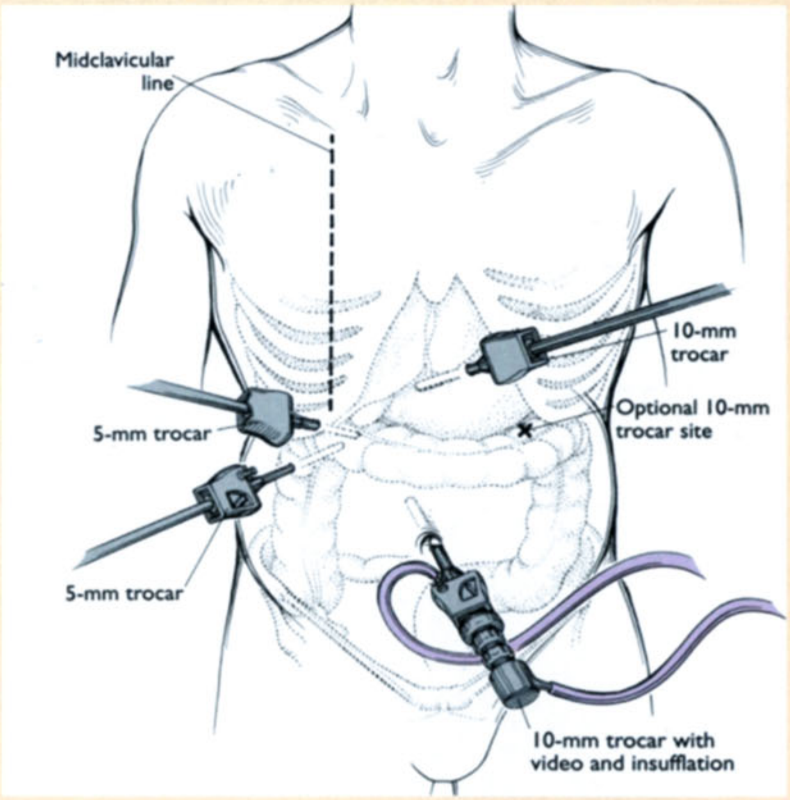


FIGURE 6-2.

The patient is placed in a 30° Trendelenburg position with arms extended. Access to the peritoneal cavity is gained infraumbilically using a 10-mm sheath via a closed (Veress needle) or open (Hasson trocar) technique. Following insufflation with carbon dioxide to 15 mm Hg, the laparoscope is inserted and the peritoneal cavity inspected. The patient is then shifted to a reverse Trendelenburg position and rolled toward the left to allow better visualization of the gallbladder and surrounding structures. Two right subcostal 5-mm trocars and an epigastric 10-mm trocar are then placed under laparoscopic direction. Occasionally, a fifth trocar is placed in the left subcostal position for retraction allowing better visualization of hilar structures.

Procedure

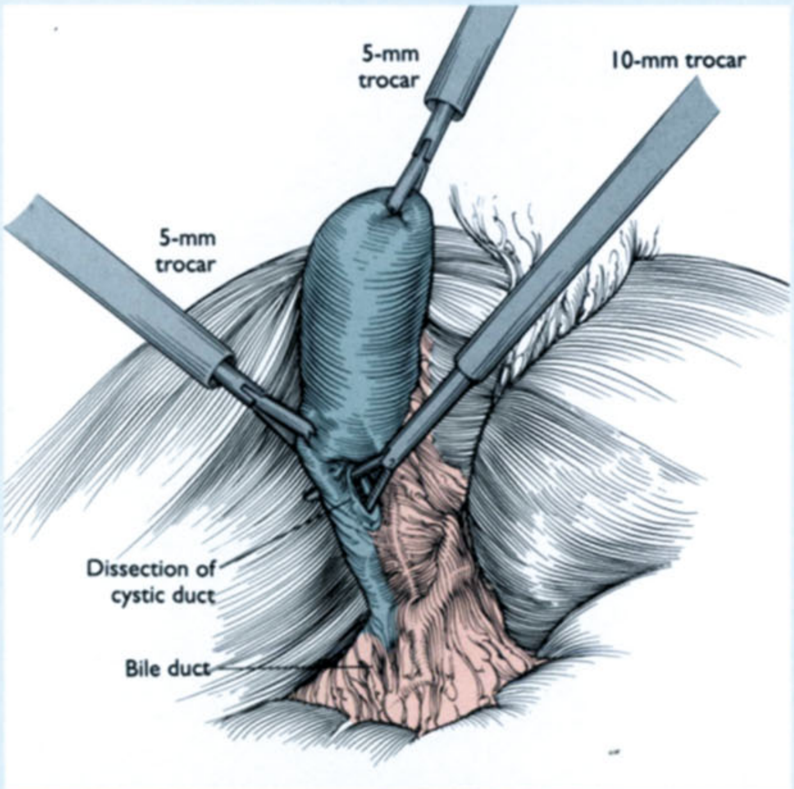


FIGURE 6-3.

With traction on the fundus of the gallbladder in a cephalad direction and on the infundibulum inferolaterally to the right, the cystic duct is placed on tension at a right angle to the common bile duct, minimizing the chance of confusing the two. The dissection is then begun in a right to left direction and the cystic duct identified and dissected thoroughly enough to be positive about its identity.

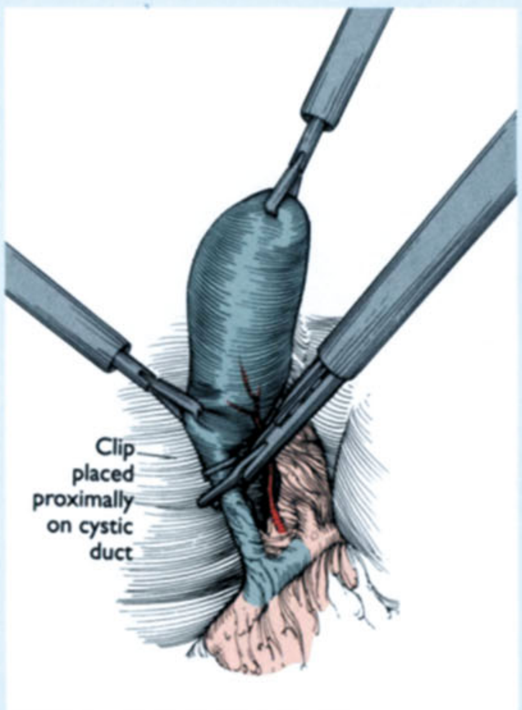


FIGURE 6-4.

Once the cystic duct has been dissected and identified with confidence, it is occluded with a clip at the gallbladder end.

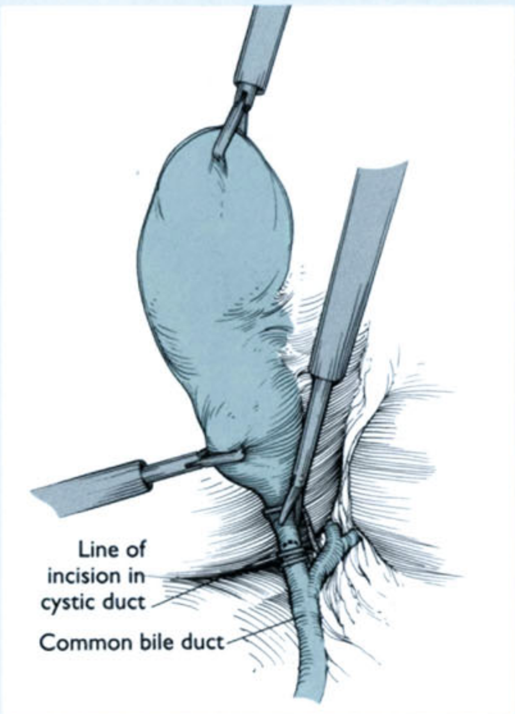


FIGURE 6-5.

At this point a cholangiogram is performed if indicated. Two clips are then placed on the common duct end of the cystic duct and it is divided with scissors.

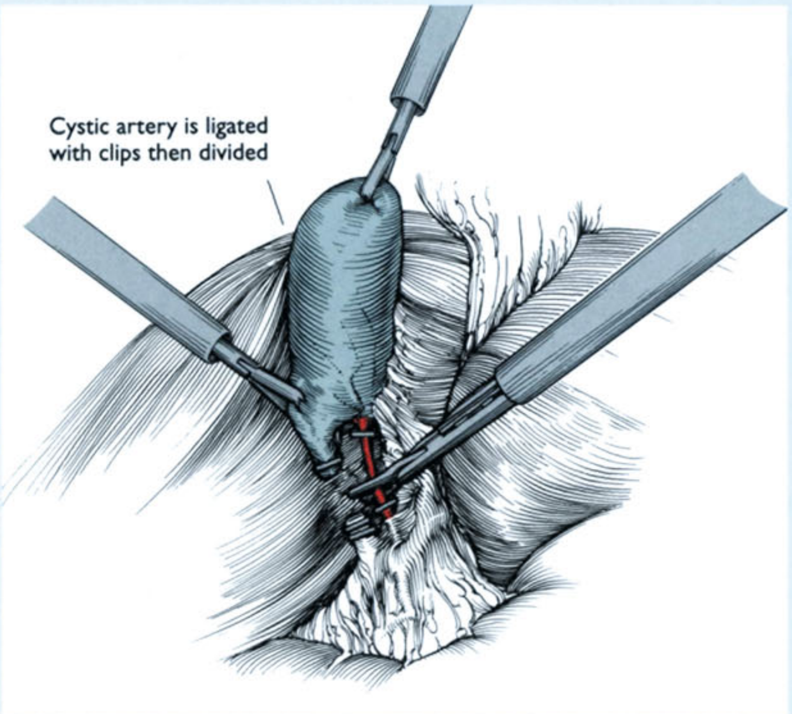


FIGURE 6-6.

Once the cystic duct has been divided the dissection is continued toward the left, and the cystic artery is identified. This is divided between three clips in similar fashion.

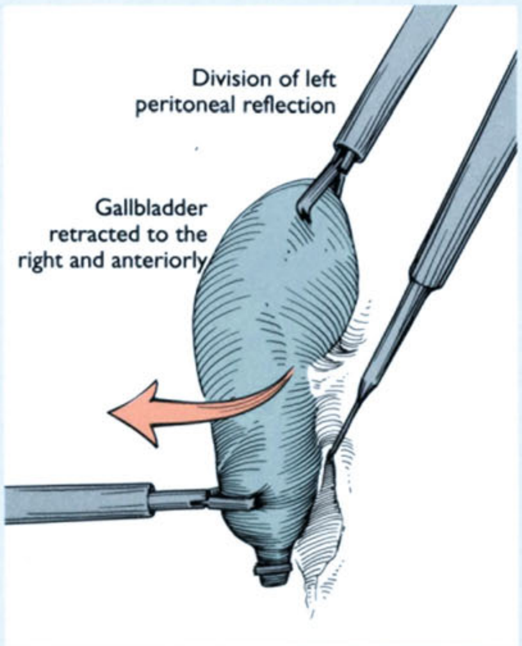


FIGURE 6-7.

The neck of the gallbladder is then rolled to the right to place the peritoneal reflection along the left margin of the gallbladder on tension. Anterior tension also greatly assists in this portion of the dissection. The peritoneal reflection is then divided using a hook cautery instrument.

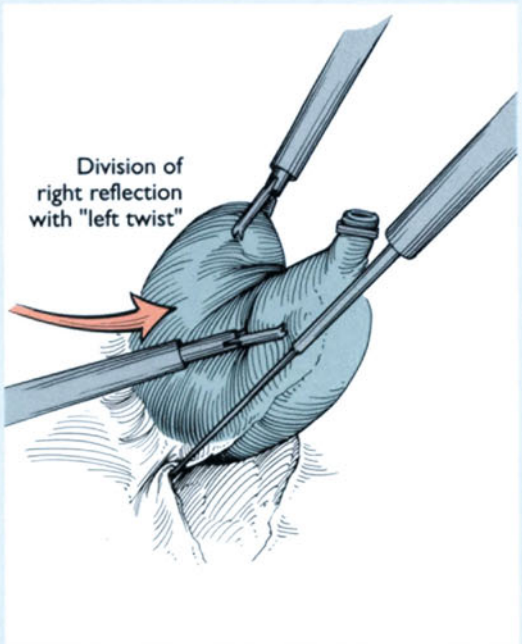


FIGURE 6-8.

In similar fashion, the right peritoneal reflection is divided by using the "left twist" maneuver to place it under adequate tension. Great care must be exercised during this dissection to identify the posterior branch of the cystic artery which occasionally branches off the cystic artery below the site of division. Should this be encountered it is doubly clipped and divided.

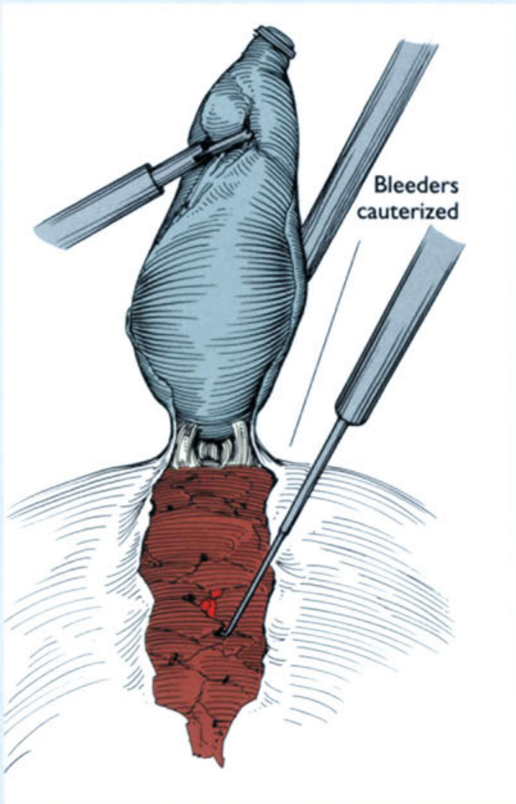


FIGURE 6-9.

With the peritoneal reflections incised, the gallbladder is separated from the liver bed using the cautery, being careful to note any accessory bile ducts entering the gallbladder directly from the liver bed. Any bleeding points are controlled with electrocautery.

Procedure

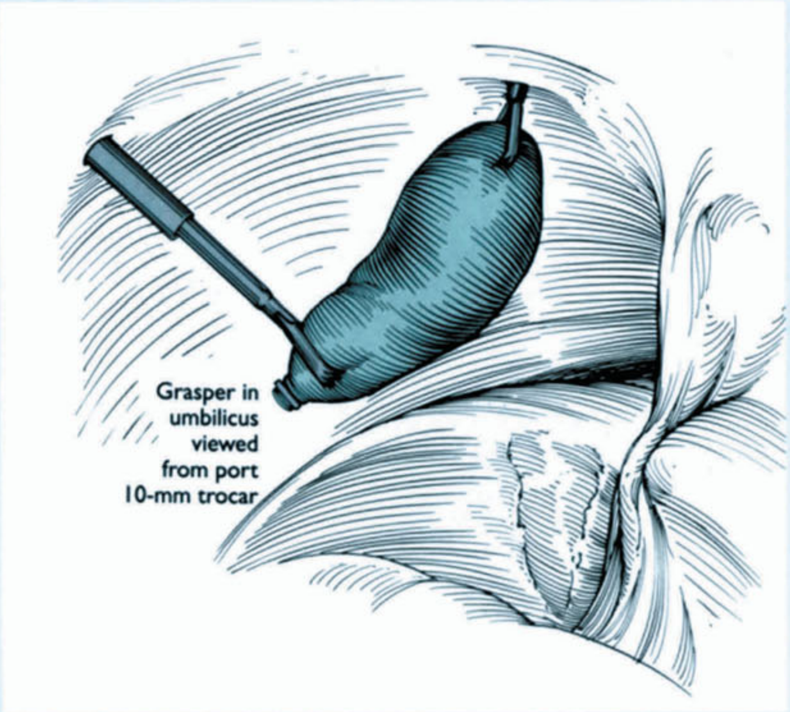


FIGURE 6-10.
After thoroughly irrigating the subhepatic and perihepatic spaces, the gallbladder is suspended by the fundus and the patient returned to a flat position. The laparoscope is shifted to the subxiphoid port and the neck of the gallbladder grasped with the extractor inserted via the umbilical port.

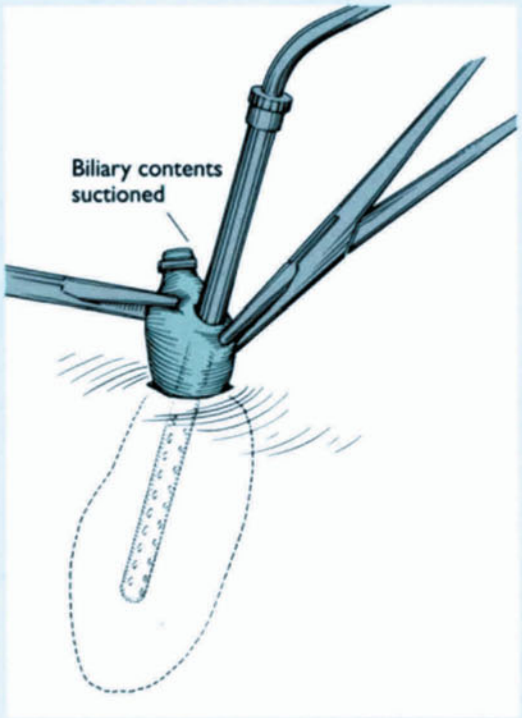


FIGURE 6-11.
The neck of the gallbladder is then retracted through the abdominal wall, simultaneously removing the umbilical port. The laparoscope is directed to the umbilical site to be certain there is no intraperitoneal spillage during the extraction procedure. The gallbladder neck is then incised and bilious contents suctioned.

Alternative Procedure

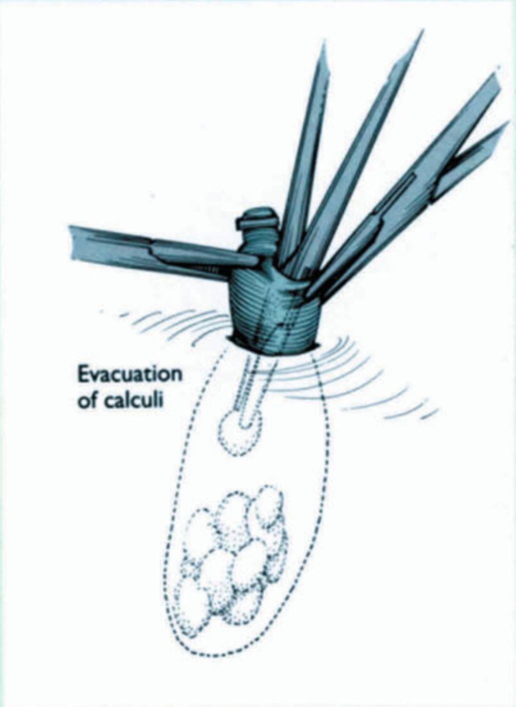


FIGURE 6-12.
Should the gallbladder prove too bulky to extract via the umbilical incision, it is evacuated of calculi. If the thickened gallbladder is still too large the fascial defect is enlarged to allow for its removal.

Results

Death is rare following laparoscopic cholecystectomy and is usually secondary to unrelated events (Table 6-4). The rates of conversion to an open procedure range from 1.8% to 8.5% and generally decrease with increasing operator experience. Major complications such as bile duct injury or injury to other abdominal viscera have been relatively rare and also appear to relate to the experience of the operating surgeon.

The conclusion of the National Institute of Diabetes and Digestive and Kidney Diseases Consensus Development Conference was that laparoscopic cholecystectomy has become the treatment of choice for many patients, providing the advantages of decreased pain and disability and, potentially, substantially reduced cost. It has been estimated that approximately 85% of the more than 500,000 patients undergoing cholecystectomy annually are appropriate candidates for laparoscopic technique.

Table 6-4. Results of laparoscopic cholecystectomy

Author and study	Number	Open, %	Mortality, %	Major complications, %	Bile duct injury, %
The Southern Surgeons Club [2]	1518	4.7	0.07	1.5	0.5
Cuscheri and coworkers [3]	1236	3.6	0.00	1.6	0.3
Soper and coworkers [4]	618	2.9	0.00	1.6	0.2
Spaw and coworkers [5]	500	1.8	0.00	1.0	0.0
Wolfe and coworkers [6]	381	3.0	0.90	3.4	0.0
Bailey and coworkers [7]	375	5.0	0.30	0.6	0.3
Graves and coworkers [8]	304	6.9	0.00	0.7	0.3
Peters and coworkers [9]	283	2.8	0.00	2.1	0.4
Schirmer and coworkers [10]	152	8.5	0.00	4.0	0.7

References

1. Bobbs J: Case of lithotomy of the gallbladder. *Trans Ind State Med Soc* 1868, 18:68.
2. The Southern Surgeon's Club: A prospective analysis of 1518 laparoscopic cholecystectomies. *N Engl J Med* 1991, 324:1073–1078.
3. Cuscheri A, Dubois F, *et al.*: The European experience with laparoscopic cholecystectomy. *Am J Surg* 1991, 161:385–387.
4. Soper N, Stockman P, Dunnegan D, Ashley S: Laparoscopic cholecystectomy: the new "gold standard"? *Arch Surg* 1992, 127:917–921.
5. Spaw A, Reddick E, Olsen D: Laparoscopic laser cholecystectomy: analysis of 500 procedures. *Surg Laparosc Endosc* 1991, 1:2–7.
6. Wolfe B, Gardiner B, Leary B, Frey C: Endoscopic cholecystectomy: an analysis of complications. *Arch Surg* 1991, 126:1192–1196.
7. Bailey R, Zucker K, Flowers J, *et al.*: Laparoscopic cholecystectomy: experience with 375 consecutive patients. *Ann Surg* 1991, 214:531–540.
8. Graves H, Ballinger J, Anderson W: Appraisal of laparoscopic cholecystectomy. *Ann Surg* 1991, 213:655–662.
9. Peters J, Gibbons G, Innes J, *et al*: Complications of laparoscopic cholecystectomy. *Surgery* 1991, 110:769–778.
10. Schirmer B, Edge S, Dix J, *et al*: Laparoscopic cholecystectomy: treatment of choice for symptomatic cholelithiasis. *Ann Surg* 1991, 213:665–676.

CHAPTER

7

Laparoscopic Cholangiography

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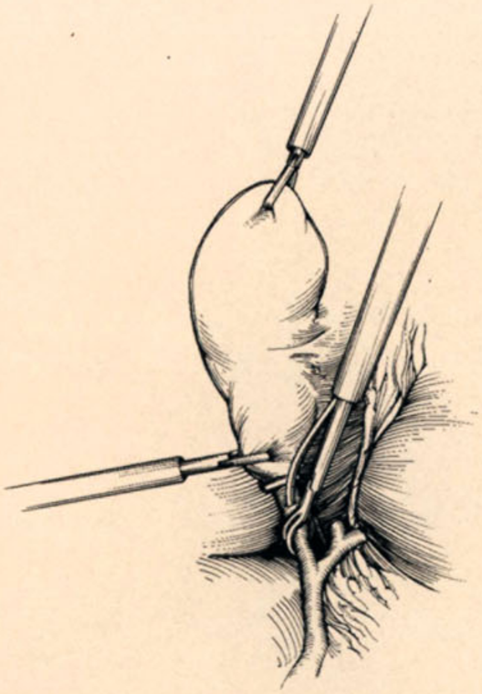
Theodore N. Pappas



Gallstones were first described by Alexander Trallianus, a Greek physician in the fifth century [1]. It was not until the early 1600s that their pathologic significance became known when Francis Glisson related from personal experience the symptoms of biliary colic followed by icterus, and provided accounts of the expulsion of stones through the intestinal tract. The first surgical treatment described was in 1676 when Joenisius extracted gallstones from a biliary fistula of the abdominal wall following spontaneous drainage of an abscess. In the mid 1700s, Jean Louis Petit advocated percutaneous cholecystostomy in cases where the gallbladder had become adherent to the abdominal wall. But it was John Bobbs of Indianapolis in 1867 who performed the first elective open cholecystostomy on a patient who, during exploration for an abdominal mass, was found to have hydrops of the gallbladder [2]. In 1882 Carl Langenbuch [3] of Berlin performed the first human cholecystectomy in a 43-year-old patient with a 16-year history of biliary colic. Langenbuch advocated the procedure for those cases of cholelithiasis and cholecystitis "in which both the patient and the physician have reached the end of their patience" [3]. The practical foundation for the development of operative cholangiography (Table 7-1) was provided in 1882 and 1890 by Von Winiwarter and Ludwig Courvosier who successfully treated common duct obstructions via a cholecystenterostomy and choledochotomy, respectively [1].

Twenty-six years after the discovery of radiographs in 1895, the first radiographic imaging study of the biliary tree was performed. The first successful attempt at visualization of the biliary tract was accomplished by Burkhardt and Muller in 1921 by percutaneously injecting an iodinated compound into the gallbladder [2]. At the third Argentine congress of surgery in Buenos Aires in 1931, Pablo Mirizzi [4] introduced the technique and value of intraoperative cholangiography. Mirizzi described injection through the gallbladder, cystic duct, and common bile duct as a means of not only identifying unsuspected stones, but avoiding and recognizing injuries to the ductal system.

The introduction of laparoscopic cholecystectomy by Mouret, a gynecologist from France, and its subsequent popularization by Dubois [5] in Europe and Reddick and Olsen [6] in the United States presented unique challenges and further controversy in the management of choledocholithiasis. The question of when to perform intraoperative cholangiography during laparoscopic cholecystectomy has been addressed by a number of authors [7–22]. Although controversial prior to the era of laparoscopic cholecystectomy [23–39], the increased incidence of ductal injuries during laparoscopic cholecystectomy and refinement of laparoscopic cholangiographic techniques has prompted many to advocate a nonselective approach. The first published description of laparoscopic-guided cholangiography was by Spaw and coworkers [40] in 1991. Successful laparoscopic management of common duct calculi has been subsequently demonstrated by a number of investigators [41–44], reducing the need for endoscopic retrograde cholangiopancreatography in the identification and clearance of these stones.

Table 7-1. Milestones in laparoscopic intraoperative cholangiography

Year	Investigator	Contribution
1882	Carl Langenbuch	First cholecystectomy
1890	Ludwig Courvosier	Removal of common duct stone Treatise on common bile duct obstruction
1895	Roentgen	Discovery of radiographs
1901	Kelling	First laparoscopic abdominal exploration
1911	Jacobaeus	First human laparoscopy series
1918	Reich	First cholangiogram via cutaneous biliary fistula
1921	Burckhardt and Muller	Percutaneous cholecystocholangiography
1931	Pablo Mirizzi	Intraoperative cholangiography
1987	Mouret	First human laparoscopic cholecystectomy
1991	Spaw and coworkers	First published description of laparoscopic cholangiogram

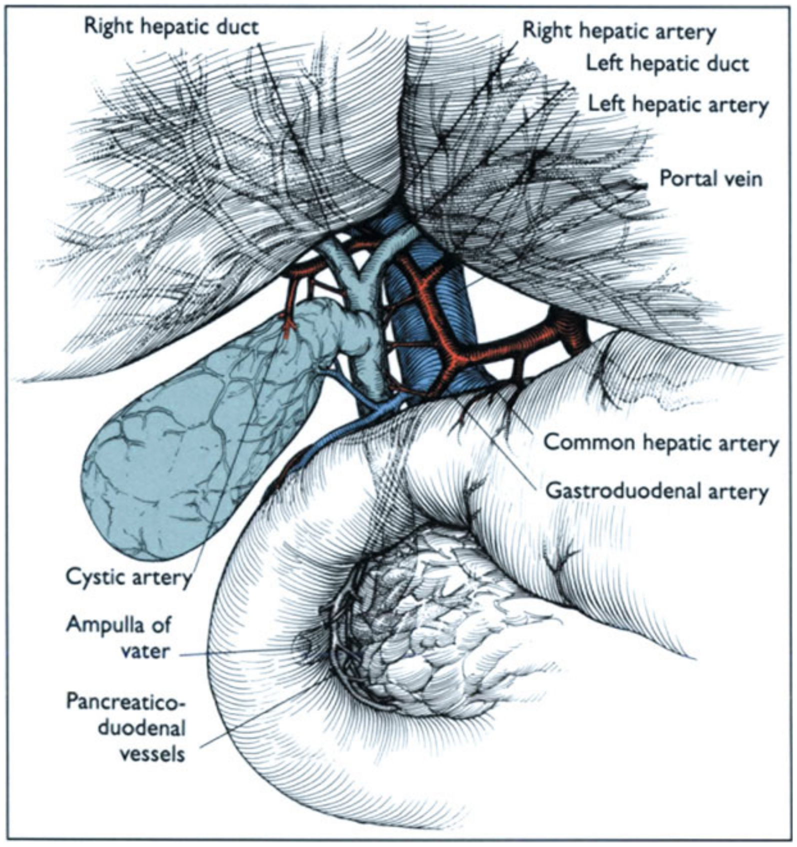


FIGURE 7-1.
Normal anatomy of the biliary system.

Anatomy

Knowledge of the anatomy and common anomolies of the biliary tree and its blood supply is prerequisite in the surgical management of gallstone disease and in the performance of operative cholangiography (Figure 7-1). During the fifth week of gestation, the anlage of the liver, extrahepatic biliary ducts, gallbladder, and ventral part of the pancreas become evident as a ventral diverticulum from the caudal foregut [45]. The cranial sacculation of the diverticulum migrates superiorly and ventrally into the primitive septum transversum (Figure 7-2). This bud eventually forms the left and right lobes of the liver, and its growth superiorly is the mechanism for the formation of the hepatic, common hepatic, and common bile ducts. The caudal sacculation gives rise to the gallbladder and cystic duct. Vacuolization of the solid entodermal cords begins in the seventh week, forming the lumen of these ducts and the gallbladder. At the 7-mm stage, concurrent rotation of both the duodenum and the ventral pancreatic bud occurs with a consequent rotation of the proximal extrahepatic duct leading to the posteromedial insertion of the common bile duct into the duodenum.

The gallbladder is divided into four parts, fundus, body, infundibulum, and neck. Uncommon anomalies (Table 7-2)

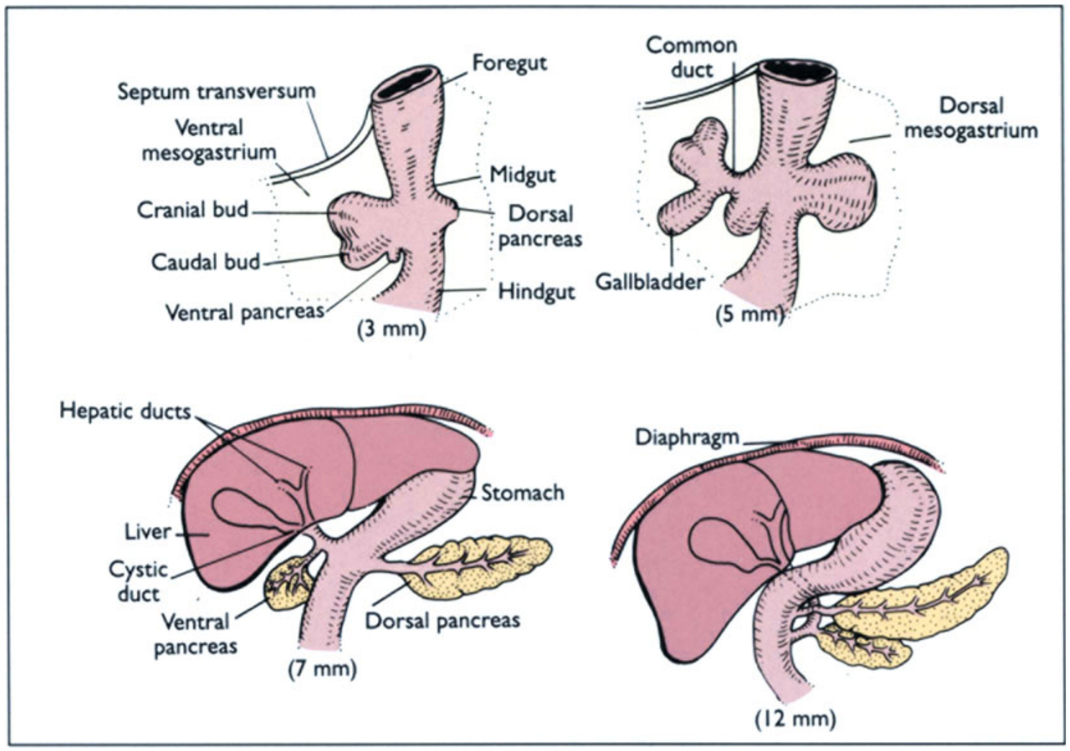


FIGURE 7-2.
Development of the extrahapatic biliary tract in the embryo. (*Adapted from* Lindner and Green [45]; with permission.)

Table 7-2. Anomalies of the extrahepatic biliary tree and vessels of significance during laparoscopic cholecystectomy

Structure	Anomaly
Gallbladder	Agenesis Double gallbladder Phrygian cap Intrahepatic gallbladder Floating gallbladder
Cystic duct	Posterior common duct junction Long parallel course Spiral course (anterior or posterior) Drainage into right hepatic duct
Hepatic ducts	Drainage of right hepatic duct into the cystic duct/gallbladder neck Accessory ducts
Cystic artery	Accessory cystic artery Origin from left hepatic artery Origin from gastroduodenal artery Origin medial to common ducts Short cystic artery
Right hepatic artery	Replaced right hepatic artery Accessory right hepatic arteries

of the gallbladder encountered include agenesis, double gallbladder, and indentation of the fundus giving rise to the Phrygian cap anomaly. The cystic duct leads from the neck of the gallbladder to the common hepatic duct, their confluence forming the common bile duct. The mode of junction of the cystic duct with the common hepatic duct is frequently anomolous [45]. The cystic duct in the majority of cases enters the lateral aspect of the common duct at an acute angle. Recognized variations include entry of the cystic duct into the posterior aspect of the common duct, a parallel junction of varying distance, entry into the right hepatic duct, and spiraling of the duct anterior or posterior to the common duct with a medial insertion (Figure 7-3). The common bile duct is divided into supraduodenal, retroduodenal, pancreatic, and intraduodenal segments for descriptive purposes and varies in length from 5 to 10 cm with an average diameter of 5 mm. The supraduodenal segment runs in the right free border of the hepatoduodenal ligament along with the common hepatic artery to the left and the portal vein dorsally. The pancreatic segment may be entirely retropancreatic or within the parenchyma of the pancreatic head. The intraduodenal common bile duct enters posteromedially into the second portion of the duodenum, emptying via the ampulla of Vater into the duodenal lumen. The right and left hepatic ducts are formed within the liver parenchyma and join just inferior to the porta hepatis to form the common hepatic duct. Anomalies of the hepatic ducts are rare and of two types: 1) drainage of the right hepatic duct, and 2) drainage of both hepatic ducts into the neck of the gallbladder [46]. More commonly found are accessory bile ducts, with an estimated incidence of 10% to 28% [46,47]. These are aberrant ducts draining individual segments of liver and are likely the only route of drainage for their respective segments (Figure 7-4).

The cystic artery arises from the right hepatic artery in over 90% of individuals [48,49]. In 15%, an accessory cystic artery will be present, usually arising from the right hepatic artery. Other points of origin for the cystic artery include the left hepatic and gastroduodenal arteries. Variations in the relation of the cystic artery to the cystic and common ducts are common. In 75% of cases the cystic artery branches from the right hepatic artery in the angle between the common hepatic duct and the cystic duct [50,51]. When arising to the left of the bile ducts, it will in most cases cross anteriorly. In 10% to 15% of cases the cystic artery leaves the right hepatic artery just before that ves-

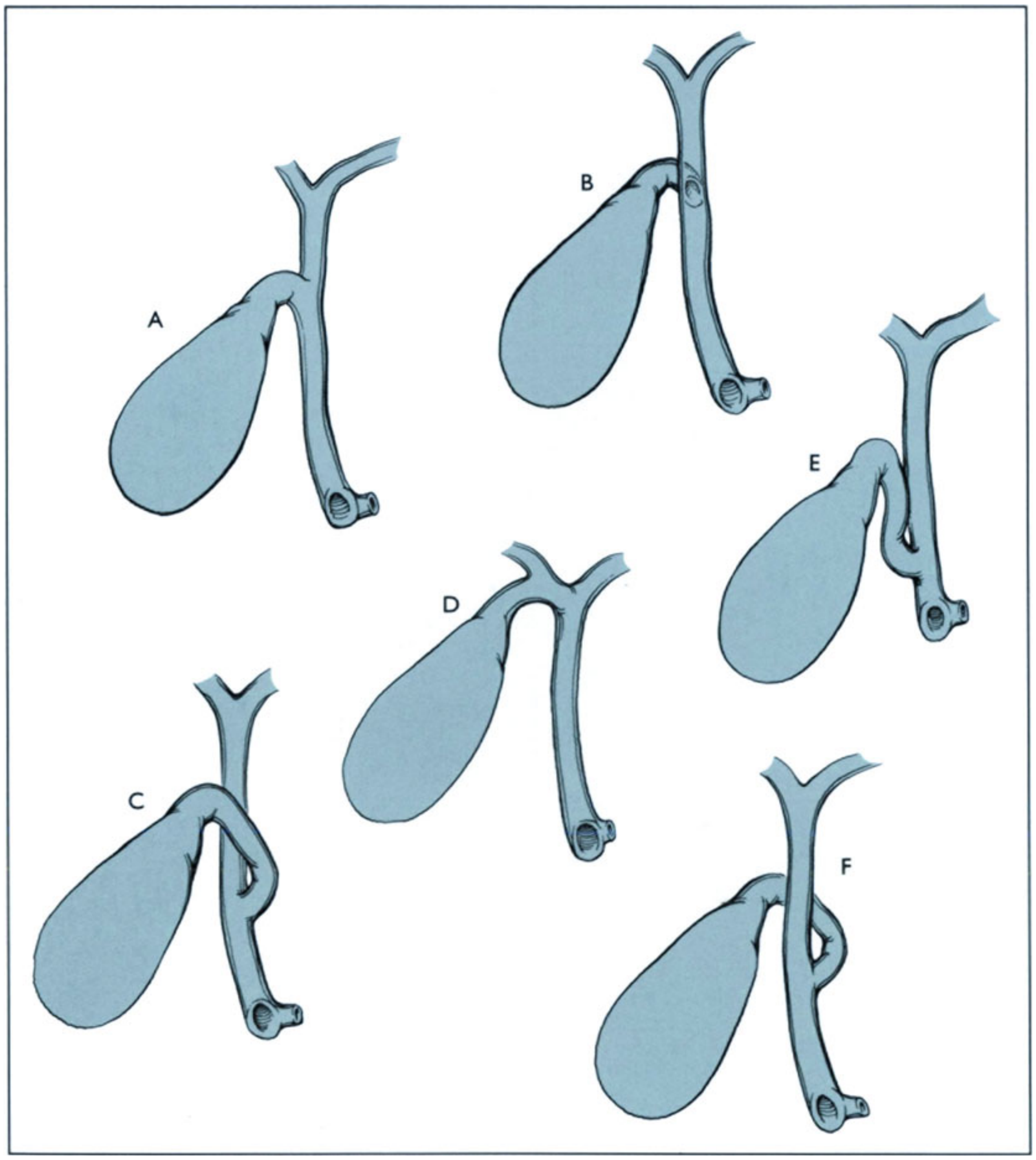


FIGURE 7-3.

Common variations in the anatomy of the cystic duct. **A**, Normal junction of cystic and common ducts. **B**, Posterior junction. **C**, Parallel junction. **D**, Drainage into the right hepatic duct. **E**, Spiral junction crossing anteriorly. **F**, Spiral junction crossing posteriorly.

sel enters the right lobe of the liver. In this instance, the cystic artery is very short and the right hepatic artery may be mistaken for the cystic artery. The right hepatic artery arises from the main hepatic trunk in 80% of cases [49], passing behind the common hepatic duct in the majority of individuals (Figure 7-5). A replaced right hepatic artery is found in 15% to 20% of cases [50]. In all instances reported by Daseler and coworkers [50], the replaced right hepatic arteries were noted to pass posterior to the common bile duct. Accessory right hepatic arteries are present in 5%, most commonly with one artery arising from the hepatic trunk and the other from the superior mesenteric artery. In one third of cases, the accessory right hepatic arteries both arise from the hepatic trunk.

Pathophysiology, Presentation, and Differential Diagnosis

Cholodocholithiasis is present in 8% to 15% of individuals with cholelithiasis. Those stones that form *de novo* within the common ducts are termed primary common duct stones and are usually composed of calcium bilirubinate. Stasis within the duct promotes colonization with enteric bacteria that secrete beta-glucuronidase, an enzyme that deconjugates soluble bilirubin-diglucuronide to form the less soluble compound, bilirubin. This situation may arise with posttraumatic biliary strictures, sclerosing cholangitis, oriental cholangiohepatitis, parasitic infestation, the presence of foreign bodies, and anomalies of the intrahepatic and extrahepatic ducts associated with dilatation. Hemolytic anemias are associated with primary stones, thought to be the result of an increased load of bilirubin presented to the liver. Stones discovered within the common ducts more than 2 years following cholecystectomy are arbitrarily classified as primary duct stones. Secondary stones form within the gallbladder and pass through the cystic duct or a cholecystocholedochal fistula into the choledochus. They are of cholesterol or mixed composition.

The clinical manifestations and therefore presentations of common duct stones are quite variable. Common duct stones may be asymptomatic as is indicated by the incidental finding of stones in 5% to 10% of patients undergoing routine cholangiography during cholecystectomy. Asymptomatic stones are also detected during selective intraoperative cholangiography performed in response to mild liver function elevations and common duct dilatation on preoperative ultrasound. Symptoms, when present, are the result of obstruction and include biliary colic, jaundice, and manifestations of cholangitis. With partial or intermittent obstruction, pruritis, intermittent jaundice, and episodic abdominal pain may be present. With greater degrees of obstruction, the patient experiences biliary colic and jaundice, and if infection occurs, fever and chills. Evidence of septic shock indicates the presence of infected bile under pressure within the ducts. Laboratory studies in patients with cholangitis include an elevated leukocyte count and increased alkaline phosphatase and bilirubin levels.

Diagnosis and Indications for Intraoperative Cholangiography

Cholangiography in the diagnosis or confirmation of a common duct stone can be performed intraoperatively, endoscopically, and percutaneously via a transhepatic approach. Techniques for the removal of stones identified are also available with each modality. The indications for intraoperative laparoscopic cholangiography (Table 7-3) are controversial. Many advocate routine performance of operative cholangiography citing the increased incidence of bile duct injuries during laparoscopic cholecystectomy and the loss of tactile perception in assessing the ducts [8,9,11,13,17, 18,20,22,52]. This approach allows for the identification of unsuspected stones and the delineation of the anatomy prior to dissection. We and others [7,12,14,15,21] prefer a selective approach toward laparoscopic cholangiography. These studies have shown that laparoscopic cholecystectomy can be performed safely without performing routine cholangiography. The available literature and our experience do not

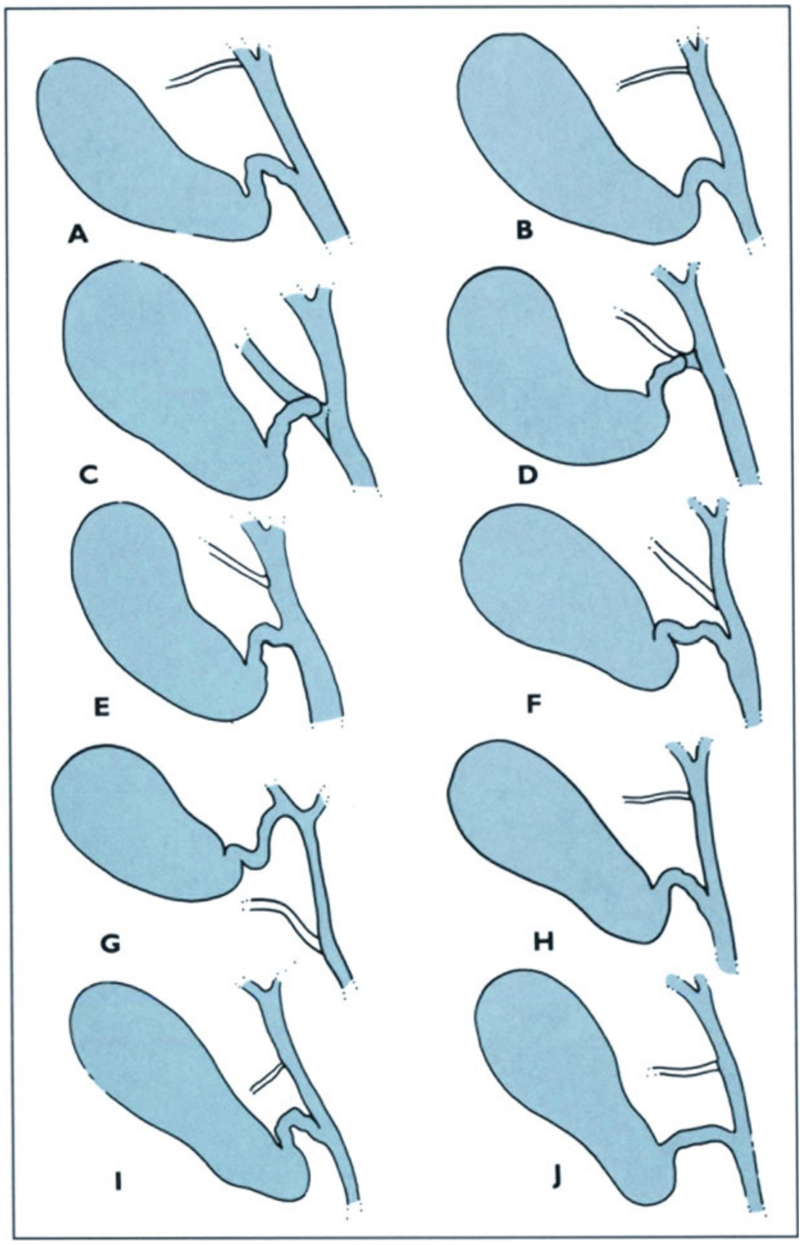


FIGURE 7-4.
A through **J**. Types of accessory hepatic ducts.

support the argument that routine cholangiography leads to a reduction in the clinical syndrome of retained common duct stones. Flowers and coworkers [8], in a review of 364 laparoscopic cholecystectomies, reported retained stones in two of 199 (1.0%) patients in whom cholangiography was not attempted, and in one of 165 (0.6%) patients undergoing attempted cholangiography. A review by the authors of the Duke experience with selective cholangiography during laparoscopic cholangiography has noted retained stones in 2.1% of patients (Unpublished data). In a prospective study by Clair and coworkers [7], of 514 patients undergoing laparoscopic cholecystectomy, retained stones were noted in four of 453 (0.9%) patients deemed low risk for choledocholithiasis in whom cholangiography was not performed. The avoidance of bile duct injuries through the use of routine cholangiography during laparoscopic cholecystectomy is unsupported by the literature as well. Large reviews suggest that the main contributing factor leading to bile duct injuries is inexperience of the operating surgeon [53]. In studies addressing the role of cholangiography, the incidence of bile duct injuries in patients undergoing laparoscopic cholecystectomy using a selective approach toward chlolangiography ranges from 0% to 0.5% [7,12,14]. Thus, it is apparent that selective cholangiography can be performed with no clear increase in retained stones or bile duct injuries.

Described in the following section is the technique of transcystic cholangiography. In addition, the technique of cholecystocholangiography is detailed as an alternative. The reported advantages of this method include simplicity, speed, and the delineation of the anatomy prior to dissection of the cystic duct [22,54,55]. Arguments against this technique including the potential to force stones out of the gallbladder and into the common bile duct and decreased reliability are not supported by the relatively small body of literature currently available.

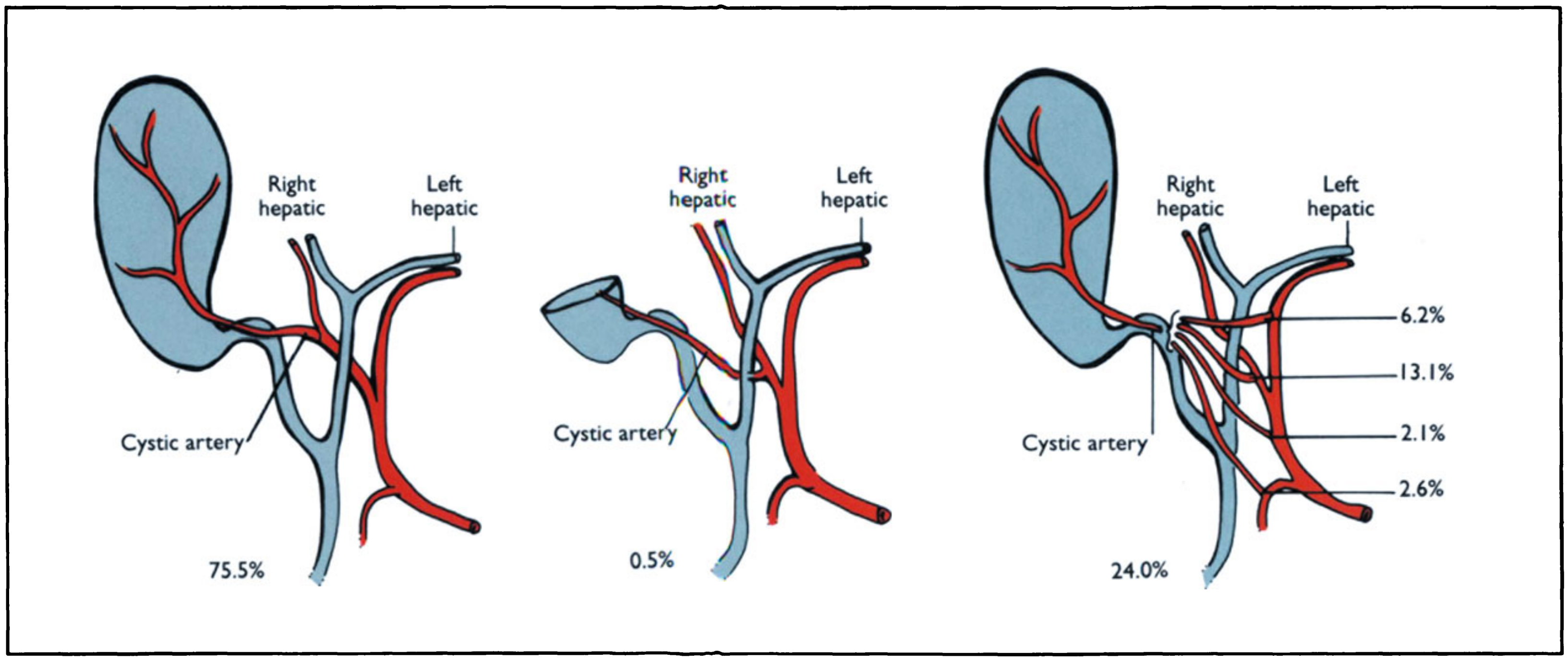


FIGURE 7-5.
Variations in the origin and course of the cystic artery. (*Adapted from* Anderson [51]; with permission.)

Table 7-3. Indications for cholangiography

Routine	Radiographic evidence of common duct stones
Uncertain anatomy	Dilated cystic duct
Abnormal liver function tests	Pancreatitis
Dilated common bile duct	Cholangitis
Jaundice	Single faceted stones (during open cholecystectomy)
Multiple small stones in gallbladder	Maintenance of surgical skills

sel enters the right lobe of the liver. In this instance, the cystic artery is very short and the right hepatic artery may be mistaken for the cystic artery. The right hepatic artery arises from the main hepatic trunk in 80% of cases [49], passing behind the common hepatic duct in the majority of individuals (Figure 7-5). A replaced right hepatic artery is found in 15% to 20% of cases [50]. In all instances reported by Daseler and coworkers [50], the replaced right hepatic arteries were noted to pass posterior to the common bile duct. Accessory right hepatic arteries are present in 5%, most commonly with one artery arising from the hepatic trunk and the other from the superior mesenteric artery. In one third of cases, the accessory right hepatic arteries both arise from the hepatic trunk.

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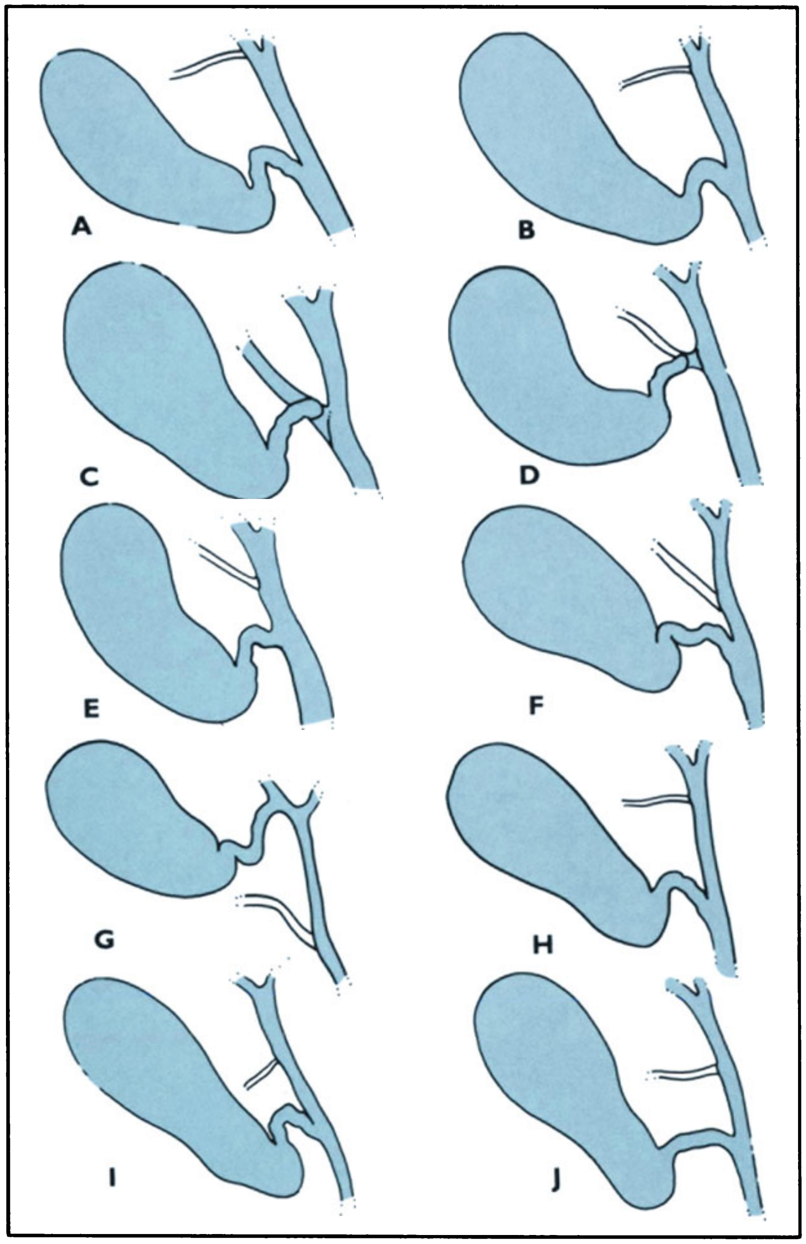

FIGURE 7-4.
A through **J**. Types of accessory hepatic ducts.

support the argument that routine cholangiography leads to a reduction in the clinical syndrome of retained common duct stones. Flowers and coworkers [8], in a review of 364 laparoscopic cholecystectomies, reported retained stones in two of 199 (1.0%) patients in whom cholangiography was not attempted, and in one of 165 (0.6%) patients undergoing attempted cholangiography. A review by the authors of the Duke experience with selective cholangiography during laparoscopic cholangiography has noted retained stones in 2.1% of patients (Unpublished data). In a prospective study by Clair and coworkers [7], of 514 patients undergoing laparoscopic cholecystectomy, retained stones were noted in four of 453 (0.9%) patients deemed low risk for choledocholithiasis in whom cholangiography was not performed. The avoidance of bile duct injuries through the use of routine cholangiography during laparoscopic cholecystectomy is unsupported by the literature as well. Large reviews suggest that the main contributing factor leading to bile duct injuries is inexperience of the operating surgeon [53]. In studies addressing the role of cholangiography, the incidence of bile duct injuries in patients undergoing laparoscopic cholecystectomy using a selective approach toward chlolangiography ranges from 0% to 0.5% [7,12,14]. Thus, it is apparent that selective cholangiography can be performed with no clear increase in retained stones or bile duct injuries.

Described in the following section is the technique of transcystic cholangiography. In addition, the technique of cholecystocholangiography is detailed as an alternative. The reported advantages of this method include simplicity, speed, and the delineation of the anatomy prior to dissection of the cystic duct [22,54,55]. Arguments against this technique including the potential to force stones out of the gallbladder and into the common bile duct and decreased reliability are not supported by the relatively small body of literature currently available.

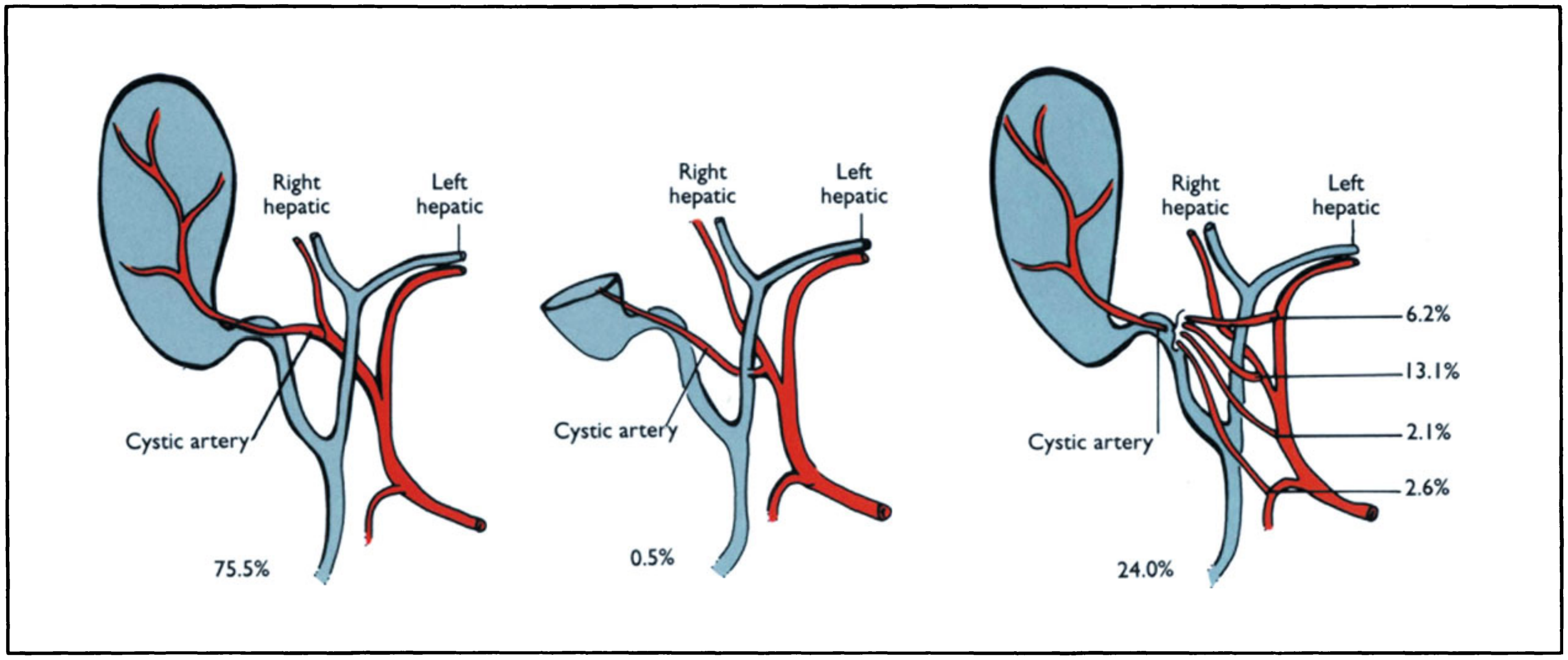

FIGURE 7-5.
Variations in the origin and course of the cystic artery. (*Adapted from* Anderson [51]; with permission.)

Table 7-3. Indications for cholangiography

Routine	Radiographic evidence of common duct stones
Uncertain anatomy	Dilated cystic duct
Abnormal liver function tests	Pancreatitis
Dilated common bile duct	Cholangitis
Jaundice	Single faceted stones (during open cholecystectomy)
Multiple small stones in gallbladder	Maintenance of surgical skills

Surgical Technique

Figures 7-6 through 7-15 depict the surgical technique for transcystic laparoscopic cholangiography.

Set-up

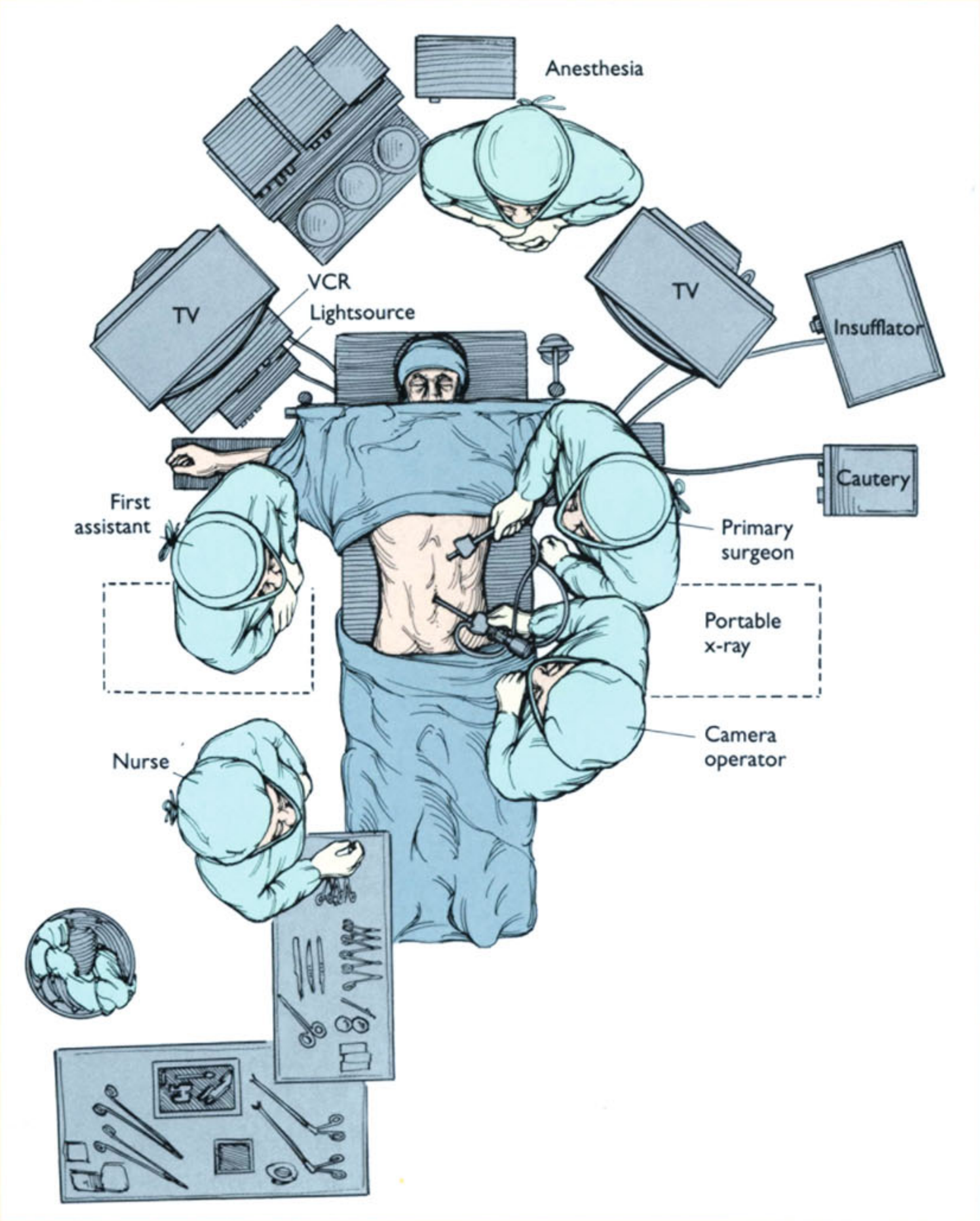

FIGURE 7-6.
The patient is placed supine on the operating table with care taken to remove objects that might obscure visualization of the ducts during cholangiography, including water mattresses. The radiology technician is alerted prior to the beginning of the procedure. As in laparoscopic cholecystectomy, a pneumoperitoneum is established with carbon dioxide insufflation through an infraumbilically placed Veress needle (or alternatively a Hasson trocar if open).

Set-up

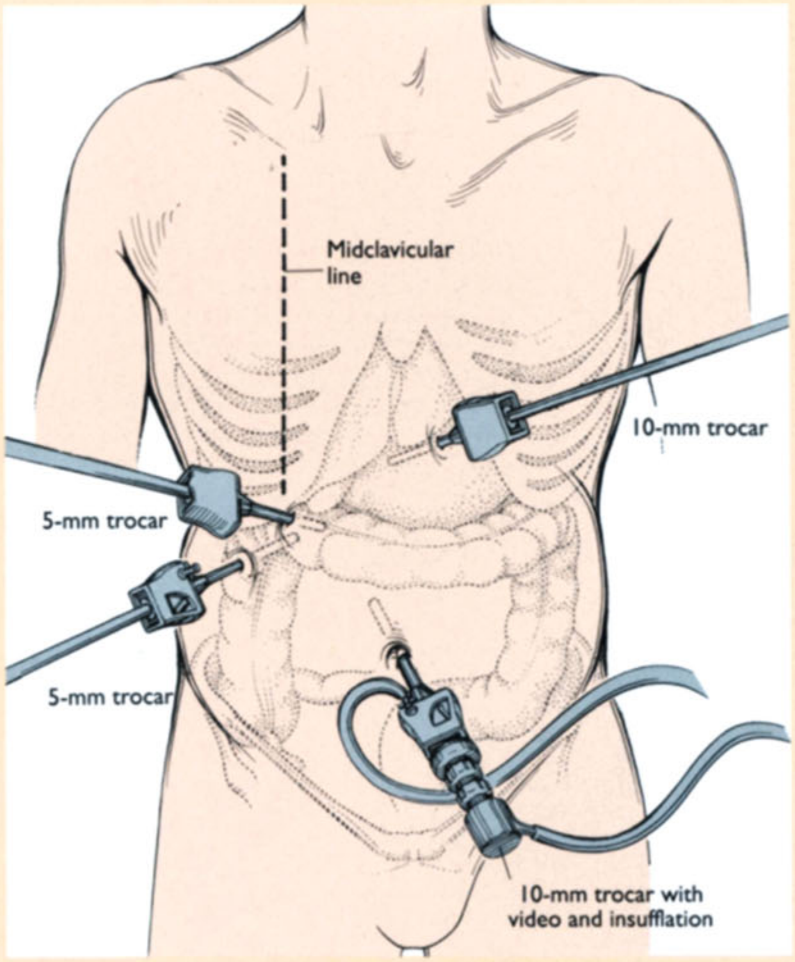

FIGURE 7-7.

Following creation of a pneumoperitoneum, a 10-mm sheath is placed infraumbilically and the laparoscope is inserted. Five-millimeter sheaths are placed in the right upper quadrant as follows: anterior axillary line inferior to the liver edge, and midclavicular between the axillary sheath and xiphoid process. A 10-mm sheath is placed midline approximately 5 cm below the xiphoid process.

Procedure

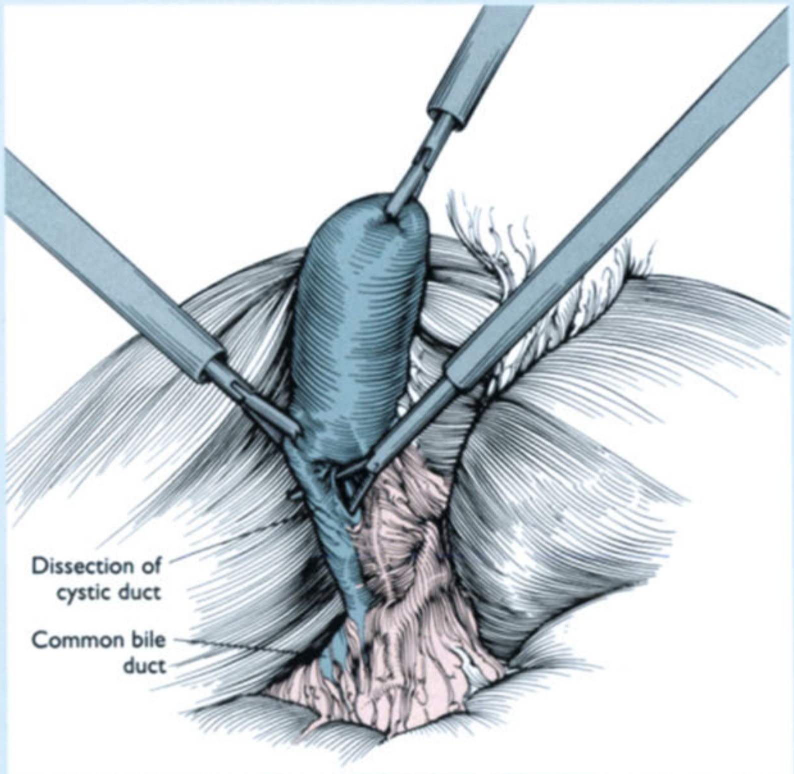

FIGURE 7-8.

Traction of the gallbladder fundus is applied in the cephalad direction with a grasper placed through the midclavicular port. The cystic duct is identified and dissected free. To minimize the risk of common duct injury, the dissection of the cystic duct should always begin at the junction of the infundibulum of the gallbladder and the cystic duct.

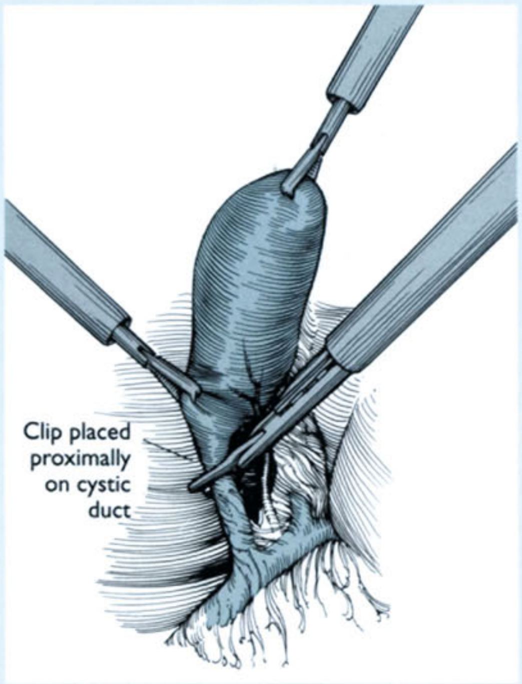

FIGURE 7-9.
The endoscopic clip applier is then passed through the 10-mm epigastric sheath and a single clip placed across the proximal cystic duct to prevent spillage of gallbladder contents into the abdomen. If the anatomy is unclear at this point, the surgeon may omit the placement of this clip.

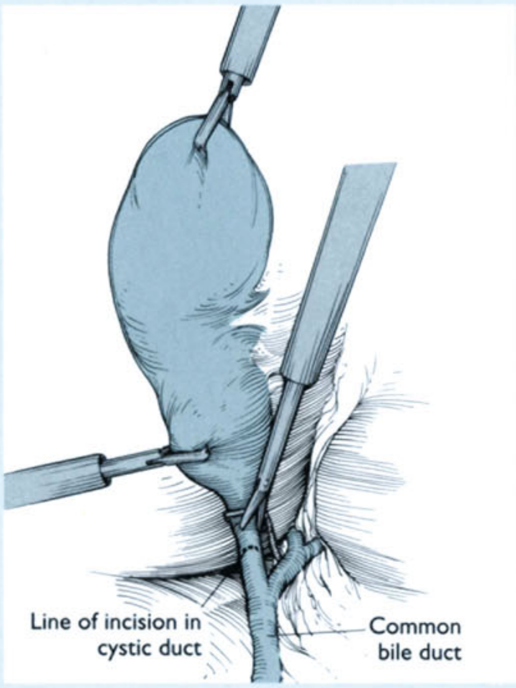

FIGURE 7-10.
Endoscopic scissors are then passed through the epigastric sheath and the cystic duct incised along one half its circumference just distal to the previously placed titanium clip.

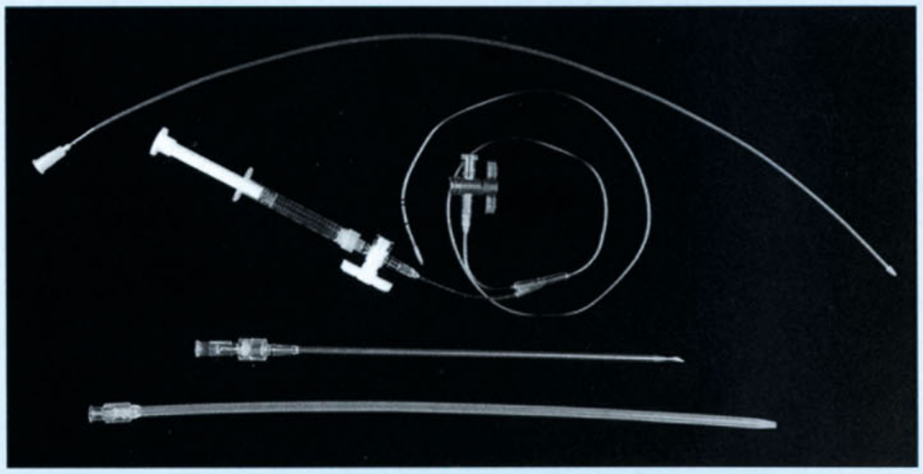

FIGURE 7-11.
Photograph of the Taut (Taut Inc.; Geneva, IL) (*top*) and balloon-tip cholangiocatheters and access cannulas. The authors use a 4-French balloon-tip cholangiocatheter (*second from the top*) passed through an Olsen cholangiogram fixation clamp (Karl Storz Endoscopy-America, Inc.) in performing transcystic cholangiography. Several alternatives exist including the Taut catheter depicted (*top*) as well as standard central venous access catheters and ureteric catheters. Access into the peritoneal cavity can be obtained through one of the existing ports assisted by either a specially designed hollow-core clamp or adapter sheath (*bottom*) designed to minimize the loss of CO_2 or through a separate percutaneous puncture using a 14- or 15-gauge angiocatheter or similar catheter (*second from the bottom*). In the latter case, the puncture site is chosen to afford the optimal angle for catheter guidance into the cystic duct.

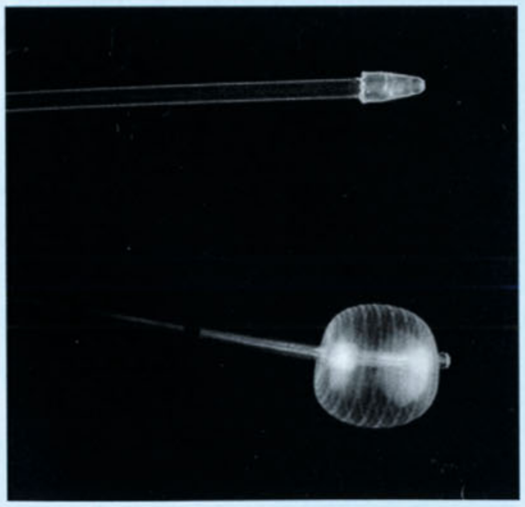

FIGURE 7-12.
Photograph showing the Taut and balloon-tip cholangiocatheter tips.

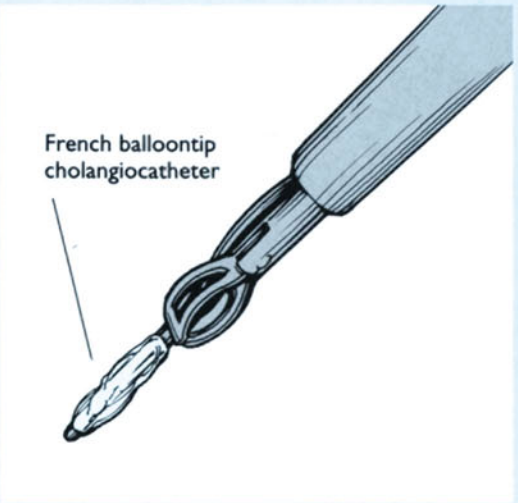

FIGURE 7-13.

The balloon-tip cholangiocatheter is placed through the hollow core of the cholangiography clamp and passed through the epigastric or midclavicular port into the peritoneal cavity. In situations where the retraction provided by forceps in these ports is necessary for adequate exposure, a fifth cannula may be inserted or the cholangiocatheter passed through a percutaneously placed angiocatheter obviating the need for another port.

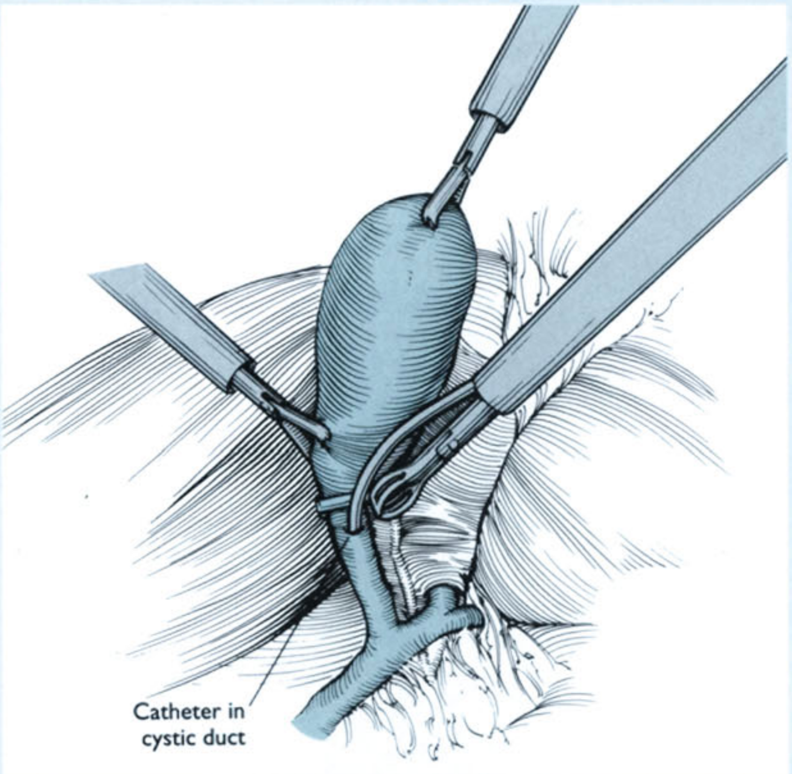

FIGURE 7-14.

The catheter is guided into the partially transected proximal cystic duct. When not using the cholangiogram clamp, the endoscopic grasper may be used in maneuvering the catheter. If difficulty is encountered in passing the catheter into the duct, a guidewire passed through the cholangiocatheter into the duct may facilitate this step. The catheter is inserted 4 to 5 mm.

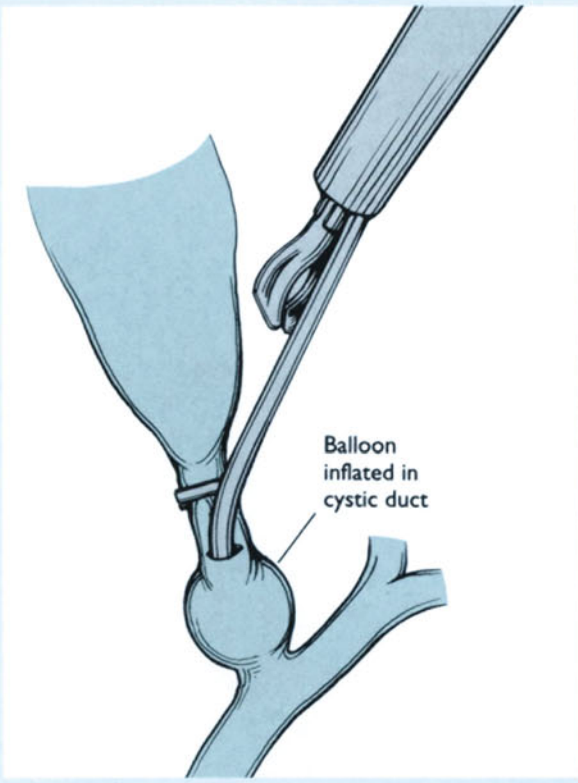

FIGURE 7-15.

The balloon is then inflated to secure the positioning of the catheter and prevent extravasation of contrast when injected. Prior to infusion of contrast, the laparoscope is removed from the abdomen and care taken to ensure that all radioopaque objects are removed from the radiographic field. Ten cc of half-strength Renografin (Sanofi-Winthrop, New York, NY) are then infused via the catheter and the radiograph obtained during infusion. Care must be taken to ensure that the tip does not migrate into the common bile duct, which will produce a cholangiogram with no retrograde flow. In the case of a cystic duct that is tightly adherent to the common bile duct, inflation of the balloon within the cystic duct may cause an indentation in the wall of the common duct, giving the false impression of a stone. Many institutions advocate the use of digital fluoroscopy in place of standard radiography.

Alternative Technique

Figures 7-16 through 7-28 depict the alternative technique of cholecystocholangiography.

Alternative Procedure

FIGURE 7-16.
Alternative number one. A standard nonballoon-tip catheter may be used alternatively in conjunction with the cholangiography clamp.

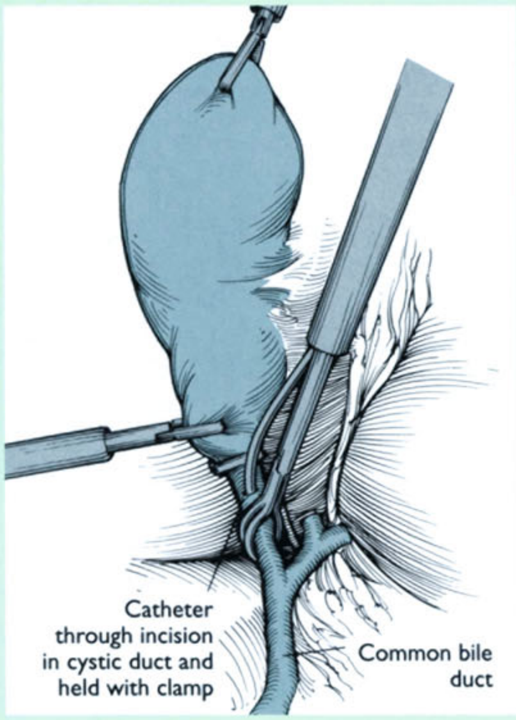

FIGURE 7-17.
Alternative number one. The catheter is guided into the cystic duct and its position is then secured with the clamp and the contrast infused as outlined in Figure 7-15.

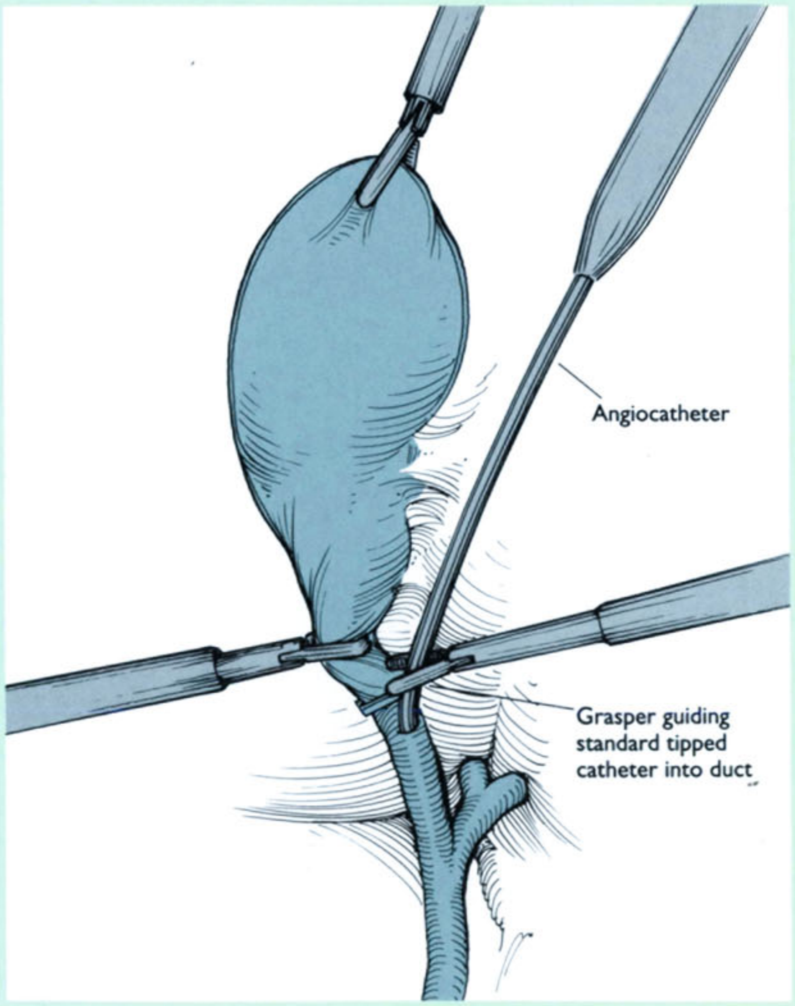

FIGURE 7-18.
Alternative number two. The standard-tip catheter is passed percutaneously through the anterior abdominal wall into the peritoneal cavity and guided toward the cystic duct using the endoscopic graspers. The catheter is inserted into the partially transected proximal cystic duct and secured into place by the application of a clip onto the cystic duct. The contrast is infused and the radiograph obtained as outlined in Figure 7-15.

Alternative Procedure

FIGURE 7-19.
Photograph of properly performed cystic duct cholangiogram.

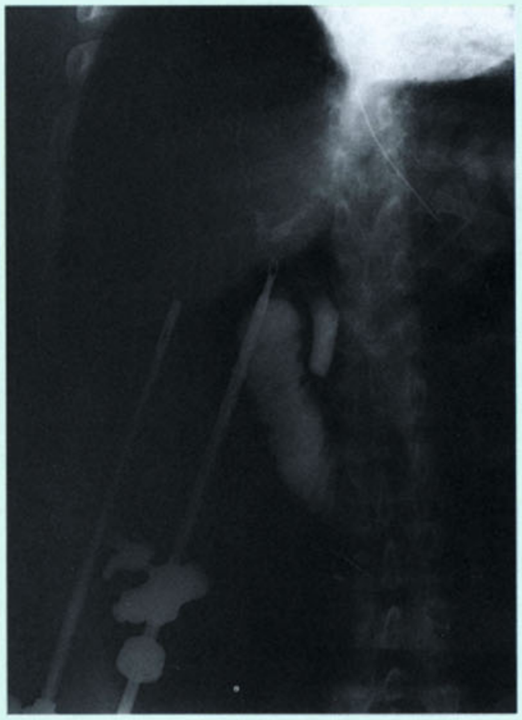

FIGURE 7-20.
Photograph of inadequate cystic duct cholangiogram.

FIGURE 7-21.
Photograph of cystic duct cholangiogram with stones.

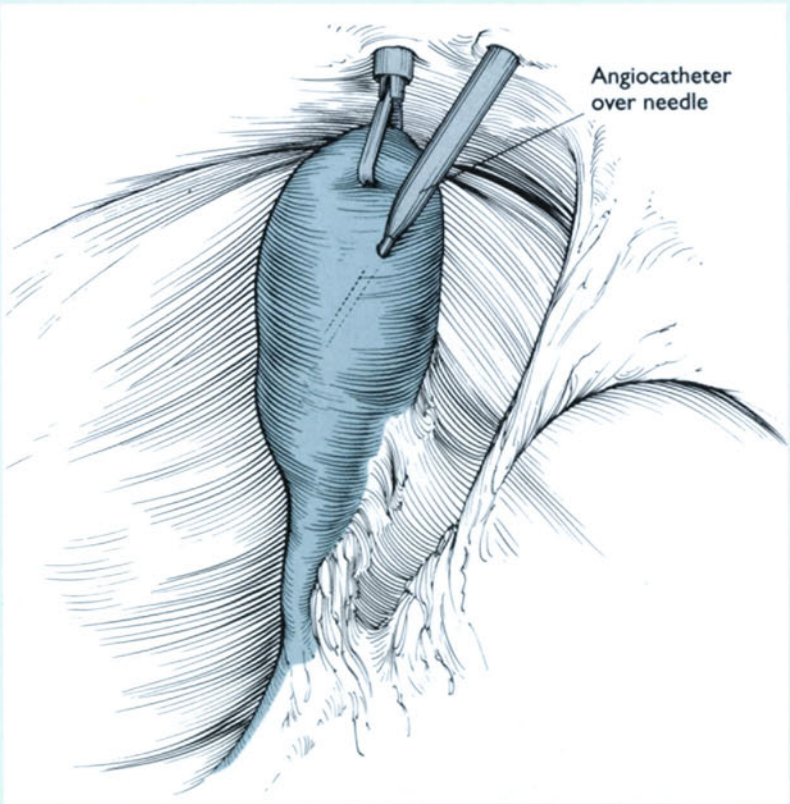

FIGURE 7-22.
An alternative to transcystic cholangiography is cholecystocholangiography. Following insufflation and insertion of the sheaths, the fundus is retracted anteriorly to the abdominal wall by an endoscopic grasper placed through the midclavicular sheath. A 14-gauge, 6-inch angiocatheter is then placed percutaneously into the gallbladder fundus under direct visualization.

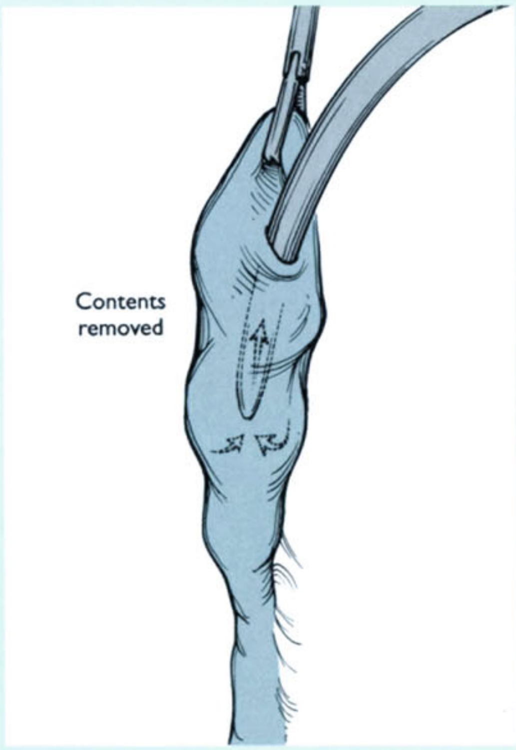

FIGURE 7-23.
The needle is withdrawn leaving the sheath intraluminal and the contents of the gallbladder aspirated.

Alternative Procedure

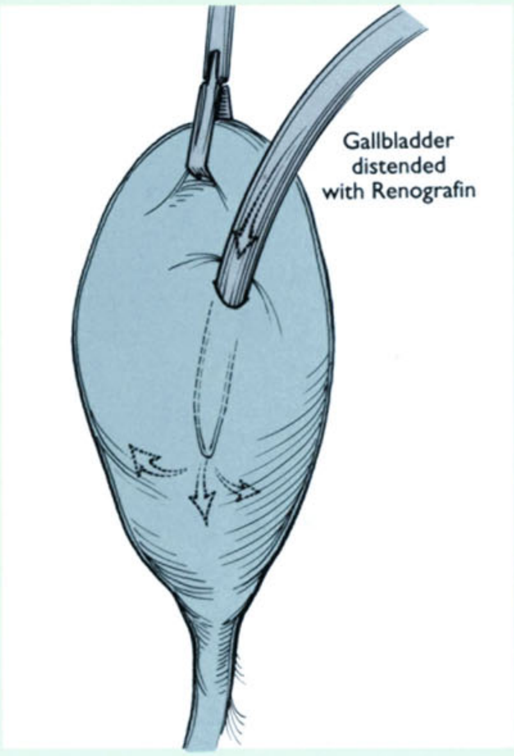

FIGURE 7-24.
Full-strength Renografin is then placed into the gallbladder via the angiocatheter with a total volume equal to the volume of contents aspirated plus 30 cc.

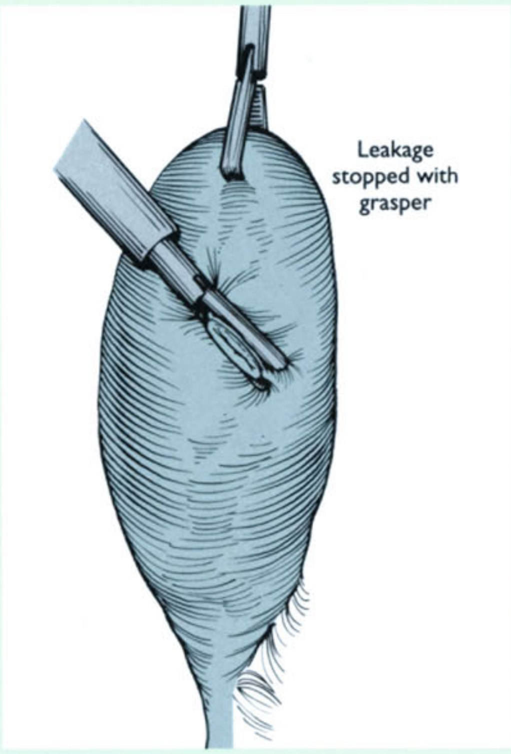

FIGURE 7-25.
The catheter is then withdrawn and its insertion site in the fundus grasped with an endoscopic grasper placed via the axillary sheath to prevent spillage of contrast. Cephalad retraction with this grasper is maintained and the radiograph obtained.

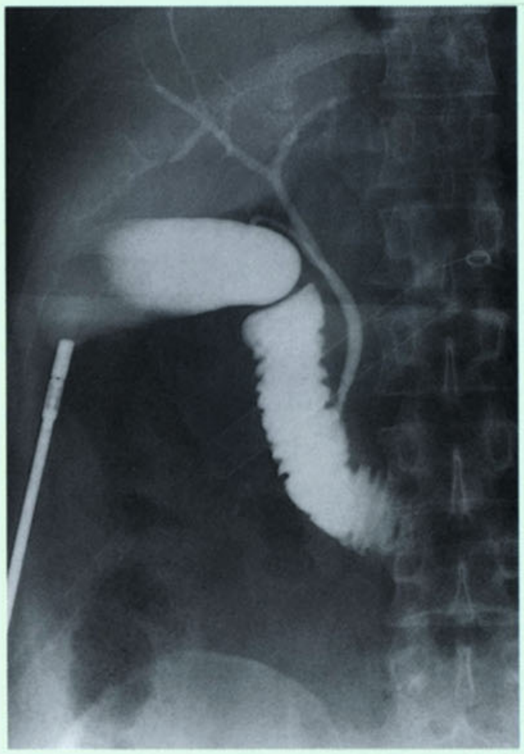

FIGURE 7-26.
Photograph of normal cholecystocholangiogram.

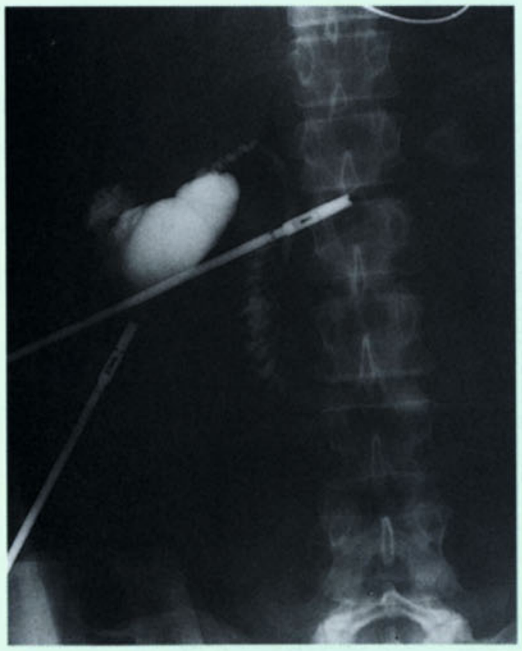

FIGURE 7-27.
Photograph of inadequate cholecystocholangiogram.

FIGURE 7-28.
Photograph of cholecystocholangiogram with stones.

Table 7-4. Laparoscopic cholangiography series

Study	Indication	Route	Patients, n	Attempted, n	Success, %	Cholangiography associated injuries, n	Abnormal, %*	Positive stones, n	Abnormal anatomy, n	False positive, %	Unsuspected stones, %*	Retained stones, %
Flowers and coworkers [8]	Routine/ selective	Cystic duct	384	165	91	NR	11.0	5	4	2	2.6	0.8
Van Campenhount and coworkers [9]	Routine	Cystic duct	107	107	71	NR	24.0	10	8	NR	10.5	0
Sackier and coworkers [17]	Routine	Cystic duct	516	489	94.9	2	15.7	35	34	2.7	NR	0
Phillips and coworkers [18]	Routine	Cystic duct	58	58	92	0	18.9	6	5	0	9	0
Bruhn and coworkers [52]	Routine	Cystic duct	100	99	89.9	0	10.1	3	6	3.4	3.4	0
Soper and Dunnegan [12]	Randomized	Cystic duct	115	56	94.6	0	8.9	2	3	0	3.6	0
Clair and coworkers [7]	Selective	Cystic duct	514	36	83	0	NR	1	NR	0	NR	0.8
Pietrafittra and coworkers [54]†	Routine	Gall-bladder	25	25	80	0	0.0	0	NR	0	0	NR
Kuster and coworkers [22]	Routine	Cystic duct	200	200	68	3	11.1	NR	NR	4.4	NR	NR
Kuster and coworkers [22]	Routine	Gall-bladder	105	105	89.6	0	3.1	3	NR	0	2.9	NR

*Total number of cholangiograms is the denominator.
†Success defined as the ability to infuse dye into the common duct.
NR—not reported.

Results

Table 7-4 describes the laparoscopic cholangiography experience in the recent literature. Technical success, defined as the ability to obtain a cholangiogram of sufficient quality to allow interpretation, appears to be over 90% in most hands. Although the follow-up was not complete in most studies, the percentage of patients experiencing the clinical syndrome of retained stones was less than 1% in the selective approach. These studies incorporated preoperative endoscopic retrograde cholangiopancreotography (ERCP) in those individuals with a high risk for common bile duct stones. Abnormal anatomy, most commonly a short cystic duct, was present in 5% to 10%, although the clinical utility of this information was not readily apparent in these studies.

The ability to perform duct explorations safely during laparoscopic cholecystectomy [41–44] has diminished the dependence on preoperative ERCP characteristic of the early laparoscopic experience. Bile duct injuries are a potential complication occurring during transcystic cholangiography [17,22]. With the success of postoperative common duct stone clearance via ERCP approaching 95%, and the predominantly benign course of unsuspected stones, the selective approach toward performing cholangiography is practiced by the authors although the studies addressing this issue are small and controversial.

References

1. Glenn F, Grafe W: Historical events in biliary tract surgery. *Arch Surg* 1966, 93:848–852.
2. Beal J: Historical perspective of gallstone disease. *Surg Gynecol Obstet* 1984, 158:181–189.
3. Langenbuch C: Ein Fall von Exstirpation der Gallenblase wegen chronischer Cholelithiasis: Heilung. *Berliner Klinische Wochenschrift* 1882, 19:725–727.
4. Mirizzi P: La cholangiograffa durante las operaciones de las vias biliares. *Biol Soc Cir Buenos Aires* 1932, 16:1133.
5. Dubois F, Icard P, Berthelot G, *et al.*: Coelioscopic cholecystectomy: preliminary report of 36 cases. *Ann Surg* 1990, 211:60–62.
6. Reddick E, Olsen D: Laparoscopic laser cholecystectomy: a comparison with mini-lap cholecystectomy. *Surg Endosc* 1989, 3:131–133.
7. Clair D, Carr-Locke D, Becker J, *et al.*: Routine cholangiography is not warranted during laparoscopic cholecystectomy. *Arch Surg* 1993, 128:551–555.
8. Flowers J, Zućker K, Grahams S, *et al.*: Laparoscopic cholangiography: results and indications. *Ann Surg* 1992, 215:209–216.
9. Van Campenhout I, Prosmanne O, Gagner M, *et al.*: Routine operative cholangiography during laparoscopic cholecystectomy: feasibility and value in 107 patients. *Am J Radiol* 1993, 160:1209–1211.
10. Stiegmann G, Goff J, Mansour A, *et al.*: Precholecystectomy endoscopic cholangiography and stone removal is not superior to cholecystectomy, cholangiography, and common duct exploration. *Am J Surg* 1992, 163:227–230.
11. Phillips E: Routine versus selective intraoperative cholangiography. *Am J Surg* 1993, 165:505–507.
12. Soper N, Dunnegan D: Routine versus selective intra-operative cholangiography during laparoscopic cholecystectomy. *World J Surg* 1992, 16:1133–1140.
13. Hunter J: Avoidance of bile duct injury during laparoscopic cholecystectomy. *Am J Surg* 1991, 162:71–76.
14. Lillemoe K, Yeo C, Talamini M, *et al.*: Selective cholangiography: current role in laparoscopic cholecystectomy. *Ann Surg* 1992, 215:669–676.
15. Cantwell D: Routine cholangiography during laparoscopic cholecystectomy. *Arch Surg* 1992, 127:483–484.
16. Corder A, Scott S, Johnson C: Place of routine operative cholangiography at cholecystectomy. *Br J Surg* 1992, 79:945–947.
17. Sackier J, Berci G, Phillips E, *et al.*: The role of cholangiography in laparoscopic cholecystecomy. *Arch Surg* 1991, 126:1021–1026.
18. Phillips E, Berci G, Carroll B, *et al.*: The importance of intraoperative cholangiography during laparoscopic cholecystectomy. *Am Surg* 1990, 56:792–795.
19. Sackier J, Adams J, Bagnato V, *et al.*: Techniques and value of intraoperative cholangiography in laparoscopic cholecystectomy. *Contemp Surg* 1992, 41:89–107.
20. Berci G, Sackier J, Paz-Partlow M: Routine or selected intraoperative cholangiography during laparoscopic cholecystectomy. *Am J Surg* 1991, 161:355–360.
21. Scott-Combes D: Bile duct stones and laparoscopic cholecystectomy. *BMJ* 1991, 303:1281–1282.
22. Kuster G, Gilroy S, Graefen M: Intraoperative cholangiography for laparoscopic cholecystecomy. *Surg Gynecol Obstet* 1993, 176:411–417.
23. Huguier M, Bornet P, Charpak Y, *et al.*: Selective contraindications based on multivariate analysis for operative cholangiography in biliary lithiasis. *Surg Gynecol Obstet* 1991, 172:470–474.
24. Yip A, Lam K: An evaluation of routine operative cholangiography. *Aust N Z J Surg* 1988, 58:391–395.
25. Mansberger J, Davis J, Scarborough C, *et al.*: Selective intraoperative cholangiography. *Am Surg* 1988, 54:31–33.
26. Pasquale M, Nauta R: Selective versus routine use of intraoperative cholangiography: an argument. *Arch Surg* 1989, 124:1041–1042.
27. Kakos G, Tompkins W, Turnipseed W, *et al.*: Operative cholangiography during routine cholecytectomy. *Arch Surg* 1972, 104:484–488.
28. Gregg R: The case for selective cholangiography. *Am J Surg* 1988, 155:540–545.
29. McCormick J, Bremner D, Thomson J, *et al.*: The operative cholangiogram: its interpretation, accuracy and value in association with cholecystectomy. *Ann Surg* 1974, 180:902–906.
30. Stark M, Loughry C: Routine operative cholangiography with cholecystectomy. *Surg Gynecol Obstet* 1980, 151:657–658.
31. Rolfsmeyer E, Bubrick M, Kollitz P, *et al.*: The value of operative cholangiography. *Surg Gynecol Obstet* 1982, 154:369–371.
32. Shively E, Wieman T, Adams A, *et al.*: Operative cholangiography. *Am J Surg* 1990, 159:380–385.
33. Nienhus, L: Routine operative cholangiography: an evaluation. *Ann Surg* 1961, 154:192–202.
34. Wayne R, Cegielski M, Bleicher J, *et al.*: Operative cholangiography in uncomplicated biliary tract surgery: review of 354 cholangiography studies in patients without indication of common duct pathology. *Am J Surg* 1976, 131:324–327.
35. Holliday H, Farringer J, Terry R, *et al.*: Operative cholangiography: review of 7,529 operations on the biliary tree in a community hospital. *Am J Surg* 1980, 139:379–382.
36. Mullen J, Carr R, Rupnik E, *et al.*: 1,000 cholecystectomies, extraductal palpation, and operative cholangiography. *Am J Surg* 1976, 131:672–675.
37. Thurston O: Nonroutine operative cholangiography. *Arch Surg* 1974, 108:512–515.
38. Saltzstein E, Evani S, Mann R: Routine operative cholangiography: analysis of 506 consecutive cholecystectomies. *Arch Surg* 1973, 107:289–291.
39. Pace B, Cosgrove J, Breuer B, *et al.*: Intraoperative cholangiography revisited. *Arch Surg* 1992, 127:448–450.
40. Spaw A, Reddick E, Olsen D: Laparoscopic laser cholecystectomy: analysis of 500 procedures. *Surg Laparosc Endosc* 1991, 1:2–7.
41. Sackier J, Berci G, Paz-Parlow M: Laparoscopic transcystic choledocholithotomy as an adjunct to laparoscopic cholecystectomy. *Am Surg* 1991, 57:323–326.

42. Reddick E, Olsen D, Bailey A, *et al.*: Laparoscopic laser cholecystectomy and choledocholithiasis. *Surg Endos* 1990, 4:133–134.
43. Jacobs M, Verdeha J, Goldstein H: Laparoscopic choledocholithotomy. *J Laparoendosc Surg* 1991, 1:79–82.
44. Quattlebaum J, Flanders H: Laparoscopic treatment of common bile duct stones. *Surg Laparosc Endosc* 1991, 1:26–32.
45. Lindner H, Green R: Embryology and surgical anatomy of the extrahepatic biliary tract. *Surg Clin North Am* 1964, 44:1273–1285.
46. Goor D: Anomalies of the biliary tree: report of a repair of an accessory bile duct and review of the literature. *Arch Surg* 1972, 104:302–309.
47. Lichtenstein M, Nicosia A: The clinical significance of accessory hepatobiliary ducts. *Ann Surg* 1955, 141:120–124.
48. Benson E, Page R: A practical reappraisal of the anatomy of the extrahepatic bile ducts and arteries. *Br J Surg* 1976, 63:853–860.
49. Flint E: Abnormalities of the right hepatic, cystic, and gastroduodenal arteries, and of the bile-ducts. *Br J Surg* 1922, 10:509–519.
50. Daseler E, Anson B, Hambley W, *et al.*: The cystic artery and constituents of the hepatic pedicle. *Surg Gynecol Obstet* 1947, 85:47–63.
51. Anderson J: *Grant's Atlas of Anatomy*. 8th ed. Baltimore: Williams and Wilkins; 1983.
52. Bruhn E, Miller F, Hunter J: Routine fluoroscopic cholangiography during laparoscopic cholecystectomy: an argument. *Surg Endosc* 1991, 5:111–115.
53. Club SS: A prospective analysis of 1518 laparoscopic cholecystectomies. *N Engl J Med* 1991, 324:1073–1078.
54. Pietrafitta J, Schultz L, Graber J, *et al.*: Cholecystocholangiography during laparoscopic cholecystectomy: cholecystcholangiography or cystic duct cholangiography. *J Laparoendosc Surg* 1991, 1:197–206.
55. Tinckler L: Transcholecystic operative cholangiography: an alternative technique. *Ann Roy Coll Surg Engl* 1991, 73:39–43.

CHAPTER

8

Laparoscopic Management of Choledocholithiasis

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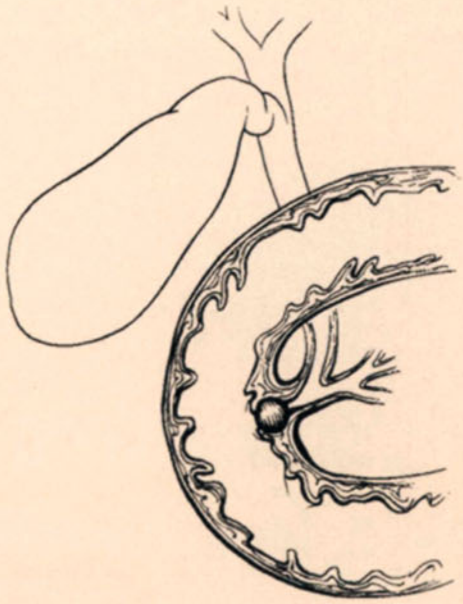
Theodore N. Pappas



Although the first cholecystectomy was performed by Langenbuch in 1882 [1], the common bile duct was not explored until 1890 [2–4]. For nearly 80 years, surgical common bile duct exploration was the treatment of choice for choledocholithiasis. The era of nonoperative or minimally invasive treatment of common duct stones was ushered in by the introduction of interventional radiologic methods for stone extraction in 1964 [5], followed by the development of retrograde endoscopic techniques first introduced in 1974 [6,7].

Since the advent of laparoscopic cholecystectomy in 1987 [8,9], gallbladder surgery has been irrevocably changed. Large series documenting the safety, efficacy, and patient acceptance of this less invasive procedure have been reported [10–14]. Although it was initially believed that laparoscopic exploration of the bile duct was not feasible, it is now clear that successful transcystic or supraduodenal bile duct exploration is possible and technical success can be expected in the majority of patients [11,13–38]. The aim of this chapter is to describe the indications and technique of laparoscopic transcystic common bile duct exploration for the surgeon currently performing laparoscopic cholecystectomy.

Anatomy and Pathophysiology

The common bile duct (choledochus) is contained within the porta hepatis along with the portal vein and common hepatic artery (Figure 8-1). It is formed by the confluence of the common hepatic duct and the cystic duct within the hepatoduodenal ligament and courses through the pancreas and into the medial side of the second portion of the duodenum. There it usually forms a short common channel with the pancreatic duct (the ampulla), which ends in the papilla of Vater opening into the lumen of the duodenum. The length of the common bile duct is inconstant because of the variable insertions of the cystic duct and length of the intraduodenal segment.

It is especially important to understand the tenuous blood supply of the choledochus because its sacrifice may lead to ischemic stricture. All three of the gastroduodenal, common hepatic, and right hepatic arteries contribute to a network of small axial branches, the most prominent being located on the sides of the bile duct. These are usually called the "three o'clock" and the "nine o'clock" arteries, signifying their position relative to the bile duct's cross section (Figure 8-1). Because of their location, circumferential dissection of the bile duct should be avoided.

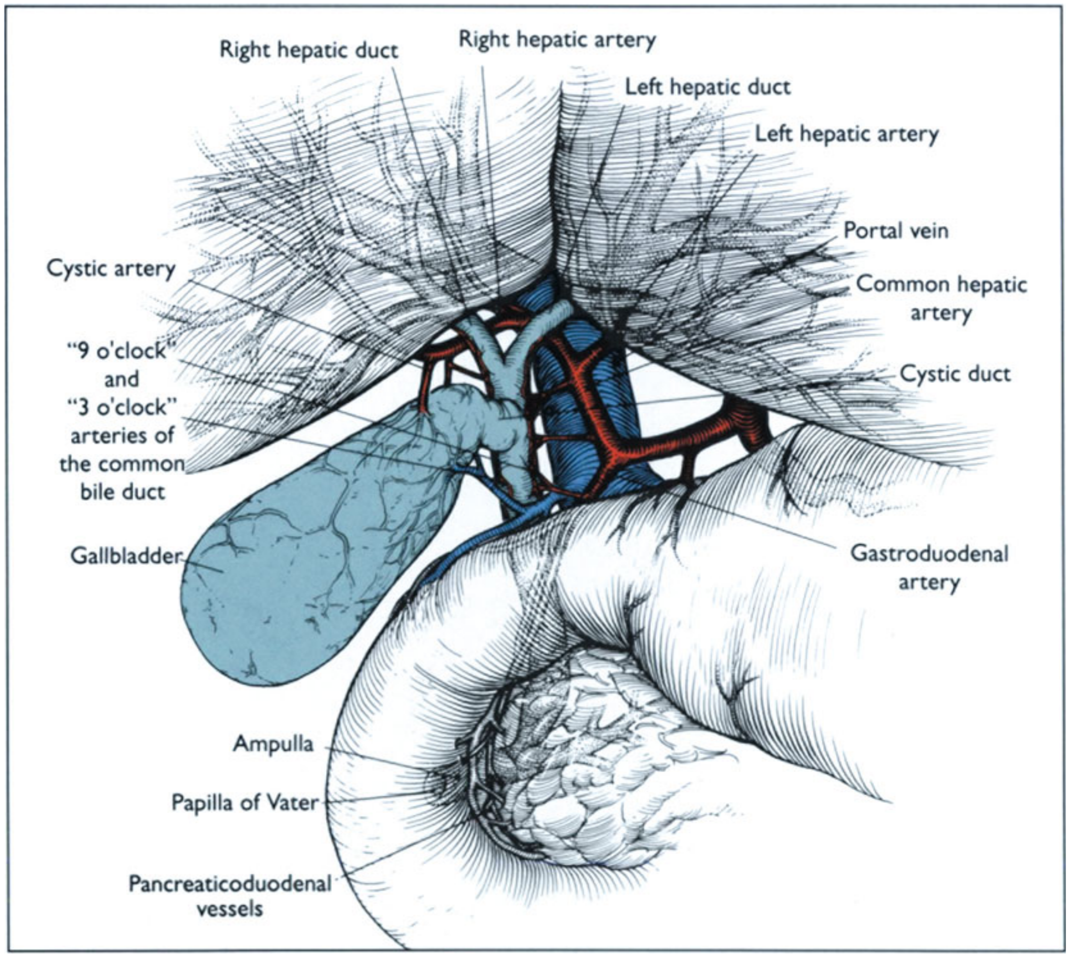


FIGURE 8-1.
The biliary system. Note the blood supply of the common bile duct arising from the gastroduodenal, common hepatic, and right hepatic arteries.

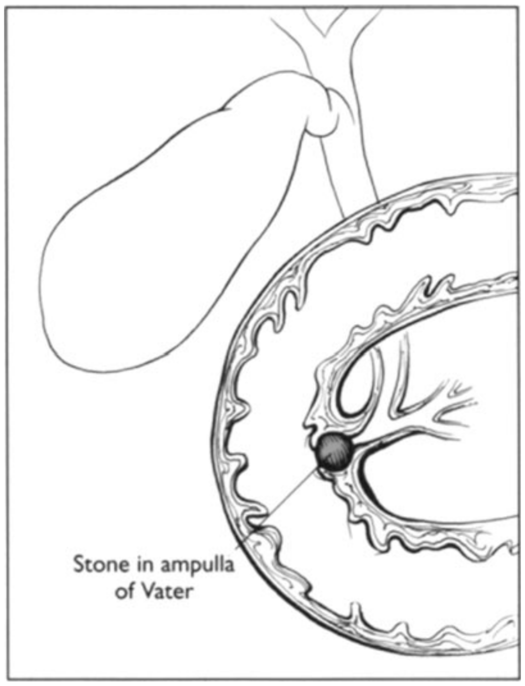


FIGURE 8-2.
Choledocholithiasis. In this case, a cholesterol gallstone has traveled down the cystic duct into the common bile duct and lodged at the ampulla of Vater.

Choledocholithiasis is defined as the presence of stones in any portion of the common bile duct, although the most frequent location is at its most narrow portion at the papilla (Figure 8-2). Stones in the common hepatic duct comprise only about 5% of all stones in the biliary system [39]. Approximately 8% to 15% of patients under 60 years of age, and as many as 15% to 60% of patients over the age of 60 years undergoing cholecystectomy have common duct stones [40]. The most common type are *secondary* common bile duct stones, which arise from the gallbladder and gain access to the common bile duct via the cystic duct. *Retained* common duct stones are defined as stones discovered up to 2 years following cholecystectomy with the presumption that choledocholithiasis was present at the time of operation. Finally, *primary* common duct stones are stones that develop *de novo* in the common bile duct. Somewhat arbitrarily, common duct stones discovered more than 2 years following cholecystectomy are classified as primary.

Clinical Presentation

When calculi become lodged in the common bile duct they cause obstruction to bile flow, increased pressure within the duct, and subsequent distention of the proximal biliary system. The classic presentation of choledocholithiasis, therefore, consists of 1) acute right upper quadrant pain (biliary colic) caused by increased pressure within the biliary tract; and 2) jaundice as a result of the obstruction to bile flow. However, the presence of clinically detectable symptoms is directly related to the degree of obstruction and it is well known that many common bile duct stones allow some bile flow to continue. In order to make the diagnosis of choledocholithiasis, therefore, a high index of suspicion must be maintained for all patients with gallstones. A large number of clinical criteria have been established in an attempt to predict which patients with cholelithiasis are at risk for common bile duct stones (Table 8-1). In general, preoperative clinical, laboratory, and radiologic data are reliable in predicting the absence of choledocholithiasis in greater than 95% of cases [41,42]. Because of the large number of patients with gallstones, however, this still leaves a significant number of cases in which common bile duct stones found at the time of surgery were entirely unsuspected [43].

Management of Choledocholithiasis

In the present era of minimally invasive surgery, endoscopic retrograde cholangiopancreatography (ERCP), and sophisticated interventional radiology, many patients with choledocholithiasis can be safely and successfully managed without the need for a right upper quadrant incision and open common bile duct exploration. Notable exceptions include patients with cholangitis, gallbladder perforation, pancreatitis, suspicion of carcinoma, or large impacted stones in which time consuming minimally invasive techniques must often be relinquished for standard and proven medical and surgical therapy.

Patients with uncomplicated choledocholithiasis, however, are excellent candidates for minimally invasive techniques. For the purposes of the laparoscopic surgeon, these patients generally fall into two categories: 1) patients with cholelithiasis who are suspected to have choledocholithiasis as a result of their preoperative evaluation; and 2) patients who are undergoing laparoscopic cholecystectomy and are found to have choledocholithiasis intraoperatively. The management strategies for these two groups of patients are slightly different.

For patients suspected of having choledocholithiasis preoperatively, the decision must be made whether to obtain a preoperative ERCP for the purpose of retrieving the stones from the common duct. This has been termed *clearing the duct*. The reported success rate of ERCP for the removal of common bile duct stones preoperatively approaches 95% [13,38,44–48], although this level of success may not be achieved in centers with limited ERCP experience. Also, since the positive predictive value of clinical parameters for choledocholithiasis is at best about 50% [12,41,42,49,50], use of routine preoperative ERCP will subject many patients to unnecessary examination [50–53]. The relative indications for clearing the duct preoperatively are given in Table 8-2 and suggest a strategy for selective preoperative ERCP.

A particularly noteworthy indication for preoperative ERCP is the presence of choledocholithiasis in an elderly patient. This has the advantage of making the subsequent laparoscopic cholecystectomy more expeditious since cholangiogram or duct exploration will not be required. Furthermore, some investigators have questioned whether these patients even need a subsequent cholecystectomy since the risk of recurrent biliary tract problems following endoscopic stone removal in elderly patients (roughly 10%

Table 8-1. Clinical, laboratory, radiologic, and intraoperative criteria for possible choledocholithiasis

Clinical presentation
Jaundice (present, recent, or recurrent)
Light colored feces (stools devoid of bile pigment or "acholic" stools)
Dark urine (containing bilirubin)
Fever (present or recent)
Laboratory values
Serum bilirubin > 1.2 mg/dL
Serum alkaline phosphatase > 250 U/L
Radiologic studies
Multiple small gallstones
Common bile duct diameter > 6 mm
Common bile duct calculi
Intraoperative findings
Multiple small gallstones
Common bile duct diameter > 10 mm
Cystic duct diameter > 5 mm

in 5 years) compares favorably with the risk of cholecystectomy [51,54–58]. Thus, not all patients with choledocholithiasis must have a cholecystectomy.

If both the laparoscopic surgeon and the endoscopist are experienced in stone removal and the patient is a good operative candidate, preoperative ERCP is not necessary, and patients may be taken directly to laparoscopic cholecystectomy with plans for retrieval of stones via a laparoscopic approach or postoperatively via an endoscopic approach. Also, regardless of the extensiveness of the preoperative evaluation, some cases of choledocholithiasis will be discovered intraoperatively following cholangiography. It is in these two scenarios that there is a role for laparoscopic treatment of common bile duct stones.

Surgical Technique

Figures 8-3 through 8-12 depict the surgical technique for laparoscopic transcystic common bile duct exploration.

Table 8-2. Indications for preoperative ERCP in patients suspected of choledocholithiasis

Clinical suspicion of choledocholithiasis and:
Presence of multiple stones
Small cystic duct and/or common bile duct (may preclude safe transcystic exploration)
Elderly patient
High operative risk
Endoscopist with limited experience in stone retrieval (if eventually required postoperatively)
Surgeon with limited experience in laparoscopic treatment of choledocholithiasis
Wishes of the patient (strong desire to avoid open procedure)

ERCP—endoscopic retrograde cholangiopancreatography.

Procedure

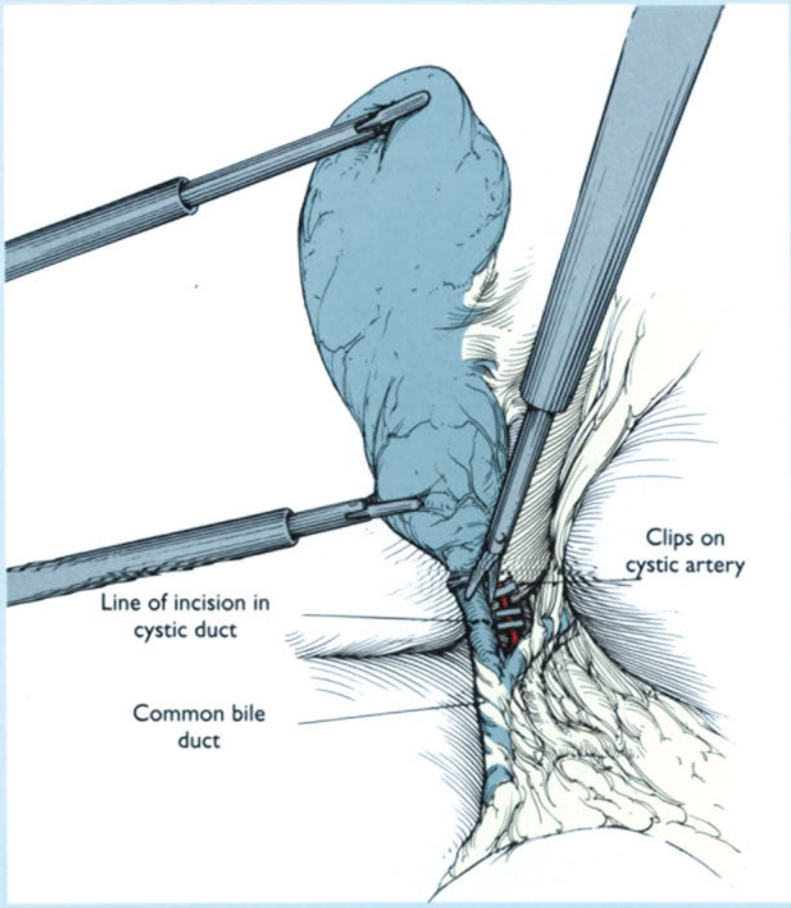


FIGURE 8-3.

The procedure is performed at the time of laparoscopic cholecystectomy following intraoperative cholangiogram. The cystic artery is identified and doubly clipped. The cystic duct is identified and clipped on the gallbladder side to prevent bile and stone spillage. The cholangiocatheter is removed. If the cholangiogram has been obtained via the cystic duct, then the cystic duct incision is used for transcystic cholangioscopy. If no cystic duct incision has been made (as in the figure), then the gallbladder is retracted superomedially placing traction on the cystic duct, and the duct is incised one half its full diameter, approximately 1.5 to 2.0 cm proximal to its junction with the common hepatic duct.

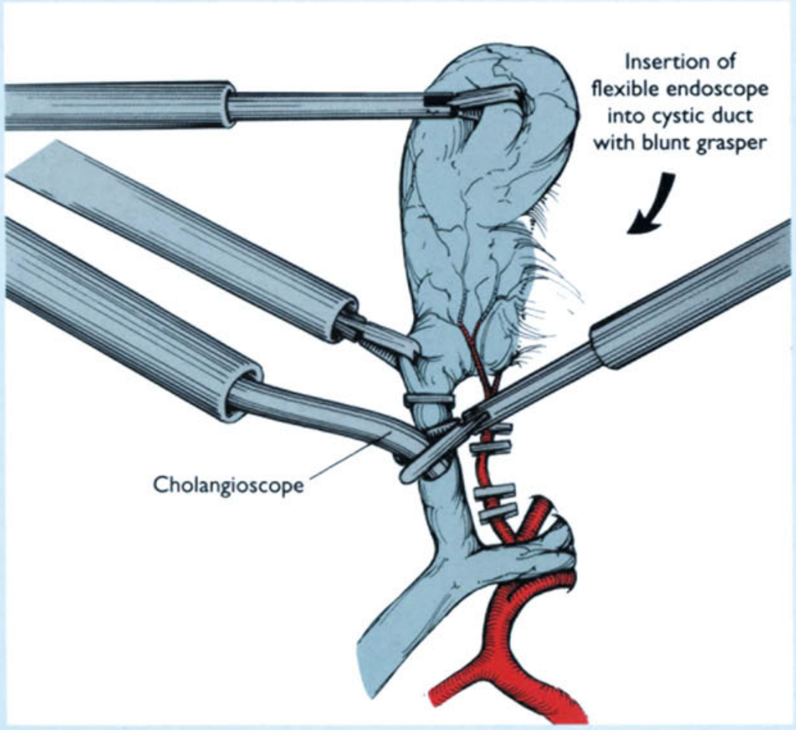


FIGURE 8-4.

A 2.7- to 3.3-mm outer diameter flexible endoscope is passed through the right upper quadrant trocar and advanced into the cystic duct. Obviously, the smaller the diameter of the endoscope, the easier passage will be. Many small scopes are available (ACMI-Circon, Olympus, Intramed Laboratories, Karl Storz Endoscopy), although they may have been originally designed as ureteroscopes or choledochoscopes. Care should be taken to grasp the scope with noncrushing forceps only. Some authors advocate the use of a hydrophilic guidewire to facilitate ductal access [21,23,28,32,59].

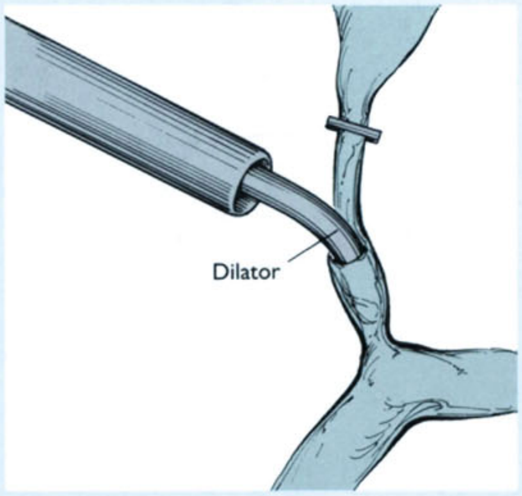


FIGURE 8-5.

If the smallest available scope cannot be advanced through the cystic duct, the cystic duct may be gently dilated with either mechanical tapered dilators or an angioplasty balloon system. Cystic duct dilatation can be safely performed up to 4 mm; dilatation beyond 8 mm is not recommended [32]. Obviously, rigorous dilatation of a tight cystic duct should be avoided and the procedure abandoned if the cholangioscope does not pass entirely. If the cystic duct–common duct junction is disrupted by forcible dilatation, open exploration may be required for repair. The administration of glucagon 2 mg intravenously may also be of benefit by providing smooth muscle relaxation of the cystic duct.

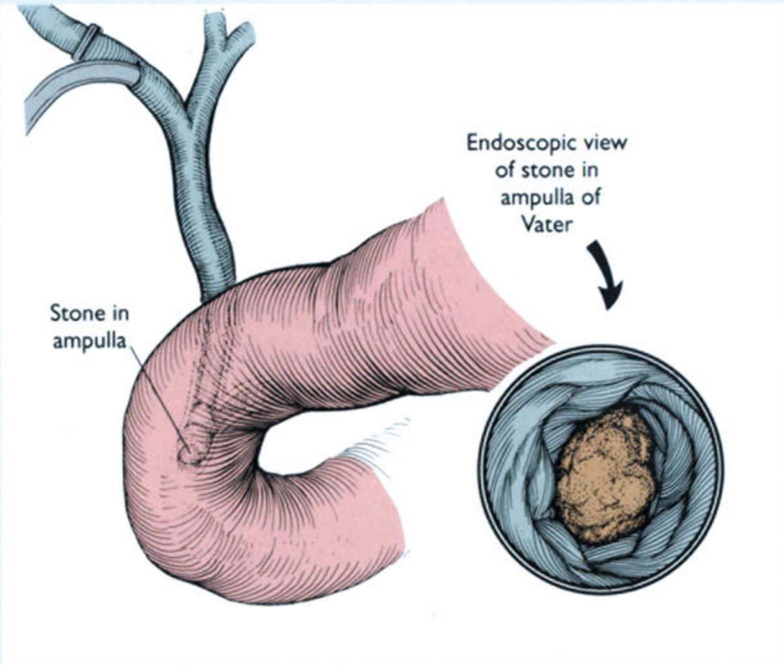


FIGURE 8-6.

Once the cholangioscope is in the common bile duct, the video camera should be removed from the laparoscope and placed on the cholangioscope for maximum resolution. The cholangioscope is gently advanced distally in the common duct until stones are visualized (*inset*). The common hepatic duct can sometimes be visualized by gently twisting the cholangioscope superiorly to negotiate the acute angle of the junction of cystic and common hepatic ducts. Excessive effort, however, may cause tearing of the ductal system and should be avoided.

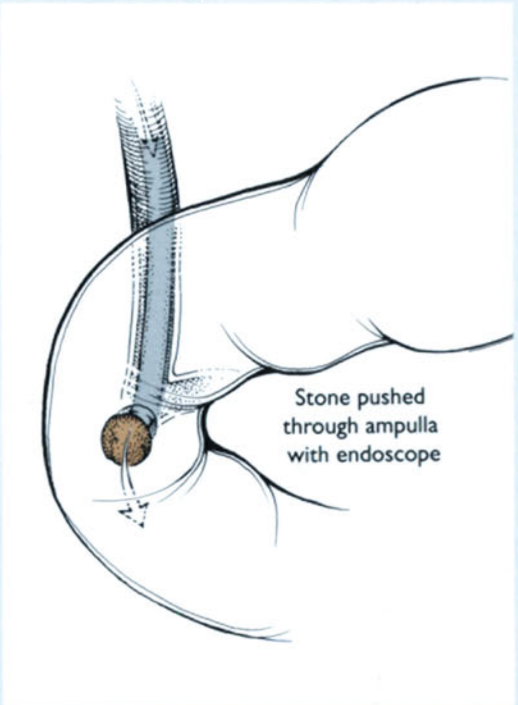


FIGURE 8-7.

When stones are encountered they may often be made to pass through to the duodenum just by gently pushing with the cholangioscope.

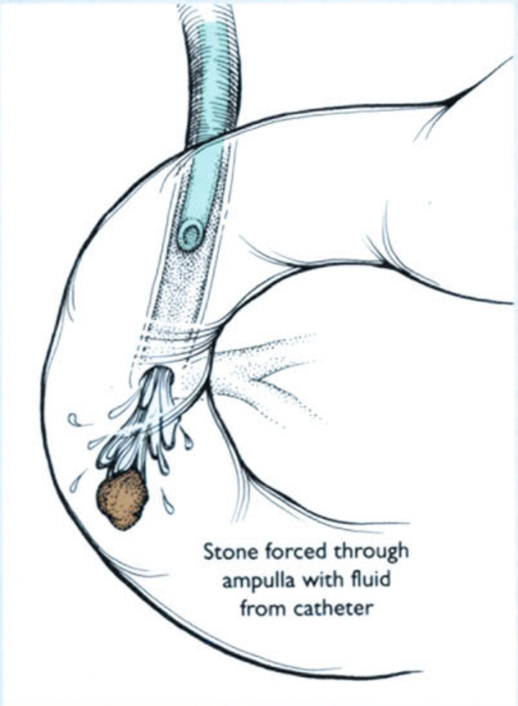


FIGURE 8-8.

If the stones do not pass with gentle scope manipulation, a number of maneuvers may be attempted. A red rubber catheter or similar device may be passed into the cystic duct for flushing of the common duct.

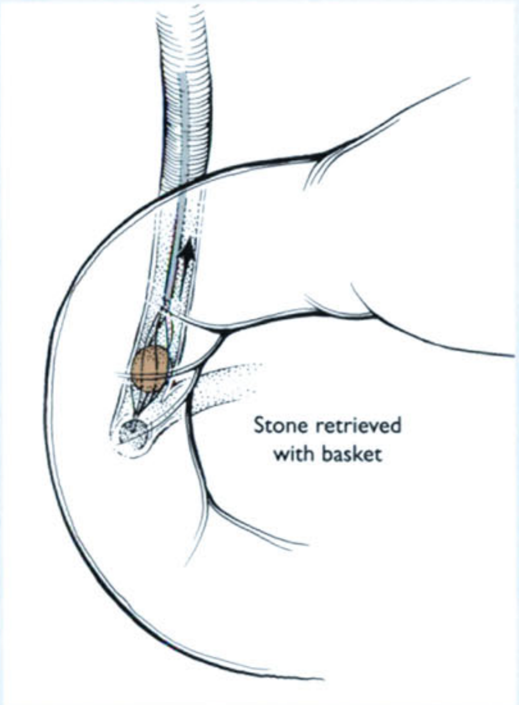


FIGURE 8-9.

If the cholangioscope has a sufficiently large operating channel (1–1.5 mm), then a stone basket may be used for retrieval.

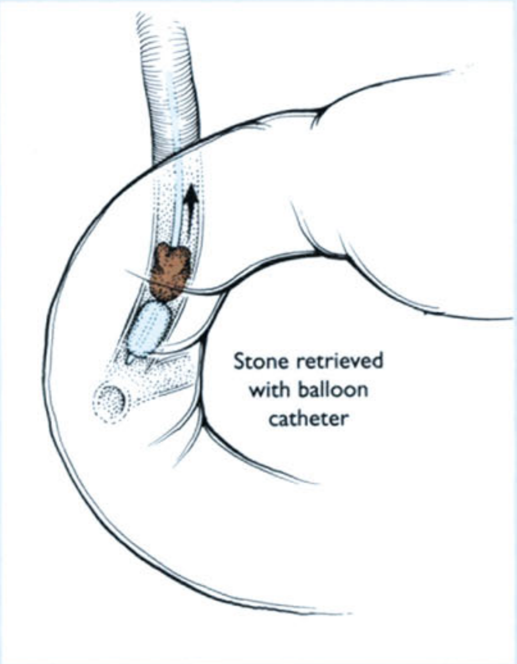


FIGURE 8-10.
Lastly, a 3-French Fogarty embolectomy catheter may be used to retrieve the stone. This may be difficult as the stone may be withdrawn into the common hepatic duct and rendered irretrievable.

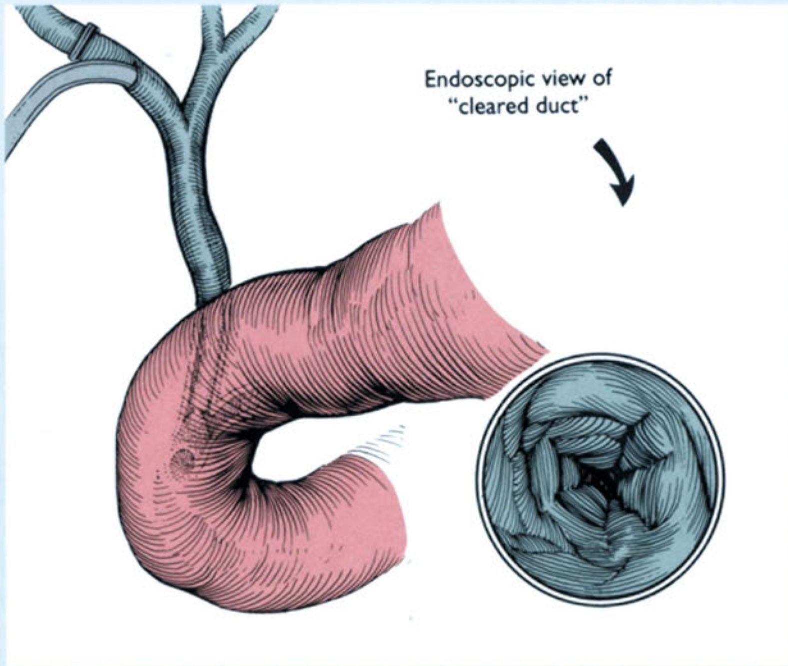


FIGURE 8-11.
When the stones have been removed, the cholangioscope is again inserted and the ampulla visualized.

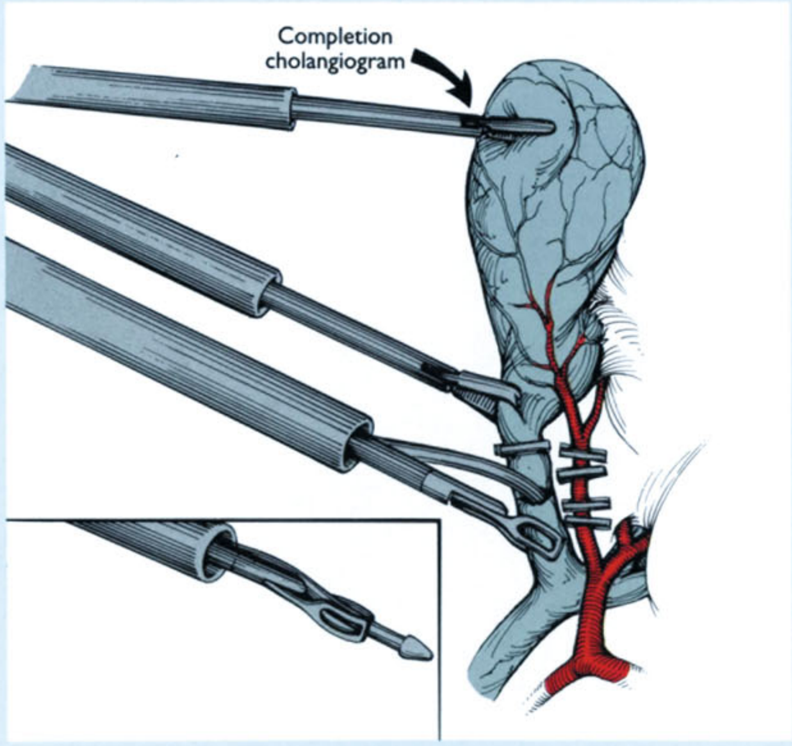


FIGURE 8-12.
A completion cholangiogram is then performed to confirm ductal clearance. Cystic duct control following extensive dilatation and manipulation is critical. Although simple endoscopic clips may be routinely employed after cholecystectomy alone, single or double endoscopic loop sutures are preferable after transcystic exploration. A subhepatic Jackson-Pratt closed-system drain is placed prior to closure.

Results

The reported experience for laparoscopic treatment of choledocholithiasis is given in Table 8-3. Although this chapter describes the most popular method of transcystic bile duct exploration, a variety of other methods for stone identification and extraction have been suggested, including the use of the pulsed dye laser or electrohydraulic lithotripsy [13,23,24,27,28,32,34,59], transcystic placement of a T-tube for laser use [20,28,30,32], placement of common bile duct introducer sheaths for multiple stones [32], bile duct exploration under fluoroscopic control [23,32,33], balloon-catheter–assisted antegrade stone advancement [26], intraoperative ultrasound or ERCP [60], laparoscopic sphincter dilatation [26,28], and supraduodenal laparoscopic common bile duct exploration [11,18,20,23,25,28–30,32,37,59,61].

Regardless of the method employed, traditional surgical principles must be adhered to as well as the useful adage of "do no harm." As with open bile duct exploration [62–65], there are potential risks of common duct complications, especially duct ischemia, stricture formation, and biliary sepsis. Whether endoscopic sphincterotomy is preferable to open common bile duct exploration continues to be debated [66–71], and its comparison with laparoscopic duct exploration has not been definitively studied. However, as the reported success of endoscopic duct clearance following laparoscopic cholecystectomy is excellent [12,15,38,45,46], and in view of the well-documented evidence that most stones less than 3.0 mm in diameter may pass spontaneously without symptoms [72], persisting with the laparoscopic approach in a difficult common bile duct is probably not warranted.

Table 8-3. Results of laparoscopic treatment of choledocholithiasis compiled from various studies

Study	Cases of choledocholithiasis, *n*	Successful laparoscopic extraction, *n*	Transcystic approach, *n*	Supraduodenal approach, *n*	Unsuccessful laparoscopic extraction, *n*	No further therapy, *n*	Open CBDE, *n*	Post-operative ERCP, *n*	Postoperative lithotripsy/ radiologic extraction, *n*	Complications
Appel and coworkers [26]	8	7	7		1		1			
Bagnato and coworkers [16]	16	11			5		5			
Sackier and coworkers [21,22], Shapiro and coworkers [23], Cuschieri and Berci [28], Hunter and Soper [32]	69	52	52		17		17			
Cuschieri and coworkers [10], Cuschieri and Berci [28]	25	25	12	16	7		1	6		
Dion and coworkers [29]	5	5	3	2						
Cuschieri and Berci [28]	27	27	0	27						
Gelin [30]	58	26	25	1	32		21	10	1	3*
Cuschieri and Berci [28], Hunter and Soper [32], Ido and coworkers [34]	26	22	18	4	4		4			5†
Ido and coworkers [34]	13	11	11		2			1	1	
Jacobs and coworkers [18]	8	7		8	1				1	
Ko and Airan [11], Cuschieri and Berci [28]	25	20	16	4	5		4	2		
Larson and coworkers [13], Vitale and coworkers [38]	50	20	20		30		26	4		
Newman and coworkers [35]	1	1	1							
Petelin [19], Cuschieri and Berci [28]	65	62	60	2	3		1	2		
Carrol and coworkers [27], Cuschieri and Berci [28]	66	59	56	3	7		4	3		4‡
Quattlebaum and Flanders [20]	15	5	3	2	10	3		6	1	
Reddick and coworkers [15], Spaw and coworkers [24], Reddick and coworkers [59]	29	7			22	3	3	16		
Smith and coworkers [36]	1	1	1							
Stoker and coworkers [25]	5	5		5						
Swanstrom and Sangster [37]	28	26	25	1	2		2			4§
Totals	540	399								

*Death at 2 months (1), transient bilary leak (1), subphrenic abscess (1).
†Transient hypermylasemia or hyperbilirubinemia (4), subhepatic abscess (1).
‡Transient hypermylasemia (2), minor wound infection (1), pneumothorax (1).
§Persistent bile drainage (1), perforation of duct with no clinical sequelae (1), ampullary laceration (1), retained stone (1).
CBDE—common bile duct exploration; ERCP—endoscopic retrograde cholangiopancreatography.

59. Reddick EJ, Olsen D, Spaw A, *et al.*: Safe performance of difficult laparoscopic cholecystectomies. *Am J Surg* 1991, 161:377–381.
60. Ascher SM, Evans SRT, Goldberg J, *et al.*: Intraoperative bile duct sonography during laparoscopic cholecystectomy: experience with a 12.4-MHz catheter-based US probe. *Radiology* 1992, 185:493–496.
61. Zucker KA: The expanding role of therapeutic laparoscopy in general surgery. *Ann Surg* [Residents Edition] 1992;3.
62. McSherry CK, Glenn F: The incidence and causes of death following surgery for nonmalignant bilary tract disease. *Ann Surg* 1980, 191:271–275.
63. White TT, Hart MJ: Cholangiography and small duct injury. *Am J Surg* 1985, 149:640–643.
64. Scher KS, Scott-Conner CE: Complications of biliary surgery. *Am Surg* 1987, 53:16–21.
65. Sheridan WG, Williams HOL, Lewis MH: Morbidity and mortality of common bile duct exploration. *Br J Surg* 1987, 74:1095–1099.
66. Neoptolemos JP, Davison BR, Shaw DE, *et al.*: Study of common bile duct exploration and endoscopic sphincterotomy in a consecutive series of 438 patients. *Br J Surg* 1987, 74:916–921.
67. Miller BM, Kozarek RA, Ryan JA, *et al.*: Surgical versus endoscopic management of common bile duct stones. *Ann Surg* 1988, 207:135–141.
68. Stiegmann GV, Pearlman NW, Goff JS, *et al.*: Endoscopic cholangiography and stone removal prior to cholecystectomy: a more cost-effective approach than operative duct exploration? *Arch Surg* 1989, 124:787–790.
69. Pappas TN, Slimane TB, Brooks DC: 100 Consecutive common duct explorations without mortality. *Ann Surg* 1990, 211:260–262.
70. Stain SC, Cohen H, Tsuishoysha M, Donovan AJ: Choledocholithiasis: endoscopic sphincterotomy or common bile duct exploration. *Ann Surg* 1991, 213:627–634.
71. Stiegmann GV, Goff JS, Mansour A, *et al.*: Precholecystectomy endoscopic cholangiography and stone removal is not superior to cholecystectomy, cholangiography, and common duct exploration. *Am J Surg* 1992, 163:227–230.
72. Greiner L, Müunks C, Heil W, Jakobeit C: Gallbladder stone fragments in feces after biliary extracorporeal shock-wave lithotripsy. *Gastroenterology* 1990, 98:1620–1624.

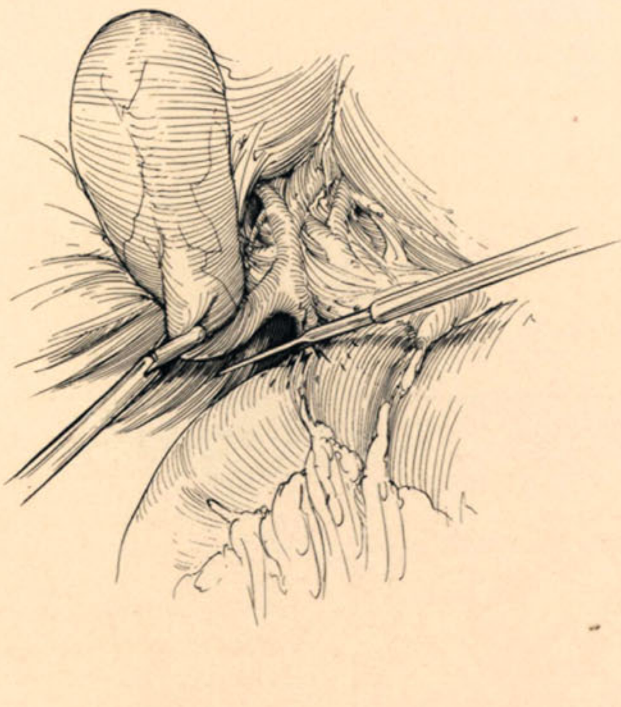
CHAPTER

9

Complications of Laparoscopic Cholecystectomy

Gene D. Branum

Theodore N. Pappas



Laparoscopic cholecystectomy has been documented to be a safe and effective procedure in the treatment of symptomatic gallbladder disease. Widespread satisfaction among patients and surgeons has led to its position as the current treatment of choice for symptomatic gallstones. As the popularity of laparoscopic cholecystectomy grew, it became clear that there was a learning curve associated with the procedure during which there was a higher than expected rate of complications, especially major biliary ductal complications. This was related largely to unfamiliarity with new instruments and technology and the conversion from a three-dimensional, hands-on technique to a two-dimensional, video-assisted technique.

The early prospective study by the Southern Surgeons Club documented a low overall complication rate of less than 5% and a bile duct complication rate of 0.5% [1]. Series were reported, however, with bile duct complication rates as high as 3%, a sixfold increase from the expected rate of open cholecystectomy [2]. The follow-up study of over 9000 cholecystectomies revealed that the risk of bile duct injury in any one surgeon's experience was increased during a learning curve that lasted primarily the first 15 cases and reached nadir at 50 cases [3].

A review of the intraoperative video tapes that accompany many injuries reveals that nearly all biliary complications associated with laparoscopic cholecystectomy are preventable (Table 9-1). Moreover, major complications not associated with the biliary tract are also preventable if a set of simple principles is applied. Errors in the identification of ductal or arterial anatomy lead to the most dire complication's, and adequate visualization of the cystic duct entering the gallbladder is the goal in every laparoscopic cholecystectomy.

Anatomy

A detailed knowledge of normal and anomalous hepatobiliary anatomy is necessary to avoid complications. Common anomalies of the hepatic arterial and biliary ductal anatomy occur that may increase the hazards of laparoscopic cholecystectomy (Fig. 9-1). The gallbladder usually lies to the right of the common bile duct with the cystic duct–common duct union lying just above the first portion of the unmobilized duodenum. This junction may occur anywhere in the extrahepatic biliary tract, however, from the hepatic ducts above the bifurcation to the intrapancreatic common bile duct, and may occur anywhere around its circumference. In addition, there are anomalous accessory ducts that may join the common or cystic duct directly from the hepatic parenchyma. These anomalous connections or ductal structures occur in 10% to 15% of patients. While an anomalous insertion of the cystic duct may make the dissection more tedious and identification of the anatomy difficult, if the gallbladder cystic duct junction is identified correctly, major complications should not ensue. However, identification of accessory ducts and their avoidance is critical to safe completion of laparoscopic cholecystectomy.

Aberrant anatomy of the hepatic artery, especially the right hepatic artery, is present in 15% to 20% of cases. Commonly seen patterns of the branching of the right hepatic artery include a medial right hepatic artery that runs posterior to the common duct (60%), a medial right hepatic artery that runs anterior to the common duct (25%), and an aberrant right hepatic artery arising from the superior mesenteric artery and running posterior to the common duct in 15% to 20% of the cases. The posterior or aberrant right hepatic artery is in danger in any dissection low on the cystic duct or when the common duct is misidentified as the cystic duct and dissected free in the portahepatis. The artery may be injured by cautery, clipping, laser, or traction.

Biliary Complications

Common patterns of injury have been recognized (Table 9-2). The classic injury and its variants are the most common and devastating injuries, while burn injuries, bile leaks, and retained stones are also encountered.

The Classic Injury

The classic laparoscopic biliary injury results when the common bile duct or common hepatic duct is misidentified as the cystic duct during the initial dissection phase of the cholecystectomy (Fig. 9-2).

Table 9-1. Factors contributing to intraoperative injury

Problem	Result
Inexperience with equipment	Poor visualization, exposure
Inadequate training, proctoring	Overconfidence, misidentification of anatomy, failure to convert prior to injury
Inability to perform cholangiography	Misidentification of anatomy
Misunderstanding of electrosurgical principles	Thermal injury

Table 9-2. Patterns of injury

- Classic injury: resection of extrahepatic biliary tree
- Cystic duct–common duct injury
- Cystic duct–right hepatic duct injury
- Right hepatic duct clip/transection
- Lateral common bile duct tear/laceration
- Burn-induced stricture
- Cystic duct leak

Variations of the classic injury

A common variation of the classic injury occurs when appropriately placed clips are applied to the proximal cystic duct, but because of inappropriate dissection and traction with tenting of the common bile duct, the distal clips are placed on the common duct. The cystic duct is then divided near the common duct junction leading to total proximal biliary leakage and obstruction of the common bile duct. Patients with short or nonexistent cystic ducts are particularly prone to this injury. Figure 9-3 depicts a variation of the classic injury.

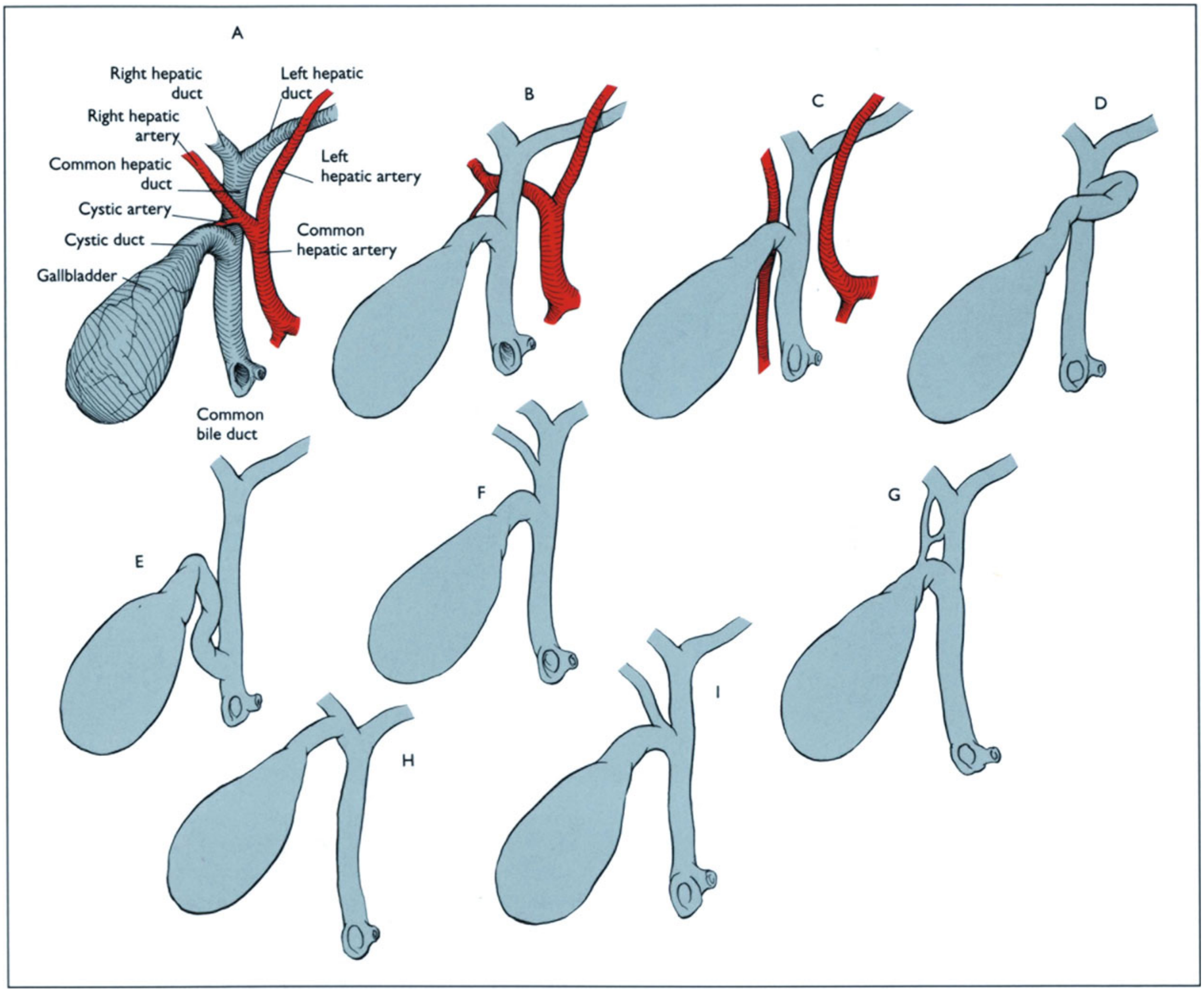


FIGURE 9-1.

Common anomalies of the hepatic arterial and biliary ductal anatomy that may increase the hazards of laparoscopic cholecystectomy. **A**, Conventional arterial and ductal anatomy. **B**, Right hepatic arterial branch posterior to the common hepatic duct. **C**, Replaced right hepatic artery arising from the superior mesenteric artery. **D** through **I**, Variants of cystic and accessory duct insertion into the extrahepatic biliary tree.

Classic Injury

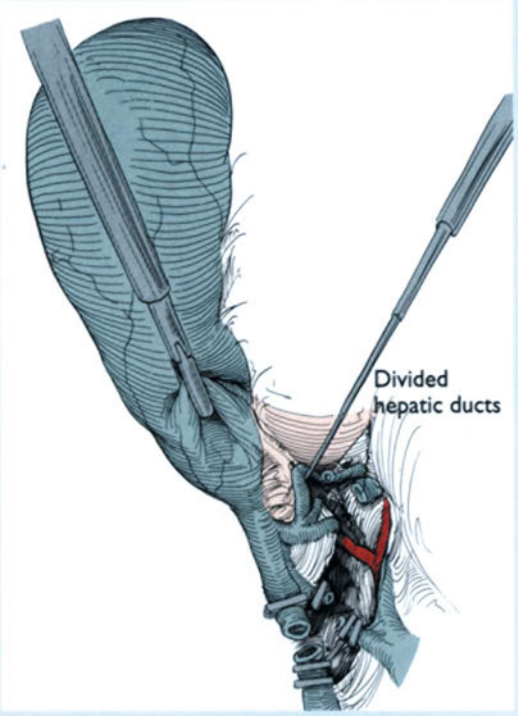


FIGURE 9-2.
A small vessel that accompanies or approaches the common duct is misidentified as the cystic artery and is clipped and divided. The major ductal structure is then dissected free from surrounding portal structures, clipped, divided, and removed with the gallbladder. This leads not only to common duct injury but resection of a segment of the major extrahepatic biliary tree. The injury is often associated with right hepatic arterial injury because of its proximity as the ductal structures are dissected free from what is thought to be the gallbladder bed. The proximal duct structures are transected anywhere from just below to well above the bifurcation of the hepatic duct.

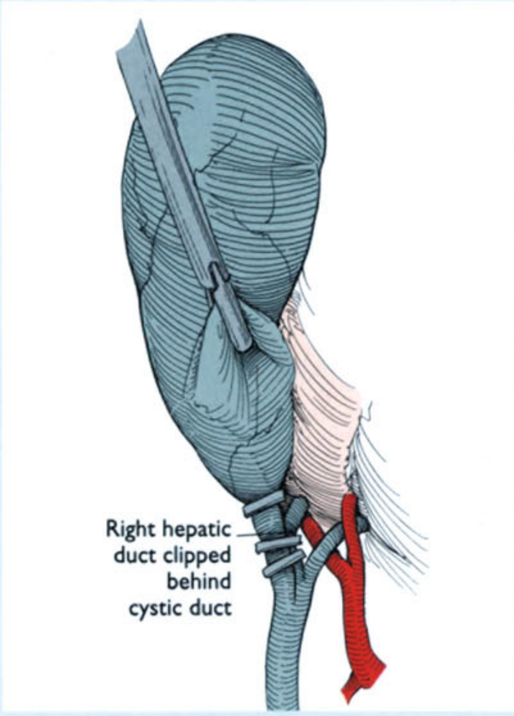


FIGURE 9-3.
Right hepatic ductal injury is prone to occur when the cystic duct has its origin from the right hepatic duct or when inappropriate cephalad retraction is applied to the infundibulum. The cystic duct is appropriately clipped in its proximal position but the distal clips are placed on the right hepatic duct, resulting in its division. Biliary leakage results and right hepatic arterial injury is common.

Thermal Injury

The second most common type of major biliary injury occurs when excessive laser or cautery usage leads to a biliary stricture. This may occur when injudicious use of the laser or cautery is used during the initial exposure of the cystic duct (Fig. 9-4). Early instructional tapes mistakenly described division of the cystic duct with the laser or cautery instruments. Transmission of heat through the ductal structures can have disastrous results. Thermal injury leads to coagulation and disruption of the blood supply to delicate ductal structures, and normal biliary systems with their small caliber as well as systems with anomalous blood supplies are particularly prone to injury (Fig. 9-5). These injuries may present weeks to months postoperatively and are particularly challenging to reconstruct.

Thermal Injury

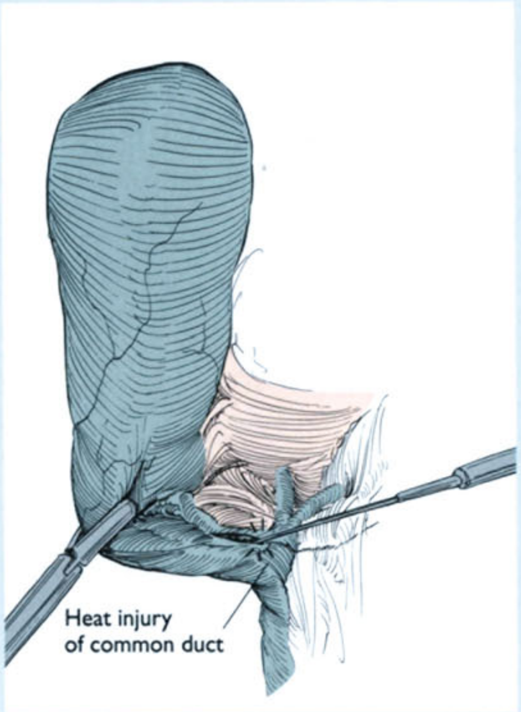


FIGURE 9-4.
Electrocautery or laser applied inappropriately during initial cystic duct dissection. The applied energy may coagulate the blood supply and/or directly damage the common bile duct, resulting in scarring and stricture.

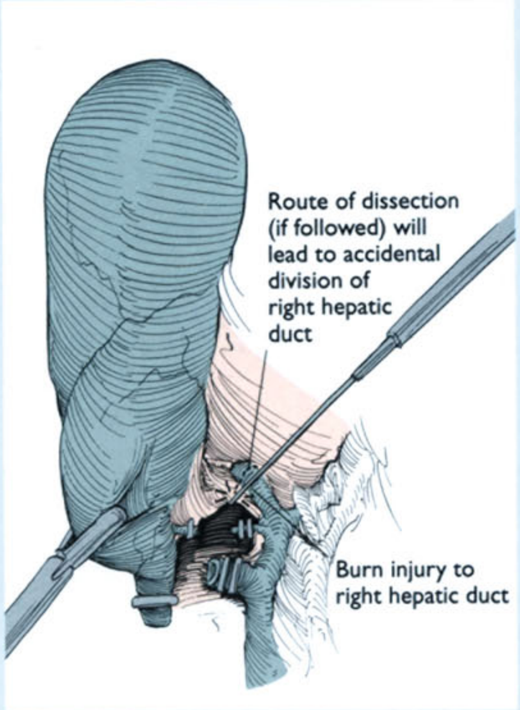


FIGURE 9-5.
Electrocautery or laser dissection applied at an inappropriate distance from the wall during dissection of the gallbladder from its bed may result in right hepatic ductal transection or stricture.

Biliary Leakage

Various injuries to the biliary tree or other technical problems may lead to bile leakage following laparoscopic cholecystectomy. The classic injury and its variants, a partial tear of a ductal structure (Fig. 9-6), an injured accessory ductal structure, or the cystic duct may leak bile postoperatively. Leakage from the gallbladder bed or small accessory ducts is difficult to recognize at the time of operation. Significant leakage, however, will eventually result in biliary ascites or pain leading to investigation. Bile leakage in the absence of major ductal injuries usually responds to stenting, drainage of the ascites with percutaneous catheters, or a combination of the two. Leakage from the cystic duct stump may occur when clips are inappropriately placed and fall off or when they are placed too aggressively and cause crush necrosis of the duct (Fig. 9-7). This is particularly prone to occur in cases of acute cholecystitis when the tissues are edematous and friable. Chromic gut ties may be safer than clips in the acute situation.

Biliary Leakage

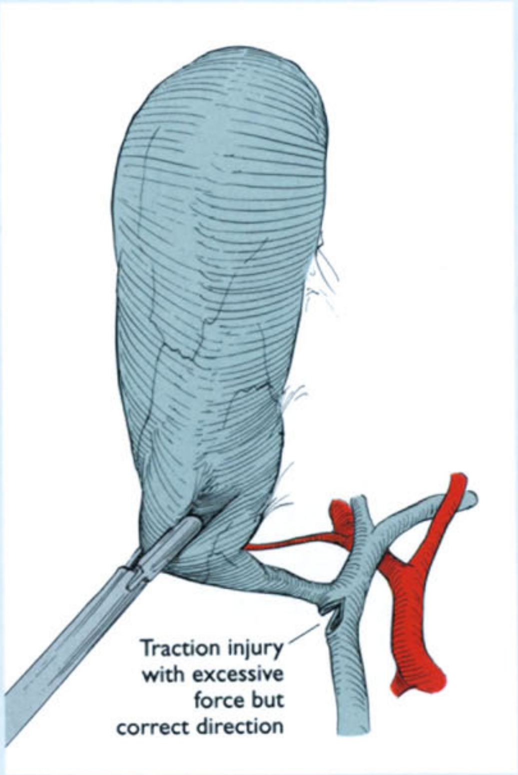


FIGURE 9-6.
A tear in the lateral wall of the common bile duct may be caused by overly aggressive lateral retraction of the infundibulum, leading to a postoperative bile leak.

FIGURE 9-7.
Inaccurately placed clips may fall off of the cystic duct during subsequent manipulation of the gallbladder or cystic artery, leading to a postoperative bile leak.

Diagnosis

Biliary injury is unlikely to be recognized at the time of the initial operation, though a review of videotapes of procedures in which injuries occur reveals that there are clues to the injury at the time of the procedure [4]. Specific clues to the presence of biliary injury include a "cystic" duct with a larger diameter than usual, presence of unexplained golden hepatic-type bile, unusual hemorrhage, hemorrhage from sites that are difficult to control, or the division of two distinct ductal structures.

A majority of patients have pain as their initial presenting symptom of injury (Table 9-3). Complete biliary obstruction and cholangitis are uncommon. Significant postoperative pain is unusual following laparoscopic cholecystectomy and any patient with disproportional pain that persists following the procedure should undergo endoscopic retrograde cholangiopancreatography (ERCP) or computed tomography scan (Table 9-4). A simple noninvasive test to evaluate for a leak is radionuclide imaging using ^{99m}Tc-IDA. Small leaks that pool in the gallbladder fossa or Morrison's pouch may be detected with nuclear scans and biliary ascites may be present throughout the peritoneal cavity or pool in various dependent sites.

If a leak or obstruction is suspected, ERCP is the first investigational method in a treatment algorithm (Fig. 9-8). ERCP will demonstrate complete bile duct obstruction in the classic injury or one of its variants, and in cases of incomplete obstruction or leak allows for other interventional procedures such as stenting, stricture dilation, sphinc-

Table 9-3. Signs and symptoms of injury

Sign or symptom	Cause
Abdominal pain	Chemical/bacterial peritonitis
Fever	Cholangitis, peritonitis
Nausea/vomiting	Peritonitis, ileus
Abdominal distension	Ileus, biloma
Jaundice	Bile duct obstruction
Anorexia	Ileus, biloma, obstruction

Table 9-4. Methods for diagnosis of injury

Method	What it demonstrates	Therapy available
ERCP	Distal ductal anatomy, leaks, sites of stricture	Papillotomy balloon, stones
Computed tomography scan	Bile collection, ductal dilation	Drainage of abscess/biloma
Percutaneous transhepatic cholangiogram	Proximal ductal anatomy, sites of leaks, disruption, strictures	Stents for duct identification/ drainage, balloon
Radionuclide	Bile leak/collection, obstruction	None

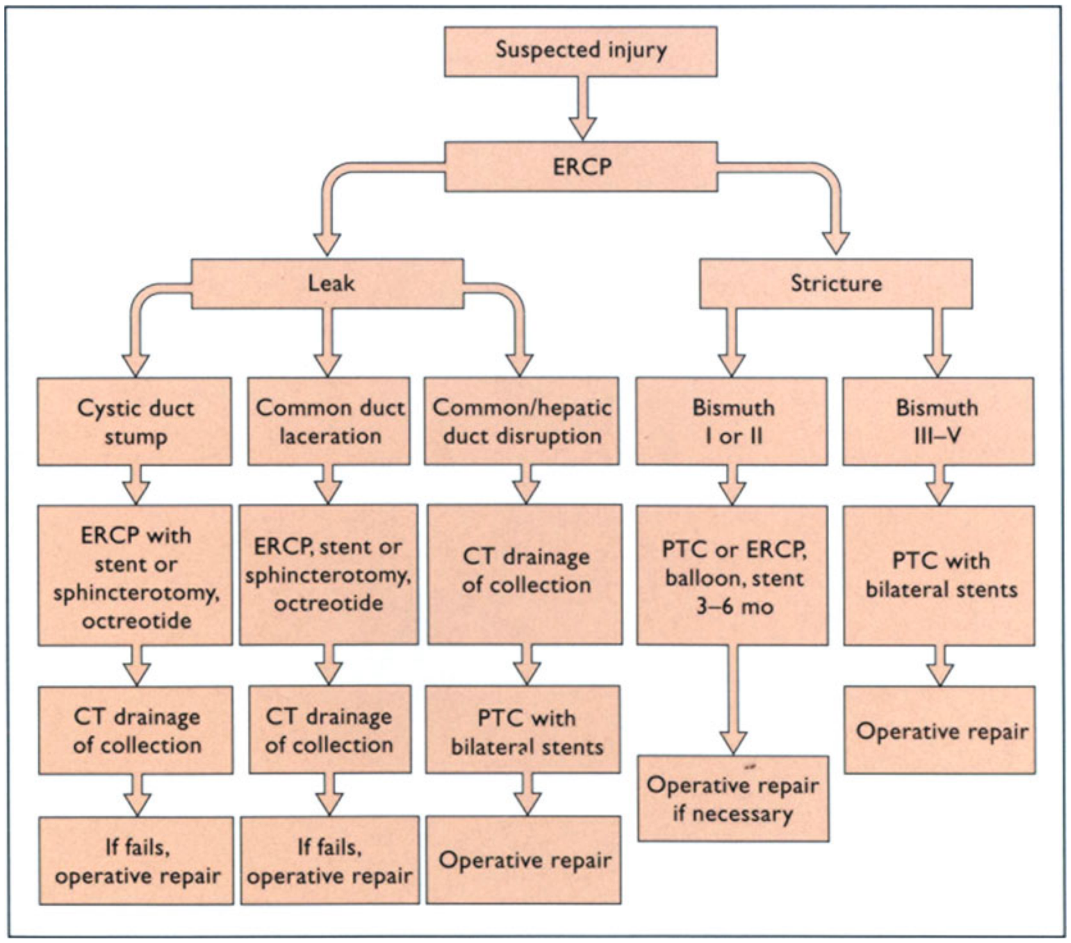


FIGURE 9-8. Treatment algorithm for biliary injury. CT—computed tomography; ERCP—endoscopic retrograde cholangiopancreatography; PTC—percutaneous transhepatic cholangiogram.

terotomy, or stone extraction. Percutaneous transhepatic cholangiogram (PTC), on the other hand, is useful to delineate proximal biliary injuries and anatomy, and to identify the source of a bile leak if present. Stents placed during PTC are important for intraoperative identification of damaged ductal structures and should be placed bilaterally if exploration and repair are planned. The performance of a computed tomography scan following the placement of percutaneous drainage tubes and injection of contrast may facilitate the drainage of bile collections and the preoperative stabilization of the patient.

Treatment

The classic injury and its variants should be treated with Roux-en-Y hepaticojejunostomy (Table 9-5). This is true whether the injury is discovered at the time of the initial operation or, as is usually the case, days to weeks after the initial procedure. Preoperative studies should adequately identify the choledochal anatomy and transhepatic stents should be placed (Fig. 9-9). Most injuries even high into the hepatic biliary radicals can be successfully treated with a Roux-en-Y hepaticojejunostomy (Fig. 9-10). It is critical that the procedure be performed by an experi-

Table 9-5. Treatment options for biliary injuries

Injury	Therapy
Ductal disruption	Hepaticojejunostomy
Stricture	Hepaticojejunostomy, balloon/stent
Bile leak	
Disruption	Hepaticojejunostomy
Duct laceration	Repair, stent/papillotomy
Accessory duct	Hepaticojejunostomy, stent/papillotomy, ligate
Cystic duct stump	Stent/papillotomy, repair, octreotide

Treatment

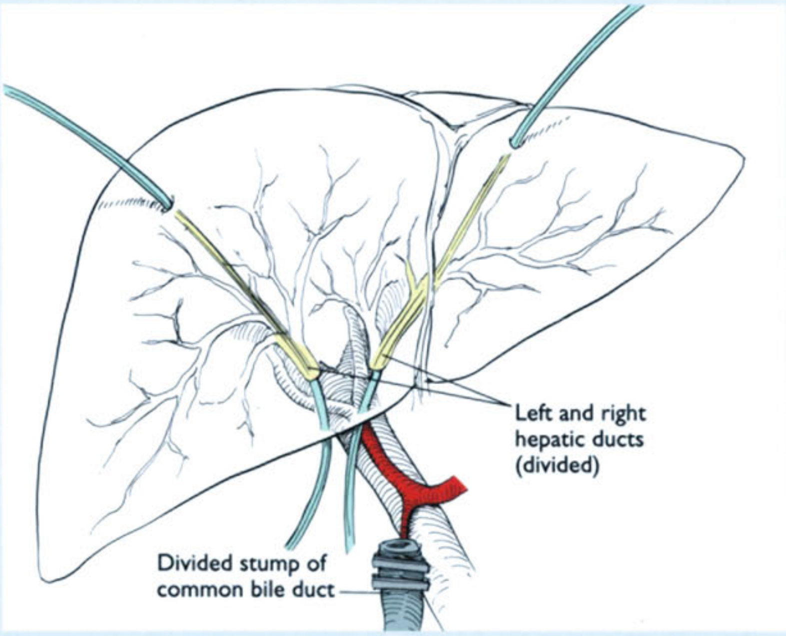


FIGURE 9-9.
Preoperative percutaneous transhepatic cholangiography should be performed and bilateral stents left in place for ductal identification at the time of exploration.

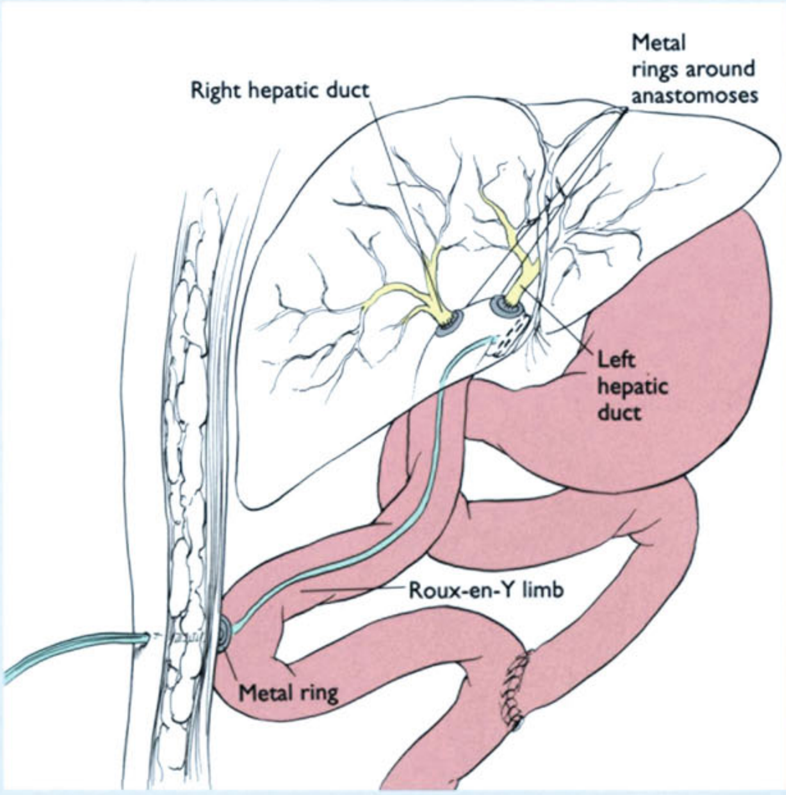


FIGURE 9-10.
Multiple anastomoses may be required, though some ducts may be filleted and anastomosed concurrently. It is critical that all scar tissue be excised and that a mucosa to mucosa anastomosis be performed on normal ductal tissue. The anastomoses should be marked with a radiopaque horseshoe and the Roux-en-Y segment should be tacked to the anterior abdominal wall and marked with clips or a coronary o-ring. This allows subsequent access to the biliary tree without percutaneous transhepatic cholangiogram.

enced hepatobiliary surgeon, as the best chance of a long-term success is at the first attempted repair.

Thermal injury can cause stricture and scarring that is reminiscent of ductal malignancy. The density and character of the damaged tissue can make intraoperative identification of the ductal anatomy and the subsequent repair very difficult. The excised scar tissue should be sent for pathologic examination. Extrahepatic ductal strictures may be caused by the inappropriate placement of a biliary clip or by thermal injury. A minority of strictures will be amenable to percutaneous or ERCP balloon dilation, though most will require hepaticojejunostomy. Bile leaks from the cystic duct or a minor common duct injury usually respond to percutaneous drainage alone or percutaneous drainage with endoscopic stenting. ERCP in such situations allows for diagnosis and treatment of contributory pathology such as retained stones. Octreotide may be useful to decrease the volume of a leak and hasten its closure. Finally, if these measures fail, operative intervention with closure of the leak may be necessary.

Table 9-6. Techniques to avoid injury

Clear, unobstructed view of the infundibulum/triangle of Calot
Firm cephalad retraction of the fundus, inferior and lateral retraction of the infundibulum
Dissect fat/areolar tissue from infundibulum toward common duct, never vice versa
Visualize absolutely the cystic duct–gallbladder junction with no other intervening tissue
Cholangiography to confirm anatomy and rule out other pathology
Accessory/anomalous ducts are rare; do not over-call
A ductal structure wider than a standard clip is the common duct until proven otherwise
Never cauterize or clip blindly to control bleeding
Irrigate as often as necessary to clear the operative field and optimize visualization
Six to eight clips are the routine maximum; the need for more should lead to conversion
Asking oneself if one should convert to open surgery probably means one should

Prevention of Injuries

Nearly all biliary injuries during laparoscopic cholecystectomy are preventable (Table 9-6) [1,4,5]. The fundus of the gallbladder and region of the portahepatis must be clearly in view on the operating monitor prior to beginning any dissection (Figs. 9-11–9-13). The operative field must not be obstructed by the stomach, duodenum, colon, or liver. Videotapes of procedures in which injuries occurred revealed that inadequate visualization, from inexperience of the surgeon or mechanical difficulties, can lead to misinterpretation of the anatomy and subsequent injury [6]. No clips should be placed nor any cuts made in a tubular structure until the cystic duct infundibular junction has been identified with certainty.

Intraoperative cholangiography is an important adjunct to the prevention of injury [5,7]. Anomalous or accessory biliary ducts may be identified, and in a minority of cases the operative plan will be altered on the basis of cholan-

Injury Prevention

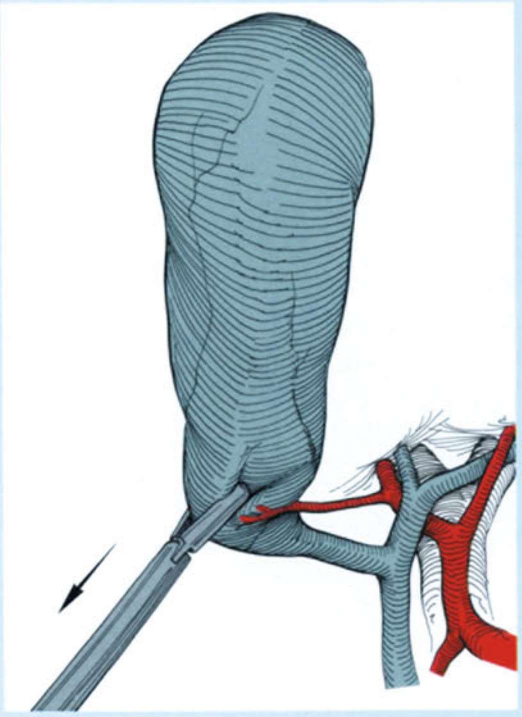


FIGURE 9-11.
Proper retraction of the gallbladder is critical to expose the cystic duct gallbladder junction. There should be maximal cephalic retraction of the fundus of the gallbladder while the infundibulum is retracted laterally and inferiorly at a 90° angle to the common bile duct. The traction should be firm but not excessive to prevent tenting of the common bile duct into the operative field.

Injury Prevention

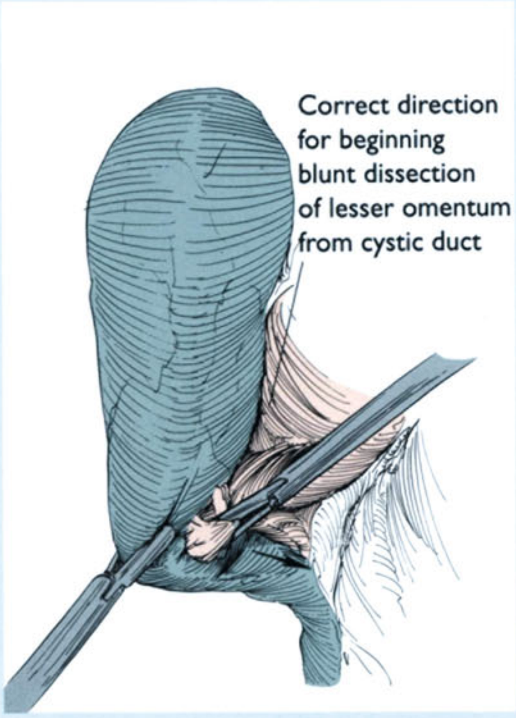


FIGURE 9-12.
The adventitial fatty tissues on the infundibulum of the gallbladder should be dissected away from the infundibulum and toward the common duct and never the opposite. This principle of dissecting away from the gallbladder holds true for the cystic artery as well.

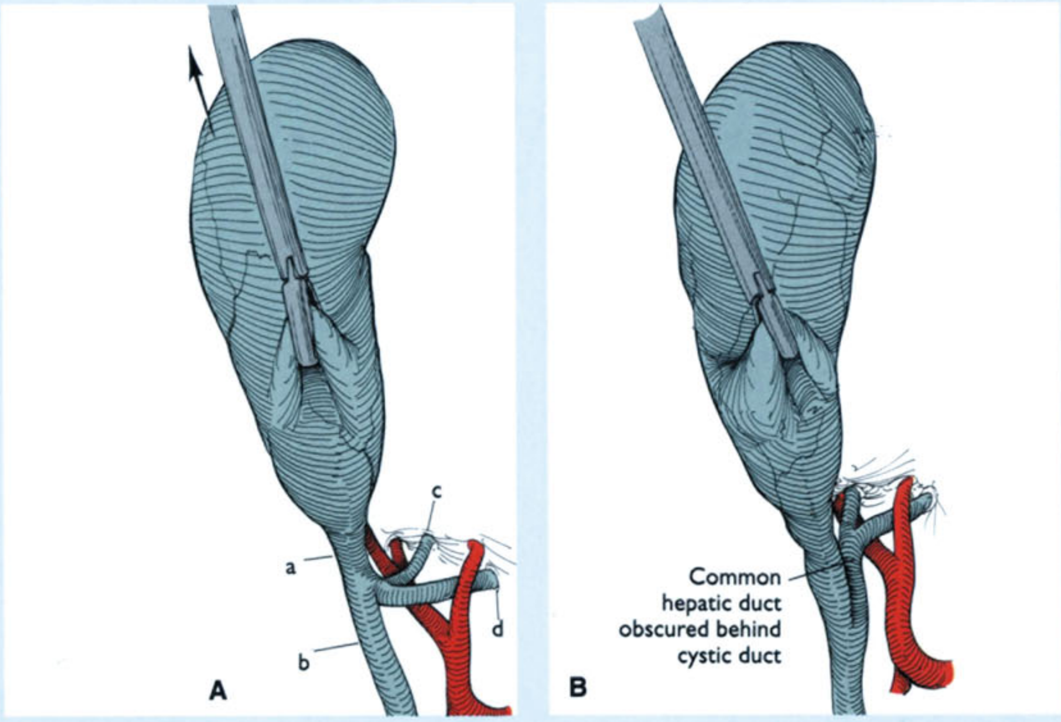


FIGURE 9-13.
A, Inappropriate firm and cephalad retraction on the infundibulum may bring the cystic duct (*a*) and common duct (*b*) into a linear configuration. This predisposes to misidentification of the common duct as the distal cystic duct, leading to the classic injury. The right (*c*) and left (*d*) hepatic duct are identified. **B**, Inappropriate medial and cephalad retraction of the infundibulum predisposes to common hepatic or right hepatic ductal injury even if the cystic duct is correctly identified.

giography. There is controversy concerning whether cholangiography is mandatory, but if any question arises regarding ductal anatomy, if dissection is at all difficult, or it is early in the experience of any surgeon, cholangiography should be performed. A recently compiled series of 171 patients with laparoscopic cholecystectomy biliary injuries indicated that if intraoperative cholangiography was performed, both the severity and Bismuth level of the injury was less severe. Moreover, in a significant number of cases, correctly interpreted cholangiography can prevent progression from one level of severity to the next [6,8].

Finally, one should always maintain a conservative attitude toward conversion of laparoscopic cholecystectomy to an open operation. Conversion to open operation should not be viewed as a complication or as inexperience but as an exercise in good judgment [4,7,9].

Miscellaneous Complications

Bleeding

Bleeding that is not associated with a bile duct injury may occur from the dissection bed near the porta, from the cystic artery stump, or from the gallbladder bed itself. Bleeding in the portahepatis should be considered a criteria for opening the patient, as injudicious placement of clips or imprecise cautery may injure the bile duct or worsen the bleeding. The cystic artery stump may be grasped and clips or ties reapplied as necessary. If this proves difficult because of the amount of bleeding, the patient should be immediately opened. Bleeding from the gallbladder bed may be compressed by the organ if it is still attached. Individual bleeding sites may be cauterized, and topical agents may be applied to the hepatic bed to tamponade bleeding. Ongoing bleeding that is difficult to control or coming from the region of the porta may be associated with bile duct injury, so converting to open cholecystectomy is indicated.

Spilled Stones

Stones may leak from the gallbladder during the dissection of the gallbladder from its bed or upon removal of the gallbladder from the abdominal cavity (Table 9-7).

Stones that are spilled into the abdominal cavity usually cause no complications, but there have been reports of subhepatic and intraperitoneal abscesses caused by free-floating stones [10]. There have been reports of stones migrating into the hepatic substance, into the gastrointestinal tract, and through the diaphragm into the lung parenchyma causing cholelithoptysis and cholelithorrhea [11]. If intra-abdominal stones remain, then prophylactic antibiotics should be administered and the abdomen should be copiously irrigated.

Electrosurgical Injury

The use of electrosurgery is obviously critical to the performance of laparoscopic cholecystectomy. A detailed review of the subject is beyond the scope of this chapter but has been recently presented [12]. The safe use of electrosurgical techniques in laparoscopic surgery requires a basic understanding of several principles (Table 9-8).

Laparoscopic surgery is performed using instruments that are between 30 and 50 cm in length. However, the field of view on the monitor as the operation proceeds is typically 5 to 10 cm in diameter. Events related to the electric current in the proximal 20 cm of the instruments, therefore, are out of view of the surgeon. Though most instruments have adequate insulation for routine use, the vast majority of the insulated portion of the instruments is out of view. If there is breakdown of this protective layer, escape of electric energy to surrounding viscera can occur.

With the expansion in laparoscopic general surgery has come a vast increase in instrumentation design. One unfortunate result is the combination of metal and plastic in trocar and cannula design. Passage of a metal cannula through a plastic collar should be condemned because of its ability to set up a capacitance couple with subsequent discharge of electric energy into hollow viscera (Fig. 9-14). The use of all metal cannulas is strongly encouraged to prevent this problem.

Finally, instruments carrying monopolar current may inadvertently contact the laparoscope. If an all metal cannula is in use, the current will pass through the trocar and pass safely through the abdominal wall. However, if a plastic cannula is in use, the current may pass to adjacent organs out of view of the field of the operation, potentially causing injury. It should be remembered that electrocautery generates intense heat when applied to tissues. Heat conducted through the biliary tree via the cystic duct, cystic artery, or surrounding tissues during dissection can cause ischemia and stricturing of the extrahepatic or intrahepatic biliary tree. Judicious use of the cautery is advised to prevent devastating injury.

Table 9-7. Potential complications of spilled stones

Abscess	Migration of stones
Subhepatic	Transdiaphragmatic
Subphrenic	Intrahepatic
Intraperitoneal	Transbronchial

Table 9-8. Electrosurgical hazards and their consequences

Hazard	Potential consequence
Insulation breakdown	Spark-gap to adjacent viscera
Combination metal/plastic trocar/cannulae	Sets up capacitance couple with discharge to adjacent viscera
Narrow field of view	Electrical events occur off-screen
Loss of tactile sensation	Intense heat generated at the ends of long instruments

Electrosurgical Injury

FIGURE 9-14.
Discharge of energy from instruments with insulation defects or in which a capacitance couple has been established may cause a burn injury to the duodenum or colon with subsequent perforation, or to the bile duct with subsequent stricture.

Results

Laparoscopic cholecystectomy has proven to be a very safe procedure. Seven major series, comprising 8856 patients, were recently reviewed (Table 9-9). Major complications including biliary injury and leakage, hemorrhage, infection, trocar and Veress needle injuries, and major organ system morbidity were less than 3% [1,12–17]. Though the rate of biliary injury, clearly the most devastating complication, is extremely low, these patients present particularly challenging problems.

The biliary injury encountered in open cholecystectomy consists primarily of postoperative stricture at the level of the cystic duct–common duct junction. Ducts that are transected are typically transected sharply and can usually be repaired primarily over a T-tube with good results, though some develop late strictures. The severity of laparoscopic cholecystectomy injuries is clearly worse, with major segments of the biliary tree removed or scarred secondary to thermal injury.

Several series detailing the management of biliary complications of laparoscopic cholecystectomy have been published. Rossi and coworkers [7] detailed the management of 11 patients who underwent biliary reconstruction after laparoscopic cholecystectomy. They emphasize several risk factors including acute or chronic inflammation and scarring in the triangle of Calot, as well as obesity. All 11 patients underwent at least one hepaticojejunostomy for reconstruction and two patients who had been repaired at outside hospitals underwent re-do intrahepatic hepaticojejunostomy. Patients with such injuries averaged almost 29 day's in the hospital and from 3 to 7 months out of work. The Mayo Clinic chronicled 22 patients with major injuries. Nineteen of these patients had injuries in the biliary tree including 11 with Bismuth type II or higher [10]. The author emphasized the high rate of bile duct injuries and reinforced the experience of others that the injuries occurred high in the biliary tree. Soper and coworkers [9] treated 20 patients with biliary complications following laparoscopic cholecystectomy. In 15 of these patients the injury was to the common bile duct or common hepatic duct. In 10 of these 15 patients the common bile duct was mistaken for the cystic duct and the classic injury or one of its variants ensued. Nine of the patients had injuries at Bismuth type II or higher. Eleven of the patients required hepaticojejunostomy for treatment, with three requiring at least one reoperation for leak or stricture. At Duke University Medical Center, 50 total patients, 38 with major injuries to the major bile ducts, were encountered [4]. Twenty-four patients had the classic injury or a variant. These patients underwent Roux-en-Y hepaticojejunostomy after evaluation and placement of transhepatic stents. Reoperation was necessary in five of these 38 patients. Right hepatic lobectomy was required in two patients for unreconstructible right hepatic ductal injury. Thirty-one of the 38 patients had injuries of Bismuth type II or higher, and 16 patients had injuries involving at least four individual intrahepatic ducts.

Despite its overall safety, these four series document the catastrophes that may occur during laparoscopic cholecystectomy. Many of these patients are young and can expect continuing morbidity and a certain percentage of mortality as examination of these series continues. Careful and meticulous preparation and dissection, as well as the principles outlined earlier as specific preventive measures must be adhered to so that these most feared complications may be avoided.

Table 9-9. Rates of injury

Study	Cases, *n*	Biliary injury, *n*(%)	Biliary leak, *n*(%)	Bleeding, *n*(%)
Litwin and coworkers [17]	2201	3(0.1)	22(1)	95(4.3)
Larson and coworkers [15]	1983	5(0.3)	7(0.4)	7(0.4)
Southern Surgeons Club [1]	1518	7(0.5)	3(0.2)	4(0.3)
Cushieri and coworkers [13]	1236	4(0.3)	0	0
Baird and coworkers [16]	800	0	3(0.4)	3(0.4)
Soper and coworkers [9]	618	1(0.2)	1(0.2)	0
Spaw and coworkers [14]	500	0	1(0.2)	1(0.2)
Total	8856	20(0.2)	37(0.4)	110(1.2)

References

1. The Southern Surgeons Club: Prospective analysis of 1518 laparoscopic cholecystectomy. *N Engl J Med* 1991, 324:1073–1078.
2. Shanahan D, Knight M: Laparoscopic cholecystectomy. *BMJ* 1992, 304:776–777.
3. Moore MJ, Bennett CL: The learning curve for laparoscopic cholecystectomy. *Am J Surg* 1995, 170:55–59.
4. Branum G, Schmitt C, Baillie J, *et al.*: Management of major biliary complications after laparoscopic cholecystectomy. *Ann Surg* 1993, 217:532–541.
5. Hunter JG: Avoidance of bile duct injury during laparoscopic cholecystectomy. *Am J Surg* 1991, 162:71–75.
6. Stewart L, Hunter J, Oddsdottir M, Way LW: Prevention of bile duct injuries during laparoscopic cholecystectomy. *Surgery* 1993, in press.
7. Rossi RL, Schirmer WJ, Braasch JW, *et al.*: Laparoscopic bile duct injuries: risk factors, recognition, and repair. *Arch Surg* 1992, 127:596–602.
8. Woods MS, Traverso LW, Kozarek R, *et al.*: Characteristics of biliary tract complications during laparoscopic cholecystectomy: a multi-intitutional study. *Ann J Surg* 1994, 167:27–33.
9. Soper N, Flye MW, Brunt LM, *et al.*: Diagnosis and management of biliary complications of laparoscopic cholecystectomy. *Am J Surg* 1992, 165:663–669.
10. Ress A, Sarr M, Nagorney D, *et al.*: Spectrum and management of major complications of laparoscopic cholecystectomy. *Am J Surg* 1993, 165:655–662.
11. Lee VS, Paulson EK, Libby E, *et al.*: Cholelithoptysis and cholelithorrhea: rare complications of laparoscopic cholecystectomy. *Gastroenterology* 1993, 105:1877.
12. Odell RC: Laparoscopic electrosurgery. In *Minimally Invasive Surgery.* Edited by Hunter JG, Sackier JM. New York: McGraw-Hill Inc.; 1993:33–41.
13. Cushieri A, Dubois F, Moviel J, *et al.*: The European experience with laparoscopic cholecystectomy. *Am J Surg* 1991, 161:385–387.
14. Spaw AT, Reddick EJ, Olsen DO: Laparoscopic laser cholecystectomy: analysis of 500 procedures. *Surg Laparosc Endosc* 1991, 1:2–7.
15. Larson GM, Vitale GC, Casey J, *et al.*: Multipractice analysis of laparoscopic cholecystectomy in 1988 patients. *Am J Surg* 1992, 163:221–226.
16. Baird DR, Wilson JP, Mason EM, *et al.*: An early review of 800 laparoscopic cholecystectomies at a university-affiliated community teaching hospital. *Am Surg* 1992, 58:206–210.
17. Litwin DEM, Girotti MJ, Poulin EC, *et al.*: Laparoscopic cholecystectomy trans-Canada experience with 2,201 cases. *Can J Surg* 1992, 35:291–296.
18. Soper NJ, Stockmann PT, Dunnegan DL, *et al.*: Laparoscopic cholecystectomy: the new "gold standard"? *Arch Surg* 1992, 127:917–923.

CHAPTER 10

Laparoscopic Cholecystojejunostomy

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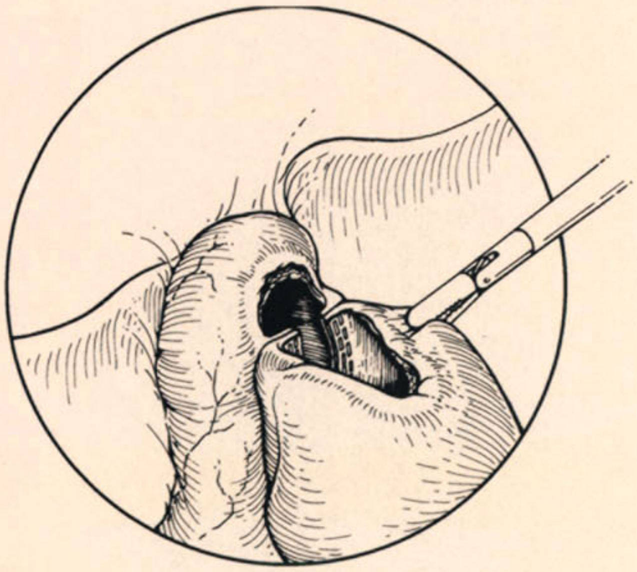


With the advent of advanced endoscopic techniques, the management of malignant obstructive jaundice has changed over the past decade. Nonoperative biliary drainage techniques have replaced surgical drainage procedures as the mainstay for palliation of pancreatic cancer. Nonoperative biliary intervention for obstructive jaundice was first developed via the transhepatic route, although this approach was associated with all the problems of puncturing the liver, particularly bile leakage and bleeding [1]. More recently, with the development of larger channel, side-viewing endoscopes [2], biliary stent placement via the endoscope has provided good decompression with a much lower incidence of complications [3]. A randomized controlled trial from the Middlesex Hospital in 1989 compared surgical bypass and endoscopic stenting in over 200 patients [4]. In this study, both young and elderly patients were included and the two groups were well balanced with equal numbers of elderly and ill patients in each group in an attempt to study a realistic spectrum of patients, a point of critique of many previous studies. There was a significantly lower complication rate after endoscopic stenting (10%) compared with surgery (28%), and the direct procedure mortality was significantly lower in the stenting group compared with surgery (4% vs 13.6%), as was the 30-day mortality (7% vs 17%). The early benefits of surgery made no difference to the overall outcome of the two groups: survival curves were identical and median survival was 5 months. Although it has been demonstrated that 10- to 12-French endoscopic stents block at 4 to 5 months and need replacing [5], only 18% of patients in the stenting group were readmitted for stent change. With the arrival of wider bore stents (Wallstent; Schneider, Minneapolis, MN) and expanding stents (Palmaz-Schatz; Johnson & Johnson, Warren, NJ), the need for readmission may be obviated as these may occlude less frequently.

The above provides compelling data to suggest the routine use of endoscopy in the management of malignant biliary obstruction. Surgical biliary bypass should be reserved for younger, fitter patients who might survive more than 6 months. Additionally, in those patients in whom a gastric bypass for duodenal obstruction is anticipated, surgical decompression of the biliary tree is recommended at that time as well. Endoscopic stenting is recommended for ill, elderly, or frail patients often with advanced malignant disease in whom survival of only 3 to 4 months might be expected [6].

Indications for laparoscopic biliary bypass should follow the above "open" surgical decompression indications. Ileus, the effects of a large abdominal incision, and necessity for pain medications, all lessened with laparoscopic procedures, may be significant advantages over the open techniques, and may allow for early mortality and morbidity results more comparable with endoscopic treatment. Currently, laparoscopic cholecystojejunostomy (CCJ) is the most technically feasible; with the advent of newer stapling laparoscopic and suturing devices, choledochojejunostomy (CDJ) may also be applicable.

Anatomy

The relevant anatomy of concern is outlined in Figure 10-1. The set-up for laparoscopic cholecystojejunostomy is depicted in Figure 10-2. The common hepatic duct starts at the union of the right and left hepatic ducts; the latter two ducts are normally 1 cm long with a diameter of 3 to 5 mm. The junction of the cystic duct and the common hepatic

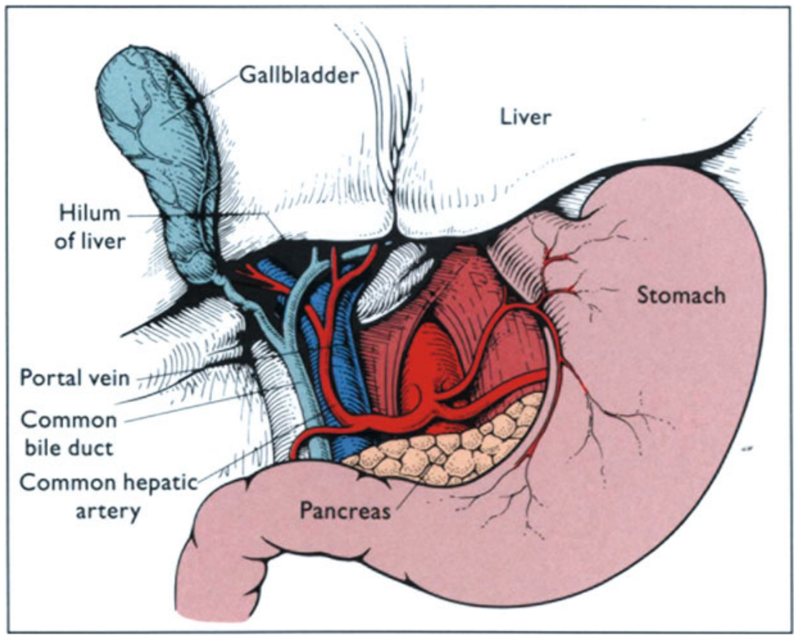


FIGURE 10-1.
Relevant anatomy for cholecystojejunostomy.

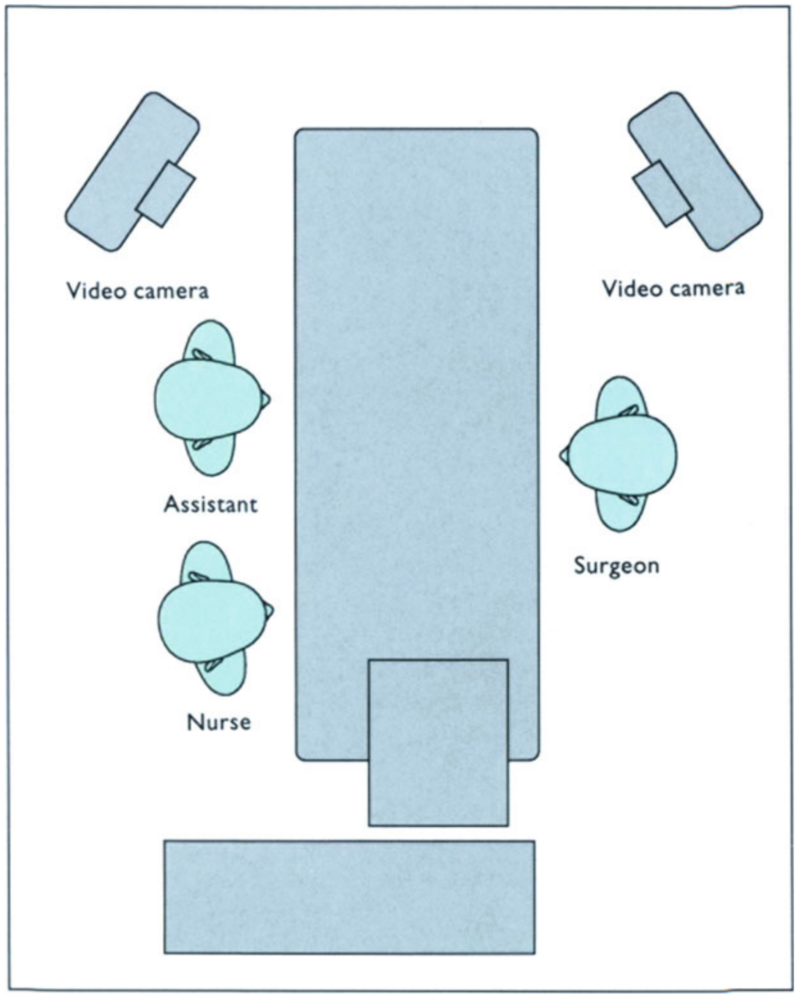


FIGURE 10-2.
The set-up for the laparoscopic cholecystojejunostomy is similar to the set-up for the laparoscopic Nissen fundoplication. The surgeon and assistants are as identified in this figure.

duct is generally considered to be the beginning of the common bile duct. The upper limit of normal of this duct is between 6 and 8 mm, and 10 and 12 mm after cholecystectomy. Intrahepatic and extrahepatic ducts usually lie anterior to their corresponding portal branches. The common bile duct, like all extrahepatic bile ducts, lies within the hepatoduodenal ligament, and then passes behind the first part of the duodenum, through the head of the pancreas, and into the wall of the duodenum to form the papilla of Vater on the medial surface of the second portion of the duodenum. The pancreatic duct of Wirsung joins the common duct in 90% of the cases forming the ampulla of Vater.

Pathophysiology, Presentation, and Differential Diagnosis

Between 75% and 92% of pancreatic malignancies are classified as ductal adenocarcinomas [7]. Acinar carcinomas comprise 2%, and are associated with panniculitis, polyarteritis, and eosinophilia presumably resulting from high circulating levels of lipase. Pancreatic cancers are more common in the head of the gland. The incidence of pancreatic cancer appears to have leveled off in the United States. In 1994, 27,000 new cases were diagnosed [8]. Unfortunately, only 10% to 15% of patients with pancreatic cancer have disease suitable for resection and possible cure by the time diagnosis is made [9,10]. This figure has not changed appreciably since the early 1970s. Since that time, with advances in imaging techniques and endoscopy, only length of survival after diagnosis has changed; cure has not [11]. Currently, 85% to 90% of patients presenting with pancreatic cancer will require some form of palliation.

The symptoms and signs that most commonly require alleviation in those patients with pancreatic cancer are jaundice, gastric outlet obstructions, and pain. In this chapter, laparoscopic options for the management of jaundice will be discussed. The laparoscopic management of gastric outlet obstruction and pain are discussed in other chapters.

Jaundice is seen in about 70% of patients with pancreatic cancer at some time [12,13]. It is present at the time of diagnosis in over 90% of patients with cancer of the head of the pancreas, as the tumor compresses the common bile duct in this region. In those patients with cancer of the body or the tail of the pancreas, jaundice is found in only 6% [14]. In these cases, jaundice is caused by compression of the common bile duct by metastatic disease in the nodes at the porta hepatis, or by impaired liver function secondary to massive metastases.

Painless jaundice, which is often said to be a cardinal sign of pancreatic cancer, is actually seen in only one third of patients. In one study, over 60% of the patients with pancreatic cancer had pain accompanying their jaundice.

Jaundice results when the serum bilirubin exceeds 3 to 5 mg/dL. The sustained elevated levels should be relieved for a variety of reasons (Table 10-1). First, prolonged jaundice can impair liver function; second, there is a 10% chance of cholangitis; and third, 25% of patients will develop a distressing pruritus not managed well by medications. Finally, the presence of the jaundice will serve as a constant reminder to the patient and family that there is uncontrollable disease within [10].

Evidence suggests that alleviation of jaundice prolongs survival [15–17], with survival times increased by almost 2 months (5.4 months for those undergoing surgical drainage versus 3.5 months for those who did not). The main criticism of these studies, however, is that those not undergoing a surgical decompression had more advanced disease, and direct conclusions from these data are difficult.

The differential diagnosis in this setting is essentially that of jaundice. Causes of hyperbilirubinemia include those associated with increased bilirubin production and those with decreased bilirubin clearance (Table 10-2). In North America, stasis of bile within the intra- and extrabiliary tracts is the most common cause of jaundice [18]. An accurate clinical history and physical examination will help narrow the scope of the differential. The insidious appearance of deep jaundice over a prolonged time frequently is indicative of neoplastic obstruction. Absence of pain, as mentioned above, is an unreliable indicator of malignant obstruction. The presence of occult blood in the stool may represent evidence of periampullary neoplasm. Courvoisier's sign (pain-

Table 10-1. Reasons to alleviate obstructive jaundice

Prolonged jaundice can impair liver function
Ten percent chance of cholangitis
Distressing pruritus in 25%
Jaundice is constant reminder to patient of uncontrollable disease within

Table 10-2. Differential diagnosis of jaundice

Increased bilirubin production	Decreased bilirubin clearance
Hemolysis	Selective defect in bilirubin clearance
Ineffective erythropoiesis	Gilbert syndrome
Reabsorption of hematomas	Crigler-Najar syndrome
Transfusions	Dubin-Johnson syndrome
	Rotor syndrome
	Cholestasis
	Hepatocellular disease
	Viral hepatitis (acute or chronic)
	Alcohol hepatitis (acute or chronic)
	Drug- or toxin-induced liver injury
	Primary biliary cirrhosis
	Acute or chronic congestive heart failure
	Sepsis
	Infiltrative diseases of the liver (including metastases)
	Biliary tract obstruction
	Choledocholithiasis
	Pancreatitis
	Tumor
	Sclerosing cholangitis

less, dilated, palpable gallbladder), is also suggestive of biliary obstruction secondary to malignancy.

The diagnosis of pancreatic cancer starts with the clinical suspicion of such. Initial investigations include computed tomography or ultrasonography for demonstration of pancreatic mass as well as dilation of bile pancreatic ducts, hepatic metastases, and extrapancreatic spread of tumor. In those patients with extensive local disease with adjacent structure invasion, hepatic metastases, or lymph node spread, palliative management of pancreatic cancer should be undertaken.

Surgical Technique

The preferred open procedures for relief of obstructive jaundice in patients with periampullary malignancy are CCJ and CDJ. In a collective review of the two procedures in 461 patients, mean survival time for CCJ and CDJ were 5.2 and 7.4 months and the mortality was 19% and 25.3%, respectively [11]. In addition, another series demonstrated that serum bilirubin concentrations returned to normal in 37.5% of patients with CCJ compared with 40.5% of patients with CDJ; the recurrence rate for jaundice after CCJ was 8.3% compared with 13.5% after CDJ [11].

These data have made CCJ an acceptable procedure provided that the cystic duct is patent and enters the common bile duct 2 to 3 cm away from the tumor mass. If any question arises regarding the patency of the cystic duct, an intraoperative cholangiogram should be performed. If the gallbladder is not present, or unsuitable for use, CDJ should be performed. To date, with current laparoscopic technology, the CCJ has been performed [19]. It is anticipated that with advances in laparoscopic techniques and instrumentation, CDJ will also be accomplished. Figures 10-3 through 10-15 depict the surgical techniques for laparoscopic CCJ.

Procedure

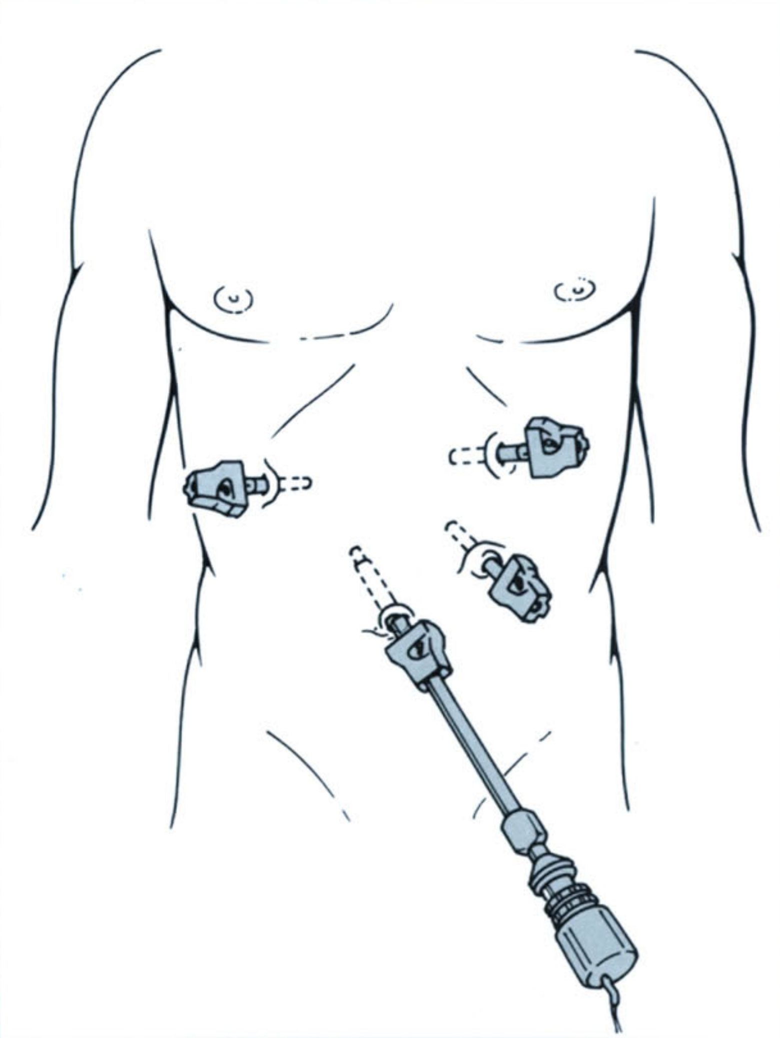


FIGURE 10-3.

Trocar placement. Trocars are placed as shown in the figure. After the umbilical port for the camera is placed, a 5-mm port is placed in the midline, supraumbilically (5–7 cm higher than the camera port). A 10-mm port is placed in the left upper quadrant of the abdomen in the anterior axillary line, 5 to 7 cm below the costal margin. Finally, a 12-mm port is placed in the right upper quadrant, in the anterior axillary line, 5 to 7 cm below the costal margin.

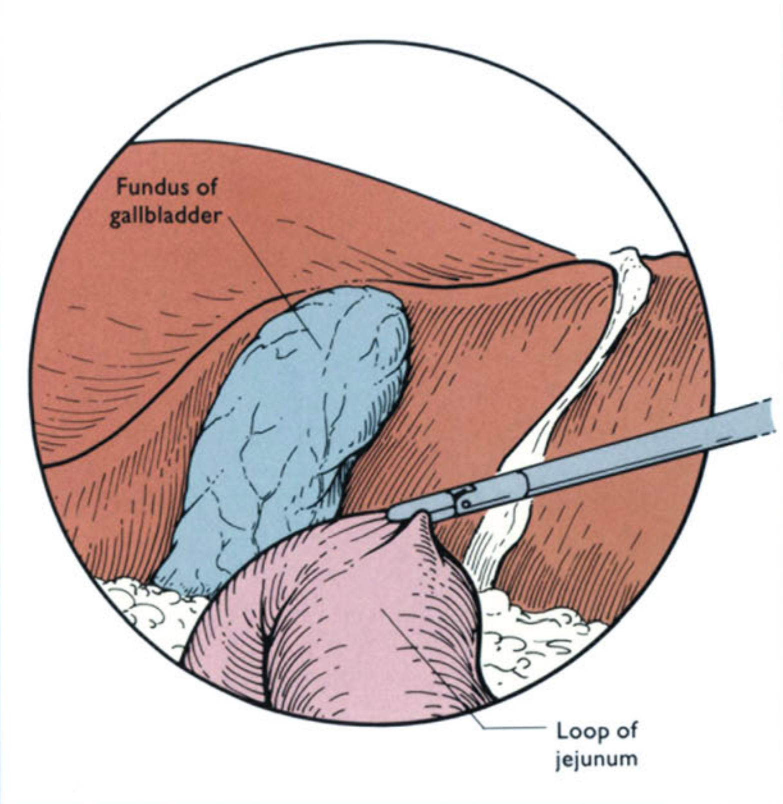


FIGURE 10-4.

Through the supraumbilical 5-mm port, a grasper is introduced into the abdomen and used to aid in a full visual inspection of the abdomen. Careful attention should be given to inspection for not only possible trocar injury but also for unsuspected pathology. More specifically, the area around the head of the pancreas and the duodenum should be inspected for tumor involvement; in cases where the tumor is large and the duodenum is involved, simultaneous performance of a gastrojejunostomy may be elected. Once it has been determined that a cholecystojejunostomy will be performed, the ligament of Treitz is identified, and the small bowel is followed and a portion of the bowel is selected and brought up to the fundus of the gallbladder in an antecolic fashion.

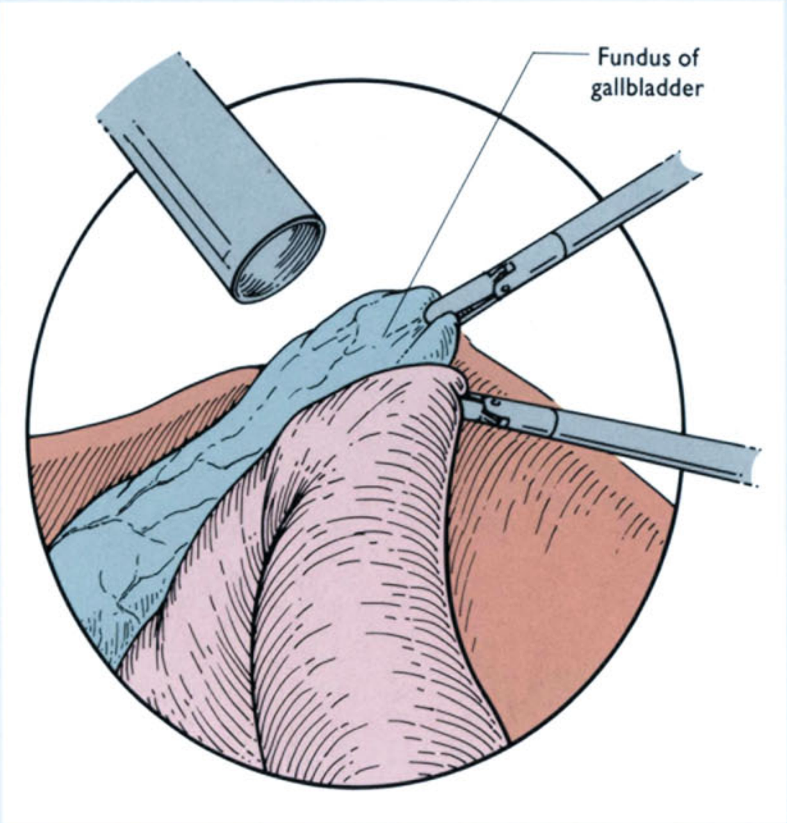
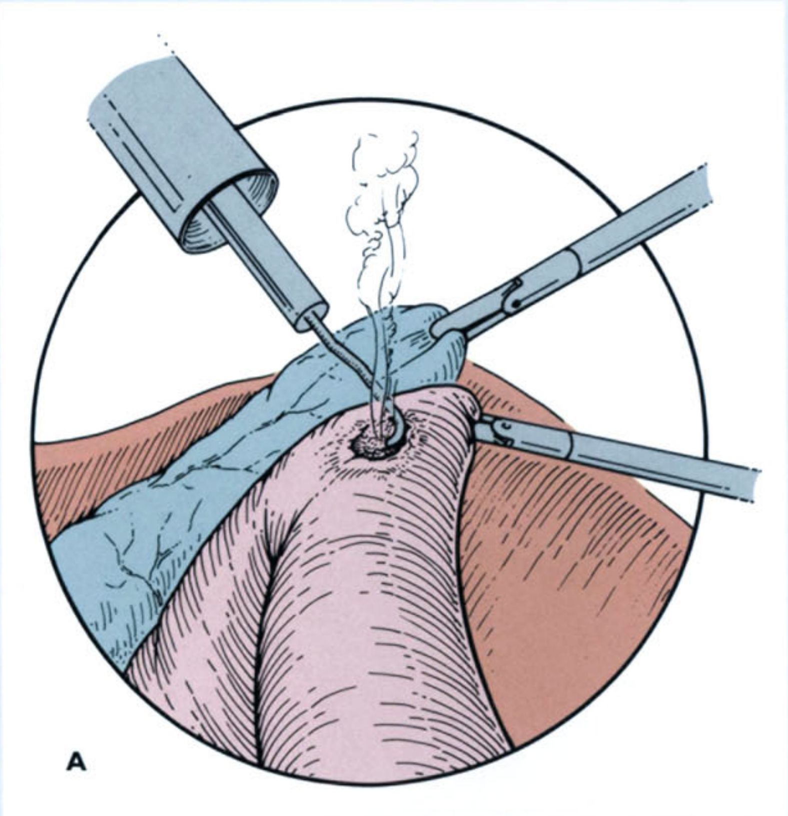


FIGURE 10-5.

A second grasper is introduced through the left upper quadrant port, and the fundus of the gallbladder is gently grasped. The jejunum and gallbladder should be placed in a position to ensure that neither the gallbladder nor bowel is tented or stretched in this position.



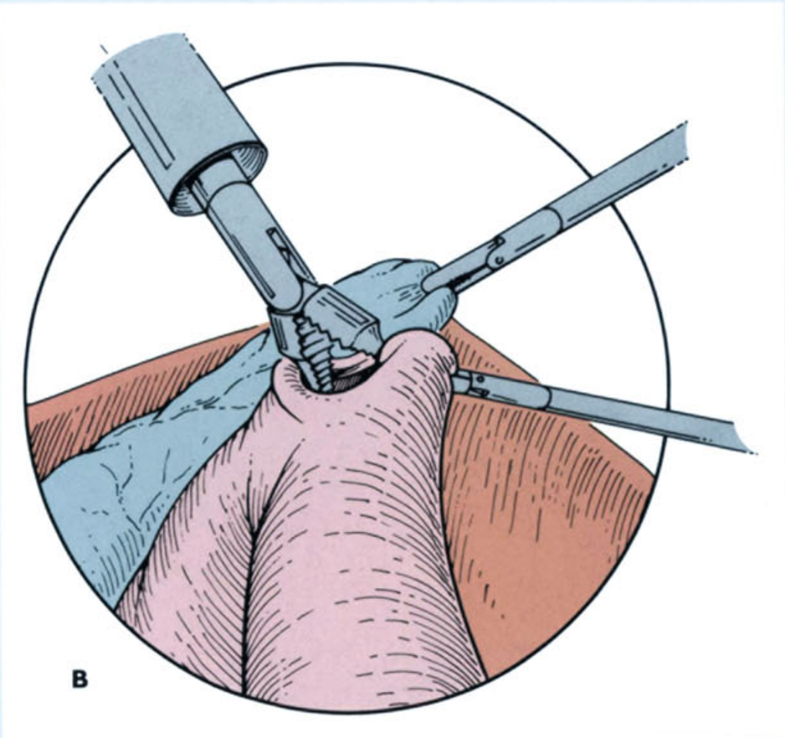


FIGURE 10-6.

A, With the aide of a down-sizer, a 5-mm cautery hook is placed through the large 12-mm trocar placed in the right upper quadrant. The cautery hook is gently applied to the antimesenteric border of the jejunum and used to create a 5-mm opening in the bowel wall. The end of the endoscopic stapler will be placed through this enterotomy. **B**, After the enterotomy has been made with the hook cautery, a spreader is placed into the abdomen and used to enlarge the enterotomy.

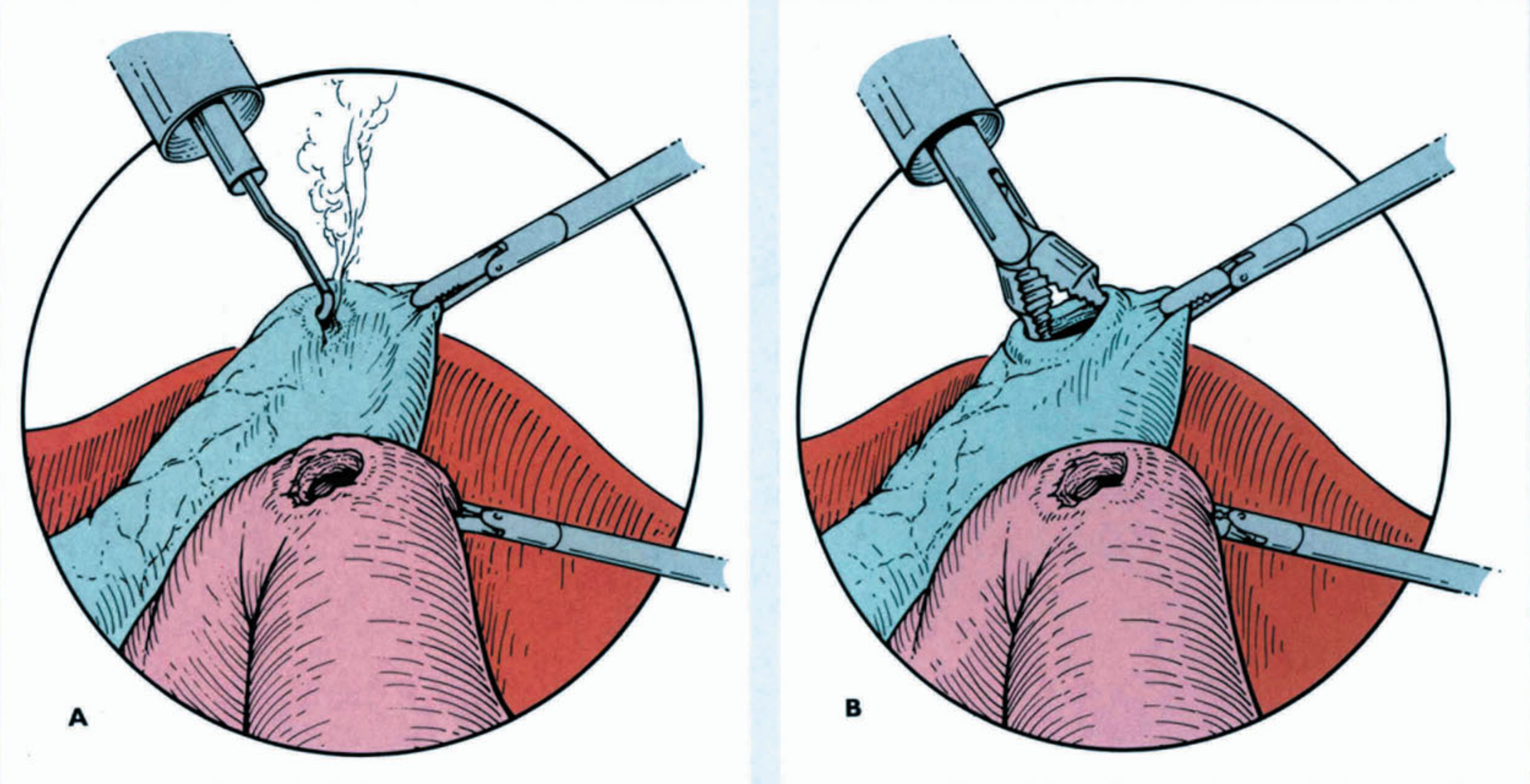


FIGURE 10-7.
A, In a fashion similar to that applied to the jejunum, a enterotomy is made in the fundus of the gallbladder. **B**, A spreader is placed into the abdomen and used to enlarge the enterotomy.

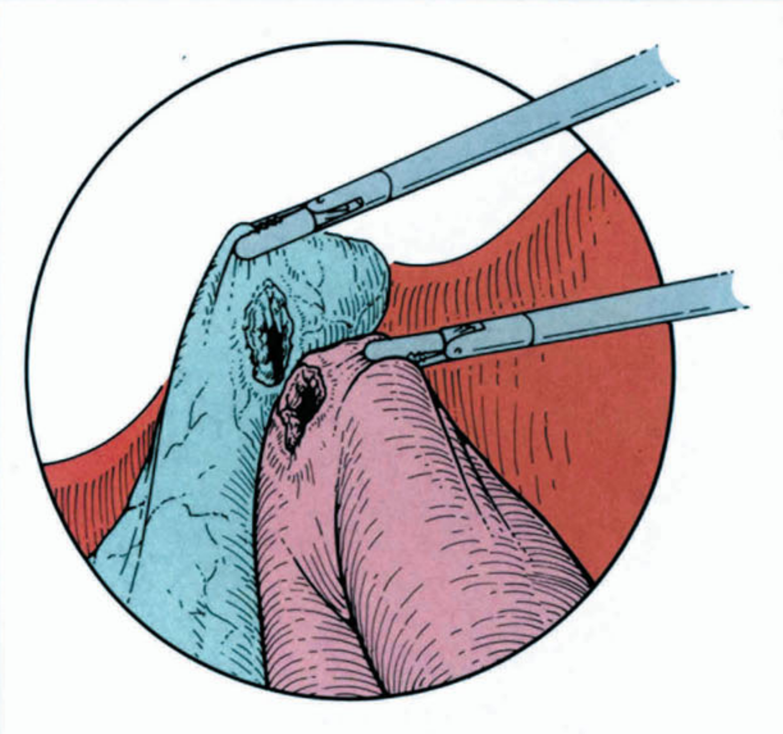


FIGURE 10-8.
The enterotomy and cholecystotomy are demonstrated as they are held in apposition. Note that the graspers used to hold each should not be removed until the stapler has been successfully placed.

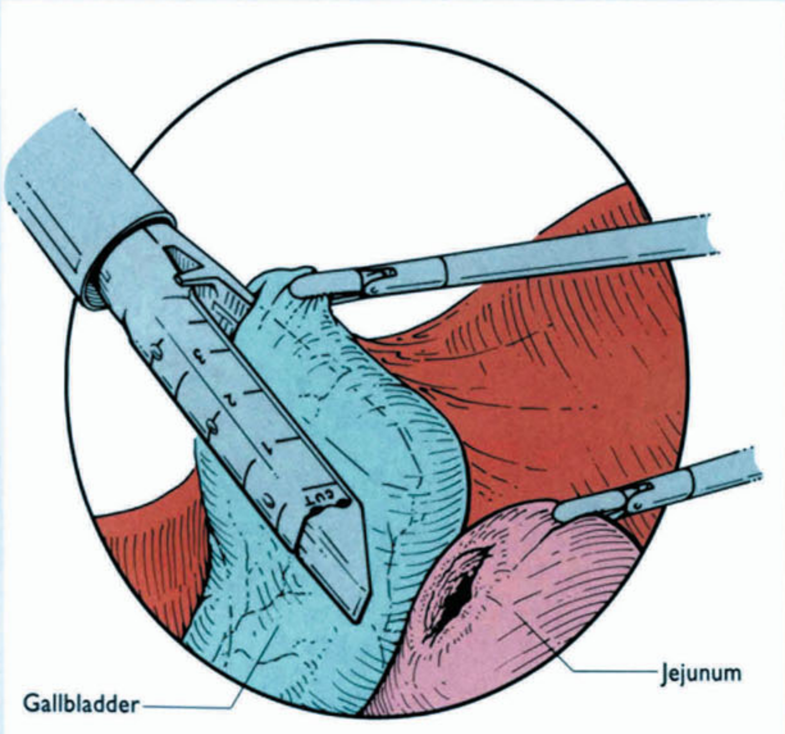


FIGURE 10-9.
A endoscopic stapler is placed into the abdomen via the 12-mm port. The jejunum is retracted from the field of view while one blade of the stapler is inserted into the cholecystotomy.

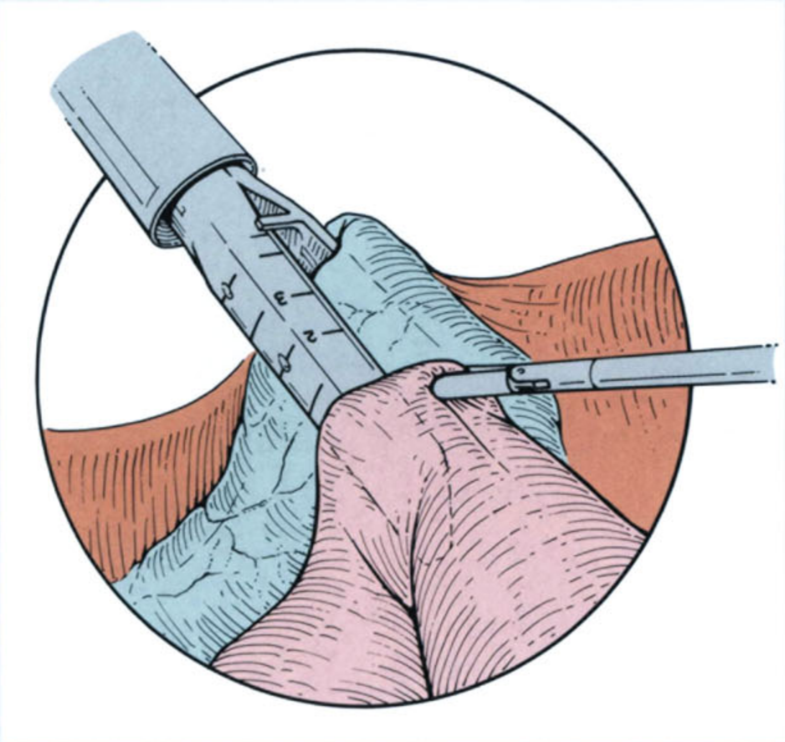


FIGURE 10-10.
The free blade of the stapler is then inserted into the jejunum via the enterotomy.

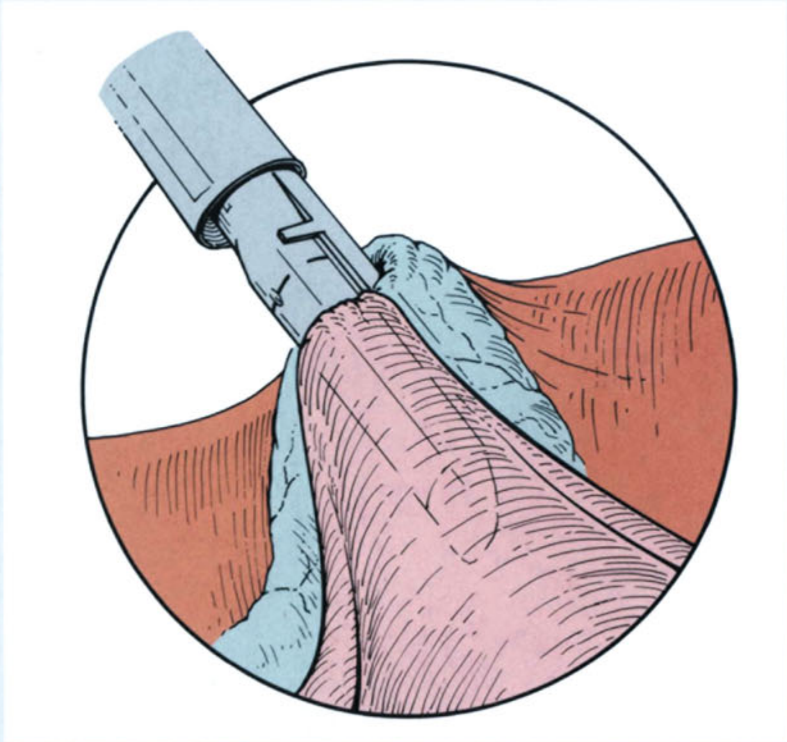


FIGURE 10-11.
Carefully, the stapler is closed. The stapler should not be fired until proper positioning and freedom from adjacent structures is verified.

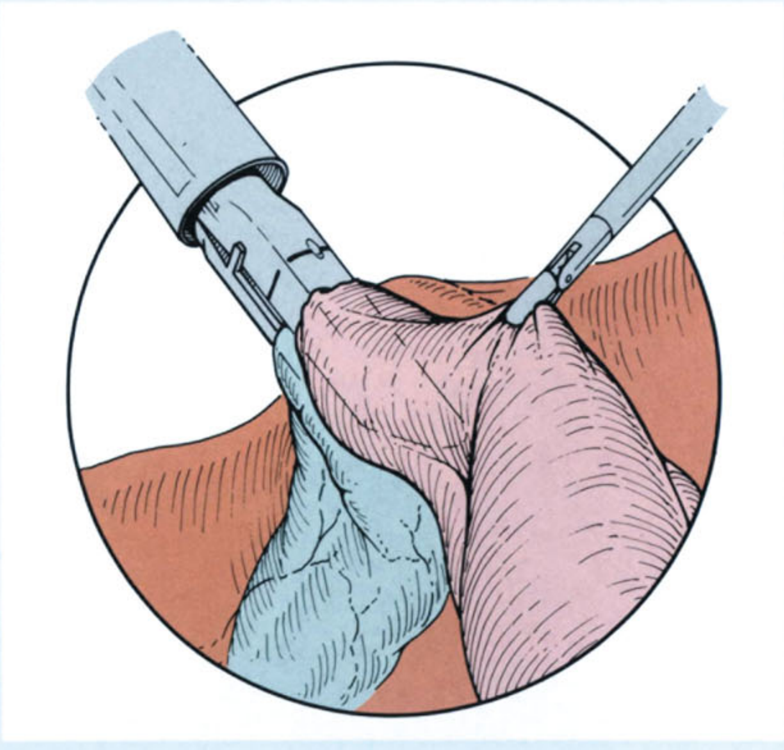


FIGURE 10-12.
Using the two graspers from the supraumbilical and left upper quadrant ports, the head of the stapler and free jejunum are mobilized and inspected to ensure that no bowel, bile duct, or colon is entrapped when the stapler was closed. Once this is verified, the stapler can be fired. After firing the stapler, it is carefully removed so that the staple line is not disrupted.

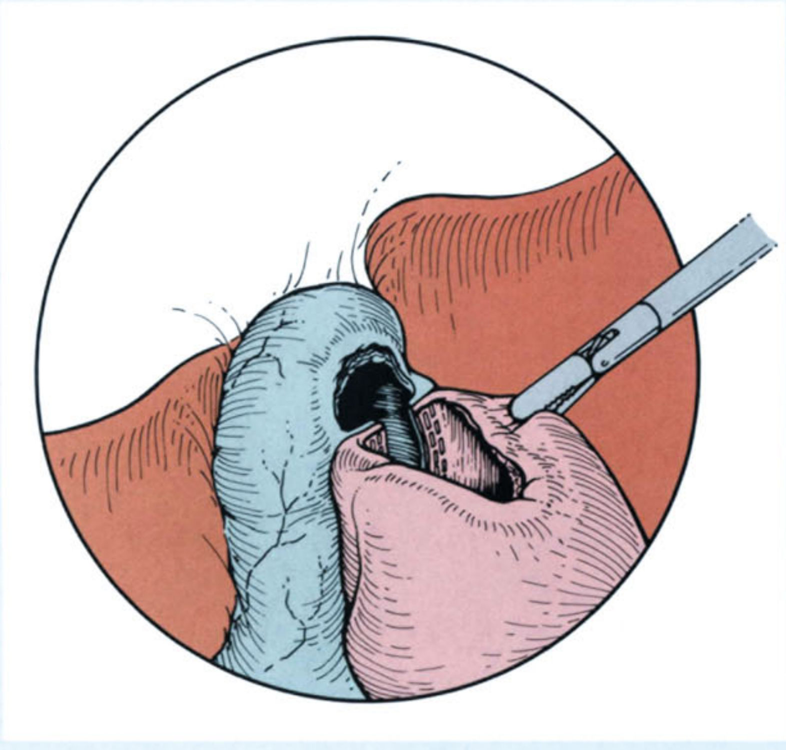


FIGURE 10-13.
After the stapler has been removed, the graspers are used to open the anastomosis and carefully inspect the staple line for integrity and hemostasis.

Alternative Procedure

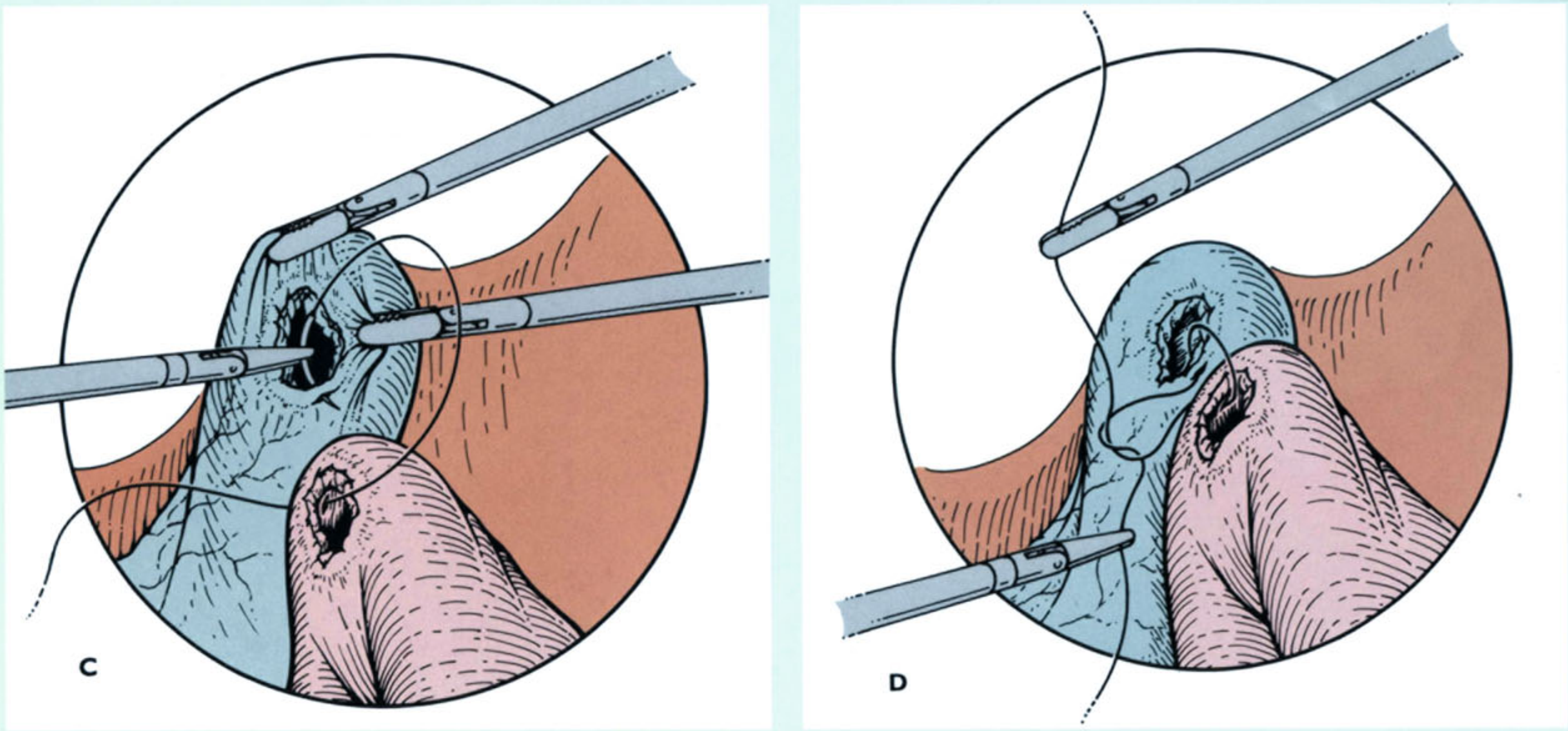


FIGURE 10-16. *(Continued)*
C, The suture is passed through the gallbladder. **D**, Finally, a knot is tied. This can be accomplished by either intra- or extracorporeal knots. Intracorporeal knot tying is illustrated here.

References

1. Hatfield AWR; Tobias R, Terblanche J, *et al.*: Preoperative external biliary drainage in obstructive jaundice: a prospective controlled clinical trial. *Lancet* 1982, ii:896–899.
2. Chari RS, Meyers WC: The liver. In *Current Practice of Surgery*. Edited by Levine BA, Copeland EM III, Howard RJ, Sugarman HJ, Warshaw AL. New York: Churchill Livingstone; 1993:1–41.
3. Spear AAG, Cotton PB, Russel RCG, *et al.*: Randomised trial of endoscopic versus percutaneous stent insertion in malignant obstructive jaundice: *Lancet* 1987, i:57–62.
4. Smith AC, Dowsett JF, Hatfield AWR, *et al.*: A prospective randomised trial of by-pass surgery versus endoscopic stenting in patients with malignant obstructive jaundice. *Gut* 1989, 30[abstract]:A1513.
5. Dowsett JF, Williams SJ, Hatfield AWR, *et al.*: Does stent diameter matter in the endoscopic palliation of malignant biliary obstruction? A randomized trial of 10 FG versus 12 FG endoprosthesis. *Gastroenterology* 1989, 96[abstract]:A128.
6. Hatfield AWR: Palliation of malignant obstructive jaundice: surgery or stent? *Gut* 1990, 31:1339–1340.
7. Ferdandez-del Castillo C, Warshaw AL: Nonendocrine neoplasms of the pancreas. In *Current Practice of Surgery*. Edited by Levine BA, Copeland EM III, Howard RJ, Sugarman HJ, Warshaw AL. New York: Churchill Livingstone; 1993:1–17.
8. Boring LS, Squires TS, Tong T, Montgomery S: Cancer statistics 1994. *Ca Cancer J Clin* 1994, 44:7–26.
9. Glasman WS, Johnson PW: Palliative surgery in carcinoma of the pancreas. *Geriatrics* 1955, 10:456–458.
10. Beal MS, Dyer GA: Disappointments in the management of patients with malignancy of the pancreas, duodenum, and common bile duct. *Arch Surg* 1970, 101:461–465.
11. Singh SM, Reber HA: Surgical palliation for pancreatic cancer. *Surg Clin North Am* 1989, 69(3):599–611.
12. Fontham ETH, Correa P: Epidemiology of pancreatic cancer. *Surg Clin North Am* 1989, 69(3):551–567.
13. Monge JJ: Survival of patients with small carcinomas of the head of the pancreas: bilio-intestinal bypass vs pancreato-duodenectomy. *Ann Surg* 1967, 166:908–912.
14. Reber HA: Palliative operations for pancreatic cancer. In *Surgical Diseases of the Pancreas*. Edited by Howard JM, Jordan GL Jr, Reber HA. Philadelphia: Lea and Febiger; 1987:725–733.
15. Sarr MG, Gladen HF, Beart RW Jr, *et al.*: Role of gastroenterotomy in patients with unresectable pancreatic carcinoma. *Surg Gynecol Obstet* 1981, 152:597–600.
16. Sarr MG, Cameron JL: Surgical management of unresectable carcinoma of the pancreas. *Surgery* 1982, 91:123–133.
17. Sarr MG, Cameron JL: Palliation of pancreatic cancer. *World J Surg* 1984, 8:906–918.
18. Roslyn JJ, Zinner MJ: Biliary ducts. In *Current Practice of Surgery*. Edited by Levine BA, Copeland EM III, Howard RM, Sugarman HJ, Warshaw AL. New York: Churchill Livingstone; 1993:1–26.
19. Fletcher DR, Jones RM: Laparoscopic cholecystojejunostomy as palliation for obstructive jaundice in inoperable cancer of the pancreas. *Surg Endosc* 1992, 6: 147–149.

CHAPTER 11

Laparoscopic Liver Biopsy

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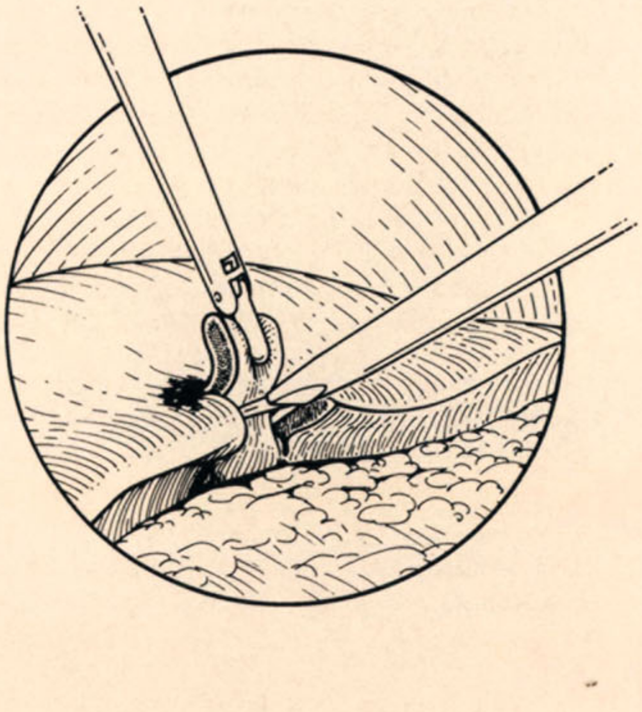
William C. Meyers



Operative management of liver disorders begins with their recognition and diagnosis. There are many initiation points that lead to diagnosis and treatment of specific disorders. Most often, cysts or solid lesions of the liver are found incidentally on ultrasound or computed tomography (CT). From this point further noninvasive or invasive tests may be performed to define pathology and guide therapy. Liver biopsy is one of the invasive tests the physician may choose to help in the diagnosis and management of the patient with liver disease. Indications for liver biopsy fall broadly into one of two categories: 1) biopsy for diagnosis of lesions identified by an imaging study; or 2) biopsy of the liver to evaluate status of the liver in diseases involving the whole liver parenchyma (Table 11-1). Percutaneous liver biopsy for the evaluation of liver masses is rarely indicated, as the information afforded is of limited value; a specimen may reveal normal liver tissue, which may represent a poorly obtained sampling of the lesion or it may reveal pathologic tissue. In either case the patient will need further operative evaluation. Laparoscopic liver biopsy adds another dimension to the diagnostic capabilities of needle biopsy: 1) the liver can be biopsied under direct vision; 2) the appearance of the liver can be assessed; 3) other abdominal pathology can be ascertained; and 4) evaluation of surrounding structures can be visualized and biopsied to assess the possibility of metastatic disease.

Disorders of the hepatobiliary system give rise to a wide variety of signs and symptoms (Table 11-2). In all cases, history and physical examination will provide important insights and clues. Although detailed description and discussion of these insights is beyond the scope of this chapter, it should be emphasized that an elaborate work-up cannot compensate for a poor initial evaluation, and moreover, a thorough initial evaluation may obviate unnecessary investigations. Important questions such as use of oral contraceptives, travel history, previous infections, or history of malignancy should never be overlooked in the evaluation of liver disease. Physical examination should be performed thoroughly since important clues as to the extent of the liver disease can be made; certainly those with advanced disease will have more obvious signs and symptomatology.

Anatomy

The liver is the largest gland in the body, with an average mass of 1500 grams in the adult. The liver resides under the rib cage, in the right upper quadrant of the abdomen, and is not palpable in the adult on physical exam. The inferior surface of the liver touches the duodenum, colon, kidney, adrenal gland, esophagus, and stomach. With the laparoscope, approximately 70% of the surface of the liver can be visualized, assessed, and evaluated. The anatomy of the liver, which is discussed below, describes the pertinent structures as appreciated by the laparoscope.

The reflections of the peritoneum, which attach the liver to the diaphragm, abdominal wall, and abdominal viscera are easily identified and define the topographic anatomy of the liver. There are three sets of ligaments. First there is the falciform ligament, which attaches the liver to the anterior abdominal wall; the ligamentum teres hepaticus (the remnant of the umbilical vein) is incorporated in its dorsal border. Second there is the anterior and posterior right and left coronary ligaments, which in continuity with the falciform connect the diaphragm of the liver; the lateral aspects of the anterior and posterior leaves of the coronary ligaments fuse to form the right and left triangular ligaments. The bare area of the liver is the area encompassed by the falciform, coronary, and triangular ligaments, superior to the vena cava, on the undersurface of the diaphragm. Even with the 30° viewing scope, the dome of the liver and the posterior ligaments are difficult to assess with the laparoscope. Finally, the gastrohepatic and hepaticoduodenal ligaments consist of the anterior layer of lesser omentum and are continuous with the left triangular ligament. The hepaticoduodenal ligament forms the anterior border of the epiploic foramen of Winslow, and contains the hepatic arteries, portal vein, and extrahepatic bile ducts.

With retraction of the anterior border of the liver, the undersurface can be evaluated. The hepaticoduodenal ligament can easily be viewed, and nodes biopsied if necessary. The topographic right and left lobes are the portions of the liver on the respective side of the falciform ligament. The caudate (Spigelian) lobe delineated anatomically by the posterior (transverse) extension of the falciform ligament (ligamentum venosum, the remnant of the ductus venosus)

Table 11-1. Indications for laparoscopic liver biopsy

Biopsy for specific lesions
Histologic diagnosis of lesion
Assess extent of metastatic disease
Biopsy for diffuse liver disease
Diagnosis of primary liver disease
Assess progression of disease
Assess response of liver to treatment
Diagnose condition of liver in metabolic disease
Define involvement of liver in multisystem liver disease

Table 11-2. Signs and symptoms of liver disease

Pain	Palmar erythema
Hepatomegaly	Pruritus/dermatitis
Muscle wasting	"White" fingernails
Sexual changes	Allergic vasculitis
Skin changes	Vitiligo
Jaundice	Acne vulgaris
Spider angiomata	Cyanosis

on the left, and the impression of the inferior vena cava on the right, is difficult to assess as it is mostly hidden from view by the hepaticoduodenal ligament and the gastrohepatic ligament. The quadrate lobe is anterior to the caudate lobe. It is bound by the gallbladder fossa on the right, the groove of falciform ligament to the left, and posteriorly by the porta hepatis (umbilical fissure) (Figure 11-1).

The lobar anatomy, as defined by the distribution of the major branches of the portal vein, seldom conforms to the topographic right and left lobes. Cantlie first reported in 1898 that the division of the right and left lobes of the liver was not the falciform ligament, but rather a line (Cantlie's line) passing through the fossa of the gallbladder and to the left of the inferior vena cava; this plane is also called the lobar fissure. Couinaud [1] further divided each of the four segments into two, resulting in a total of eight subsegments: four on the right, three on the left, and one corresponding to the caudate lobe, segment I. Segments II to IV constitute the anatomical left lobe of the liver, while segments V to VIII comprise the right. The caudate lobe is its own segment in the French nomenclature as described by Couinaud; anatomically, the branches of the portal vein in the caudate are two in number, one arising from each the right and left portal branches. Thus, the caudate is actually part of both the true left and right lobes (Figure 11-2).

The liver has a dual blood supply, three fourths of the flow volume is derived from the portal vein, and one quarter from the hepatic artery. The portal vein arises from the confluence of the superior mesenteric vein and the splenic vein. The hepatic artery most commonly derives its origin from the coeliac axis. The terms *proper* and *common* hepatic arteries refer to segments proximal and distal to the origin of the gastroduodenal artery, respectively. Many variations of the hepatic artery anatomy have been described, but these variations pose no real difficulty in laparoscopy.

The biliary drainage of the liver begins at the hepatocyte level, and these tributaries unite to form progressively larger channels. The left hepatic duct forms in the umbilical fissure (porta hepatis) from the union of the ducts of segments II, III, and IV and crosses at the base of the quadrate lobe and unites with the right hepatic duct. The right hepatic duct drains segments V to VIII, and arises from the junction of the anterior and posterior right segmental ducts. The junction of the two hepatic ducts is usually found above the right branch of the portal vein. The confluence of these ducts marks the start of the common hepatic duct. The drainage of the caudate lobe (segment I) varies considerably, but enters both the right and left hepatic duct systems in about 80% of cases; in 15% of the cases it drains only into the left hepatic duct, and only into the right in 5% of cases. Variation of hepatic duct anatomy is known, but of little consequence in this procedure. The cystic duct joins the common hepatic duct, and is thereafter called the common bile duct. The upper limit of normal of this duct is between 6 to 8 mm, and 10 to 12 mm after cholecystectomy. Intrahepatic and extrahepatic ducts usually lie anterior to their corresponding portal branches. The common bile duct, like all extrahepatic bile ducts, lies within the hepatoduodenal ligament, and then passes behind the first part of the duodenum, through the pancreas, and into the wall of the duodenum to form the papilla of Vater on the medial surface of the second portion of the duodenum; the pancreatic duct of Wirsung joins the common duct in 90% of the cases forming the ampulla of Vater.

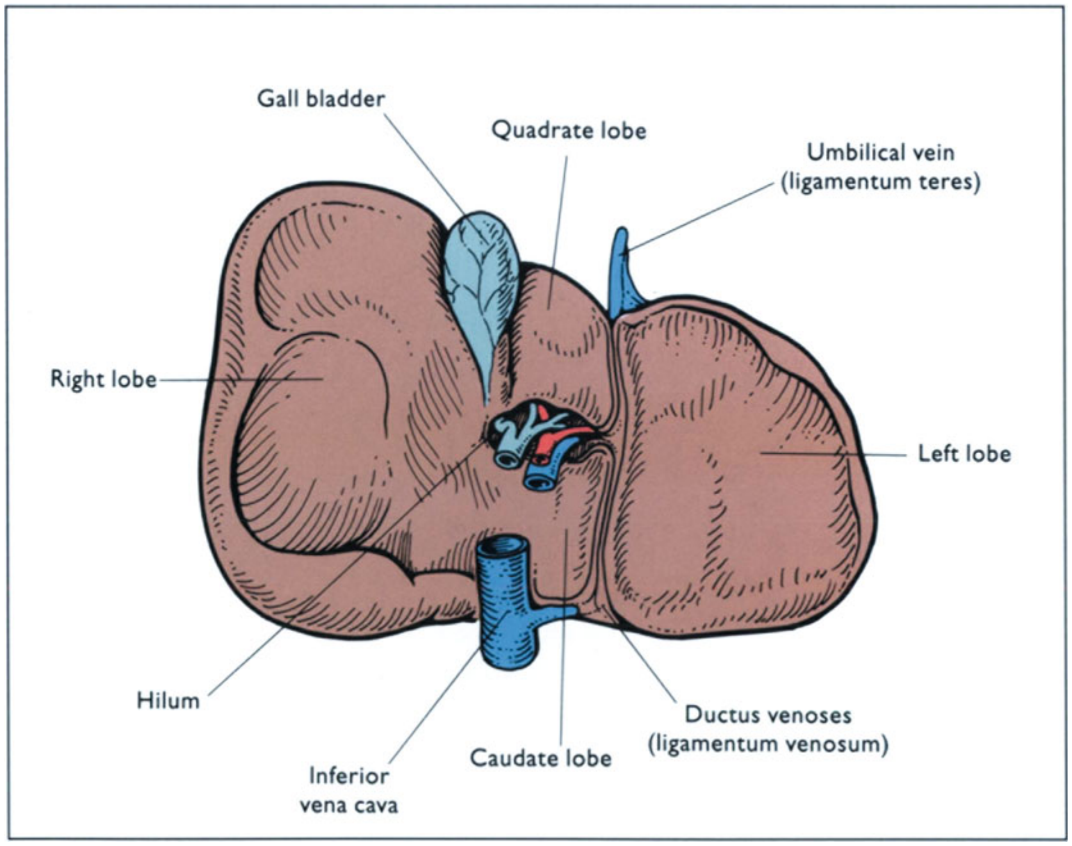


FIGURE 11-1.
This diagram represents a stylized version of liver anatomy seen from the undersurface.

Pathophysiology, Presentation, and Differential Diagnosis

As discussed previously, laparoscopic liver biopsy can be divided into two categories: 1) biopsy of a specific lesion within the liver; or 2) biopsy of the liver for assessment of parenchymal disease. The predominant application of laparoscopy in the management of liver disease is the evaluation and management of specific lesions within the parenchyma. As noted previously, a detailed work-up prior to liver biopsy allows the surgeon to determine the likelihood of success with the laparoscopic approach. Table 11-3 outlines the features of frequently observed liver lesions as well as the diagnostic imaging modality of choice. Below, some of the features of the more common diseases amenable to laparoscopic evaluation are discussed.

Malignant Liver Disease

The accuracy of laparoscopic diagnosis of malignant liver disease has been reported at 80% to 95% [1–4]. Percutaneous, blind needle biopsy has an overall accuracy of 40% to 50% [5]. The major reasons for the difference in sensitivities of the techniques are 1) the latter technique is performed without visual guidance of any sort and is therefore prone to sampling error; and 2) only the right lobe of the liver is biopsied when the method of Menghini is used [6]. In advanced cancer, when much of the liver is replaced with tumor, the accuracy of this unguided liver biopsy is around 70%. This accuracy rapidly drops to 30% when it is employed as a diagnostic study in patients with early cancer who present with normal or slightly elevated enzymes or negative scans [7]. In metastatic cancer, the blind biopsy was positive 31% of the time compared with 87.5% for laparoscopic biopsy [8].

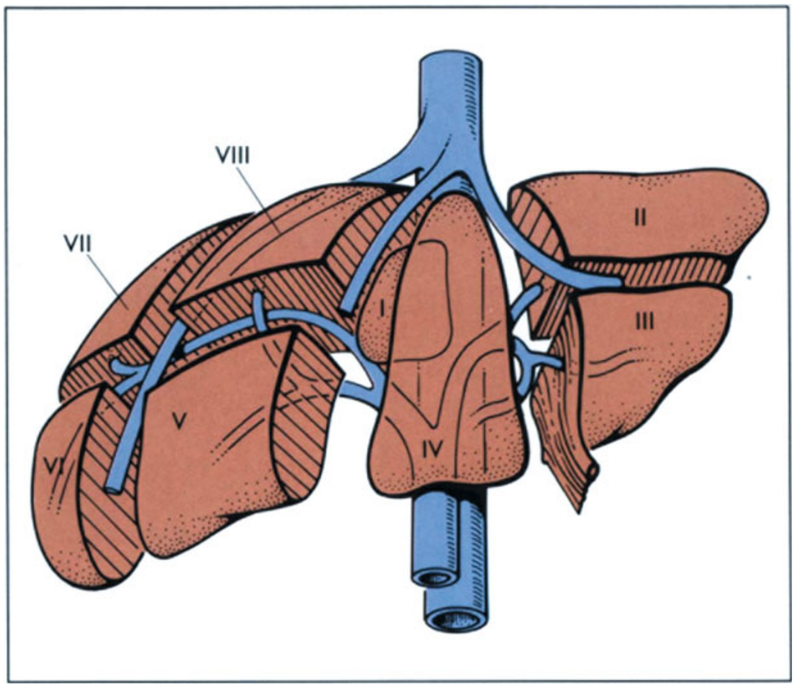


FIGURE 11-2. Segmentation of the liver according to Couinaud [1].

Table 11-3. Features of frequently observed liver lesions

Disorder	Epidemiology	Signs and symptoms	Diagnostic modality of choice	Findings
Solitary cyst	14%–30% F:M = 3:1	Fullness in abdomen Nausea and vomiting Hepatomegaly	US	Thin walls, smooth contours, anechoic mass Variable size
Adenoma	3–4 per 100,000 F>M 3rd–5th Decades Linked to OCP	Abdominal pain in 50% 10% Rupture Palpable mass in 30%	US/CT Biopsy advocated	No definitive findings, single mass Hypovascular on arteriogram
Focal nodular hyperplasia	Unknown incidence F>M Not linked to OCP	10% only with abdominal pain	US/CT Biopsy advocated	No definitive findings Tumor usually > 5 cm Tumor usually solitary
Hemangioma	2%–7% F>M 3rd–5th Decades	Pain/discomfort Hepatomegaly RUQ mass	Arteriogram IV timed sequence CT Biopsy not advocated	Vascular "puddling" on arteriogram
Hepatocellular carcinoma	1–7 per 100,000 M:F = 4–8:1 Associated with cirrhosis, HBV	Weakness/malaise Upper abdominal pain Mass in RUQ	CT-IV Biopsy advocated	No definitive findings
Metastatic cancer (colorectal)	30% Synchronous lesion	Hepatomegaly Asymptomatic (symptomatic patient nonsurgical)	CT-portography Biopsy advocated	Hypovascular lesions

CT—computed tomography; F—female; HBV—hepatitis B virus; IV—intravenous; M—male; OCP—oral contraceptive pill; RUQ—right upper quadrant; US—ultrasonography.

It seems obvious, therefore, that liver biopsy should be performed with visualization. It is also evident that there are many imaging modalities that have challenged laparoscopy as a means of "guiding" biopsy needles. Data has accumulated quoting accuracy rates of 75% to 100% for CT guided biopsy in detecting malignant liver disease [9–11]. Table 11-4 compares the relative advantages of laparoscopy and CT scan–guided liver biopsy.

More recently, the ability of the surgeon to assess liver pathology intraoperatively beyond the surface has increased with the advent of laparoscopic ultrasonic probes. These probes can be inserted through standard trocars placed in direct contact with the liver. With this direct contact, resolution is much greater than surface ultrasound. Detailed images of the hepatic parenchyma allow for more accurate evaluation and biopsy.

Cancer Staging

The ability to visualize and biopsy multiple lesions in one procedure makes laparoscopy a powerful diagnostic tool in staging early malignant disease of the liver. It is even more impressive when one considers that lesions as small as 1 mm can be identified (compared with a 5- to 10-mm resolution of CT scan). Over 70% of the liver can be visualized, and more importantly, surgical and autopsy studies demonstrate that in metastatic disease, about 90% of the liver metastases present on the surface [12,13]. Laparoscopy enables surgeons to detect and biopsy small lesions not only in the liver but also on the peritoneum or diaphragm; unnecessary radical surgery can be obviated when early diagnosis of metastatic disease is made. Additionally, an assessment of the unaffected liver can be made at the time of laparoscopy, and the severity of cirrhosis assessed. In some of these patients, transplantation may be an option.

Focal Benign Liver Disease

The differentiation between malignant and benign lesions of the liver is a common clinical problem for the hepatobiliary surgeon. Certainly, advances in diagnostic imaging assist in this task. Patients with adenomas, focal nodular hyperplasia, vascular abnormalities, granulomas, infarctions, or normal variations in liver anatomy can mimic malignant disease. Laparoscopic-directed biopsy is highly effective in diagnosing these lesions when tissue biopsy is necessary for the diagnosis [14].

Diffuse Liver Disease

Liver biopsy is also performed to assess the parenchyma of the liver. This can be done to 1) diagnose primary liver disease (*eg*, Wilson's disease); 2) assess progression of disease or response to therapy; 3) diagnose the condition of the liver in metabolic disease (*eg*, glycogen storage disease, alcoholic cirrhosis); and 4) ascertain liver involvement in multisystem disease (*eg*, amyloidosis, sarcoidosis).

It is important to note that while many of these diseases are considered diffuse liver disease, abnormalities of the liver parenchyma may not be distributed evenly throughout the liver, leading to sampling errors from blind biopsy [15,16]. Laparoscopy allows for biopsy of the most abnormal appearing tissue.

Imaging modalities, including radionuclide scanning, ultrasound, and CT have poor sensitivity and specificity in the diagnosis of cirrhosis. Percutaneous liver biopsy for the diagnosis of cirrhosis had a false-negative rate of 24% in one study; laparoscopy and biopsy decreased this rate to 9% [17]. In addition to being more accurate, laparoscopy can direct biopsy of specific areas and differentiate foci of hepatocellular carcinoma from regenerating nodules [18].

Table 11-4. Computed tomography guided biopsy versus laparoscopic guided biopsy

Computed tomography advantages	Laparoscopic advantages
Preferred for posterior and retroperitoneal lesions	Can visualize lesions as small as 1 mm in diameter
Can visualize whole liver	Can detect disease otherwise missed by computed tomography
Avoid complications associated with laparoscopy	Can see, evaluate, and biopsy other tissues for cancer staging
Better for drainage of liver abscess	Larger tissue piece can be obtained if necessary
	Control of bleeding
Computed tomography disadvantages	**Laparoscopic disadvantages**
Resolution is 5–10 mm at best	Can only see 70% of the liver (even with 30° scope)
Misses lesions on the retroperitoneum and diaphragm	Cannot examine lesions deep in parenchyma
	Cannot evaluate dome of liver, extreme right lateral, and posterior areas
	Adhesions may limit examination

Surgical Technique

Figures 11-3 through 11-9 depict the surgical technique for laparoscopic liver biopsy.

Set-up

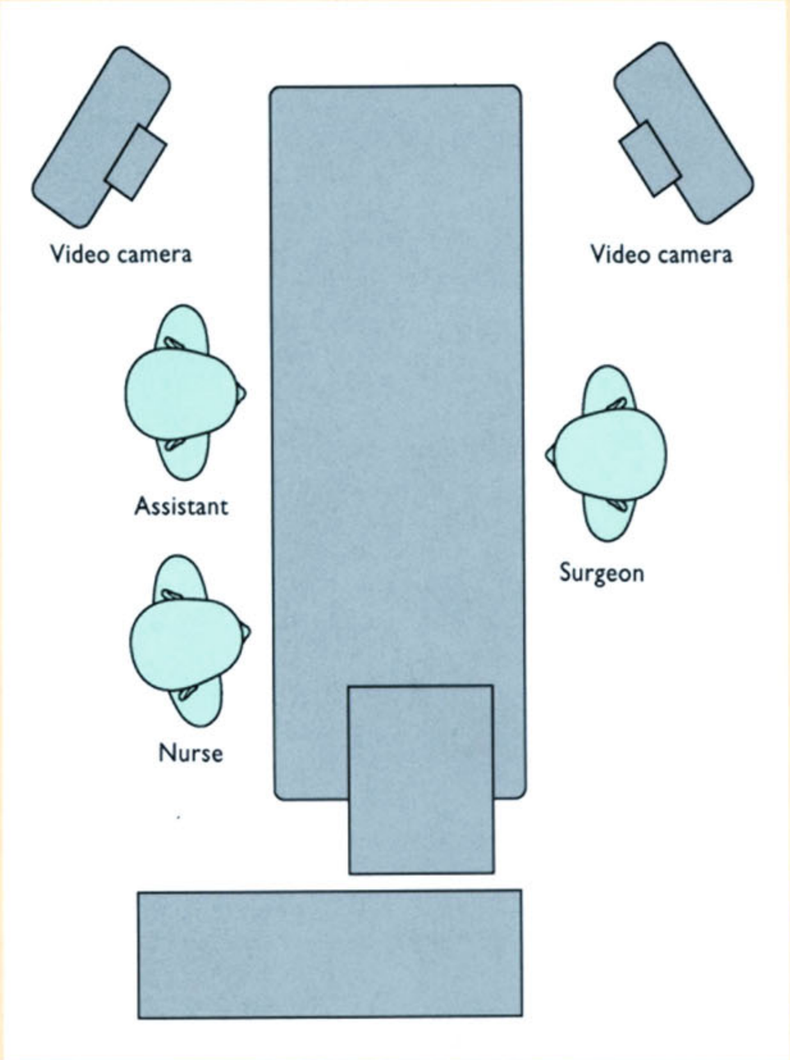


FIGURE 11-3.
The set-up for a laparoscopic liver biopsy is straight forward. The assistant operates the camera, while the surgeon uses a retracting/grasping device and a needle or pair of scissors to perform the biopsy.

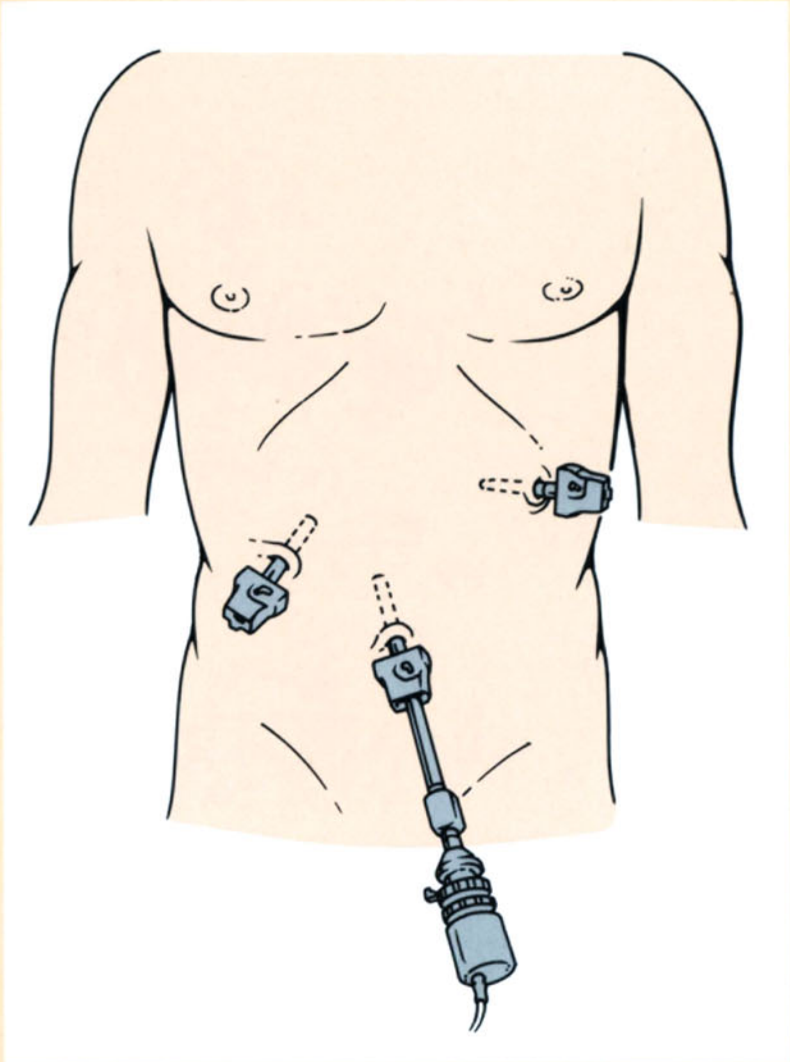


FIGURE 11-4.
Three trocars are used for this operation, although it can be performed with only two. Besides the camera port, one port is placed in a position to gain good access to the pathology in question. In this example, the pathology is in the caudate lobe; thus, a trocar is placed in the left upper quadrant, in the anterior-axillary line, 5 to 7 cm below the costal margin. The addition of a third port allows for the use of retraction of the liver facilitating the procedure. If a retraction device is used, a port sufficiently large to allow the passage of such an instrument should be placed; otherwise, 5-mm ports in addition to the camera port are usually adequate.

Procedure

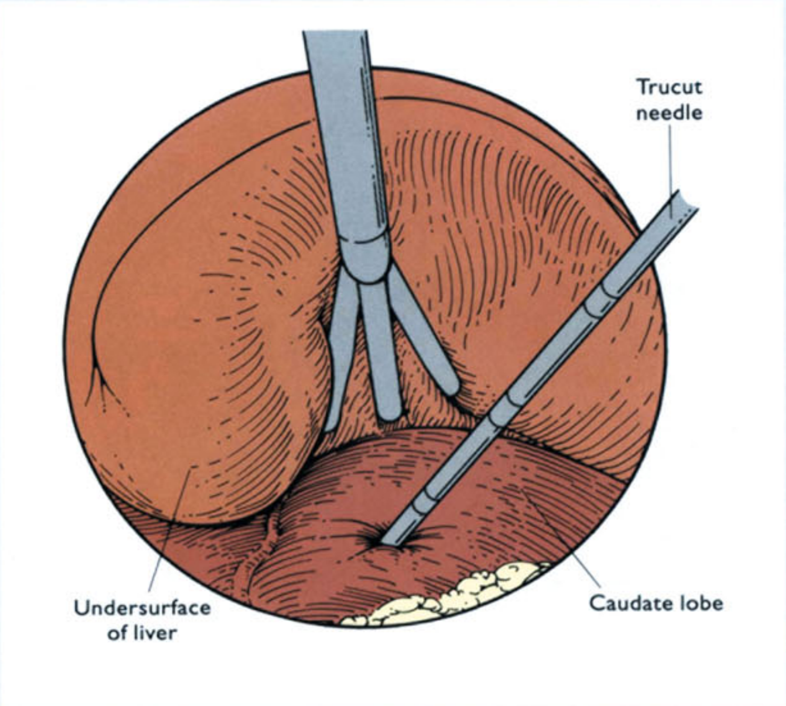


FIGURE 11-5.

With the aid of a fan retractor, the right lobe of the liver is lifted anteriorly and the undersurface of the liver is exposed. The pathology in the caudate lobe is clearly visualized. The trucut needle is passed through the 5-mm port and positioned on the liver. Care and attention must be taken when performing this procedure to ensure that the tip of the needle is not beyond the liver; it is possible to inadvertently pass the needle too aggressively beyond the other side of the liver. This is a source of concern as complications resulting from this maneuver are often never visualized. One should always familiarize oneself with the mechanism of the particular needle being used to ensure as little disruption of the liver parenchyma as possible. Should excessive bleeding ensue, pressure or cautery applied directly to the site are usually adequate to stop the bleeding.

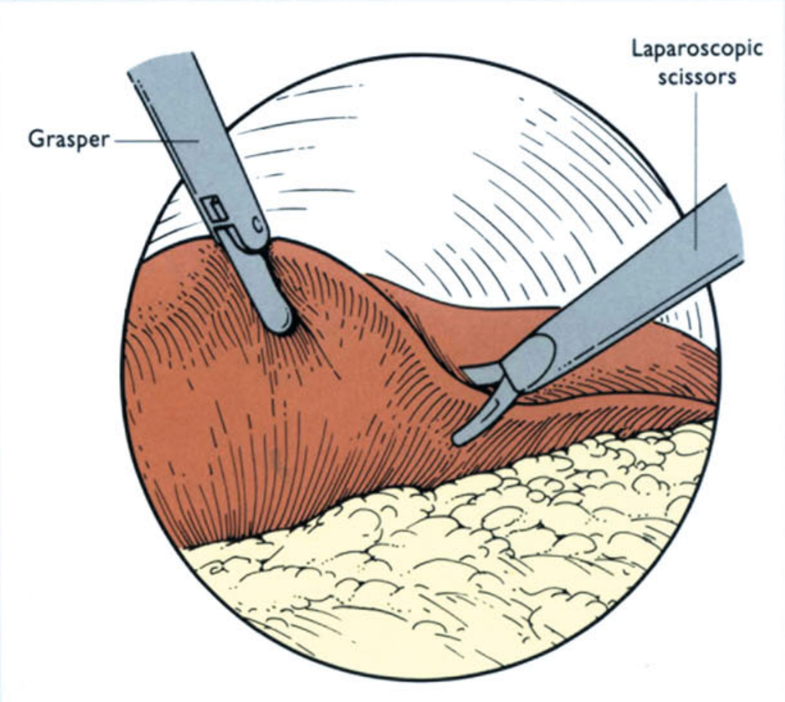


FIGURE 11-6.

A wedge biopsy of the liver can also be performed. Again the use of a second port greatly facilitates this procedure. The grasper is used to stabilize the liver, while scissors are introduced through a second port. The bleeding is usually not torrential and thus cautery can be delayed until the specimen has been removed.

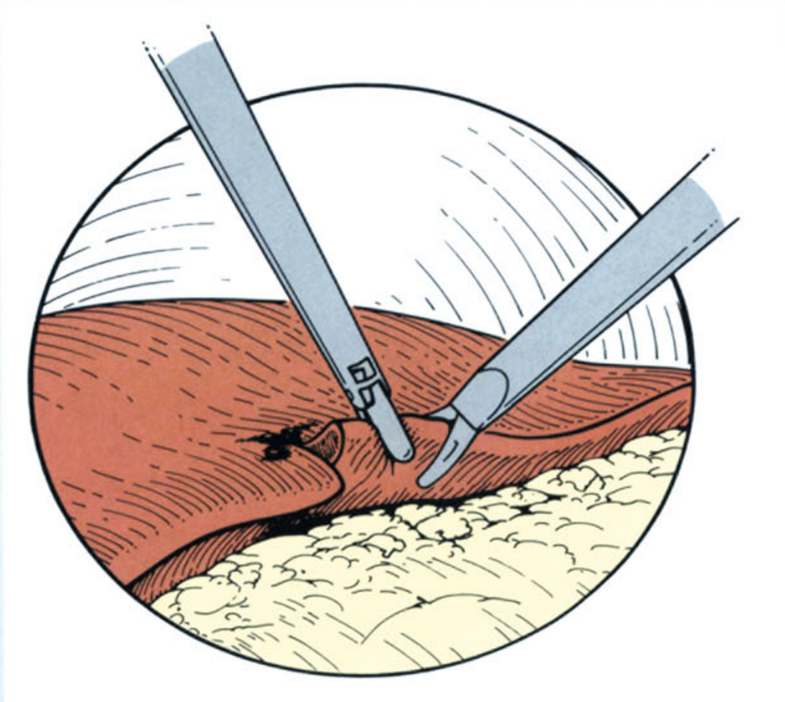


FIGURE 11-7.

The second arm of the wedge is made after the grasper has positioned the piece appropriately. Care should be exercised so that the specimen is not damaged as it is grasped.

Procedure

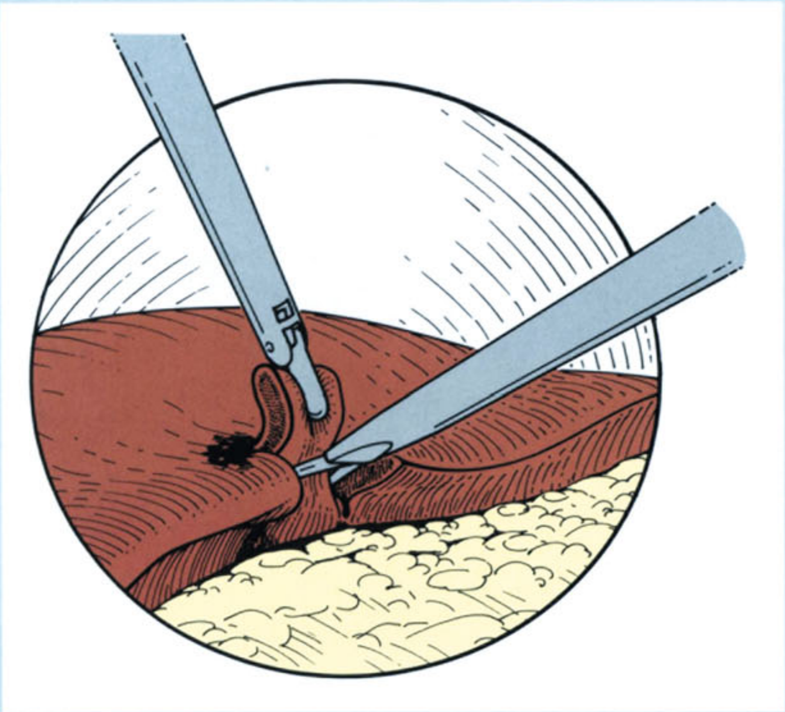


FIGURE 11-8.
The last portion of the capsule is cut and the specimen can be removed.

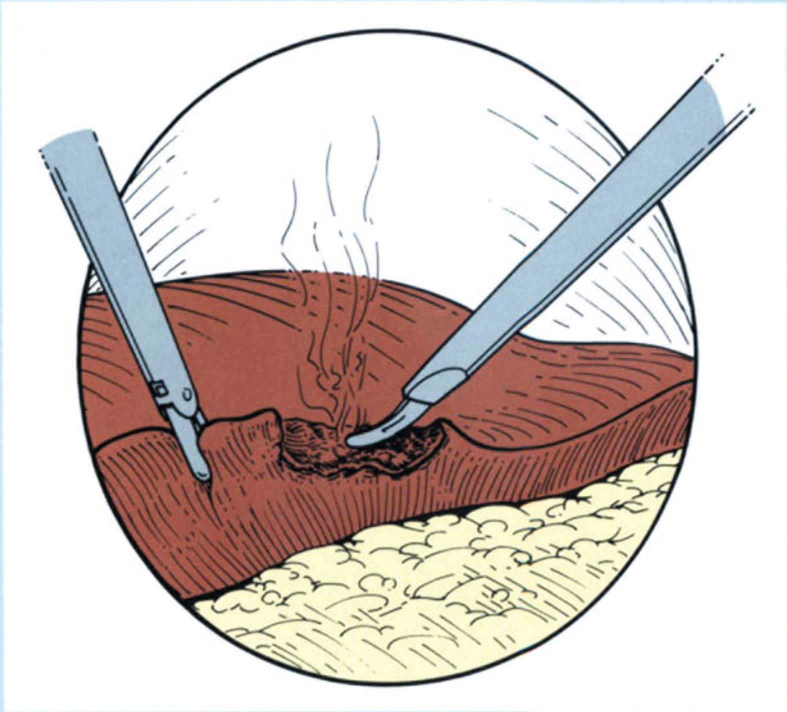


FIGURE 11-9.
The base of the biopsy site should be cauterized and hemostasis should be ensured before the instruments and trocars are removed.

Complications

Diagnostic laparoscopy is a straightforward procedure and carries a remarkably low morbidity and mortality. Postbiopsy bleeding represents the single most serious complication (outside of the risks of laparoscopy), and it has been reported to occur at a frequency of less than 1%. Bile leaks are reported to occur in less than 0.1% of cases, and even more rare are cyst perforations, infection, or tumor implantation. The overall morbidity (complications requiring surgical intervention or prolonged hospital stay) and mortality are quoted as 0.46% and 0.53%, respectively.

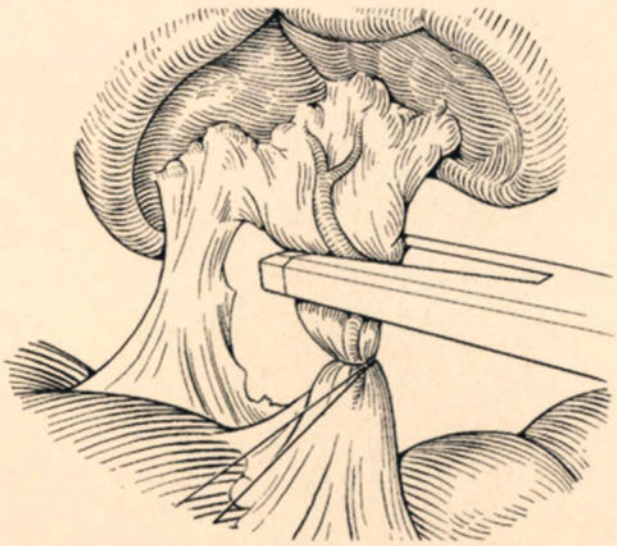
References

1. Couinaud. *Le Foce Etudes Anatomique et Chirurgicales.* Paris: Masson; 1957.
2. Kuster G, Biel F: Accuracy of laparoscopic diagnosis. *Am J Med* 1966, 42:388–393.
3. Sauer R, Fahrlaender H, Fridrich R: Comparison of the accuracy of liver scans and peritoneoscopy in benign and malignant primary and metastatic tumors of the liver. *Scand J Gastroenterol* 1973, 8:389–394.
4. Boyd WP: Relative diagnostic accuracy of laparoscopy and liver scanning techniques. *Gastroenterol Endosc* 1982, 28:104–106.
5. Conn HO, Yesner R: Reevaluation of needle biopsy in the diagnosis of metastatic cancer of the liver. *Ann Intern Med* 1963, 59:53–61.
6. Menghini G: One second biopsy of the liver: problems of its clinical application. *N Engl J Med* 1970, 283:582–585.
7. Conn HO: Percutaneous versus peritoneoscopic liver biopsy. *Gastroenterology* 1972, 63:1074–1075.
8. Jori GP, Peschle CL: Combined peritoneoscopy and liver biopsy in diagnosis of neoplasm. *Gastroenterology* 1972, 63:1016–1019.
9. Ferucci JT Jr, Wittenberg J, Mueller PR, *et al.*: Diagnosis of abdominal malignancy by radiologic fine-needle aspiration biopsy. *Am J Roentgenol* 1980, 134:323–330.
10. Zornova J, Wallace S, Ordonez N, *et al.*: Fine-needle aspiration biopsy of the liver. *Am J Roentgenol* 1980, 134:331–334.
11. Bernardino M: Percutaneous biopsies. *Am J Roentgenol* 1984, 142:41–45.
12. Hogg L, Pack GT: Diagnostic accuracy of hepatic metastases at laparotomy. *Arch Surg* 1956, 72:251–252.
13. Ozarda A, Pickren J: The topographic distribution of liver metastases: its relation to surgical and isotope diagnosis. *J Nucl Med* 3:149–152.
14. Beck KL, ed.: *Color Atlas of Laparoscopy.* Philadelphia: W.B. Saunders; 1984.
15. Soloway RD, Baggenstoss AH, Schoenfield LJ, *et al.*: Observer error and sampling variability tested in evaluation of hepatitis and cirrhosis by liver biopsy. *Am J Dig Dis* 1971, 16:1082–1086.
16. Wondwosen A, Millen JC, Mezey E: Sampling variability of percutaneous liver biopsy. *Arch Intern Med* 1979, 139:667–699.
17. Nord HJ: Biopsy diagnosis of cirrhosis: blind percutaneous versus guided direct vision techniques: a review. *Gastrointest Endosc* 1982, 28:102–104.
18. Vilardell F: The value of laparoscopy in the diagnosis of primary cancer of the liver. *Endoscopy* 1977, 9:20–22.

CHAPTER 12

Laparoscopic Splenectomy

Jeffrey C. Pence
Keith T. Oldham



The elucidation of splenic function in health and disease has been continuously evolving since Aristotle dismissed the concept that it is essential for human existence more than 2000 years ago. The first recorded splenectomy was performed by Zaccarelli in 1549 for presumed malaria in a young woman who survived at least 6 years postoperatively [1]. The nonessential nature of the spleen was reinforced in subsequent animal experimentation following Read's successful splenectomy in a dog in 1638 [2]. Quittenbaum [3], in 1826, is credited with the initial well-documented splenectomy in a young woman with probable portal hypertension and splenomegaly. The patient expired postoperatively from exsanguination. Despite this dismal early outcome, splenectomy became an acceptable practice for idiopathic hypertrophy, malarial hypertrophy, splenic anemia, leukemia, cysts, and tuberculosis, with an associated mortality rate of 13% by 1908 [4]. Furthermore, the nonoperative management of splenic injury in the early twentieth century was associated with excessive mortality [5], leading Theodor Kocher to admonish that "injuries to the spleen demand excision of the gland, [and] no evil effects follow its removal while the danger of hemorrhage is effectively stopped" [6]. This concept remained virtually unchallenged until King and Schumacker [7] in 1952 reported overwhelming sepsis in five infants following splenectomy for congenital hemolytic anemia. With subsequent confirmation of the potential for postsplenectomy sepsis, the indications for splenectomy grew increasingly selective, and splenic salvage through conservative management and splenorrhaphy in both disease and trauma was again advocated. Developing indications for splenectomy in both lymphoreticular disorders and trauma have been a focus of surgical thought about the spleen throughout the present century, particularly in the contemporary era. The advent of minimally invasive surgery, fostered by successful laparoscopic cholecystectomy, has provided impetus for additional laparoscopic approaches to other hollow viscera and solid organs. Numerous potential applications, both diagnostic and therapeutic, exist for the laparoscopic management of splenic disease and trauma.

Anatomy

The spleen arises from mesoderm by the fifth gestational week. It is a condensation of mesenchymal cells within the left dorsal mesogastrium, which suspends the stomach from the dorsal body wall, and becomes the gastrosplenic ligament through which the short gastric vessels course in adult life. The failure of mesenchymal fusion induces the formation of accessory splenic tissue. The incidence of accessory splenic tissue was 10% in a series of 3000 consecutive autopsies [8], but may be greater in hypersplenic conditions [9]. Approximately 80% of accessory spleens may be found at the splenic hilum or adjoining suspensory ligaments (Figure 12-1) [10]. The adult spleen weighs from 50 to 250 g, measures approximately 12 × 7 × 4 cm, and is located in the left hypochondrium between the diaphragm superiorly, the left kidney posteriorly, and the gastric fundus and splenic flexure of the colon anteriorly (Figure 12-2).

The arterial supply of the spleen is derived from the celiac axis via the splenic artery, which usually travels along the superior border of the pancreas to enter the splenic hilum. In 85% of cases, the splenic artery will bifurcate proximal to the hilum [11], ultimately branching into five to seven trabecular arteries, which terminate as central arteries within the splenic pulp. Splenic outflow is via the splenic vein, which ultimately joins the superior mesenteric vein to form the portal vein.

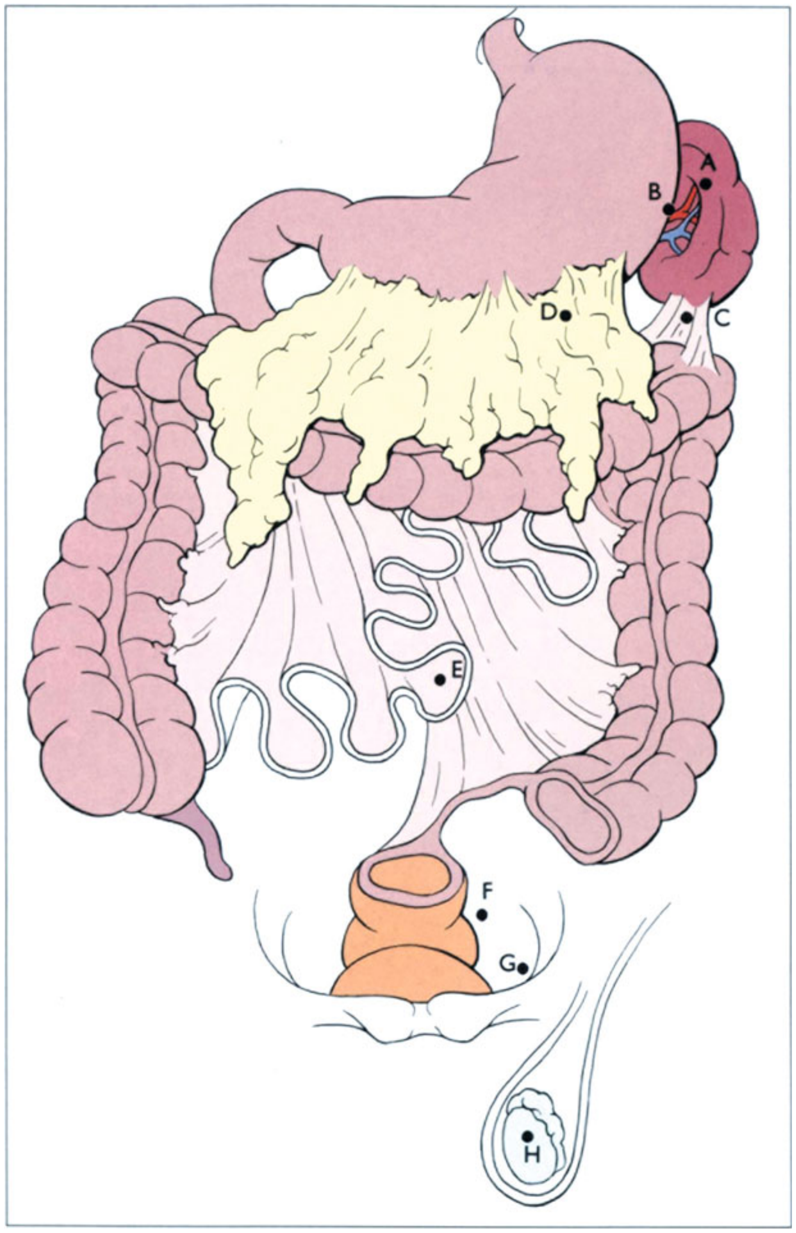


FIGURE 12-1.

Location of accessory splenic tissue. **A**, Splenic hilum. **B**, Splenic artery and tail of pancreas. **C**, Splenocolic ligament. **D**, Omentum. **E**, Mesentery. **F**, Presacral. **G**, Adnexal. **H**, Peritesticular. The splenic hilum, including the tail of the pancreas, contains two thirds of all accessory splenic tissue. (*Adapted from* Seufert and Mitrou [10]; with permission.)

Histologically, the spleen is composed of three regions: the white pulp, the red pulp, and the marginal zone. On cut section, the red and white pulp may be grossly distinguished. The white pulp consists of uniformly distributed nodules associated with the central arteries. Surrounding the central arteries are periarterial sheaths composed predominantly of T lymphocytes, plasma cells, and macrophages. These encompass 15% of the splenic mass and 25% of the body's lymphoreticular system [10]. The white pulp is entirely present, but largely hypoplastic at birth. It peaks in development by puberty secondary to antigenic stimulation, and subsequently involutes with increasing age. Follicular outgrowth responsible for specific antibody production by B lymphocytes is seen in immunologically activated states. The interface between the red and white pulp, termed the marginal zone, comprises approximately 80% of the splenic mass. In this region the central arterioles terminate either directly into venous sinuses (closed circulation) or enter splenic cords separated from the venous sinuses by fenestrated endothelium, constituting the open circulation as initially described by Billroth [12]. In this location, the latticework of cords provide an ideal substrate for splenic function.

Physiologically, the spleen has the three primary roles of filtration, storage, and immunologic function. First, with a blood flow of 300 mL/min, splenic filtration through the cords of Billroth is efficiently performed by reticular cells. Splenic filtration involves three processes: culling, pitting, and erythroclasis. Culling refers to the destruction of cellular elements secondary to senescence or associated with blood cell abnormalities. Pitting describes the removal of particulate matter or cytoplasmic inclusions, including Howell-Jolly bodies (nuclear remnants), Pappenheimer bodies (siderotic granules), and intracellular parasites from erythrocytes, with their return to the circulation. Erythroclasis involves the fragmentation of abnormal erythrocytes with liberation of fragments into the circulation for subsequent clearance by the reticuloendothelial system. The above processes rid the circulation of senescent, diseased, or damaged cellular elements.

Unlike other mammalian species, the human spleen contains no contractile capsular smooth muscle and is, therefore, not a blood storage organ. Splenomegaly conditions will, however, lead to blood pooling within widened pulp cords. The human spleen, on the other hand, may contain approximately one third of the body platelet mass and granulocytes in its true normal reservoir function [13]. Platelet sequestration may approach 98% of total body platelets in pathologic states [14].

The active role of the spleen in immunologic function is demonstrated by the types and numbers of immune competent cells found transiently or permanently within the organ. The spleen functions in the four aspects of the immune reaction, including specific and nonspecific humoral and cellular immunity. The adult spleen produces lymphocytes, monocytes, and plasma cells. Its histologic organization is well structured for opsonization,

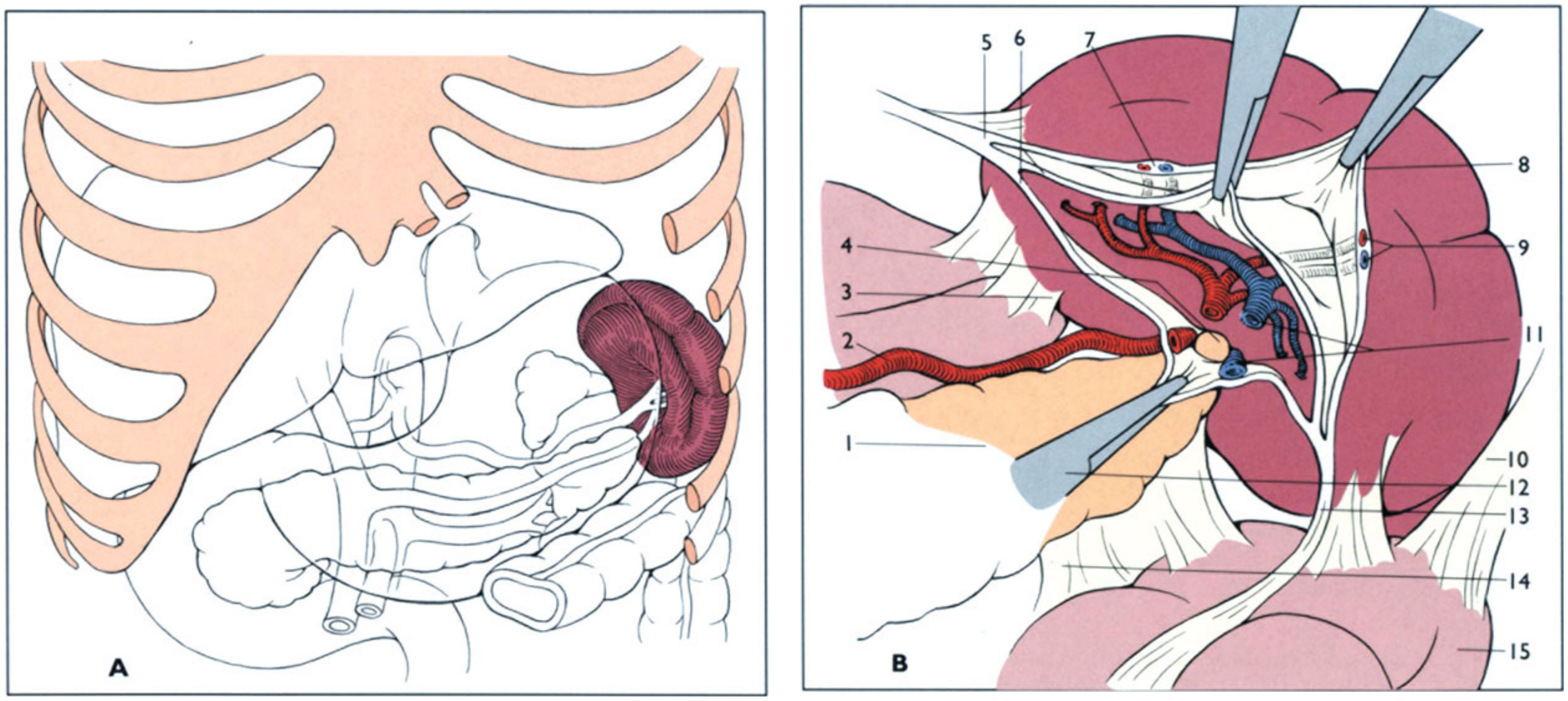


FIGURE 12-2.

A, Anatomic relationships of the spleen. **B**, Anatomy of the splenic hilus and ligamentous attachments: pancreas (*1*), splenic artery (*2*), phrenicosplenic ligament (*3*), pancreatic tail (*4*), gastrophrenic ligament (*5*), phrenicosplenic ligament (cut) (*6*), short gastric vessels (*7*), gastrosplenic ligament (*8*), left gastroepiploic vessels (*9*), phrenicocolic ligament (*10*), splenic vein (*11*), pancreaticosplenic ligament (*12*), splenocolic ligament (*13*), pancreaticocolic ligament (*14*), and splenic flexure of colon (*15*). (*Adapted from* Seufert and Mitrou [10]; with permission.)

phagocytosis, and destruction of foreign antigen. Furthermore, the spleen is paramount in the production of both tuftsin and properdin, peptide molecules critical in the stimulation of phagocytosis by reticular cells and in the complement pathway, respectively [15,16]. The spleen particularly forms novel antibodies of the IgM class following initial exposure to foreign antigen. Its most conspicuous feature is the ability to phagocytize polysaccharide encapsulated organisms. Therefore, there is specific risk of infectious complications in splenectomized individuals, as first reported by Morris and Bullock in 1919 [17]. The risk of postsplenectomy sepsis appears accentuated in infants [18]. An incidence of 4.2% with an overall mortality rate of 2.5% has been reported in a collective review of 2795 splenectomized individuals [19], although variable incidences have been reported and generally reveal mortality rates of approximately 1%. The severity of infection may also vary, including a fulminant form initially termed *overwhelming postsplenectomy infection* (OPSI) [20], characterized by hemodynamic shock, consumptive coagulopathy, and intra-adrenal hemorrhage [21]. *Streptococcus pneumoniae* has been isolated as the inciting organism in over 50% of postsplenectomy infections, followed by *Haemophilus influenzae* and *Neisseria meningitidis* [22]. As such, multivalent capsular polysaccharide vaccination is advisable in all surgically or functionally asplenic individuals, preferably prior to splenectomy in surgical patients. The efficacy of vaccination is estimated at 80%, therefore, prophylactic penicillin should be considered in addition to vaccination in asplenic patients at high risk for infection, including children and immunocompromised individuals [23].

Pathophysiology, Presentation, and Differential Diagnosis

The classic definition of hypersplenism, described by Dameshek [24], includes the four criteria of 1) cytopenias of one or more peripheral blood cell lines; 2) bone marrow hyperplasia commensurate with the cytopenias; 3) splenomegaly; and 4) correction of the cytopenias following splenectomy. It is, however, now recognized that some disorders encompassing the splenic-dependent destruction of blood elements do not manifest all four criteria. The responses to hypersplenism are simply exaggerations of normal splenic function, with cytopenias secondary to enhanced sequestration and destruction of blood cell elements within the organ.

Hypersplenism has historically been divided into primary and secondary types. Primary hypersplenism is a diagnosis of exclusion in which the spleen is histologically normal following its extirpation and in which the splenomegaly and cytopenias have no identifiable causes. True primary hypersplenism is, therefore, exceedingly rare and remains largely a diagnosis of exclusion. Secondary hypersplenism, on the other hand, occurs in association with splenomegaly of known cause. In this condition, the cords of Billroth are widened and the cord macrophages proliferate, leading to increased transit times of circulating elements with enhanced opportunity for intrasplenic destruction.

The most frequent symptom in a patient with a diseased spleen is secondary splenomegaly. However, presentation often includes evidence of the primary disease process, such as hepatomegaly, lymphadenopathy, fever, jaundice, and a hemorrhagic diathesis. When splenomegaly is symptomatic, left upper quadrant pain may be manifest as sharp, visceral pain, somatic pain, or diaphragmatic irritation. Normally, the adult spleen is not palpable. When it extends beyond the left costal margin, splenic size has increased by at least one third. Spleens weighing from 600 to 750 g (threefold normal) are palpable 59% of the time [25].

Specific indications for splenectomy are listed in Table 12-1. The most commonly encountered indications for splenectomy are splenic trauma, hypersplenism (particularly in immune thrombocytopenic purpura [ITP]), and for the staging of Hodgkin's lymphoma [26].

Despite its protected position deep in the left epigastrium, the spleen is the most often injured intra-abdominal organ in blunt trauma. The lesions may vary considerably in severity. Hemorrhage from such injuries can abate spontaneously, leading to the successful nonoperative management of splenic injuries. This has become particularly relevant when considering the potential complication of postsplenectomy sepsis. Certainly the advent of diagnostic

Table 12-1. Potential indications for splenectomy

Hematologic	**Infiltrative**
Hereditary spherocytosis	Sarcoidosis
Hereditary elliptocytosis	Gaucher's disease
Sickle cell hemoglobinopathies	Niemann-Pick disease
Thalassemia	Amyloidosis
Pyruvate-kinase deficiency	Felty's syndrome
Immune thrombocytopenic purpura	**Congestive**
Thrombotic thrombocytopenic purpura	Splenic/portal vein thrombosis
Myeloproliferative	Hepatic cirrhosis/Budd-Chiari
Myelofibrosis	Idiopathic
Acute myelogenous leukemia	**Infectious**
Chronic myelogenous leukemia	Viral (mononucleosis)
Lymphoproliferative	Malarial
Hodgkin's disease	Abscesses
Non-Hodgkin's disease	HIV-associated
Chronic lymphocytic leukemia	**Malformations**
Hairy cell leukemia	Cysts
	Aneurysms

laparoscopy in the emergency setting may assist in decisions as to operative versus conservative treatment [27].

The spleen has a significant role in the pathogenesis of ITP. ITP is characterized by thrombocytopenia, shortened platelet lifespan, compensatory megakaryocytosis, and platelet agglutinins. The spleen serves as the primary site for both platelet antibody production and the destruction of opsonized platelets. Splenomegaly itself is rarely encountered in this condition, thus making this indication particularly amenable to a laparoscopic approach. High-dose steroids lead to remission in approximately 60% of individuals. In settings of relapse, inefficacy, or intolerable side effects of steroid therapy, splenectomy is effective in approximately 72% of individuals [28].

The indications for staging laparotomy, including splenectomy, in patients with malignant lymphoma are controversial; nonetheless, many institutions will modify treatment regimens in Hodgkin's disease based on the results of staging laparotomy. The goal of exploratory laparotomy and splenectomy is to confirm the infradiaphragmatic extent of disease, given the potential inaccuracy of noninvasive techniques. In approximately 25% of instances, the histologic examination of extirpated tissue modifies the clinical stage, with more extensive disease encountered in two thirds of these cases [29]. In these instances, multiagent chemotherapy may be added to irradiation protocols. In non-Hodgkin's lymphoma, however, most patients present with discernable extensive disease without indication for operative diagnostic intervention.

Surgical Technique

Figures 12-3 through 12-9 depict the surgical technique of laparoscopic splenectomy.

Set-up

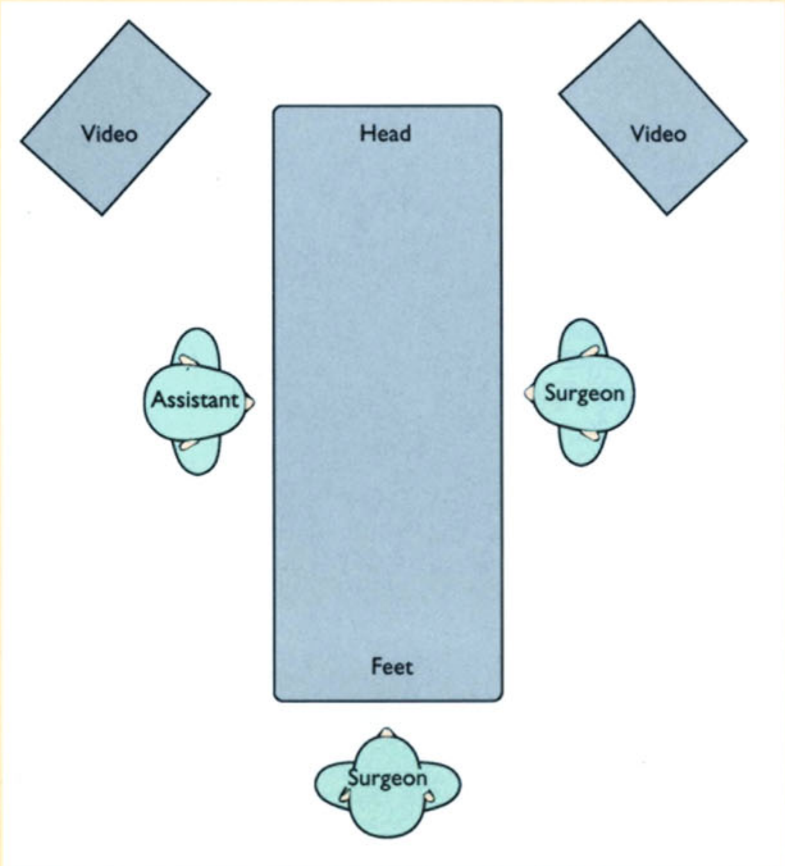


FIGURE 12-3.
Operative set-up for laparoscopic splenectomy. The video monitors are placed at the head of the operative table as for upper abdominal laparoscopy. Preoperative antibiotics, generally first-generation cephalosporins, a parenteral steroid preparation, and blood components are administered as indicated prior to the induction of general anesthesia. Following induction, nasogastric and urinary bladder catheters are inserted and secured for perioperative decompression. The operating surgeon is positioned either to the patient's left side, or in the double-access position with the surgeon between the patient's legs.

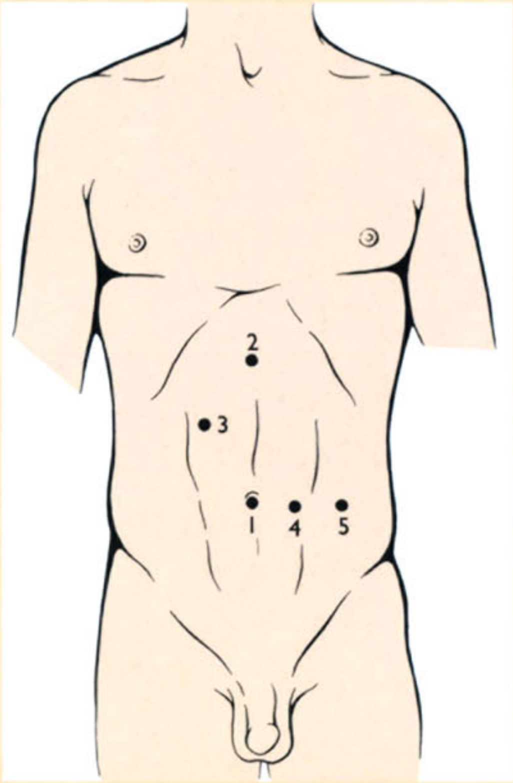


FIGURE 12-4.
The peritoneal cavity is percutaneously accessed in the infraumbilical position using an open (Hasson trocar) technique. Following the establishment of a 15-mm Hg pneumoperitoneum, a 10-mm sheath is placed infraumbilically (*1*). Using a 30- or 45-degree side-viewing laparoscope, the peritoneal cavity is inspected for technical feasibility. Two 10-mm retraction ports are then generally placed in the midline subxiphoid and right paramedian positions (*2* and *3*). Two 12-mm operating ports are placed in the left abdomen, specifically for insertion of the endoscopic stapler or endoscopic clip applier (*4* and *5*). All trocars should optimally be positioned at least five finger breadths apart to reduce instrument crossing. Additional ports may be inserted as indicated.

Procedure

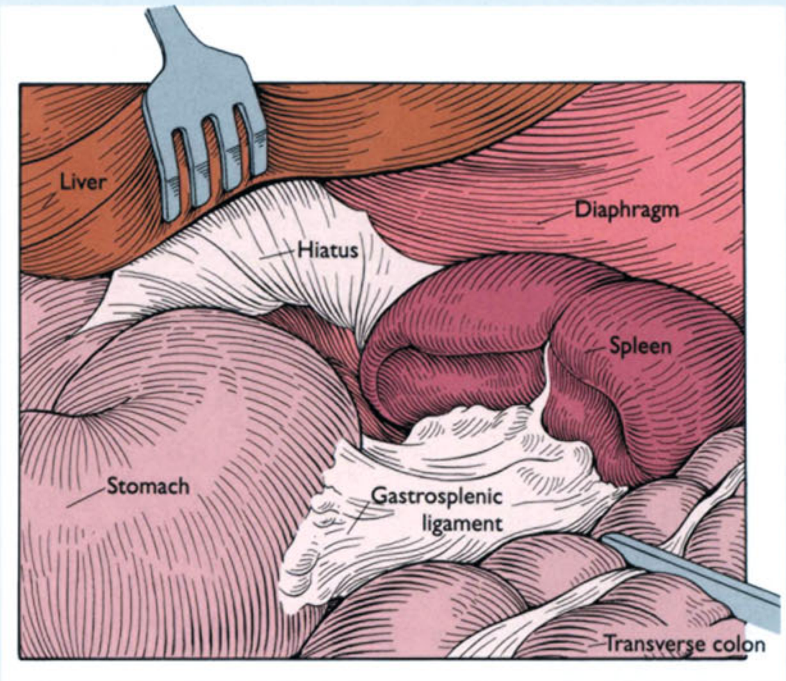


FIGURE 12-5.
The patient is placed in the reverse Trendelenburg position with the table inclined to the right. The spleen is exposed in the left upper quadrant following medial and rightward retraction on the greater curvature of the stomach and elevation of the left lobe of the liver. This may best be accomplished using a fan retractor via the subxiphoid trocar. Additional exposure is gained by caudad retraction of the splenic flexure of the colon via the supraumbilical port using atraumatic grasping forceps. Accessory splenic tissue should be sought as the suspensory ligaments and hilar regions are exposed prior to dissection.

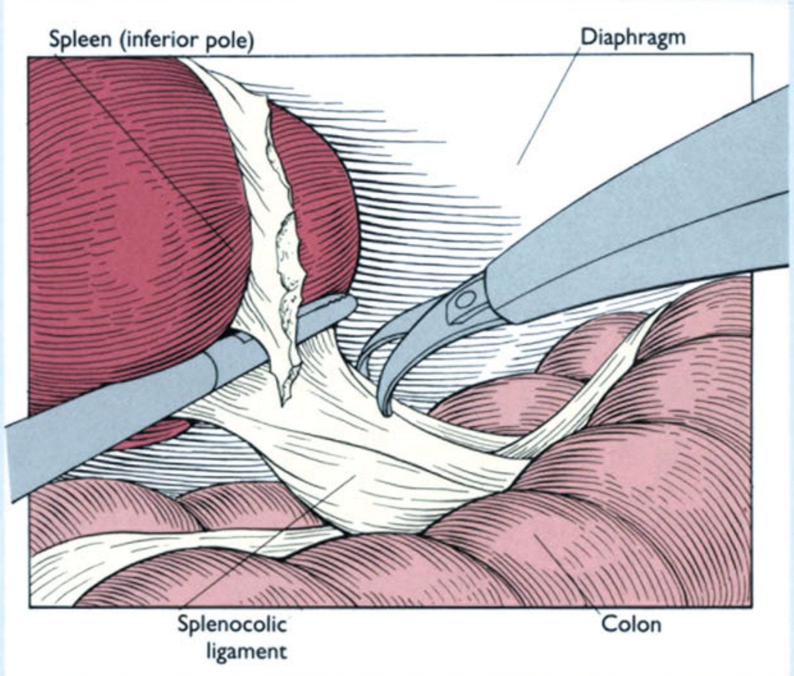


FIGURE 12-6.
The inferior pole of the spleen is mobilized by division of the generally avascular splenocolic ligament inferiorly, working in a cephalad direction using electrocautery scissors via the left paramedian port. The lateral lienorenal ligaments are left intact to provide lateral and superior countertraction against the downward retraction of the splenic flexure.

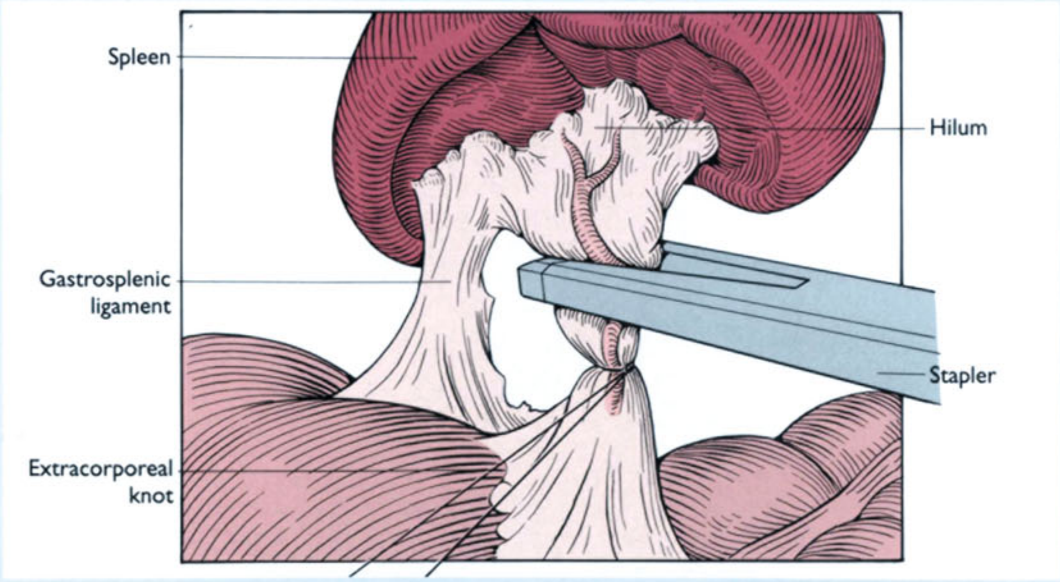


FIGURE 12-7.
The inferior margin of the splenic hilum is now exposed with continued cephalad dissection and elevation of the inferior splenic pole. Segmental (superior and inferior) splenic arteries and veins are encountered if dissection is carried along the capsular border, a practice suggested to avoid pancreatic tail injury, although capsular tears may occur with vigorous blunt dissection. Vascular control may be obtained in several ways. The application of surgical clips may be of aid in the initial control of hilar vessels. Definitive proximal control is gained by either the double ligation of individual vessels with extracorporeal knot-tying techniques using nonabsorbable suture material, or through the application of endoscopic vascular staples. The splenic parenchyma will blanch with progressive devascularization, confirming the adequate control of feeding vessels.

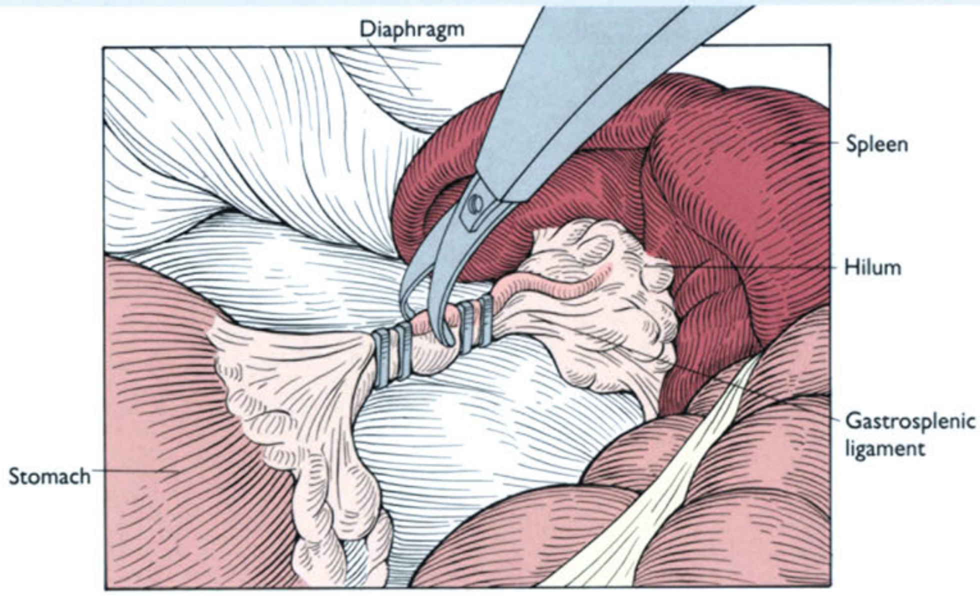


FIGURE 12-8.
The short gastric vessels are next encountered with cephalad dissection. These vessels may be individually ligated, clipped, or stapled en masse in a single pedicle as technically appropriate. As in open splenectomy, inadvertent devascularization of the greater curvature of the stomach with overzealous ligation should be particularly avoided. The splenodiaphragmatic and lienorenal attachments may now be divided with electrocautery scissors.

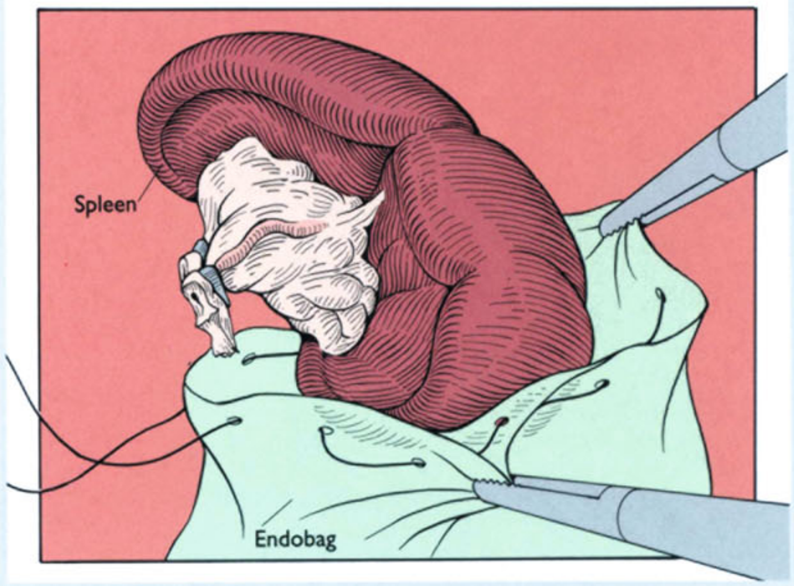


FIGURE 12-9.
The freed spleen is positioned medially using atraumatic grasping forceps while the hilar vessels, pancreatic tail, and greater curvature of the stomach are inspected for hemostasis, potential injury, and accessory splenic tissue. The left upper quadrant is irrigated and suctioned dry. Drainage is generally not indicated. The laparoscope is transferred to a lateral left port. The spleen is then maneuvered into a sterile plastic endoscopic specimen sac inserted via the umbilical port. The mouth of the sac is then closed by countertraction on the drawstring, or by the application of staples. The enclosed spleen is then brought to the umbilical trocar. At this point, the spleen may be carefully delivered through a midline fascial incision extended from the trocar puncture site, or alternatively, may be morcellated manually using a finger or instrument fracture technique and delivered progressively through the trocar site. Care must be taken to avoid sac disruption and consequent spillage of splenic remnants as this may result in splenosis. Ports are removed under direct vision and sites inspected for bleeding. All fascial trocar defects are subsequently closed with absorbable suture, the skin reapposed with suture, staples, or strip tapes, and wounds dressed.

Results

Experience in the successful performance of laparoscopic splenectomy has been limited to case reports and exceedingly small series (Table 12-2). Settings for the successful completion of laparoscopic splenectomy have included primarily ITP and staging for Hodgkin's disease. No deaths were reported. Notably, three of 10 instances required open conversion for the control of intraoperative hemorrhagic complications in these combined series, although transfusion requirements were minimal. This early experience underscores the paramount operative risk in this approach, including the need for the preoperative identification of both qualitative and quantitative coagulopathic states that may influence outcome. Other important issues regarding the laparoscopic approach to splenectomy include the need for preoperative imaging to assess splenic size or accessory splenic tissue, the influence of splenic size on successful completion and the role of preoperative embolization in altering technical feasibility, the optimal techniques for vascular control, potential splenosis during extirpation or morcellation, and the incidence of postoperative complications associated with this approach. In addition, laparoscopic manipulation of the spleen beyond diagnosis in the setting of trauma, including laparoscopic splenorrhaphy, has yet to be studied.

In conclusion, laparoscopic splenectomy can be performed efficaciously in selected cases. Both indications and contraindications for this approach remain to be defined. Undoubtedly, future experience will help guide the diagnostic and therapeutic roles of laparoscopy in splenic disease and trauma.

Table 12-2. Clinical experience with laparoscopic splenectomy

Study/year	Indication	Open conversion	Complication	Transfusion	Operative time, h	Discharge time, d
Thibault/1992	HA	Yes	Bleeding	Yes (1000 mL)	NR	NR
	ITP	No	No	No	4	2
Delaitre/1992	ITP	No	No	No	NR	6
Carroll/1992	HD	No	No	No	3	4
	HD	Yes	Bleeding	No	3	5
	ITP	No	No	No	2.5	2
Lefor/1993	ITP	No	No	No	4	7
	ITP	No	No	No	3	6
	ITP	Yes	Bleeding	No	3	4
	ITP	No	No	No	3	3
Total		3/10		1/10	3.2 (mean)	3.9 (mean)

HA—hemolytic anemia; HD—Hodgkin's disease; ITP—immune thrombocytopenic purpura; NR—not reported.

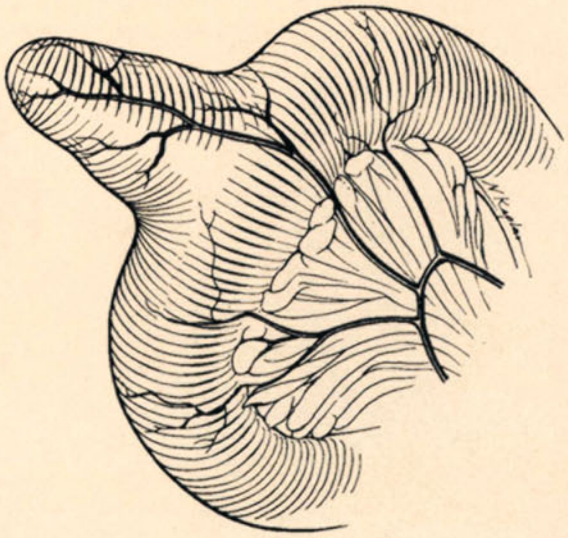
References

1. Coon WW: The spleen and splenectomy. *Surg Gynecol Obstet* 1991, 173:407–414.
2. Read A: The early history of surgery in Great Britain. Quoted by Parker G. London: Robert Hale, Ltd; 1960:42–43.
3. Quittenbaum KS: Commentarii de splenic hypertrophiae et historia extirpationis. Quoted by Simon G. Paris: Rostok; 1836.
4. Johnston GB: Splenectomy, with a statistical summary of all reported cases up to 1908. *Ann Surg* 1908, 48:56–65.
5. Bland-Sutton J: Observation on the surgery of the spleen. *Br J Surg* 1913, 1:157–172.
6. Sherman R: Perspectives in the management of trauma to the spleen: 1979 Presidential Address, American Association for the Surgery of Trauma. *J Trauma* 1980, 20:1–13.
7. King H, Shumacker HB Jr: Splenic studies: I. Susceptibility to infection after splenectomy performed in infancy. *Ann Surg* 1952, 136:239–242.
8. Halpert G, Gyorkey F: Lesions observed in accessory spleens of 311 patients. *Am J Clin Pathol* 1959, 32:165–168.
9. Erakis AJ, Filler RM: Splenectomy in childhood: a review of 1413 cases. *J Pediatr Surg* 1972, 7:382–388.
10. Seufert R, Mitrou P: The diseased spleen. In *Surgery of the Spleen*. Edited by Reber HA. New York: Thieme Inc; 1986:27–32.
11. Michels NA: The variational anatomy of the spleen and splenic artery. *Am J Anat* 1942, 70:21–72.
12. Russell SJ, Richards JDM: Medical indications for splenectomy. *Br J Hosp Med* 1989, 42:120–128.
13. Aster RH: Pooling of platelets in the spleen. *J Clin Invest* 1966, 45:645–657.
14. Hill-Zobel RL, McCandless B, Kang A, *et al.*: Organ distribution and fate of human platelets: studies of asplenic and splenomegalic patients. *Am J Hematol* 1986, 3:231–238.
15. Constantopoulos A, Najjar VA, Wish JB: Defective phagocytosis due to tuftsin deficiency in splenectomized subjects. *Am J Dis Child* 1973, 125:663–665.
16. Frank EL, Neu HC: Postsplenectomy infection. *Surg Clin North Am* 1981, 61:135–155.
17. Morris DH, Bullock FD: The importance of the spleen in resistance to infection. *Ann Surg* 1919, 70:513–521.
18. Walker W: Splenectomy in childhood: a review in England and Wales 1960-1964. *Br J Surg* 1976, 63:36–43.
19. Singer DB: Postsplenectomy sepsis. *Perspect Paediatr Pathol* 1973, 1:285–311.
20. Diamond LK: Splenectomy in childhood and the hazard of overwhelming infection. *Pediatrics* 1969, 43:886–889.
21. Van Wyck DB: Overwhelming postsplenectomy infection (OPSI): the clinical syndrome. *Lymphology* 1983, 16:107–114.
22. Ellison EC, Fabri PJ: Complications of splenectomy, etiology, prevention, and management. *Surg Clin North Am* 1983, 63:1313–1330.
23. Shaw JHF, Print CG: Postsplenectomy sepsis. *Br J Surg* 1989, 76:1074–1081.
24. Dameshek W: Hypersplenism. *Bull NY Acad Med* 1955, 31:113–136.
25. Fischer J, Wolf R, Gramm H: Die Milzszintigraphie. *Dtsch Arztebl* 1973, 70:401–403.
26. Traetow WD, Fabri PJ, Carey LC: Changing indications for splenectomy. *Arch Surg* 1980, 115:447–451.
27. Fabian TC, Croce MA, Stewart RM, *et al.*: A prospective analysis of diagnostic laparoscopy in trauma. *Ann Surg* 1993, 217:557–564.
28. Akwari OE, Itani KMF, Coleman RE, Rosse WF: Splenectomy for primary and recurrent immune thrombocytopenia purpura (ITP). *Ann Surg* 1987, 206:529–539.
29. Taylor MA, Kaplan HS, Nelsen TS: Staging laparotomy with splenectomy for Hodgkin's disease: the Stanford experience. *World J Surg* 1985, 9:449–460.
30. Thibault C, Mamazza J, Letourneau R, Poulin E: Laparoscopic splenectomy: operative technique and preliminary report. *Surg Laparosc Endosc* 1992, 2:248–253.
31. Delaitre B, Maignien B: Laparoscopic splenectomy: technical aspects. *Surg Endosc* 1992, 6:305–308.
32. Carroll BJ, Phillips EH, Semel CJ, *et al.*: Laparoscopic splenectomy. *Surg Endosc* 1992, 6:183–185.
33. Lefor AT, Melvin WS, Bailey RW, Flowers JL: Laparoscopic splenectomy in the management of immune thrombocytopenia purpura. *Surgery* 1993, 114:613–618.

CHAPTER 13

Laparoscopic Meckel's Diverticulectomy

Lewis B. Schwartz
Theodore N. Pappas



An "unusual" diverticulum of the small intestine was first described in 1598 by Fabricius Hildanus, but it remained for Johann Friedrich Meckel, the younger, to correctly recognize its embryologic origin in 1809 [1]. Since that time, complications of Meckel's diverticula have become well-recognized clinical entities, most of which are amenable to surgical diverticulectomy. With the wide dissemination of laparoscopic technology, it is not surprising that this straightforward operation can be successfully performed laparoscopically with good results [2].

Anatomy and Embryology

In the embryo, the dorsal portion of the yolk sac gives rise to the *primitive gut*, which eventually becomes the gastrointestinal system. As placental nutrition becomes established by the fifth week, the residual connection between the yolk sac and the midgut, the omphalomesenteric duct (OMD; also called the vitelline duct or yolk stalk [Figure 13-1]) undergoes obliteration and involution that is usually complete by the seventh week. The ventral portion of the yolk sac degenerates by about the tenth week. A paired system of arteries, the vitelline arteries, arise from the primitive dorsal aorta to supply the yolk sac. The right vitelline artery eventually becomes the superior mesenteric artery and the left vitelline artery involutes by about the seventh week (Figure 13-2).

A number of well-described developmental anomalies occur when the OMD and/or left vitelline artery fail to involute (Table 13-1). The most common defect arises when there is incomplete obliteration of the mesenteric portion of the OMD resulting in a true diverticulum arising from the antimesenteric border of the small intestine—a Meckel's diverticulum (Figure 13-3). Approximately 90% of anomalies of the vitelline duct are Meckel's diverticula.

The epidemiology and morphology of Meckel's diverticular can easily be remembered by the popular "rule of twos." Meckel's diverticula typically occur in 2% of the population, they are usually 2 inches long, they most commonly occur

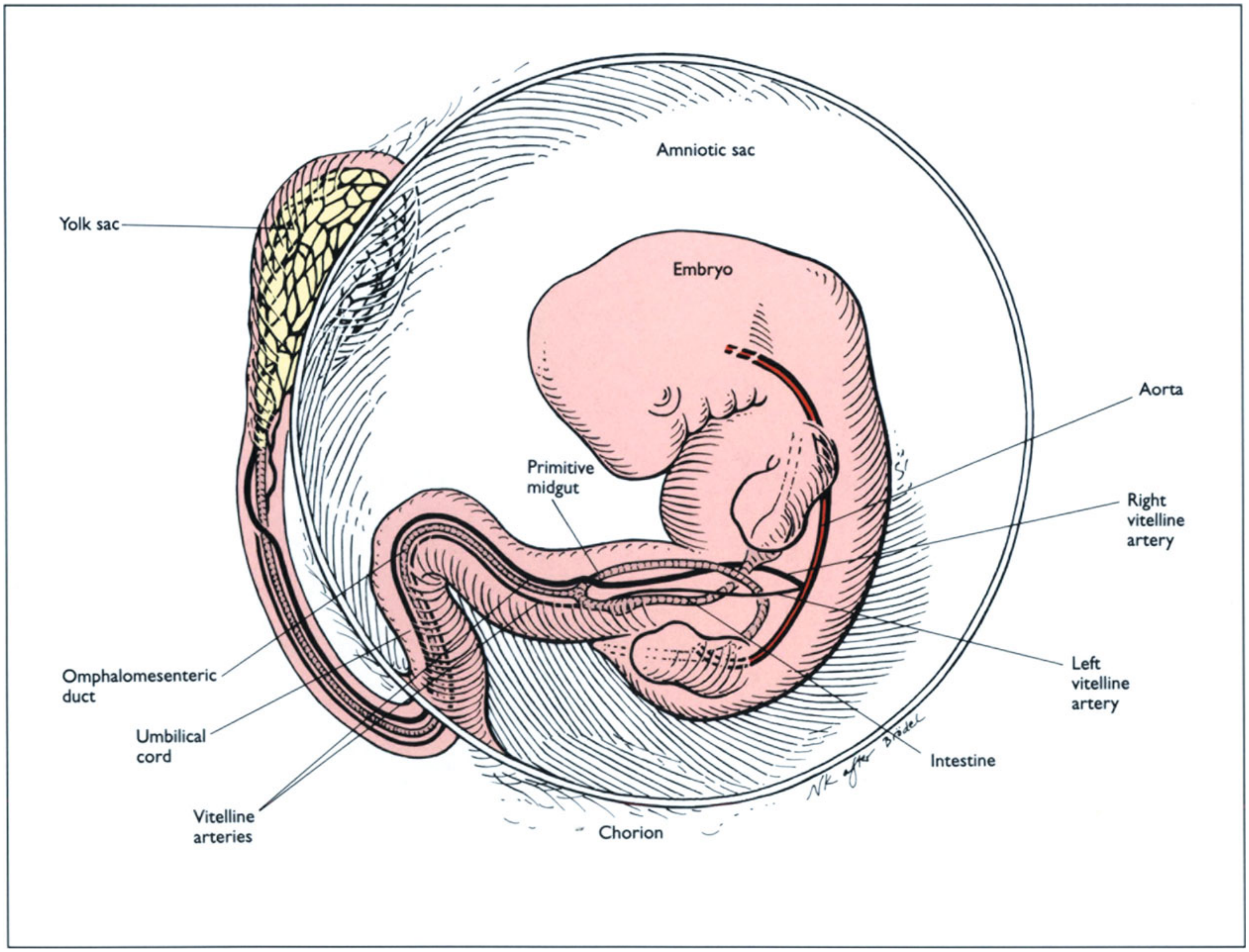


FIGURE 13-1.
The omphalomesenteric duct (also called the vitelline duct or yolk stalk) connects the yolk sac to the primitive midgut.

2 feet from the ileocecal valve, and may commonly contain two types of ectopic mucosa (gastric and pancreatic). These are only guidelines, however, as diverticula as large as 100 cm and located as far as 6.5 feet from the valve have been documented [3,4]. As stated, Meckel's diverticula are true diverticula, containing all of the mucosal, submucosal, muscular, and serosal layers that comprise the small intestine. In addition, because of the presence of pleuripotential stem cells within the yolk sac, Meckel's diverticula often contain heterotopic tissue, especially gastric and pancreatic mucosa (Table 13-2). The presence of gastric mucosa within Meckel's diverticula is responsible for their well-known predilection for ulceration and hemorrhage.

Pathophysiology

Meckel's diverticula carry an approximately 4% risk of complications throughout life [5]; earlier reports of complication rates up to 25% are probably overestimates. Over 40% of complications occur before the age of 10 years [6]. The type of complication and the clinical presentation vary greatly with age—gastrointestinal bleeding and intussusception are more common in children whereas intestinal obstruction and inflammation predominate in adults. The incidence of reported complication rates, therefore, varies significantly with the distribution of the population being studied (Table 13-3).

The most frequent complication overall is probably intestinal obstruction. Obstruction can result from a variety of mechanisms including intussusception, volvulus around fibrous or adhesive bands, or incarceration within an inguinal or femora hernia (Littre hernia). The myriad of possible mechanisms of intestinal obstruction involving Meckel's diverticula are given in Table 13-4. In children, obstruction is often caused by intussusception that typically presents with intermittent crampy abdominal pain and expulsion of dark red "current jelly" stools. In the adult population, obstruction from Meckel's diverticula is usually indistinguishable from classic small bowel obstruction, except that patients may not have undergone previous celiotomy. The symptoms and signs may include nausea, vomiting, abdominal pain and distention, and obstipation. The diagnosis may be established by physical examination, small bowel contrast examinations, and enteroclysis.

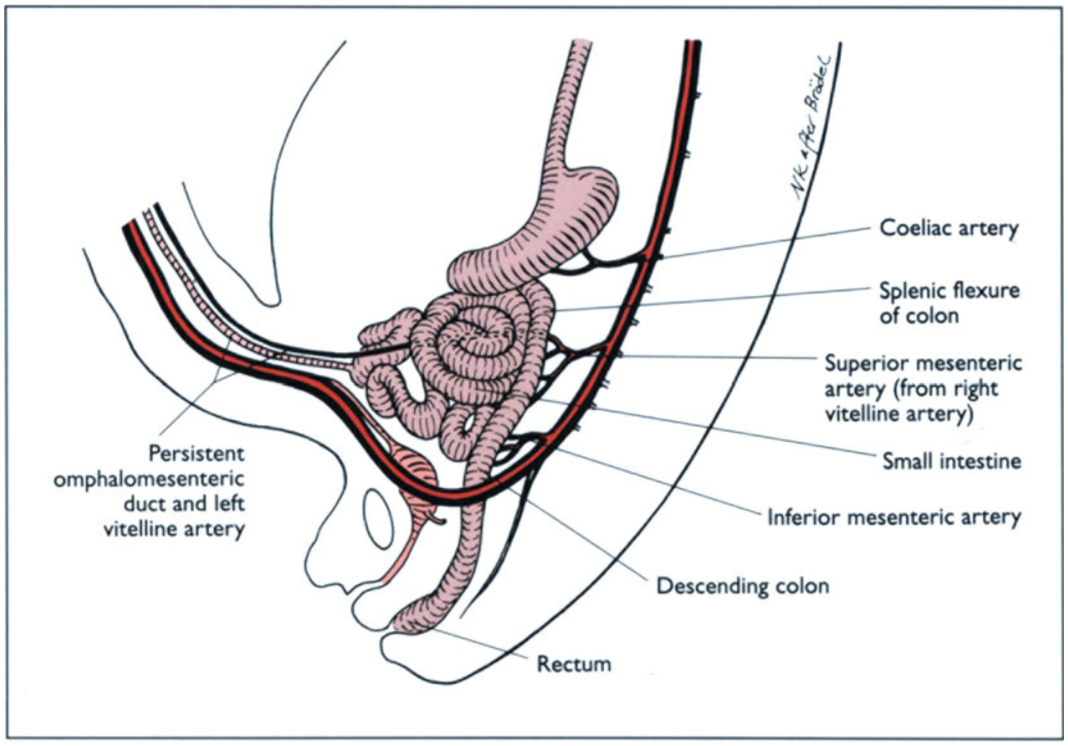


FIGURE 13-2.
Incomplete involution of the omphalomesenteric duct and left vitelline artery.

Table 13-1. Defects arising from failure of omphalomesenteric duct (OMD) and vitelline artery obliteration

Embryologic defect	Resulting abnormality
Complete failure of obliteration of OMD	Patent omphalomesenteric duct; umbilical fistula
Failure of obliteration of mesenteric portion of OMD	Meckel's diverticulum
Failure of obliteration of umbilical portion of OMD	Umbilical sinus and/or umbilical strawberry tumor
Failure of central obliteration of OMD	Vitelline cyst (enterocyst)
Incomplete involution of OMD	Omphalomesenteric band (vitelloumbilical band)
Failure of involution of left vitelline artery	Mesodiverticular band

The next most frequent complication is gastrointestinal bleeding and it is the most common mode of presentation in children [7]. Although some controversy exists, bleeding usually results from ulceration of the ileum caused by the secretion of acid from adjacent gastric mucosa within the diverticulum. The amount of blood loss varies from occult bleeding to frank bright red hemorrhage per rectum with circulatory collapse [3]. It has been stated that children are more likely to present with hematochezia while adults usually present with melena [7]. The diagnosis may be established by radioisotope scanning with ^{99m}Tc pertechnetate, first developed in 1967 by Harden and coworkers [8], which readily identifies the presence of gastric mucosa. When at least 1.8 cm^2 of gastric mucosa is present in the diverticulum, a positive scan will result. It should be noted, however, that Meckel's scans have a fairly high false-negative rate (due to the frequent absence of gastric mucosa) and are much more reliable in children than in adults. Angiography may also be helpful in establishing the diagnosis if active bleeding or a patent left vitelline artery can be demonstrated. Infrequently, perforation of the ilium or diverticulum may be the first presenting sign and the diagnosis may be established by plain abdominal x-ray film.

The third most common mode of presentation (second most common in adults) is diverticulitis. The clinical scenario is similar to acute appendicitis. The differential diagnosis is broad and includes cholecystitis, Crohn's disease, and peptic ulcer disease. It is thought that the fairly high mortality rate of diverticulectomy (6% in some series) may be attributed to the frequent delay in diagnosis of Meckel's diverticulitis. Radiologic examinations are usually not helpful and the diagnosis is most often confirmed by surgical exploration.

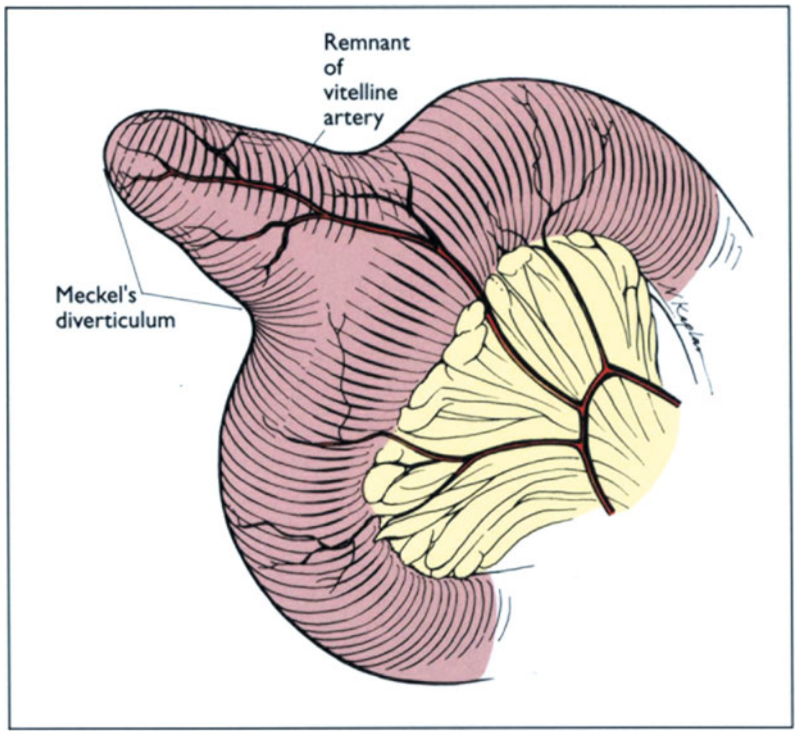


FIGURE 13-3.
Meckel's diverticulum.

Table 13-2. Types of ectopic tissue found in Meckel's diverticulum

Gastric mucosa (60%)
Pancreatic mucosa (16%)
Gastric mucosa and pancreatic mucosa (5%)
Duodenal/jejunal mucosa
Brunner's glands
Gastric and duodenal mucosa
Colonic mucosa
Accessory pancreatic tissue
Hepatobiliary tissue (see Williams [11])
Endometrial mucosa (see DeBartolo and van Heerden [15])
Lymphoid tissue (see Leijonmarck and coworkers [12])

Table 13-3. Complications of Meckel's diverticula

Study	**Soltero and Bill [5]**	**Yamaguchi and coworkers [6]**	**Mackey and Dineen [3]**	**Williams [11]**	**Leijonmarck and coworkers [12]**
Location	**Seattle**	**Japan**	**New York**	**Adelaide**	**Stockholm**
Year	**1976**	**1978**	**1983**	**1981**	**1986**
Patients, *n*	**202**	**583***	**68**	**1806***	**112**
Complications					
Obstruction	31%	40%	25%	16%	32%
Intussusception	NR	14	9	11	3
Inflammation	24	13	7	25	30
Hemorrhage	25	12	23	31	11
Perforation	12	8	12	NR	19
Littre's hernia	4	5	7	11	3
Umbilical fistula	3	3	3	4	NR
Other†	1	5	4	2	2

*Combined series.
†Neoplasms [12,16,17], foreign body impaction [18], fecalith [15], diverticular calculi [19], regional enteritis [15], trauma [6], myxoglobulosis [6].
NR—not reported.

An inguinal, femoral, or umbilical hernia containing a Meckel's diverticulum is referred to as a hernia of Littre, who first described incarcerated femoral hernias containing diverticula in 1700 [9]. The diagnosis is usually established at the time of exploration for incarceration or strangulation [3]. Other less common complications of Meckel's diverticula are listed in Table 13-3.

The development of complications in Meckel's diverticula has led many authors to advocate routine diverticulectomy when diverticula are discovered during abdominal exploration performed for other reasons [10]. More recent data, however, illustrate that the risks of routine diverticulectomy probably outweigh the benefits for most patients [5], and routine incidental diverticulectomy is no longer recommended. However, as diverticular complications are strongly related to the age of the patient and the morphology of the diverticulum, it seems reasonable to perform selective incidental diverticulectomy if the patient is very young, if the diverticulum is attached to the umbilicus by an omphalomesenteric band, or if the diverticulum has a narrow neck, configurations believed to carry significant risks of bowel entrapment or torsion [3,7,11–14].

Table 13-4. Possible etiologies of obstruction due to Meckel's diverticulum

Lead point for intussusception (the intussusception)
Volvulus around a fibrous band attached to the umbilicus (omphalomesenteric band; the remnant of the omphalomesenteric duct)
Incarceration within an inguinal, femoral, or umbilical hernia (Littre's hernia) [20,21]
Volvulus around a fibrous band attached to the ileum (mesodiverticular band; the remnant of the left vitelline artery)
Entrapment of bowel within bands due to local inflammatory reaction
Torsion (volvulus) of the diverticulum
Meckel's stone ileus (see Rudge [22])
Adenocarcinoma (see Mackey and Dineen [3])
Compression of intestine from mass effect of fluid-filled diverticulum or vitelline cyst (see Mackey and Dineen [3])

Surgical Technique

Figures 13-4 through 13-12 depict the surgical technique for laparoscopic Meckel's diverticulectomy.

Set-up

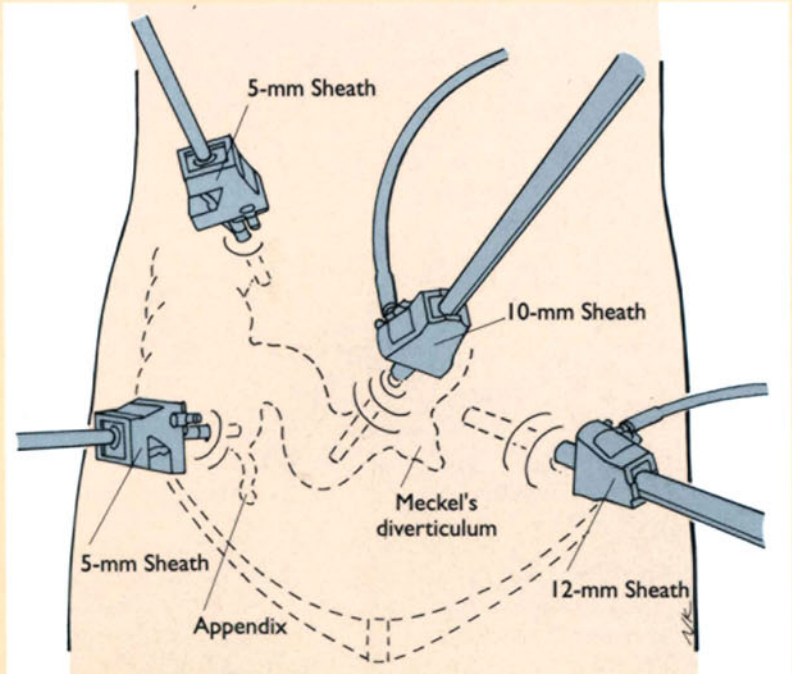


FIGURE 13-4.

The patient is placed in the 30° Trendelenburg position with the arms tucked at the sides. Access to the peritoneal cavity is gained infraumbilically via a closed (Veress needle) or open (Hasson trocar) technique. Following CO_2 insufflation to 15 mm Hg, the laparoscope is inserted via the 10-mm sheath. Five-mm sheaths are placed in the right upper quadrant and right lower quadrant. A single 12-mm sheath is placed in the left lower quadrant (to permit use of the stapling device). With the sheaths in place, abdominal exploration is performed; the gallbladder, appendix, cecum, and pelvis should be thoroughly inspected.

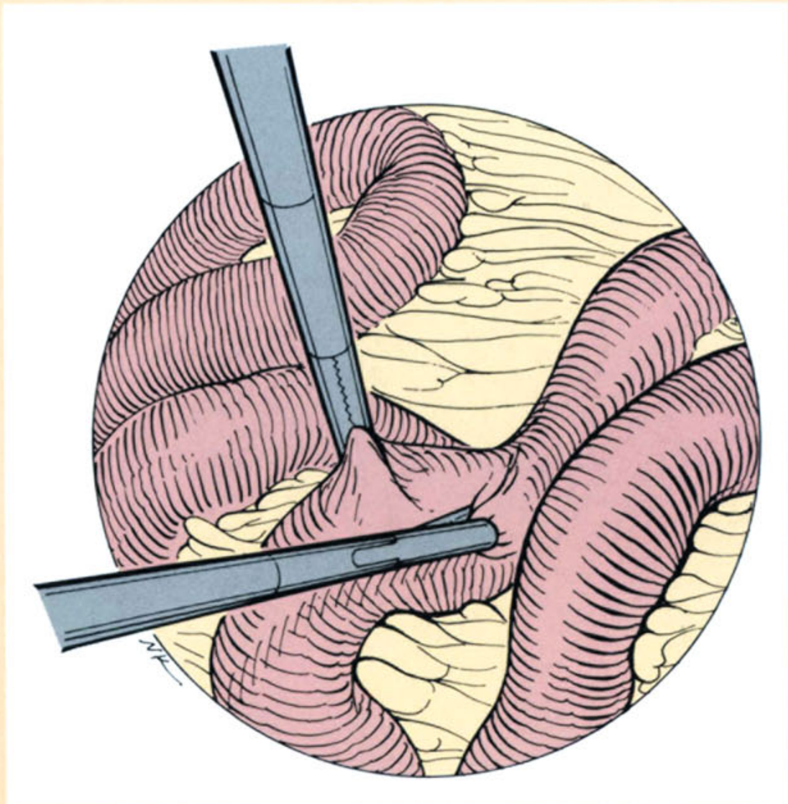


FIGURE 13-5.

The entire small bowel should be carefully visualized.

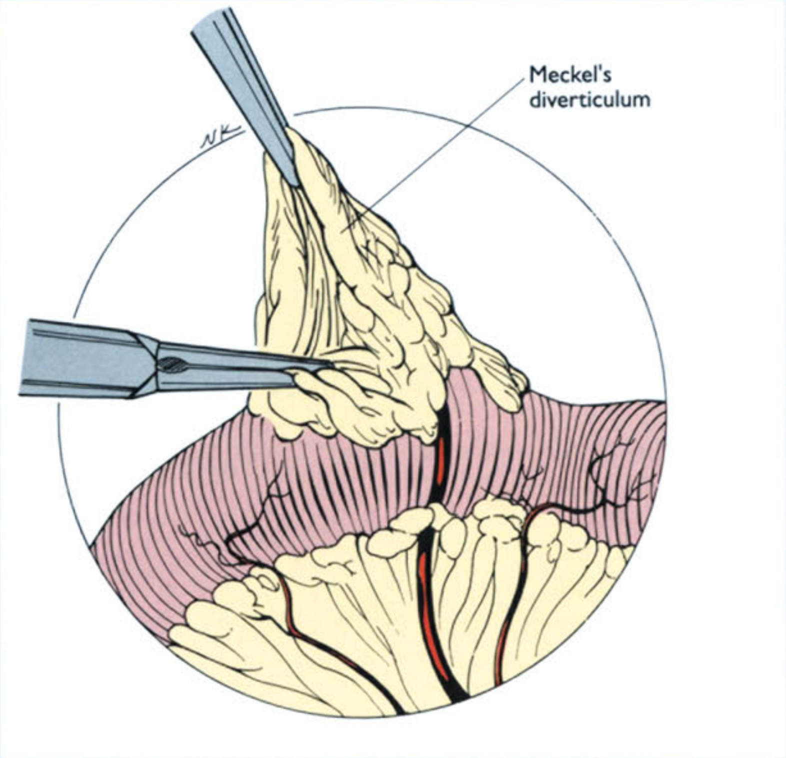


FIGURE 13-6.
The Meckel's diverticulum is grasped with forceps inserted via the right upper quadrant sheath and the dissection is begun using forceps inserted into the right lower quadrant and/or left lower quadrant sheaths. The diverticulum is carefully dissected free from the surrounding mesenteric fat.

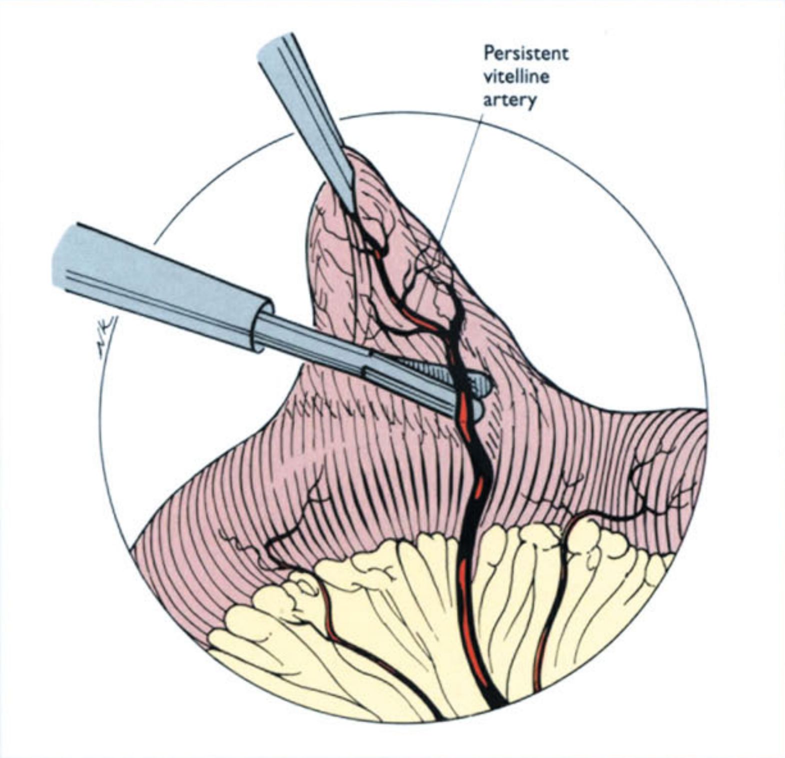


FIGURE 13-7.
A thorough search should be made for a persistent vitelline artery since this structure can be quite large and may not be adequately controlled with the stapling device.

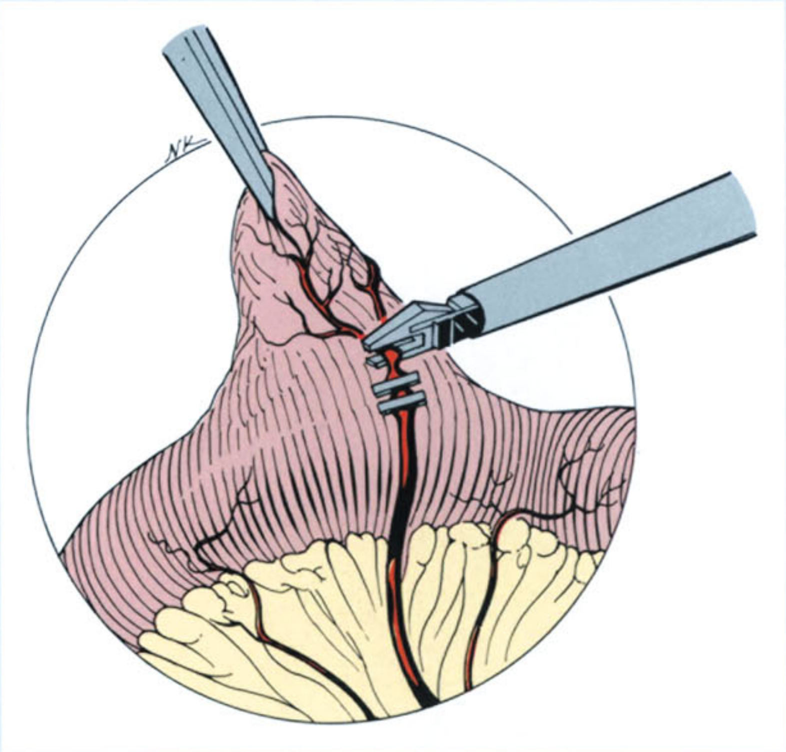


FIGURE 13-8.
If a large persistent vitelline artery is encountered, it may be doubly ligated with clips.

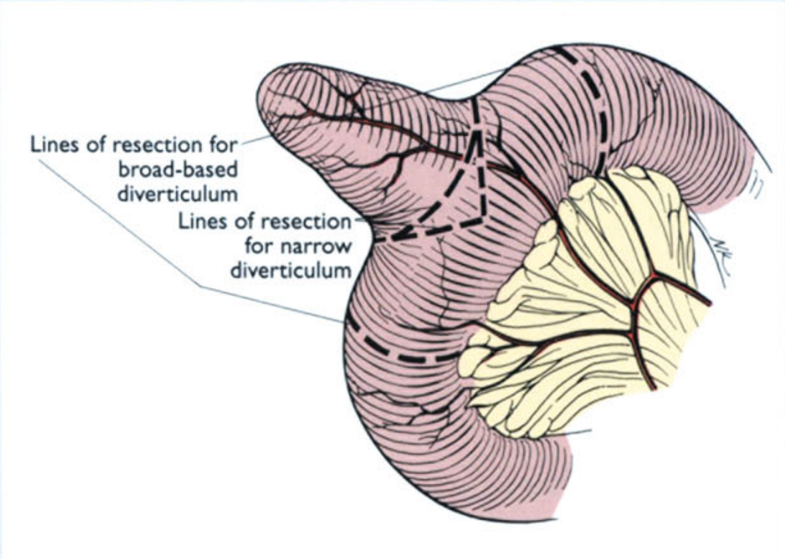


FIGURE 13-9.
The diverticulum is resected. If its base is narrow and simple staple excision would not be expected to compromise the lumen, then the line of resection should be at the base of the diverticulum [1]. If the diverticulum has a broad base, short segment small bowel resection will be necessary [2]. Either procedure may be performed expeditiously using laparoscopic techniques.

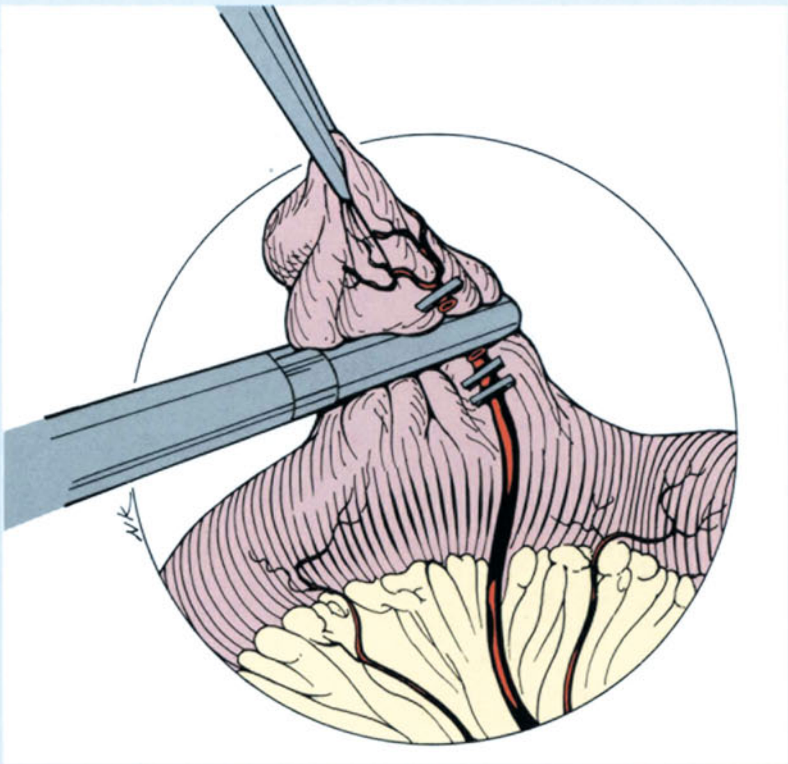


FIGURE 13-10.
Resection is performed with the stapling device. The tip of the diverticulum is grasped with forceps and the diverticulum positioned within the stapler delivered through the left lower quadrant sheath.

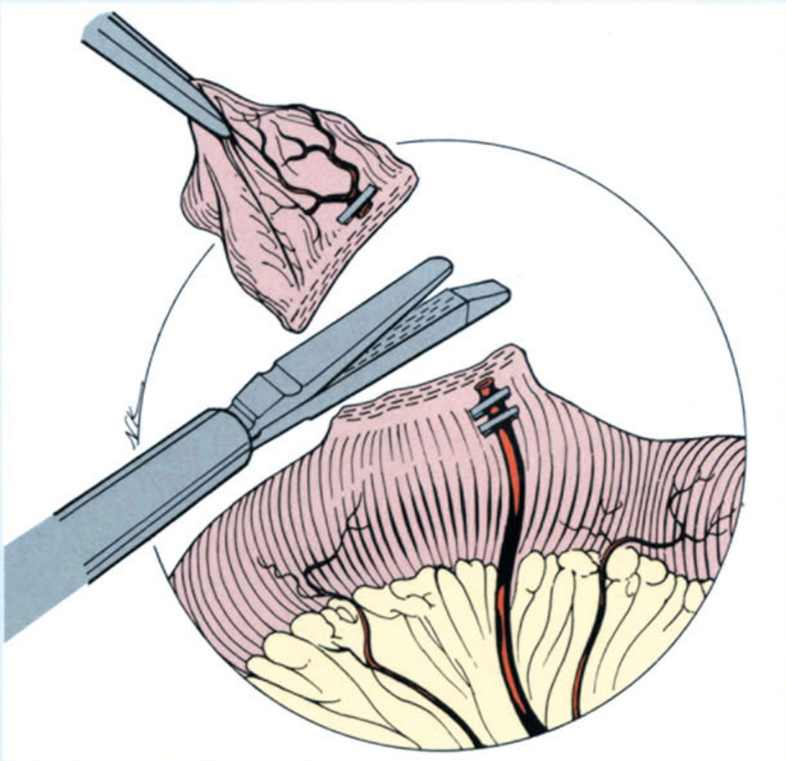


FIGURE 13-11.
The stapler is fired.

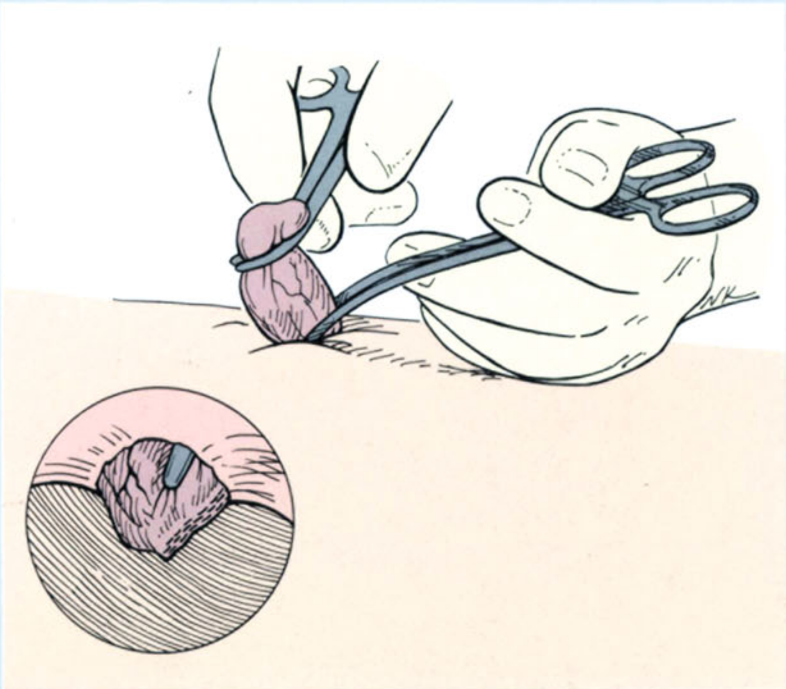


FIGURE 13-12.
The specimen can usually be delivered through the umbilical incision under direct vision.

Results

At present, the experience with Meckel's diverticulectomy is anecdotal [2]. We have performed laparoscopic diverticulectomy in a 26-year-old man with gastrointestinal bleeding and a small bowel follow through that demonstrated a Meckel's diverticulum. Pathologic examination of the specimen revealed ectopic gastric mucosa. The patient was discharged from the hospital in 48 hours and no further bleeding episodes were reported.

References

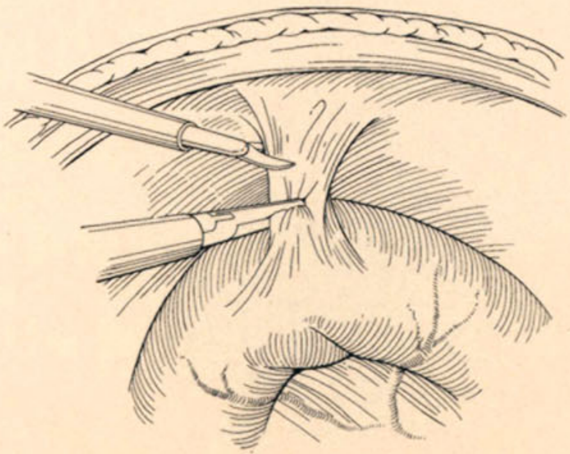
1. Meckel JF: Ueber die divertikel am darmkanal. *Arch die Physiol* 1809, 9:421–453.
2. Atwood SEA, McFrath J, Hill DK, Stephens RB: Laparoscopic approach to Meckel's diverticulectomy. *Br J Surg* 1992, 79:211.
3. Mackey WC, Dineen P: A fifty year experience with Meckel's diverticulum. *SGO* 1983, 156:56–64.
4. Moses WR: Meckel's diverticulum: report of two unusual cases. *N Engl J Med* 1947, 237:118–122.
5. Soltero MJ, Bill AH: The natural history of Meckel's diverticulum and its relation to incidental removal: a study of 202 cases of diseased Meckel's diverticulum found in King County, Washington, over a fifteen year period. *Am J Surg* 1976, 132:168–173.
6. Yamaguchi M, Takeuchi S, Awazu S: Meckel's diverticulum: investigation of 600 patients in Japanese literature. *Am J Surg* 1978, 136:247–249.
7. Turgeon DK, Barnett JL: Meckel's diverticulum. *Am J Gastroenterol* 1990, 85:777–781.
8. Harden RMG, Alexander WD, Kennedy I: Isotope uptake and scanning of the stomach in man with ^{99m}Tc-pertechnetate. *Lancet* 1967, 1:1305–1307.
9. Littre A: Observation sur une nouvelle espece de hernia. *Acad Roy Sci* 1700, 2:300.
10. Garretson DC, Frederich ME: Meckel's diverticulum. *AFP* 1990, 42:115–119.
11. Williams RS: Management of Meckel's diverticulum. *Br J Surg* 1981, 68:477–480.
12. Leijonmarck C-E, Bonman-Sandelin K, Frisell J: Meckel's diverticulum in the adult. *Br J Surg* 1986, 73:146–149.
13. Foglia RP: Meckel's diverticulum. In *Pediatric Surgery*, edn 2. Edited by Ashcraft KW, Holder TM. Philadelphia: W.B. Saunders Company; 1993:435–439.
14. Oldham KT, Wesley JR: The pediatric abdomen. In *Surgery: Scientific Principles and Practice*. Edited by Greenfield LJ, Mulholland MW, Oldham KT, Zelenock GB. Philadelphia: J.B. Lippincott Company; 1993:1872–1873.
15. DeBartolo HM, van Heerden JA: Meckel's diverticulum. *Ann Surg* 1976, 183:30–33.
16. Kusumoto H, Yoshitake H, Mochida K, Kumashiro R, Sano C, Inutsuka S: Adenocarcinoma in Meckel's diverticulum: report of a case and review of 30 cases in the English and Japanese literature. *Am J Gastroenterol* 1992, 87:910–913.
17. Weinstein EC, Dockerty WB, Waugh JH: Neoplasms of Meckel's diverticulum. *Ant Abstr Surg* 1963, 116:103–111.
18. Velanovich V, Ledbetter D, McGahren E, Nuchtern J, Schaller R: Foreign bodies within a Meckel's diverticulum. *Arch Surg* 1992, 127:864.
19. Newmark H, Halls J, Silberman R *et al.*: Two cases showing the radiologic appearance of Meckel's stone. *Am J Gastroenterol* 1979, 73:193–196.
20. Perlman JA, Hoover HC, Safer PK: Femoral hernia with strangulated Meckel's diverticulum (Littre's hernia). *Am J Surg* 1980, 139:286–289.
21. Weitzner S: Carcinoid of Meckel's diverticulum (report of a case and review of the literature). *Cancer* 1969, 23:1436–1440.
22. Rudge FW: Meckel's stone ileus. *Milit Med* 1992, 157:98–100.

CHAPTER

14

Laparoscopic Small Bowel Resection and Adhesiolysis

William N. Peugh
Steve Eubanks



Gynecologists have been practicing laparoscopic pelvic adhesiolysis and excision of endometriosis implants for many years. During the early phase of our experience with operative laparoscopy, the presence of a prior laparotomy or of an ongoing small bowel obstruction were considered relative or absolute contraindications to laparoscopy for most general surgeons. This partly stemmed from the fear of causing iatrogenic bowel injury during trocar introduction. With widespread application of these techniques over the past few years, the list of indications for laparoscopy is undergoing constant revision.

During laparoscopic cholecystectomy, surgeons found that lysis of incidentally discovered intraperitoneal adhesions could be accomplished quickly and safely. Experience with trocar placement in patients with prior laparotomies demonstrated that bowel injury is a relatively rare occurrence [1]. The use of laparoscopy as a diagnostic tool in the elective setting led to opportunities for therapeutic adhesiolysis [2] as well as adhesiolysis to expose other underlying intra-abdominal pathology. Similarly, diagnostic laparoscopy has been used to direct small bowel resection for primary jejunal disease [3].

Such elective experience has served to facilitate the application of laparoscopy to the urgent and emergent setting [4]. In several institutions laparoscopic exploration is the initial operative approach in all patients with small bowel obstruction. The availability of appropriate laparoscopic bowel instrumentation and stapling devices has facilitated the development of these laparoscopic methods for small bowel resection and adhesiolysis.

Anatomy

For the purposes of this discussion, the small bowel will be defined as the intestine extending from the ligament of Treitz to the ileocecal valve, and includes the jejunum and ileum.

The small intestine as measured in the cadaver is up to 7 meters long. The jejunum and ileum are supported from the posterior abdominal wall on a fan-shaped mesentery. The root of the mesentery is about 15 cm long, extending obliquely from the ligament of Treitz to the ileocecal valve. Between the layers of the mesentery lie the vascular supply (derived from the superior mesenteric artery and draining to the portal vein), the lymphatic drainage, and the autonomic and somatic nerve supply. The parasympathetic supply is derived from the posterior vagus, and sympathetic supply from the superior mesenteric ganglion. Somatic sensory supply is through the lesser splanchnic nerves (T9–T10).

Pathophysiology, Presentation, and Differential Diagnosis

Normal motility of the small bowel serves both to mix the intraluminal contents with enteric secretions, thus facilitating digestion, and to effect transit from one specialized area of the bowel to the next. As a direct result, the intraluminal bacterial counts rise progressively the more distal in the bowel one samples.

Mechanical bowel obstruction disturbs the transit of luminal contents. The resultant accumulation of volume in the bowel causes distension of the bowel and waves of pain as peristalsis attempts to push liquid past the obstruction. The pain is diffusely localized in the periumbilical region. In addition, stasis of intraluminal contents results in rapid bacterial overgrowth. In the presence of a closed loop obstruction or strangulation, bacterial translocation, bowel infarction, and perforation may result.

The patient presents with a history of abdominal pain, distention, nausea, vomiting, and obstipation. There may be focal pain at the site of a hernia. The duration of pain prior to the onset of emesis, degree of distention, as well as the character of the emesis may serve to suggest how proximal or distal the obstruction is. The patient may report several prior similar episodes.

On examination, the patient is usually mildly to moderately distended and has no evidence of peritoneal irritation (unless perforated). Bowel sounds are present and often are described as "tinkling" or coming in "waves and rushes." Radiographic examination reveals distended loops of small bowel, air-fluid levels, and absence of distal gas.

Table 14-1. Etiology of small bowel obstruction

Cause	Incidence, %
Adhesion	75
Hernia	8
Internal	20
External	80
Malignant tumor	8
Volvulus	3*
Inflammatory bowel disease	1
Intussusception	<1
Gallstone ileus	<1
Radiation enteritis	<1
Intra-abdominal abscess	<1
Bezoar	<1

*Varies greatly with region of the world. May represent up to 50%.

Cardinal signs and symptoms that mandate exploration include fever, tachycardia, continuous abdominal pain, leukocytosis, and peritoneal irritation, as well as a complete obstruction.

The possible etiologies of small bowel obstruction are many (Table 14-1). The three most common causes can often be treated laparoscopically. The focus of the remainder of this chapter is on the laparoscopic exploration of small bowel obstruction and treatment by adhesiolysis and small bowel resection.

Surgical Technique

The surgical approach to small bowel obstruction must be a flexible one, although basic principles of general surgery and laparoscopy should be adhered to.

1. History, physical examination, and the site of previous surgical incisions should be the initial guide. The suspected site of pathology should be determined preoperatively (upper abdomen vs lower abdomen or pelvis), because this will guide operating room set-up (Figure 14-1).
2. After initial Hasson trocar placement (Figure 14-2) and video exploration (Figure 14-3), further trocars should be placed in a triangulated pattern to avoid inadvertent intracorporeal or extracorporeal clashes between instruments.
3. Great care must be used to avoid inadvertent injury of dilated loops of bowel with the cautery. All metal portions of a cautery device should be visible whenever cautery is activated. The use of bipolar cautery scissors may be preferable to unipolar devices to prevent injury caused by transmitted current.
4. The entire small bowel should be "run" from ligament of Treitz to terminal ileum to avoid missing a point of obstruction or a potential future cause. Patients with prior laparotomies and nonobstructing adhesions may have an obstruction caused by a hernia not clinically appreciated [5].

Figures 14-4 through 14-13 depict the surgical technique for laparoscopic small bowel resection and adhesiolysis.

Set-up

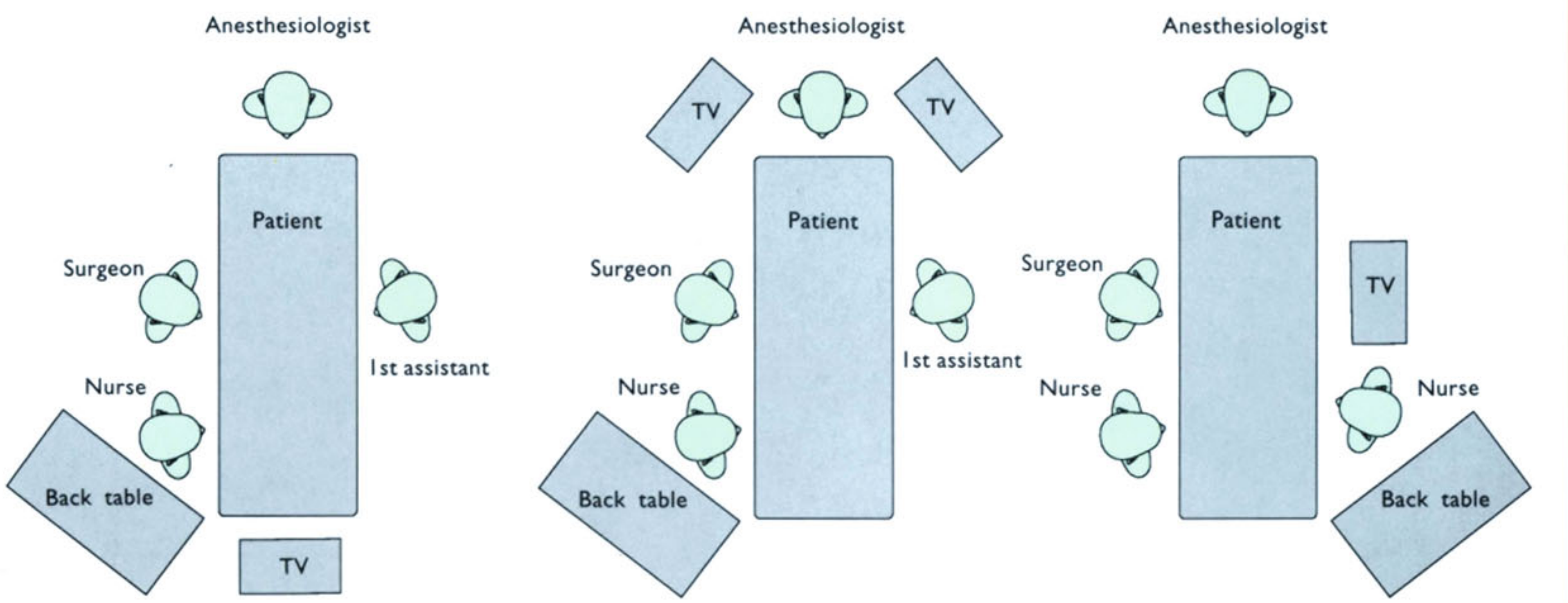


FIGURE 14-1.
The three different operating room set-ups for exploration of the small bowel. **Left**, Operating room set-up for lysis of pelvic adhesions. **Middle**, Operating room set-up for lysis of upper abdominal adhesions. **Right**, Operating room set-up for lateral abdominal adhesions.

Set-up

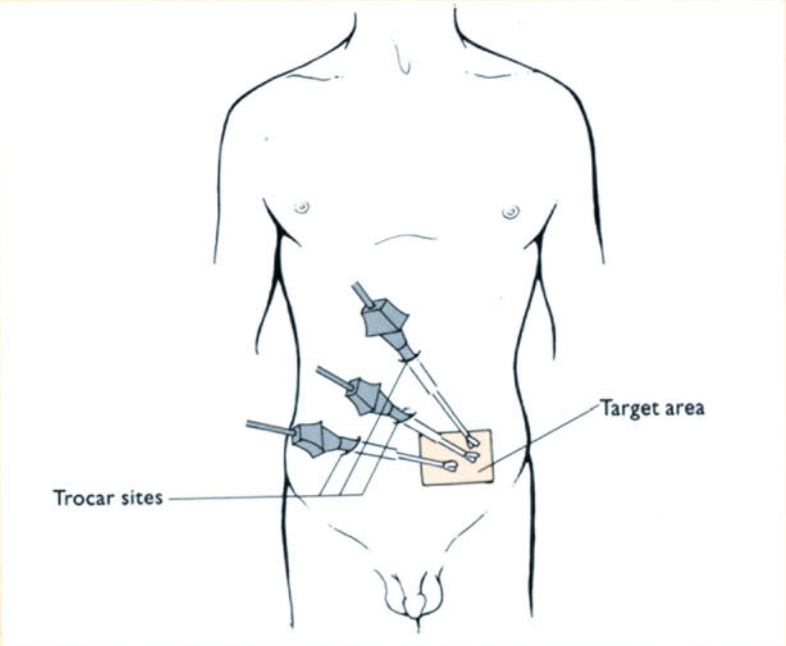


FIGURE 14-2.
Trocar placement is extremely variable for lysis of adhesions or resection of the small bowel. The exact position of the trocars depends on the location within the abdominal cavity of the target area. The location of the target area may not be identified until after the laparoscope is used to locate the point of obstruction, the area of adhesions, or the site of pathology.

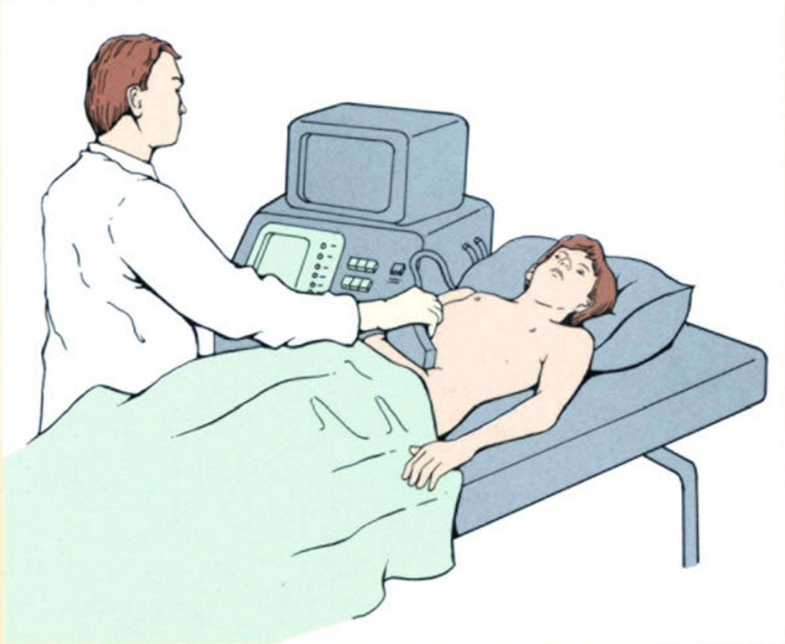


FIGURE 14-3.
The use of extracorporeal ultrasound has been demonstrated to provide valuable information for the safe placement of the Veress needle or the first trocar in patients with a "hostile" abdomen. These patients include those with multiple prior procedures, previous intra-abdominal infections, or those with dilated intestines.

Procedure

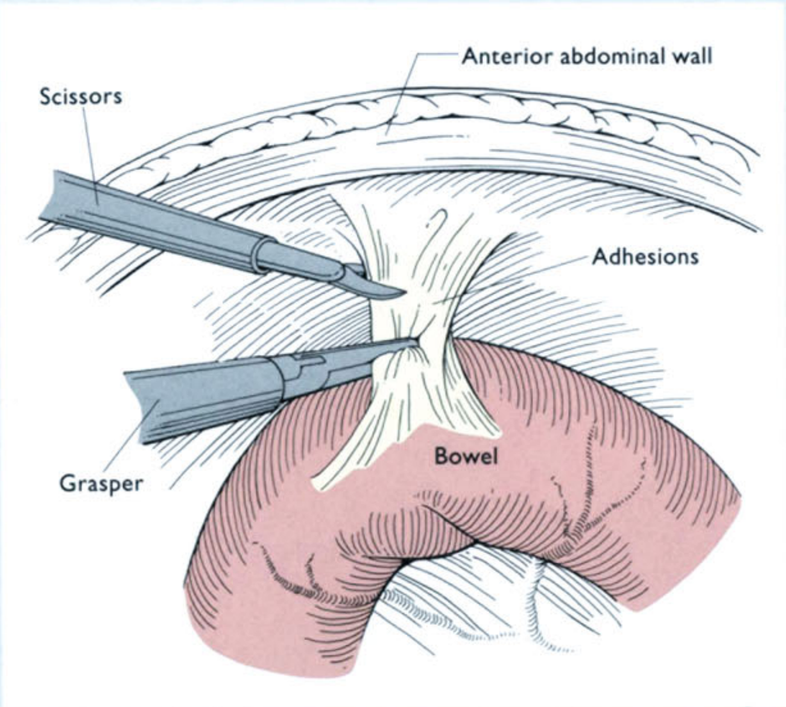


FIGURE 14-4.
Dissection is begun, and graspers and bipolar cautery scissors are introduced.

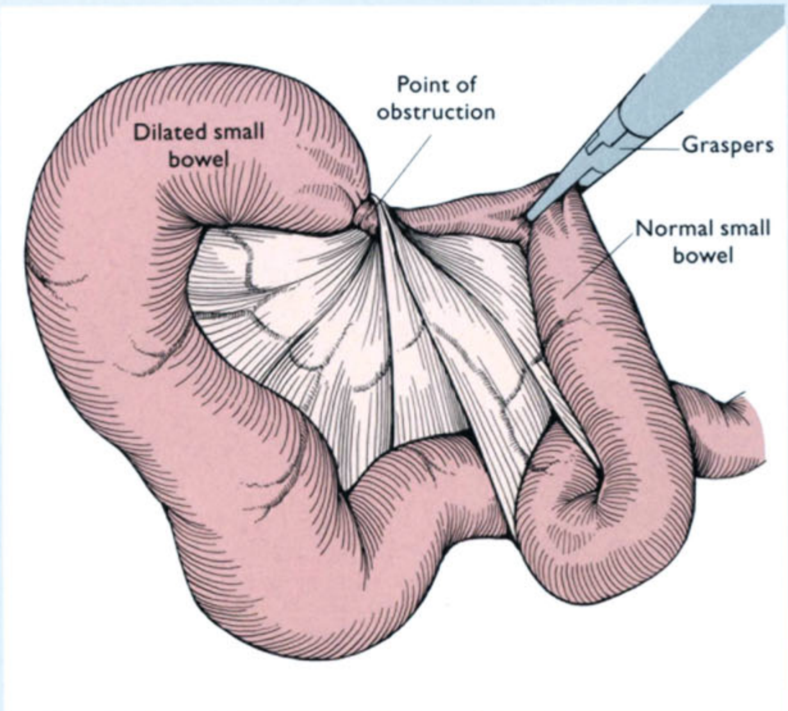


FIGURE 14-5.
The point of obstruction is identified.

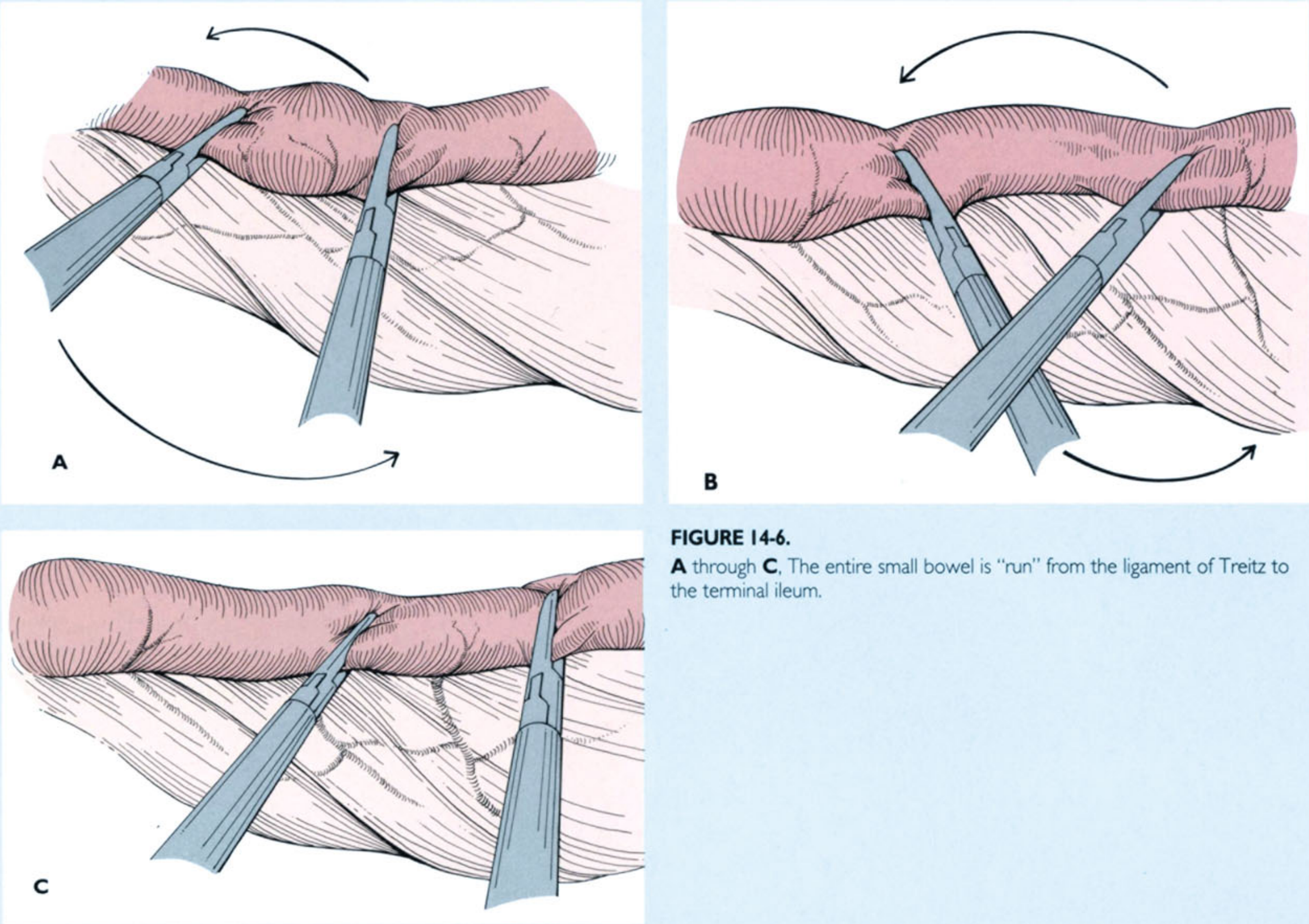


FIGURE 14-6.
A through **C**. The entire small bowel is "run" from the ligament of Treitz to the terminal ileum.

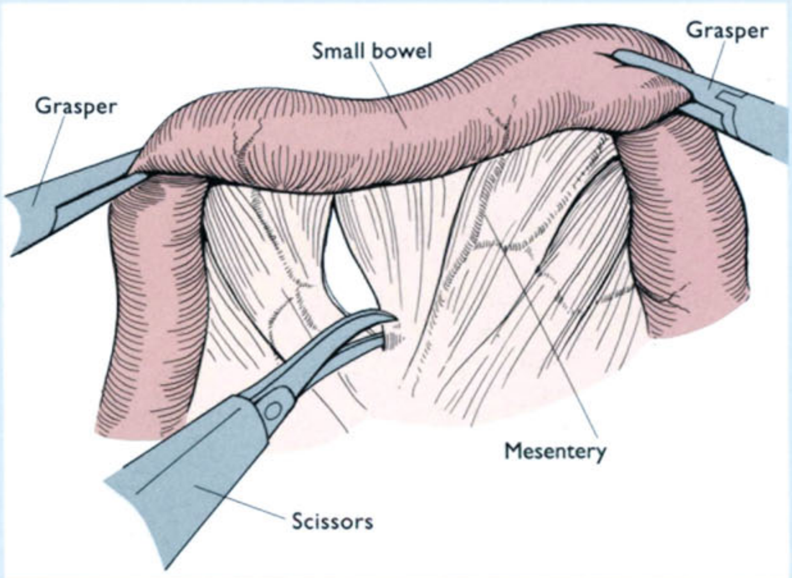


FIGURE 14-7.
A small window is created in the mesentery adjacent to the bowel wall using cautery, blunt, and sharp dissection.

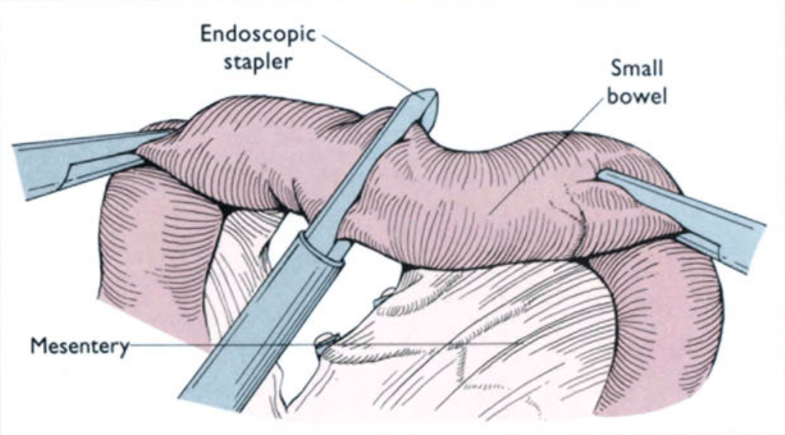


FIGURE 14-8.
The endoscopic bowel stapling device is used to divide the small bowel. Markedly dilated bowel may require more than one application of the stapler to completely divide the bowel.

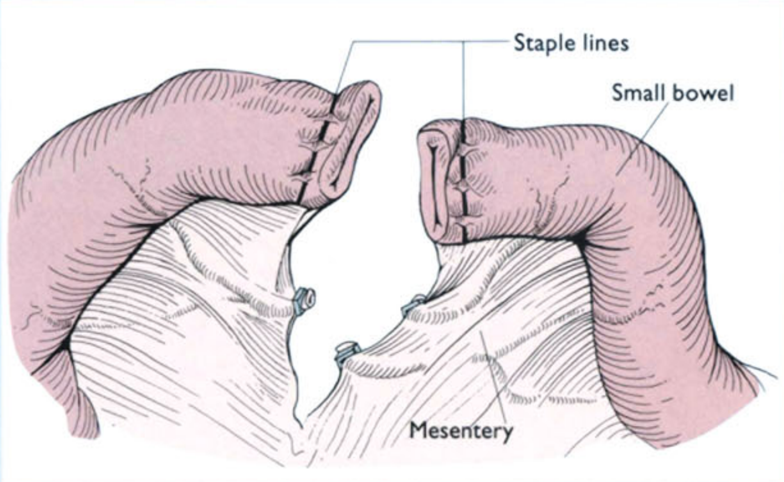


FIGURE 14-9.
The divided small bowel is demonstrated. The endoscopic stapler simultaneously divides the intestine and applies staples to prevent the spillage of bowel contents. The staple lines are also hemostatic in most situations.

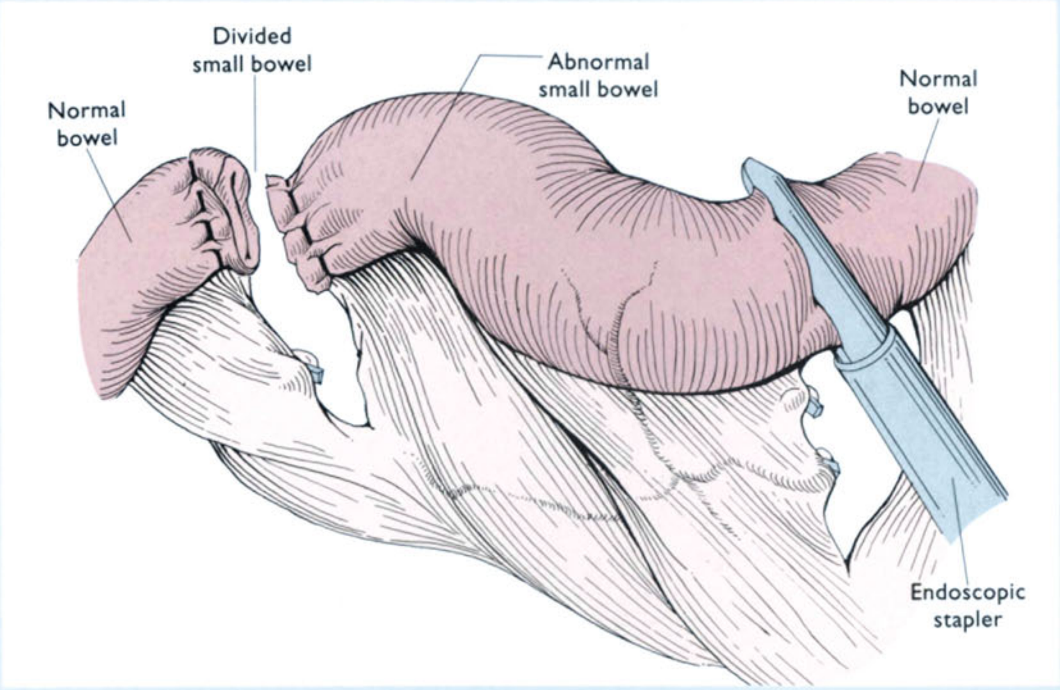


FIGURE 14-10.
A second site is selected for division of the small bowel.

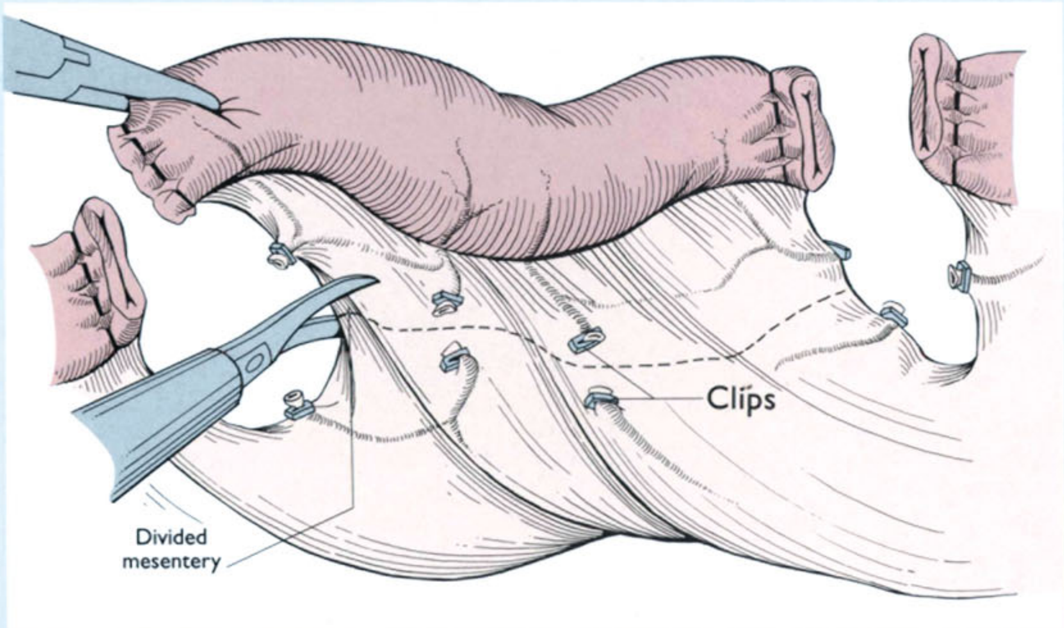
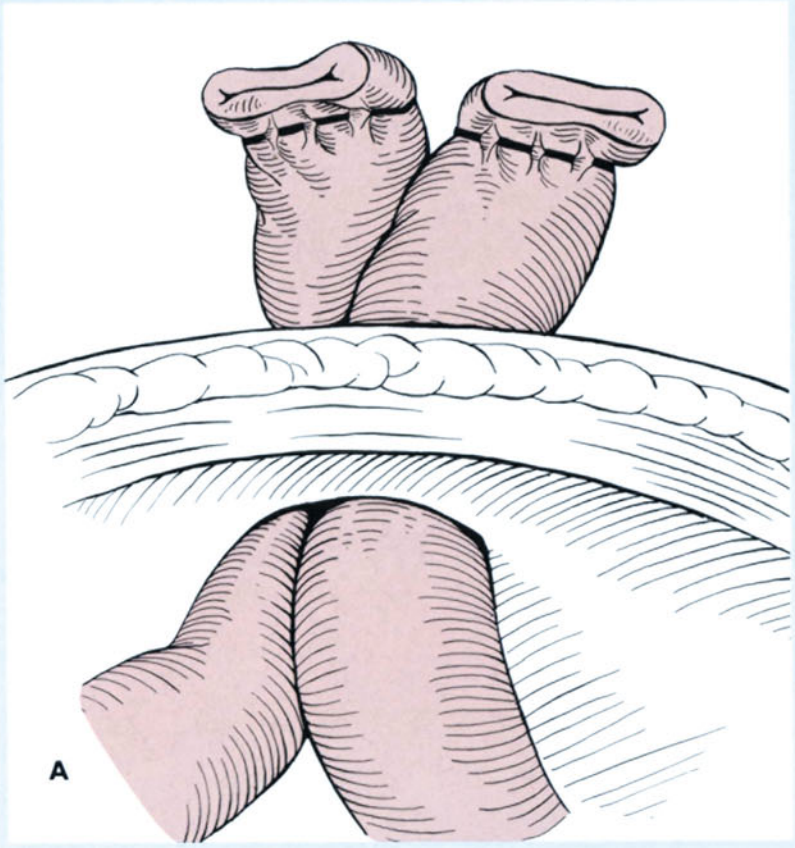
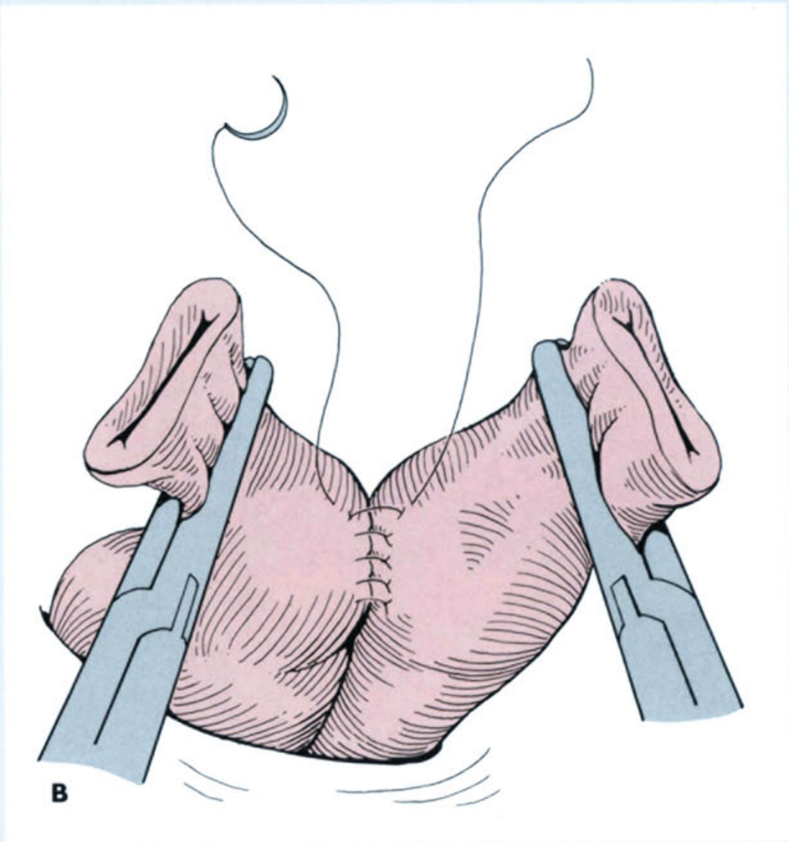


FIGURE 14-11.
The mesentery of the abnormal small bowel is divided. This can be accomplished using cautery (monopolar or bipolar), hemostatic titanium clips with sharp dissection, or with a vascular endoscopic stapler.





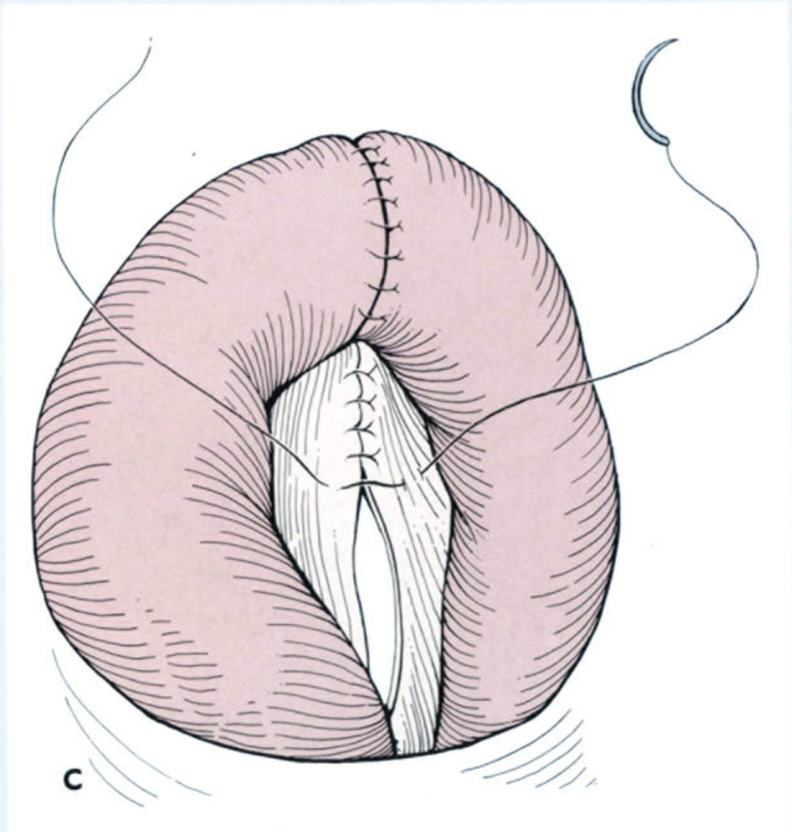


FIGURE 14-12.

A, The specimen is removed from the abdomen. **B**, The anastomosis is performed at the level of the skin using sutures or staples. **C**, The mesenteric defect is closed with sutures.

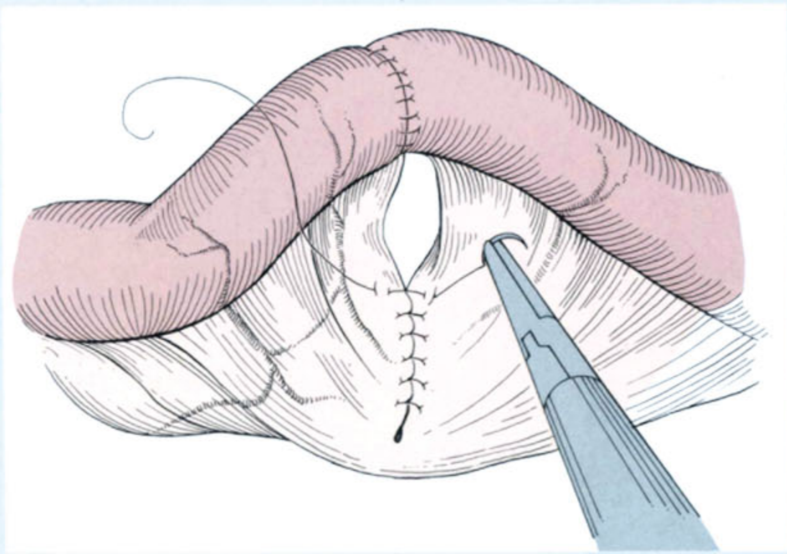


FIGURE 14-13.

The anastomosis and closure of the mesenteric defect may be performed intracorporeally.

References

1. Kaali SG, Barad DH: Incidence of bowel injury due to dense adhesions at the sight of direct trocar insertion. *J Reprod Med* 1992, 37:617–618.
2. Owens S, Yeko TR, Bloy R, Maroulis GB: Laparoscopic treatment of painful perihepatic adhesions in Fitz-Hugh-Curtis syndrome. *Obstet Gynecol* 1991, 78:542–543.
3. Cross MJ, Snyde SK: Laparoscopic-directed small bowel resection for jejunal diverticulitis with perforation. *J Laparoendosc Surg* 1993, 3:47–49.
4. Adams S, Wilson T, Brown AR: Laparoscopic management of acute small bowel obstruction. *Aust N Z J Surg* 1993, 63:39–41.
5. Keating J, Hill A, Schroeder D, Whittle D: Laparoscopy in the diagnosis and treatment of acute small bowel obstruction. *J Laparoendosc Surg* 1992, 2:239–244.

CHAPTER 15

Laparoscopic Repair of Diaphragmatic Hernia

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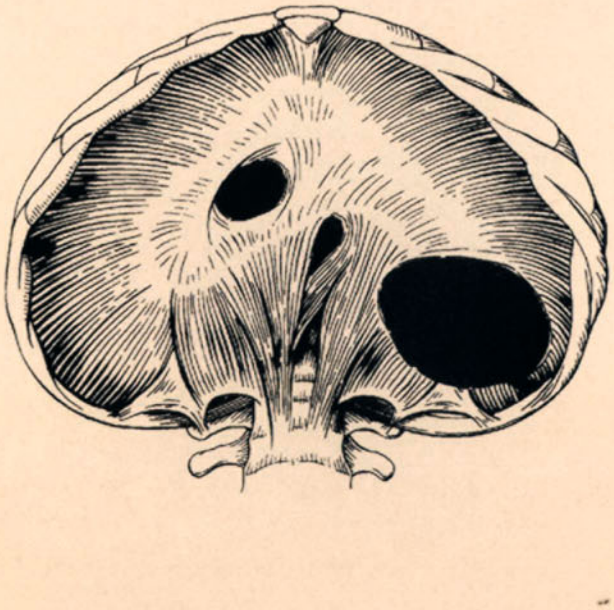
Steve Eubanks



Hernias of the diaphragm are unusual defects that can present difficult diagnostic and technical problems for the surgeon (Figure 15-1). The entity of the hernia of the thoracic diaphragm was first recognized several centuries ago. Ambroise Pare (1510–1590) first described traumatic diaphragmatic hernia in 1579 based on postmortem findings in two patients [1]. In 1769, Giovanni Battista Morgagni described herniation through the subcostosternal space [2]. This same hernia would later be referred to as Larrey's hernia [3] and descriptively known as the subcostosternal diaphragmatic hernia [4]. The posterolateral diaphragmatic hernia (foramen of Bochdalek) was described in 1848. Hiatal hernia has been recognized in autopsy studies for several centuries. Hiatal hernia was not diagnosed in living humans until early in the twentieth century following the development of diagnostic radiographic methods [5]. The technique and timing of repair of these diaphragmatic defects has been an area of controversy for many years. Recently, laparoscopic techniques have been applied to the repair of hernias of the diaphragm.

Embryology and Anatomy

The development of the diaphragm in the fetus takes place between the eighth and tenth weeks of intrauterine life [3]. The thoracic diaphragm develops from at least five anlages, the major one being the septum transversum. The connections between the two coelomic cavities are known as the pleuroperitoneal canals. Failure of the pleuroperitoneal canals to close in utero results in a congenital diaphragmatic defect. The musculature of the diaphragm migrates from the cervical myotomes and carries its innervation from the cervical nerves 3, 4, and 5 by way of the phrenic nerve.

The anatomy of the adult thoracic diaphragm consists of a central tendon with muscular sternal, costal, and lumbar portions (Figure 15-2). The lumbar portion consists of two musculotendinous crura and the arcuate ligaments. Three major openings in the diaphragm allow passage of structures from the chest to the abdomen: the aortic, esophageal, and vena cava openings [7]. The arterial supply to the diaphragm is multiple and includes the right and left phrenic arteries, the superior phrenic arteries, the pericardiophrenic arteries, and the musculophrenic arteries.

Pathophysiology, Presentation, and Differential Diagnosis

Diaphragmatic hernias are frequently divided into the categories of congenital and acquired defects (Table 15-1). The congenital defects are the posterolateral diaphragmatic hernia, the subcostosternal diaphragmatic hernia (Morgagni hernia, Larrey's hernia), and the congenital esophageal hernia. The acquired diaphragmatic hernias are divided into the categories of traumatic, hiatal, and paraesophageal (or hiatal types 1 and 2). The management of gastroesophageal reflux and associated hiatal hernias will be discussed in Chapter 2.

Congenital posterolateral diaphragmatic hernia is an unusual defect that is usually diagnosed at birth or may be diagnosed in utero by prenatal ultrasonography (Figure 15-3) [7]. This space-occupying lesion prevents normal development of the ipsilateral lung. The defect is on the left side in 88% of patients, on the right side in 10% of patients, and rarely bilateral (1%–2%) [8]. The critically ill nature of these patients and the paucity of instrumentation designed specifically for laparoscopic procedures in neonates has precluded the utilization of laparoscopic techniques in this particular patient population.

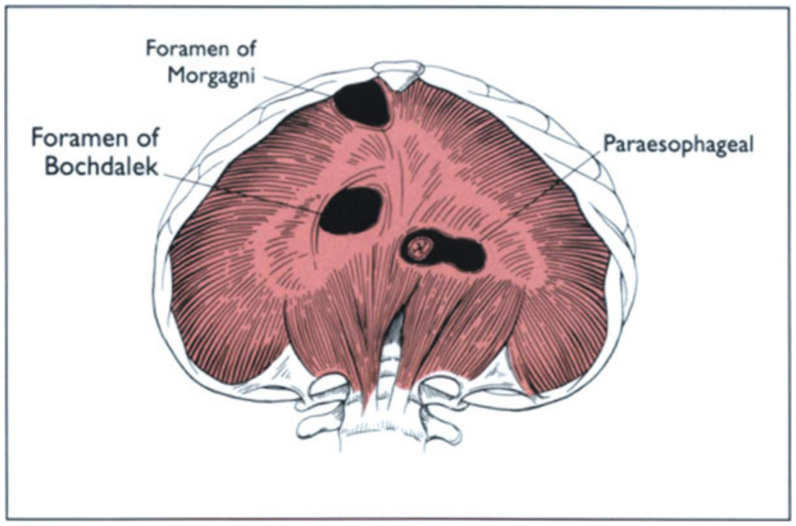


FIGURE 15-1.
Types and location of diaphragmatic hernias: paraesophageal; foramen of Bochdalek; and foramen of Morgagni.

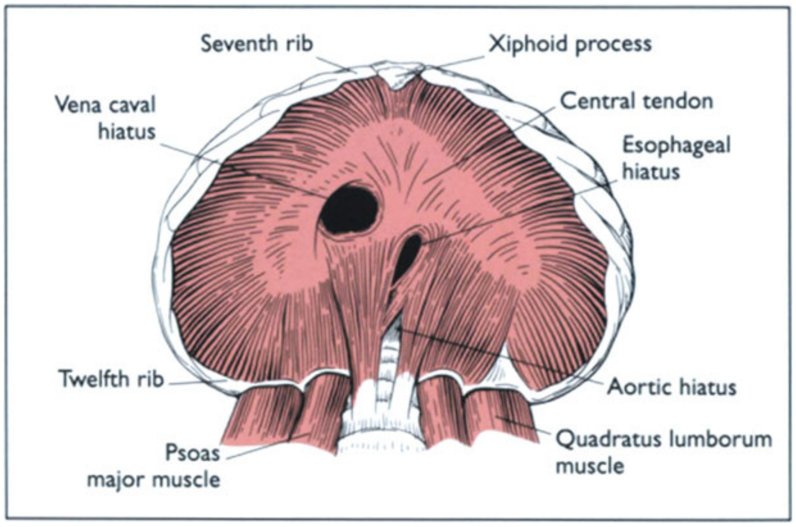


FIGURE 15-2.
Anatomy of the thoracic diaphragm.

The congenital subcostosternal diaphragmatic hernia is uncommon, representing only 3% of all surgically treated diaphragmatic hernias [6]. These defects are rarely symptomatic, and although they represent a congenital defect, they generally are found later in life [9]. These hernias are frequently mistaken for mediastinal neoplasms. Elevation of intra-abdominal pressure from conditions such as pregnancy, obesity, or trauma may exacerbate herniation of viscera. Many subcostosternal diaphragmatic hernias are detected as incidental findings on chest radiograph or computed tomography (CT) scans. Some patients may present with complaints of abdominal or chest pain, shortness of breath, or intermittent bowel obstructions. Nonoperative evaluation of these symptoms frequently fails to identify the diaphragmatic defect as the source of the problem. Historically, the majority of these hernias have been detected at laparotomy or autopsy. Recently, laparoscopy has been successfully used for the diagnosis and treatment of subcostosternal diaphragmatic hernias [9,10].

Traumatic diaphragmatic hernias may be diagnosed and repaired laparoscopically. However, the high incidence of associated visceral injuries limits the utility of laparoscopy in the management of this disorder. Furthermore, the concern for creating a life-threatening tension pneumothorax as a result of insufflating the abdominal cavity prevents most surgeons from applying laparoscopic techniques in the treatment of traumatic diaphragmatic hernias. “Gasless” laparoscopy is a technique which may be used by the trauma surgeon for the evaluation of the abdominal cavity and diaphragm without increasing the risk of a tension pneumothorax.

Paraesophageal hernias may be divided into three categories: 1) sliding hiatal hernia; 2) herniation of the gastric fundus with a normally positioned gastroesophageal junction; and 3) a hernia in which both the gastroesophageal junction and the fundus herniate into the thorax. Paraesophageal hernias may become extremely large and eventually contain the entire stomach within the thoracic cavity. Life-threatening complications may result from gastric incarceration and subsequent strangulation, perforation, volvulus of the stomach, or sepsis resulting from mediastinitis or abdominal abscess.

A sliding hiatal hernia occurs when the gastroesophageal junction migrates cephalad through the esophageal hiatus due to a loss or weakening of the attachment of the gastroesophageal junction to the pre-aortic fascia and the median arcuate ligament [10]. Gastroesophageal reflux is the symptom primarily associated with a sliding hiatal hernia.

Paraesophageal hernias are usually diagnosed with the aid of upper gastrointestinal studies. These defects may also be identified from chest radiographs, upper endoscopy, or CT. Occasionally, the paraesophageal hernia may be an incidental finding at the time of laparotomy or laparoscopy.

Laparoscopy has been successfully used in the treatment of paraesophageal hernias. In many cases, the hernia can be easily reduced into the abdominal cavity and the repair completed without a conventional abdominal incision. The repair is effected by the reduction of the stomach into the abdominal cavity, the excision of the hernia sac, the approximation of the edges of the diaphragmatic defect (or alternatively a mesh patch covering a large defect), and fixation of the stomach in an intra-abdominal position. Antireflux procedures are frequently combined with the repair of paraesophageal hernias. The surgeon may also elect to fix the stomach in an abdominal position by placing a gastrostomy tube or suturing the fundus of the stomach to the anterior abdominal wall or diaphragm.

Table 15-1. Types of hernias of the diaphragm

Congenital	
	Posterolateral (foramen of Bochdalek)
	Subcostosternal (Morgagni hernia, Larrey's hernia)
	Esophageal hiatus
Acquired	
	Traumatic
	Hiatal
	Paraesophageal

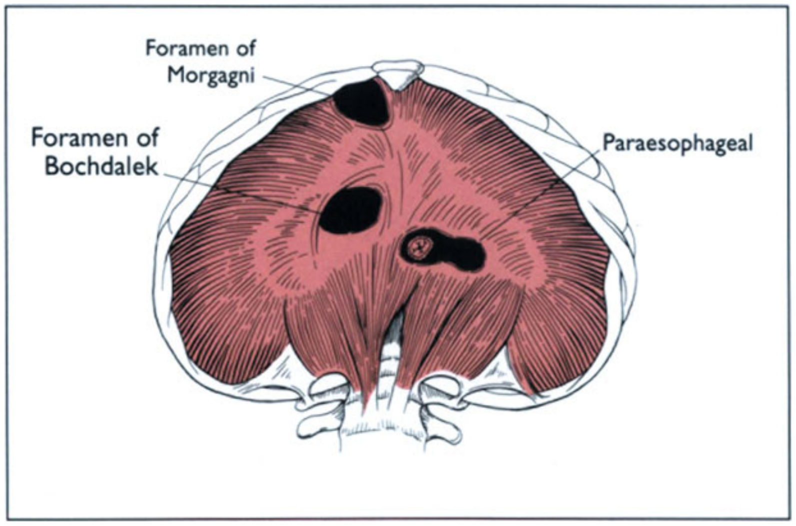


FIGURE 15-3.
The congenital diaphragmatic hernia of Bochdalek is a posterolateral defect that results from a failure of the pleuroperitoneal canal to close at 8 weeks gestation. Eighty percent occur on the left side and occasionally they are bilateral. The size of the defects range from a very small hole to near total or total absence of the hemidiaphragm.

Surgical Technique

Figures 15-4 through 15-17 depict the surgical technique for laparoscopic repair of diaphragmatic hernia.

Set-up

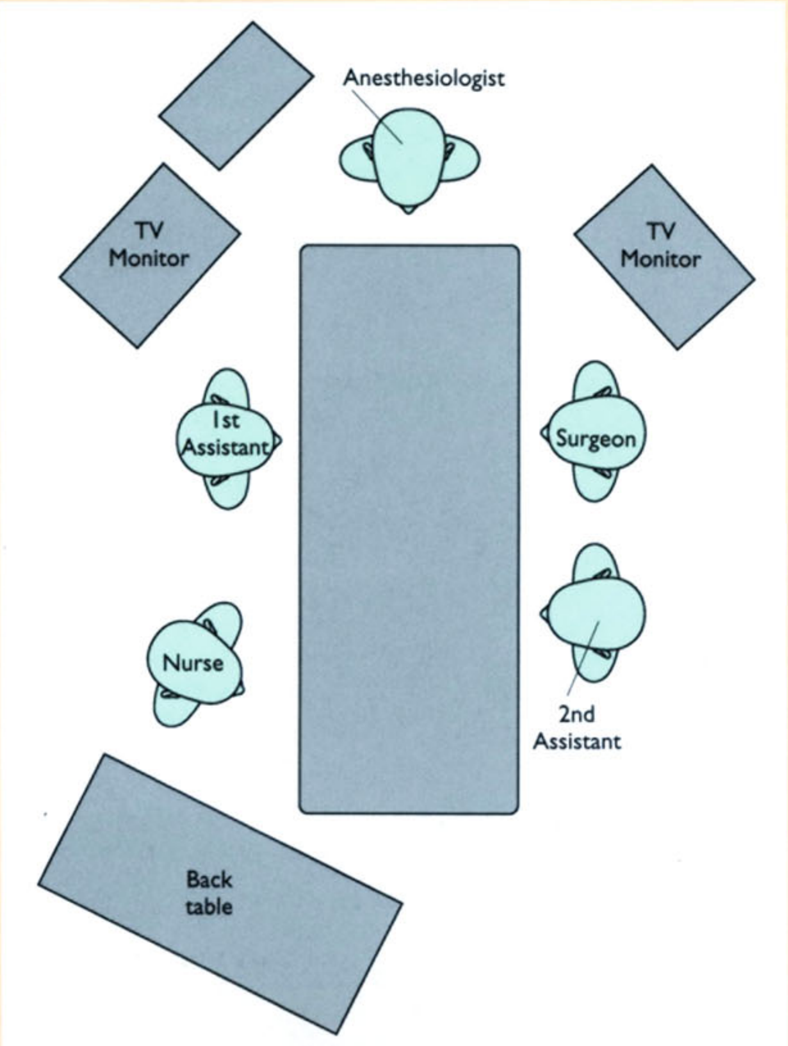


FIGURE 15-4.
The operating room set-up for the laparoscopic repair of a diaphragmatic hernia. The position of equipment and personnel is identical to that for the laparoscopic Nissen fundoplication or laparoscopic cholecystectomy.

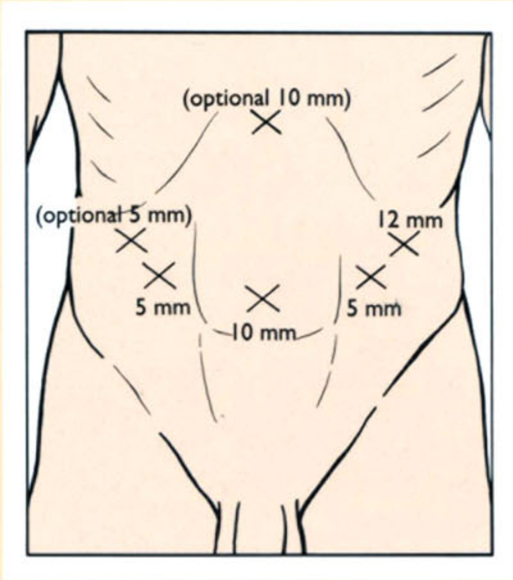


FIGURE 15-5.
Trocars are placed through the supraumbilical abdominal wall. Four trocar sites are routinely employed with a fifth and sixth site occasionally required. A 10-mm midline trocar is placed for providing access for the laparoscope. A 12-mm trocar is required if use of the hernia stapler is anticipated. The remaining sites are routinely 5 mm with the exception of an epigastric 10-mm site if the liver retractor is needed.

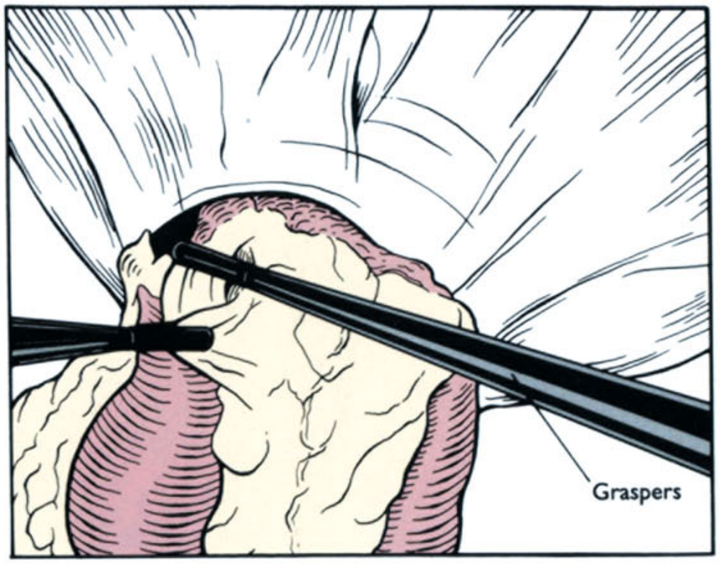


FIGURE 15-6.
The diaphragmatic defect is identified and the contents of the hernia sac are reduced into the abdominal cavity. Atraumatic graspers are used to grasp the omentum and the antimesenteric surface of the bowel. Sharp dissection may be necessary if the incarcerated contents of the hernia are adherent to the hernia sac.

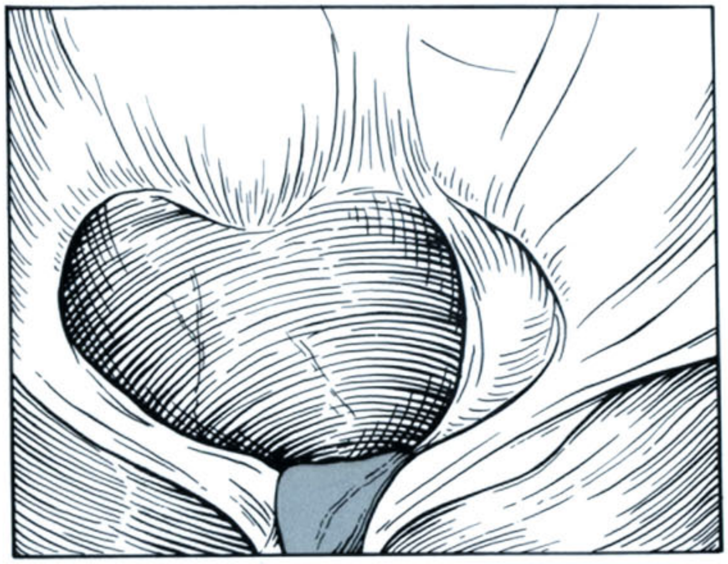


FIGURE 15-7.
The empty hernia sac is examined after reduction of the contents of the sac. A decision is made at this point regarding the need for dissection of the hernia sac in order to better delineate the edges of the defect.

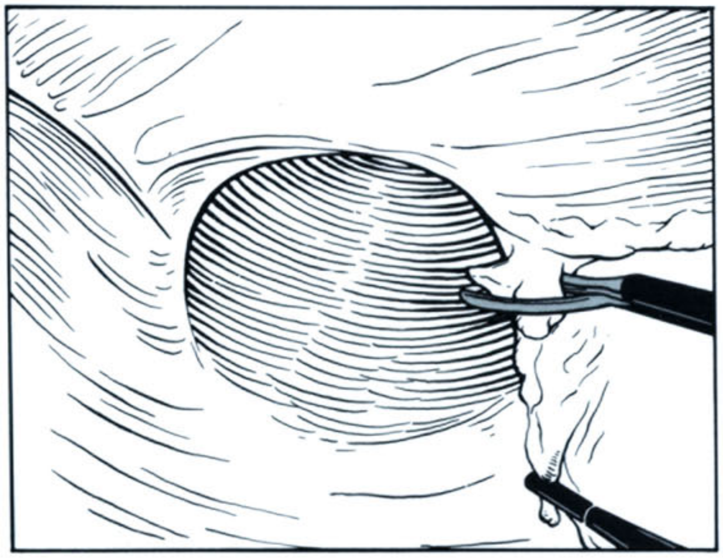


FIGURE 15-8.
Removal of the hernia sac is carried out using sharp dissection with the endoscopic scissors and cautery. Extreme caution must be exercised during this phase of the procedure in order to prevent the development of a tension pneumothorax. Precise identification of the proper tissue planes must be established in order to avoid inadvertent entry into the pericardium.

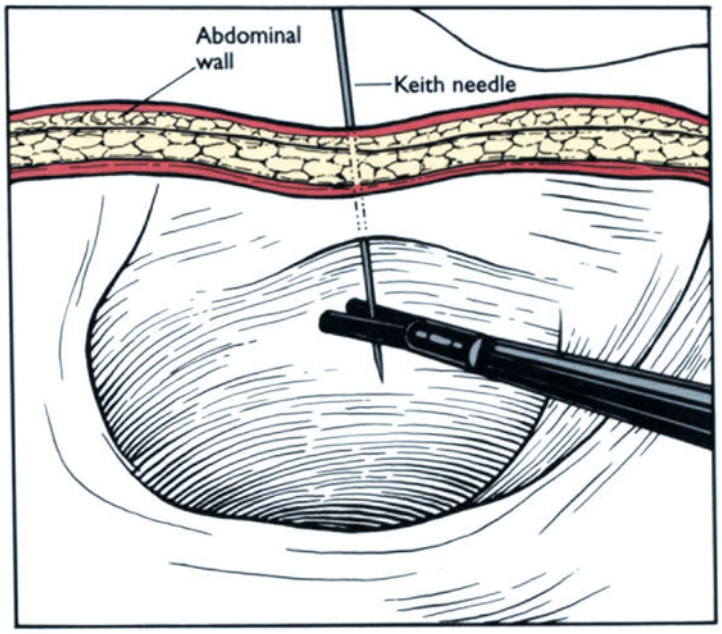


FIGURE 15-9.
A heavy monofilament suture on a Keith needle is passed through the anterior abdominal wall via a 2-mm skin incision. The needle is grasped intra-abdominally and passes through the edge of the diaphragm. An alternative method for repairing the diaphragmatic defect would include laparoscopic suturing or use of the hernia stapler to secure the edge of the diaphragmatic defect to the anterior abdominal wall. An extremely large hernia defect that cannot be approximated without excessive tension should be closed with prosthetic materials.

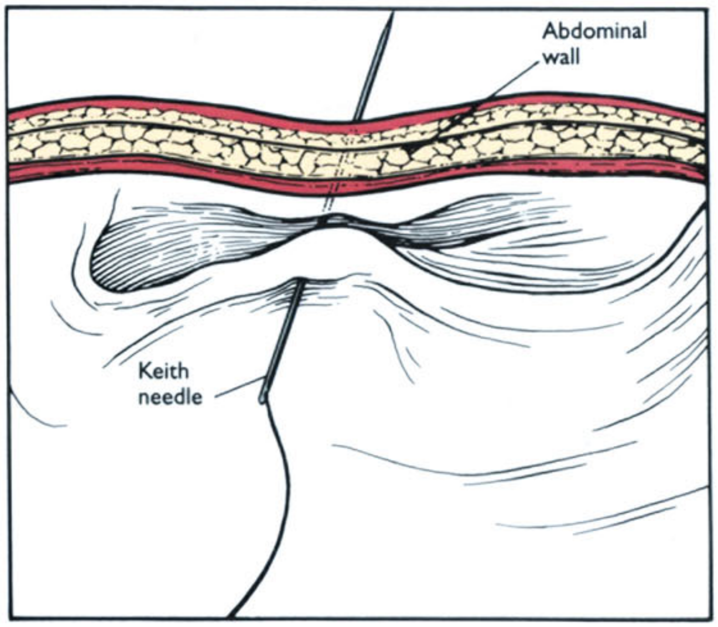


FIGURE 15-10.
Multiple horizontal mattress sutures are placed through the abdominal wall and edge of the hernia defect. Two or three mattress sutures are usually required to approximate these tissues.

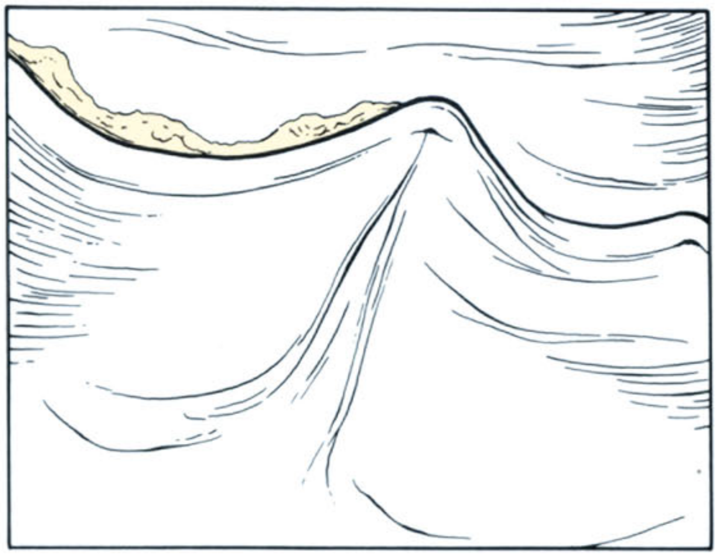


FIGURE 15-11.
The repaired hernia is demonstrated. The sutures are tied in a fashion that allows the knots to be buried underneath the skin at the fascia level.

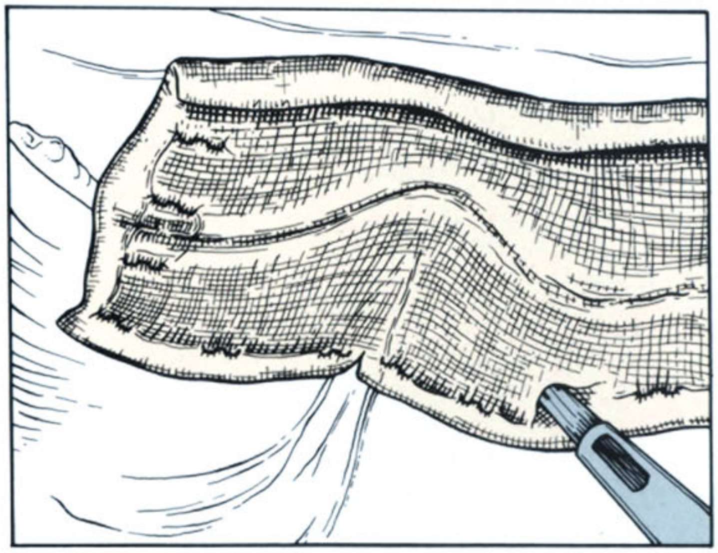


FIGURE 15-12.
The repaired hernia may be reinforced with the placement of synthetic mesh. This is secured circumferentially using a laparoscopic hernia stapler.

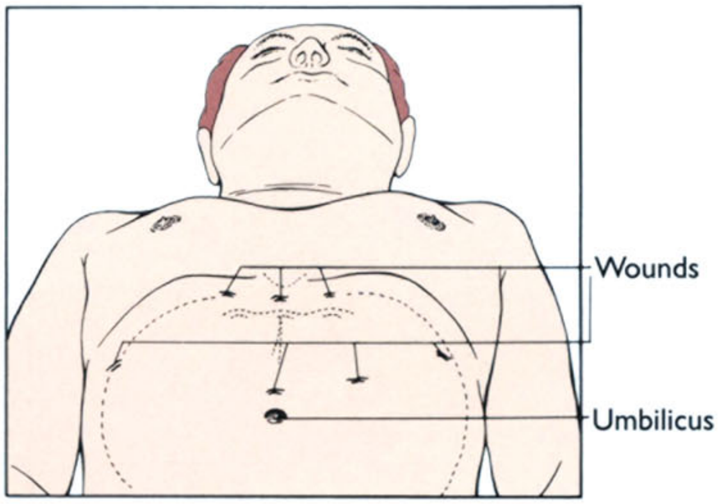


FIGURE 15-13.
The complete repair is demonstrated. The closed trocar sites and small counter incisions provide an excellent cosmetic result.

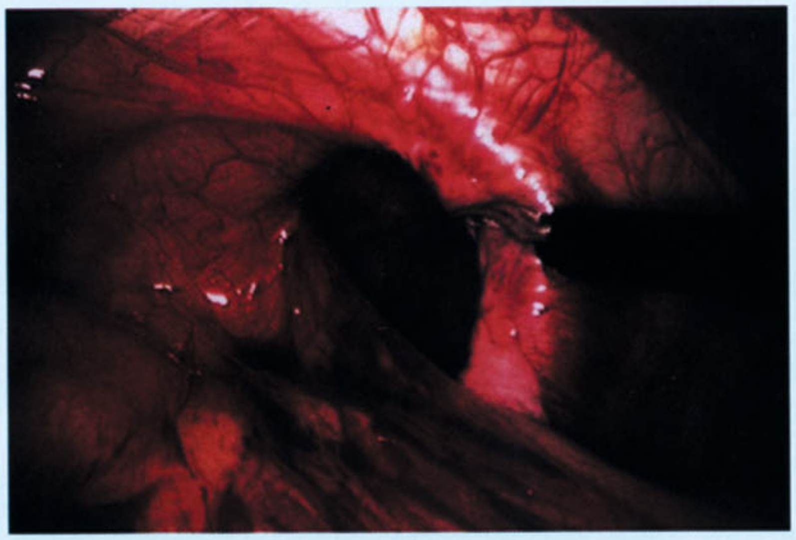


FIGURE 15-14.
The paraesophageal hernia is demonstrated with the previously incarcerated stomach reduced into the abdominal cavity. Releasing the graspers caused the stomach to quickly return to the thoracic portion of the hernia. This demonstrates the need to divide the adhesions between the gastric surface and the hernia sac. This is accomplished using the laparoscopic scissors with cautery to maintain excellent hemostasis.

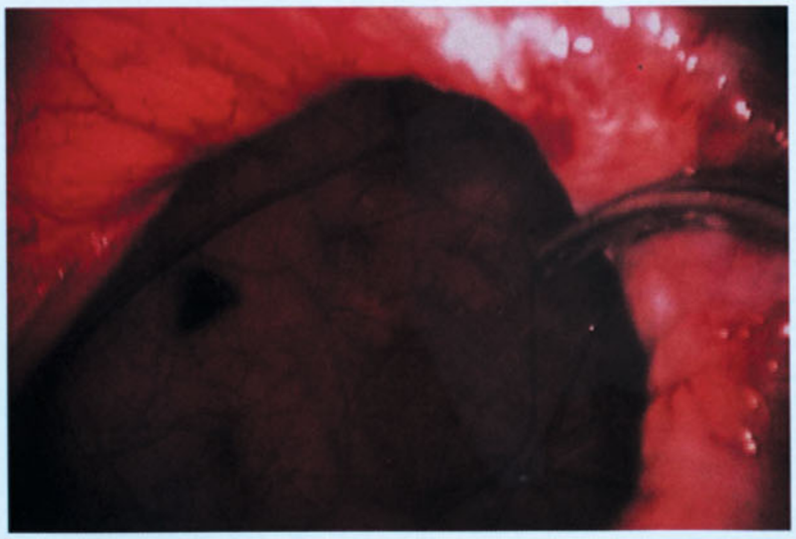


FIGURE 15-15.
The empty paraesophageal hernia sac is examined. The edges of this defect are clearly demarcated and therefore there is no need for extensive dissection of the hernia sac. Division of the edge of the sac along the diaphragmatic opening is carried out without removing the hernia sac. An attempt should be made to mobilize the esophagus at the gastroesophageal junction to allow elevation of the esophagus toward the anterior abdominal wall. This allows an assessment of the posterior aspect of the hernia defect. The right and left crura should be approximated with interrupted or running sutures if this maneuver can be accomplished without excessive tension on the tissue.

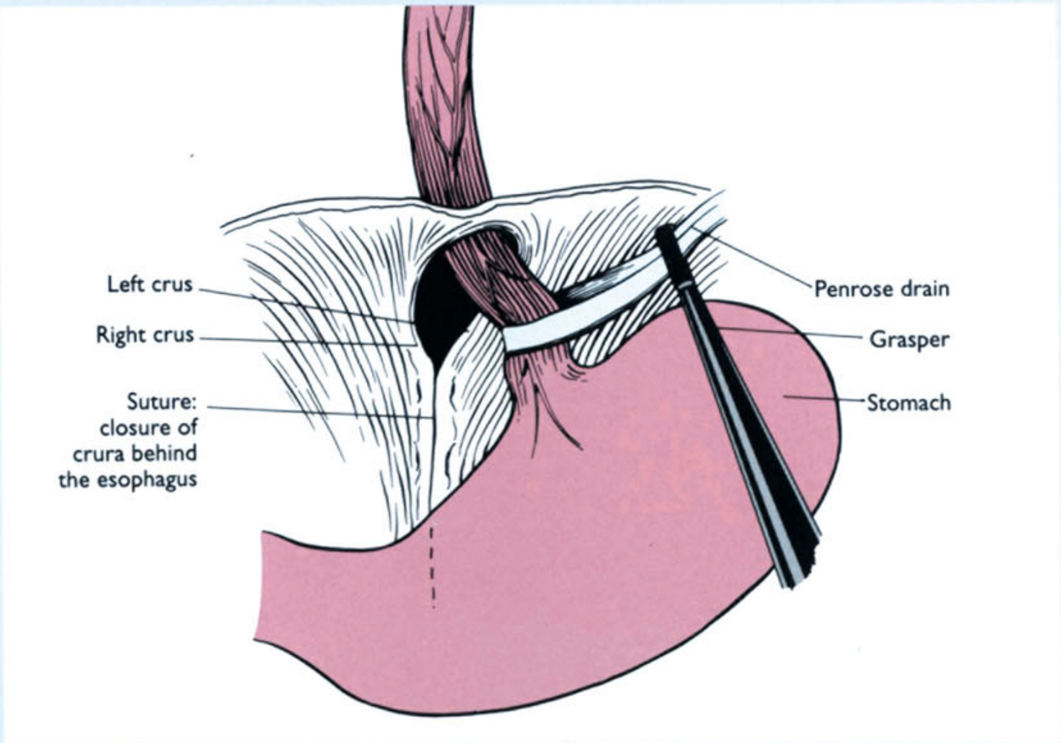


FIGURE 15-16.
The right and left crura are approximated with sutures as the esophagus is elevated with a Penrose drain. Care should be taken to avoid injury to the anterior or posterior vagus nerves during this portion of the procedure.

Procedure

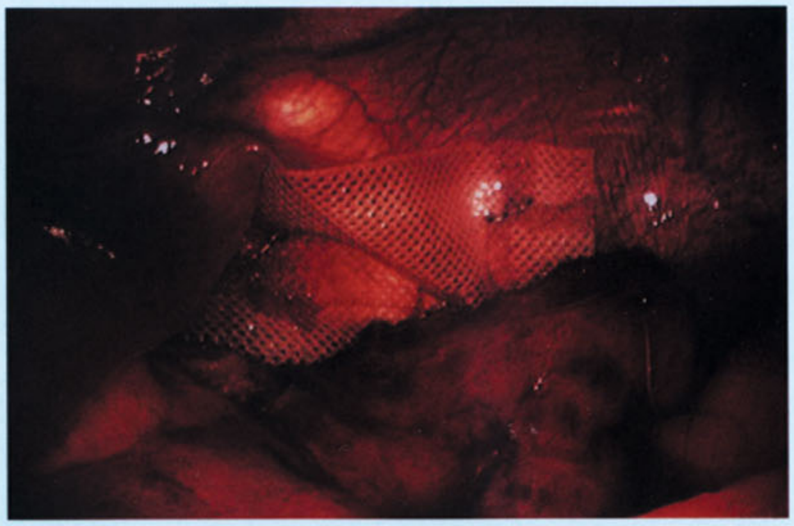


FIGURE 15-17.

A repair of the paraesophageal hernia using mesh may be required in those cases in which the defect is too large to be closed by suture approximation of the crura. The mesh should be fashioned to fit over the esophagus at the gastroesophageal junction. The mesh is secured to the diaphragm using the laparoscopic hernia stapler. The stomach should be fixed intra-abdominally either by suturing the greater curvature of the fundus to the diaphragm (as shown) or by placement of a gastrostomy tube.

References

1. Morgagni GB: Seats and causes of diseases. Zellts 54. *Monograph on Hernia of the Diaphragm*; 1769.
2. Thomas TV: Subcostal diaphragmatic hernia. *J Thorac Cardiovasc Surg* 1972, 63:278.
3. Harrington SW: Various types of diaphragmatic hernias treated surgically: report of 430 cases. *Surg Gynecol Obstet* 1948, 86:735.
4. Bochdalek: *Einige Betrachtungen uber die Entstehung des angeborenen Zwerchfellbruches. Als Beitrag zur pathologischen Anatomie der Hernien. Vierteljahrschrift fur die praktische Heilkunde.* 1948; 19:89–97.
5. Skinner D: Hiatal hernia and gastroesophageal reflux. In *Textbook of Surgery*, 14th ed. Edited by Sabiston DC. Philadelphia: W.B. Saunders Company; 1991:704–715.
6. Sabiston DC, Spencer FC, eds: *Surgery of the Chest*, 5th ed. Philadelphia: W.B. Saunders Company; 1990:958–960.
7. Grosfield JC: Surgically correctable causes of respiratory distress: congenital diaphragmatic hernia. In *Textbook of Surgery*, 14th ed. Edited by Sabiston DC. Philadelphia: W.B. Saunders Company; 1991:1163–1165.
8. deLorimier AA: Congenital malformations and neonatal problems of the respiratory tract. In *Pediatric Surgery*, 4th ed. Edited by Welch KJ, Randolph JG, Ravitch MM, O'Neill JA, Rowe MI. Chicago: Year Book Medical Publishers; 1986:639–640.
9. Newman L, Eubanks S. Bridges M, Lucas G: Laparoscopic diagnosis and treatment of Morgagni hernia. *Surg Laparosc Endosc* 1995, 5:27–31.
10. Perdikis G, Hindus R: Paraesophageal hiatal hernia. In *Hernia*, 4th ed. Edited by Nyhus L, Condon R. Philadelphia: J.B. Lippincott Company; 1995:543–554.

CHAPTER 16

Laparoscopic Appendectomy

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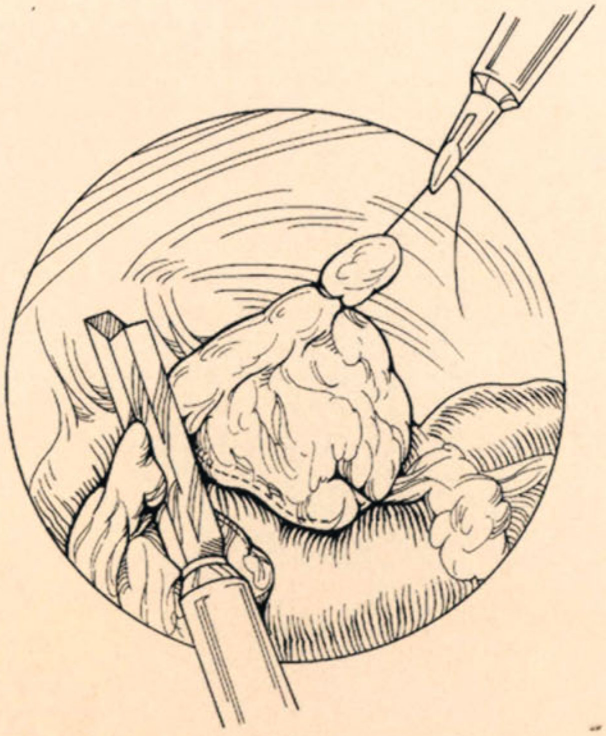
Theodore N. Pappas



Although the first reported appendectomy was performed in 1735, it took over 150 years to recognize acute appendicitis as a clinical entity amenable to surgical therapy (Table 16-1). The standard open surgical approach via a right lower quadrant incision first suggested by McArthur [1] and McBurney [2] in 1894 has stood the test of time and has been the mainstay of treatment for acute appendicitis. Appendectomy has become one of the most frequently performed surgical procedures in the United States; approximately 12% of males and 23% of females undergo appendectomy during their lifetime [3].

Because of improvements in anesthesia, perioperative surgical care, and early diagnosis, the reported mortality of acute appendicitis is as low as 0.05% for nonperforated cases and 0.27% for perforation [4]. Despite these advances, significant problems still remain in the treatment of acute appendicitis. Routine appendectomy for acute appendicitis still carries a wound infection rate of approximately 5% [5,6]. Mostly because of delay in diagnosis, appendiceal perforation still occurs in 13% to 29% of cases, with its attendant increased risk of wound infection, intra-abdominal abscess formation, systemic septic complications, and death. The rate of negative appendectomies, or those patients explored for appendicitis in which the appendix is histologically normal, remains constant at roughly 10% to 20%, depending on the institution [6,7]. These problems, coupled with the rapid evolution of laparoscopic surgical methods, have led to the development of the technique of laparoscopic appendectomy, first performed by Kurt Semm in 1982 [8]. Consideration of the laparoscopic approach is perhaps the first significant advantage in the treatment of acute appendicitis for over 100 years.

Anatomy

The vermiform appendix is a narrow tubular structure arising from the posterior cecum at the confluence of the taenia coli. It is usually stated that the appendix is 1 cm wide and about 10 cm long, although variations in size and location are the rule [9]. The position of the appendiceal tip is especially inconstant. The "normal" location in the right lower quadrant overlying the sacral promontory is observed in only about 40% of cases (Figure 16-1). Other common locations include posterior to the cecum (retrocecal), in the pelvis (pelvic appendix) and posterior to the terminal ileum (retroileal). There is much dispute over the relative frequencies of the various appendiceal positions.

Table 16-1. Milestones in the diagnosis and treatment of appendicitis*

Year	Investigator	Location	Contribution
1735	Claudius Amyland	England	First report of appendectomy (via a scrotal incision for hernia and fecal fistula)
1771	Lorenz Heister	Germany	First autopsy description of abscess adjacent to a gangrenous appendix
1827	François Melier	France	Described six autopsy cases of appendiceal gangrene and first suggested surgical removal
1848	Henry Hancock	England	First reported drainage of a periappendiceal abscess
1880	Lawson Tait	England	First appendectomy for gangrenous appendix (not reported until 1890)
1883	Abraham Groves	Canada	Appendectomy for acute inflammation (not reported until 1934)
1886	Reginald Fitz	USA	First used the term "appendicitis" and described its clinical syndrome
1886	R.J. Hall	USA	Removed a perforated appendix during an exploration for incarcerated inguinal hernia
1887	Edward R. Cutler	USA	Performed appendectomy for unruptured appendicitis (reported in 1889)
1982	Kurt Semm	Germany	First report of laparoscopic appendectomy

*Adapted from Williams [21]; with permission.

Pathophysiology, Presentation, and Differential Diagnosis

Acute appendicitis is caused by obstruction followed by infection. Because of the presence of a fecalith, lymphoid hyperplasia, or tumor, the lumen of the appendix becomes obstructed and the resultant luminal distention leads to the sensation of poorly localized crampy pain via stimulation of the visceral afferent nerves of the appendix and small intestine. The pain is usually periumbilical in location and it is not unusual for the patient to complain of being only uncomfortable rather than frankly painful. Also, at this stage the patient may complain of anorexia and nausea.

As with all epithelial-lined structures in the body, obstruction of the appendix eventually leads to stasis and infection. Intraluminal bacteria invade the appendiceal wall and serosal inflammation results. When the inflamed serosa contacts the parietal peritoneum, the somatic nerves of the peritoneum are stimulated and the previous nonspecific pain becomes localized to the right lower quadrant. At this point, the patient may also exhibit vomiting, fever, chills, or diarrhea.

Abdominal tenderness is the sine qua non of acute appendicitis. Tenderness usually occurs in the right lower quadrant and may or may not be located at McBurney's point (two thirds the distance from umbilicus to the right anterior superior iliac spine). Many specific clinical signs may be elicited in acute appendicitis (Table 16-2) although none are as reliable as the sum of the clinical picture.

Vital signs and laboratory studies may also be helpful when acute appendicitis is suspected. Minor elevations in pulse and temperature are frequent although fevers above

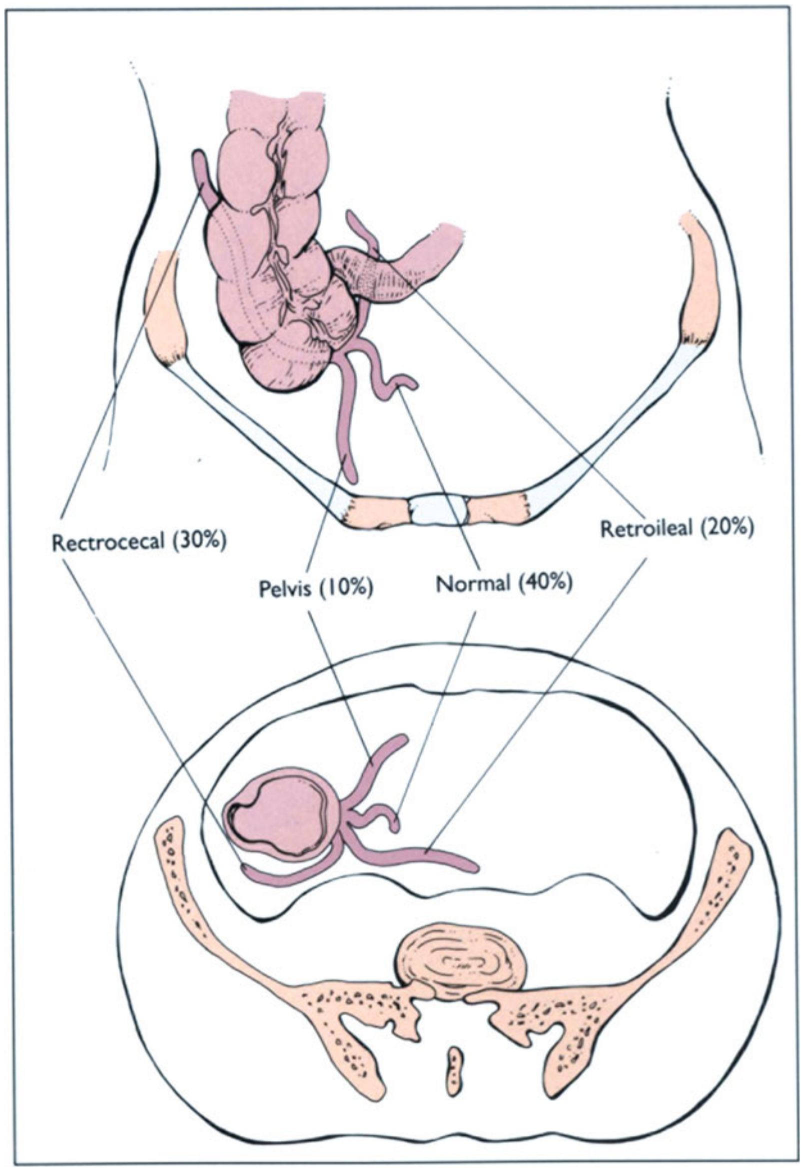


FIGURE 16-1.
The variability of the appendiceal tip. Bottom portion shows sagittal section; numbers in parentheses indicate frequencies of anatomic location.

Table 16-2. Clinical signs of acute appendicitis

Sign	Indication
Pain on gentle percussion	Peritoneal inflammation
Pain on coughing	Peritoneal inflammation
Rebound tenderness	Peritoneal inflammation
Rovsing's sign (pain in the right lower quadrant on palpation of the left lower quadrant)	Peritoneal inflammation
Voluntary muscle guarding	Peritoneal inflammation
Cutaneous hyperesthesia (increased tactile sensation of the skin of the right lower quadrant)	Peritoneal inflammation
Psoas sign (increased pain on flexion of the hip)	Irritation of the psoas muscle
Obturator sign (increased pain on internal rotation of the flexed thigh)	Irritation of the obturator internus muscle
Pain on rectal examination	Possible pelvic appendix

38.5°C are rare in uncomplicated cases. It is often stated that less than 4% of patients with acute appendicitis have entirely normal white blood cell and differential counts [10]; their presence, however, should not preclude continued observation or exploration.

Exhaustive lists for the differential diagnosis of acute appendicitis have been presented (Table 16-3). For practical purposes, however, the most common alternative diagnoses include gastroenteritis, pelvic inflammatory disease, urinary tract infection, tubal (ectopic) pregnancy, pyelonephritis, mittelschmerz (ovulatory pain, ruptured follicular cyst), diverticulitis, ureterolithiasis, and Crohn's disease. Because of the myriad of conditions which can easily mimic acute appendicitis, it is not uncommon for a normal appendix to be found at the time of operation [6,7]. The most frequent final diagnoses are depicted in Figure 16-2.

In the present era, appendectomy may be performed via an open or laparoscopic approach. The traditional open procedure has the advantage of proven success and should probably continue to be employed for cases of acute appendicitis in which the diagnosis is fairly certain. Proponents of laparoscopic appendectomy, however, generally feel that the visual abdominal survey is superior to the exploratory capabilities of a McBurney incision and it is most useful in cases in which the diagnosis is uncertain [11–13]. Other purported advantages of the laparoscopic approach are listed in Table 16-4. Although laparoscopic appendectomy has safely been performed in cases of acute appendicitis [14–19], perforation [15,17,18], and appendicitis during pregnancy [20] and childhood [19], the alleged advantages have never been confirmed through large randomized clinical trials.

Table 16-3. Differential diagnosis of acute appendicitis

Gastroenteritis	Perinephric abscess
Pelvic inflammatory disease	Hydronephrosis
Urinary tract infection	Omental torsion
Tubal (ectopic) pregnancy	*Yersinia* enterocolitis
Pyelonephritis	Psoas abscess
Mittelschmerz (ovulatory pain; ruptured follicular cyst)	Rectus sheath hematoma
Diverticulitis	Cecal ulcer
Ureterolithiasis	Intestinal obstruction
Crohn's disease	Ovarian torsion
Acute cholecystitis	Ruptured corpus luteum cyst
Carcinoma of the cecum or ascending colon	Endometriosis
Meckel's diverticulitis	Congenital ureteropelvic junction obstruction
Perforated duodenal ulcer	Amebiasis
Pneumonia	Liver abscess
Osteomyelitis	Malaria
Typhoid fever	Mesenteric thrombosis
Acute porphyria	Pancreatitis
Hepatitis	Spontaneous bacterial peritonitis
Diabetes mellitus	

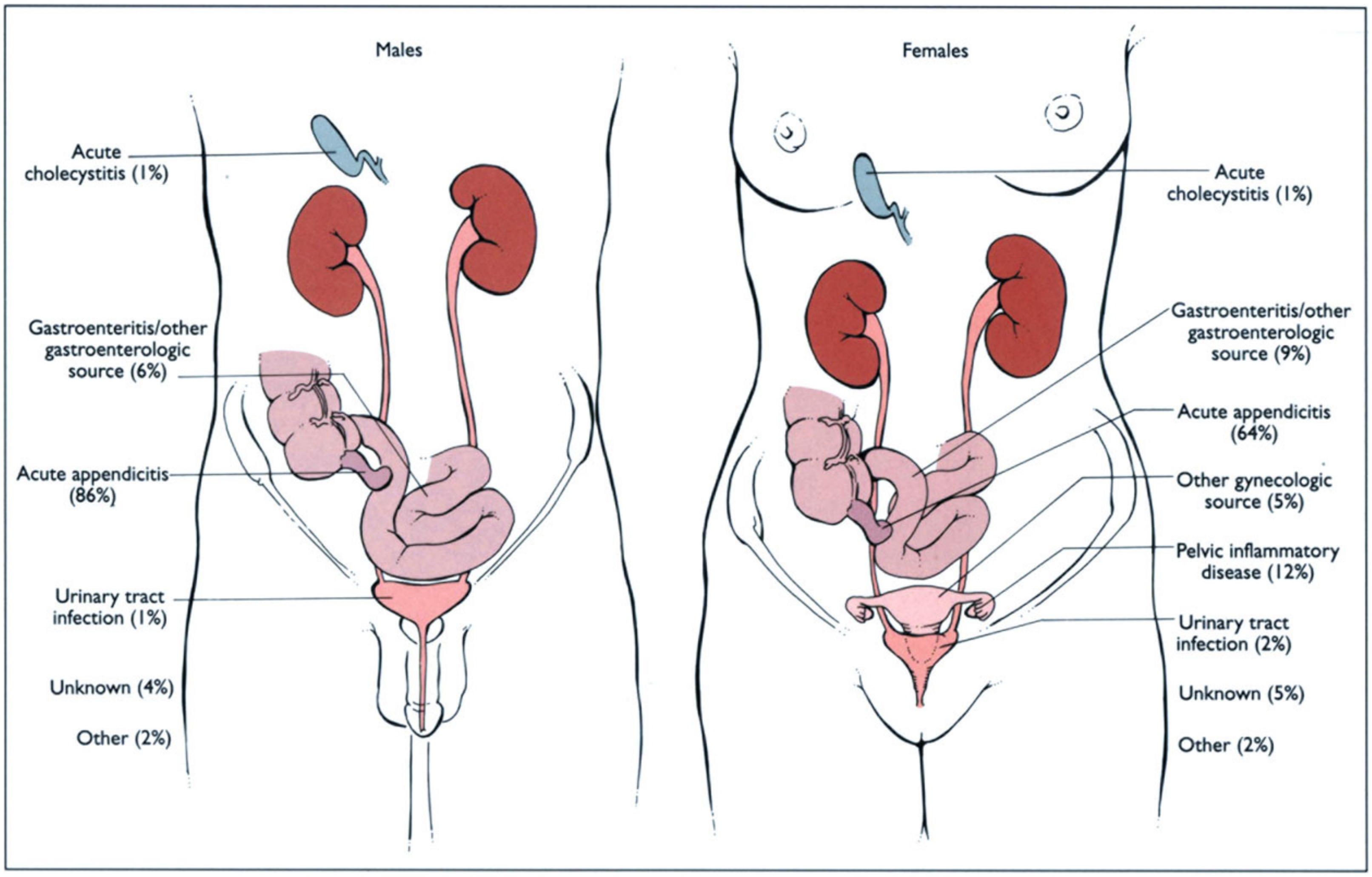


FIGURE 16-2.
Left, Final diagnoses in 636 male patients explored for acute appendicitis. **Right**, Final diagnoses in 364 female patients explored for acute appendicitis. (From Lewis and coworkers [7]; with permission.)

Table 16-4. Possible advantages of laparoscopic appendectomy

Increased diagnostic accuracy
Reduction in the negative appendectomy rate
Superior abdominal visualization
Decreased need for ancillary radiologic studies
Limitation of diagnostic delay
Decreased wound infection rate
Decreased postoperative pain
Decreased major complication rate
Decreased hospital stay
Earlier return to full activity
Technically easier to perform incidental appendectomy during cholecystectomy
Decreased intra-abdominal adhesion formation
Decreased cost

Surgical Technique

Figures 16–3 through 16–20 depict the surgical technique for laparoscopic appendectomy.

Set-up

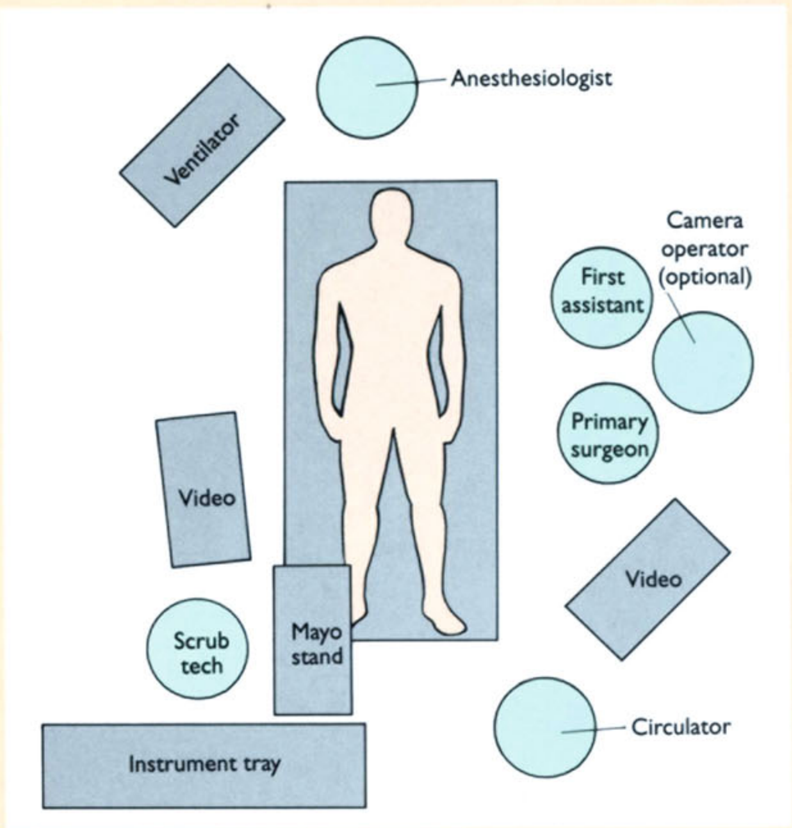


FIGURE 16-3.
Operative set-up for laparoscopic appendectomy. A preoperative dose of antibiotics is administered when the decision for operative intervention is made. Foley and nasogastric catheters are placed after induction of general anesthesia. Unlike laparoscopic cholecystectomy, it is most helpful to position the video monitors as shown as opposed to at the head of the table.

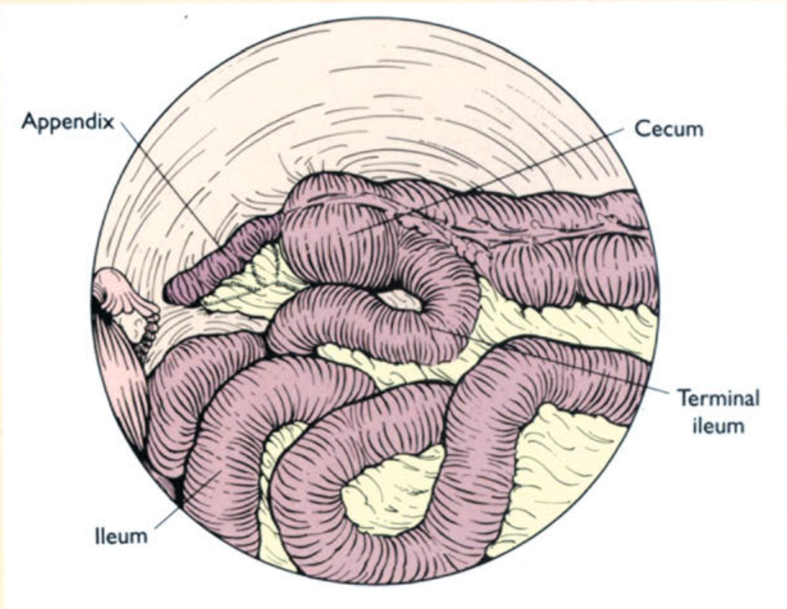


FIGURE 16-4.
The patient is placed in the 30° Trendelenburg position with the arms tucked at the sides. Access to the peritoneal cavity is gained infraumbilically using a 10-mm sheath via a closed (Veress needle) or open (Hasson trocar) technique. Following carbon dioxide insufflation to 15 mm Hg, the laparoscope is inserted via the 10-mm sheath and the peritoneal cavity is inspected. The liver, gallbladder, small intestine, portions of the large intestine, bladder, uterus, and ovaries can usually be visualized. At this time, the cecum and appendix are identified in the right lower quadrant.

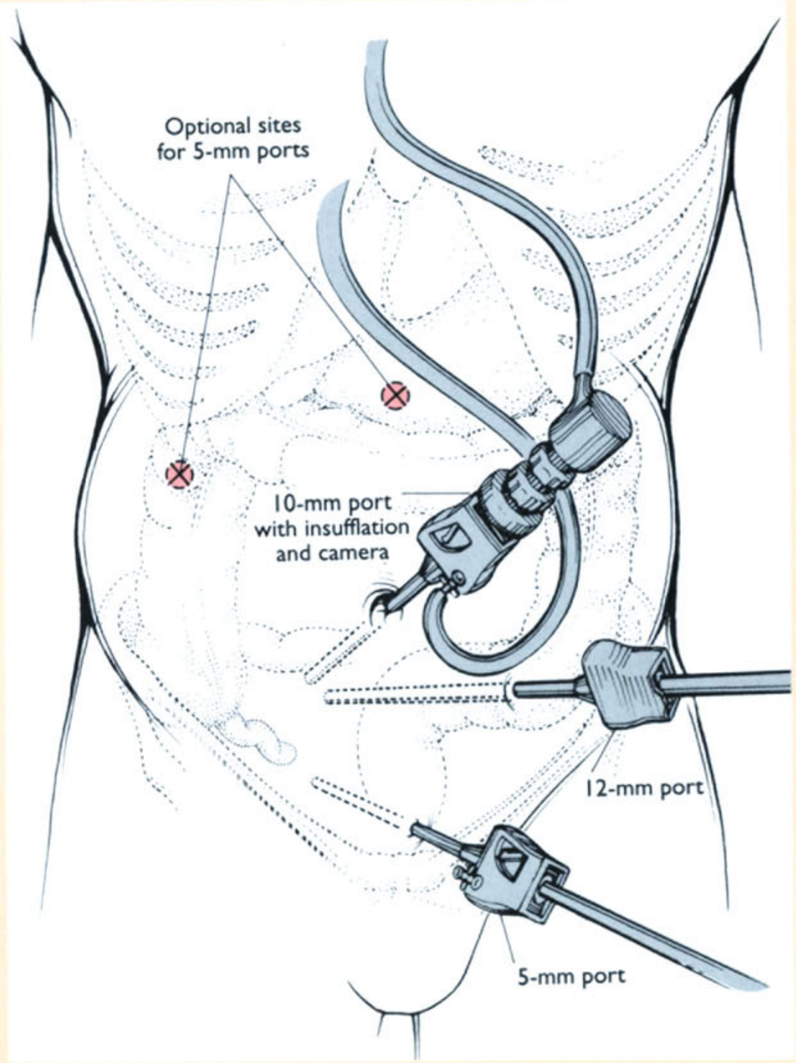


FIGURE 16-5.
Three additional sheaths are placed under laparoscopic guidance with abdominal transillumination and avoidance of the epigastric vessels. Five-mm sheaths are placed in the right upper quadrant (midclavicular line 5 fingerbreadths above the umbilicus) and at McBurney's point, and a 10-mm sheath is placed in the left lower quadrant at the midclavicular line. Slight alterations in sheath placement may be desired according to the observed location of the appendix within the abdomen. As in all cannula placement strategies, sheaths should be at least 5 fingerbreadths from each other to minimize instrument crossing during the dissection. If the exposure is difficult, a third 5-mm sheath may be placed in the midline superior to the pubic symphysis.

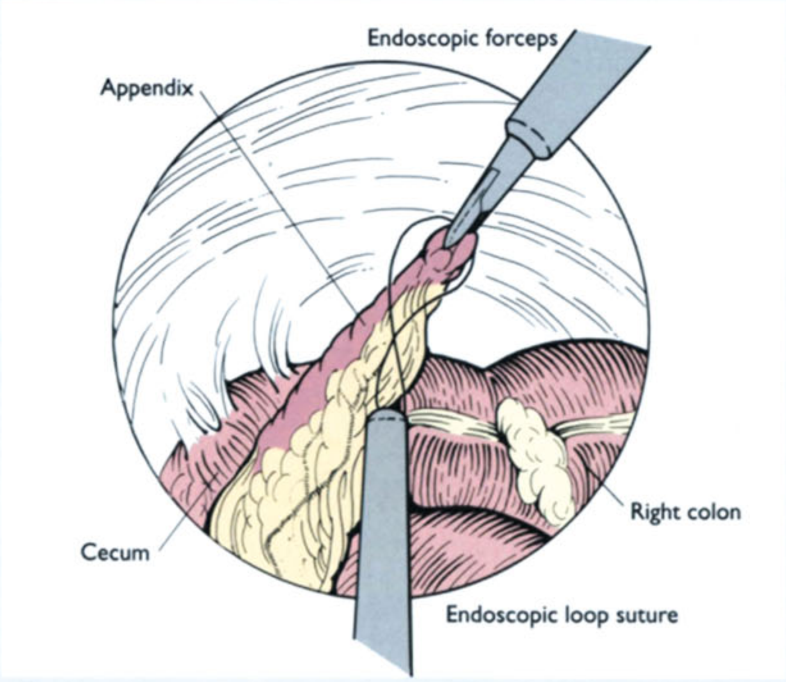


FIGURE 16-6.
The dissection is performed with the patient in 30° Trendelenburg position and tilted slightly to the left. Traction is provided by forceps inserted via the McBurney's point sheath and an endoscopic loop suture is placed around the appendiceal tip via the 10-mm left lower quadrant sheath. An endoscopic loop suture is not divided; it will be used for traction for the remainder of the procedure.

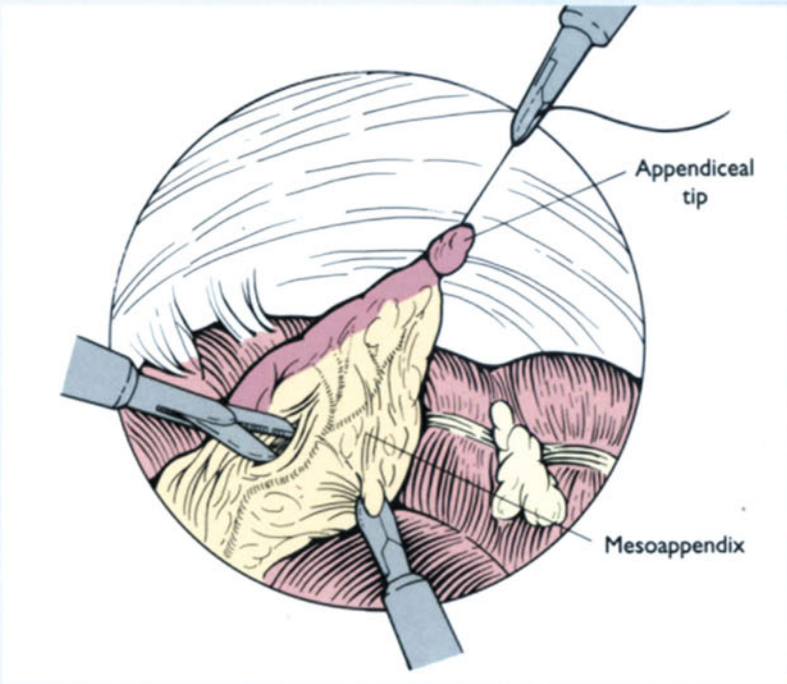


FIGURE 16-7.
The dissection of the mesoappendix is begun using blunt-tipped forceps. Using the endoscopic loop suture and grasping forceps for traction, a plane is developed between the appendiceal base and the mesoappendix.

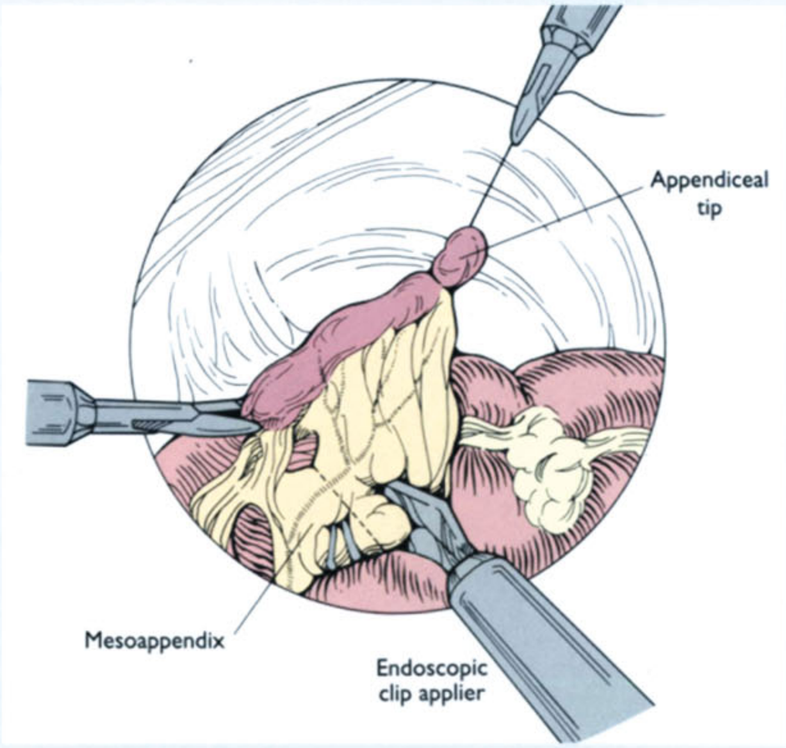


FIGURE 16-8.
The mesoappendix is clipped using an endoscopic clip applier delivered through the 10-mm left lower quadrant sheath. A double row of clips is applied proximally for security.

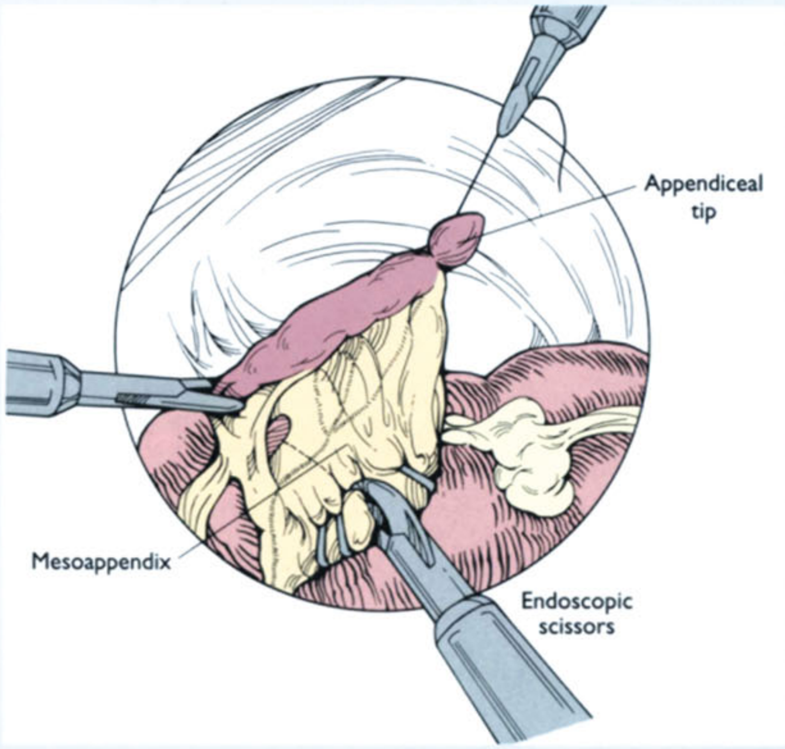


FIGURE 16-9.
Isolated portions of the mesoappendix are divided using endoscopic scissors between the clips.

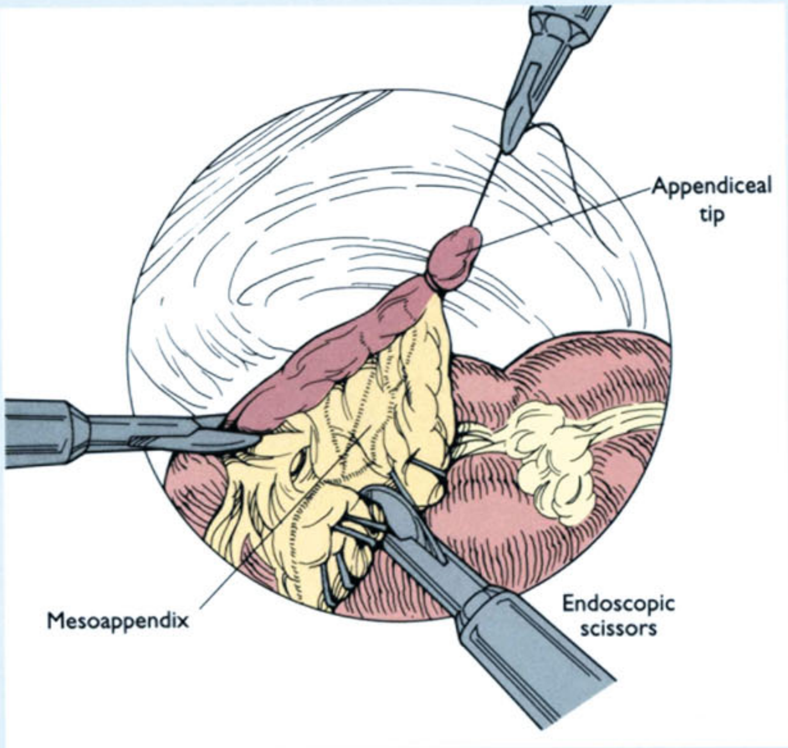


FIGURE 16-10.
The dissection of the mesoappendix is continued in a stepwise fashion toward the appendiceal base.

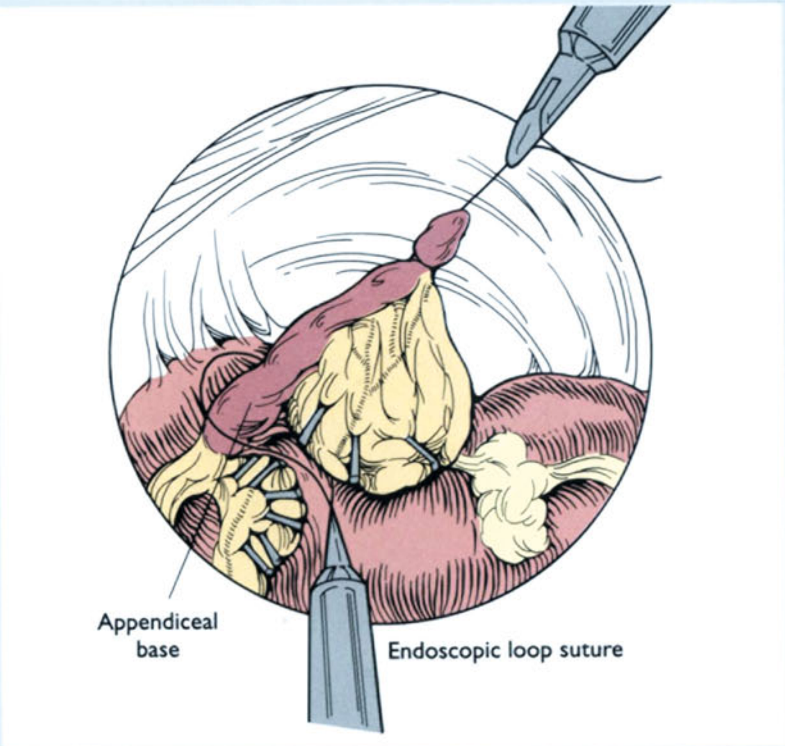


FIGURE 16-11.
When the stump has been completely isolated, three endoscopic loop sutures are placed around the appendiceal base. The appendix will be divided between the second and third loop leaving two loops intact for proximal control.

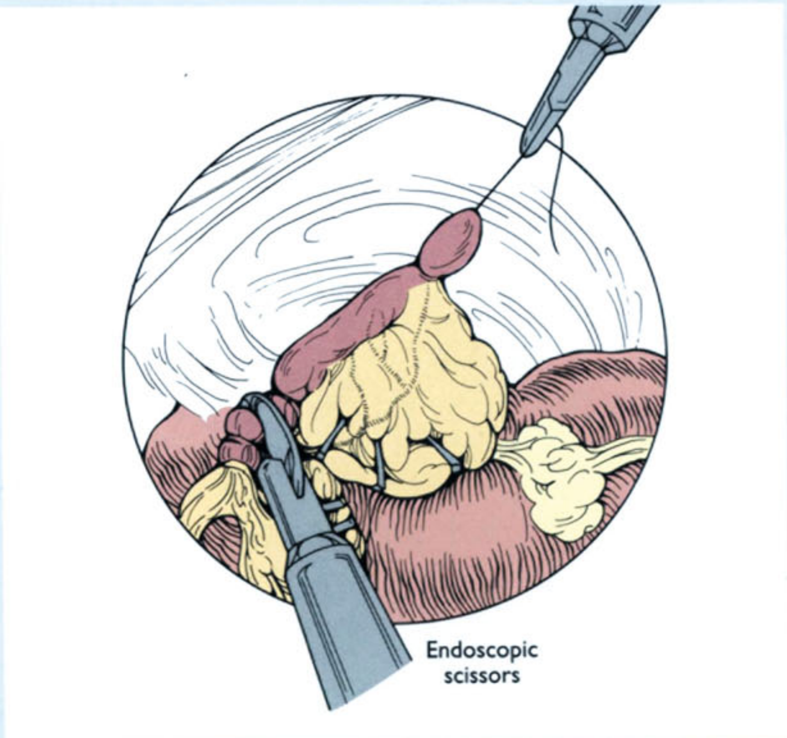


FIGURE 16-12.
The appendix is divided sharply.

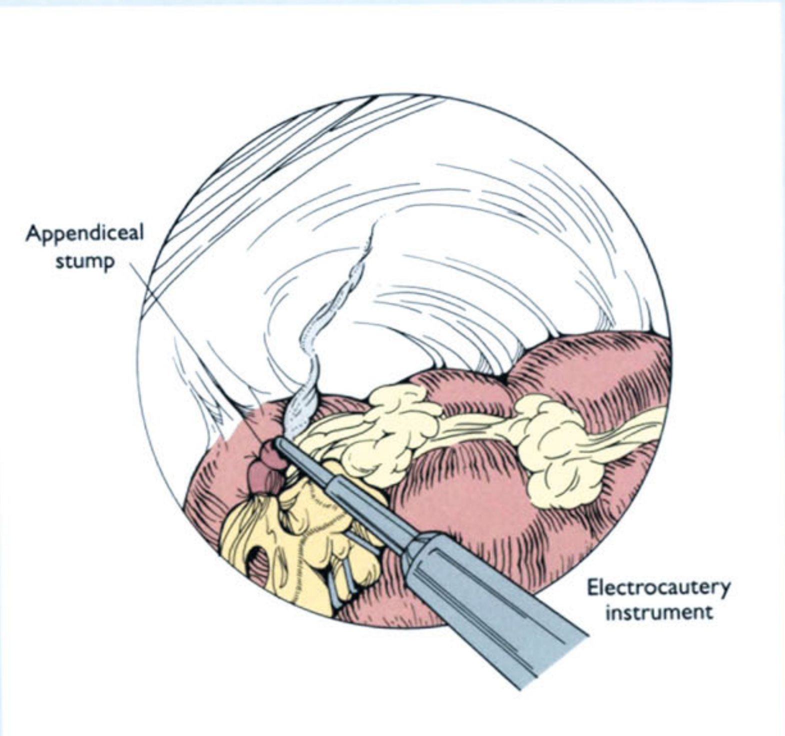


FIGURE 16-13.
The residual mucosa of the appendiceal stump is cauterized completely. Some authors recommend inversion of the appendiceal stump [30,31] although, as in open appendectomy, this is probably not necessary [32].

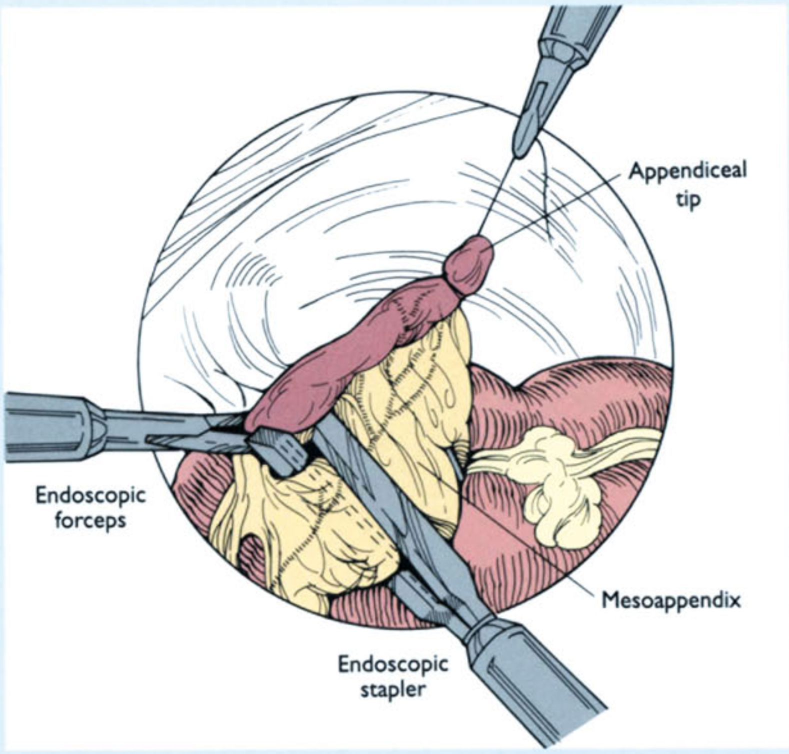


FIGURE 16-14.
An alternative technique to the use of clips and endoscopic loop sutures is the endoscopic stapling device. Portions of the mesoappendix are isolated and the stapler fired. Proper use of the stapler decreases operative time considerably.

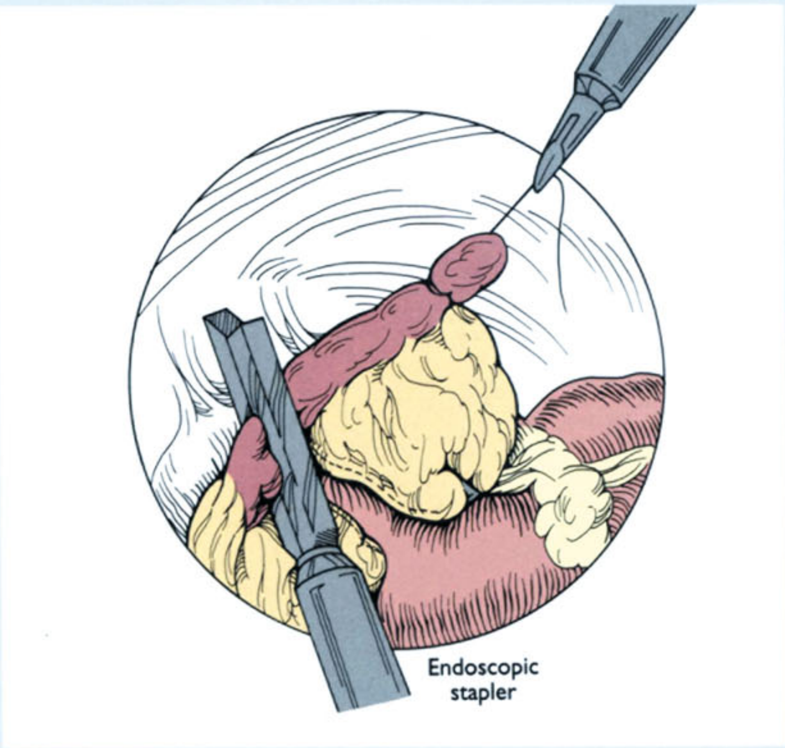


FIGURE 16-15.
The stapler may also be used to divide the appendix.

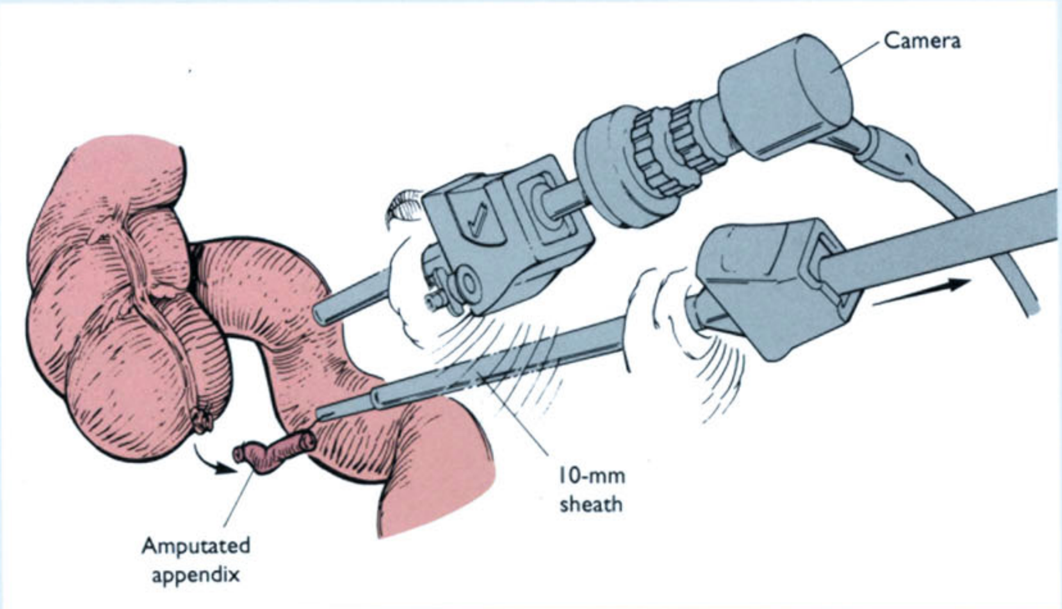


FIGURE 16-16.
One advantage of laparoscopic appendectomy is the ability to remove the appendix without contacting the wound edges, which theoretically lessens the risk of wound infection. After division of the appendix, the tip (or retained endoscopic loop suture) is grasped with a forceps via the 10-mm sheath and withdrawn entirely into the sheath.

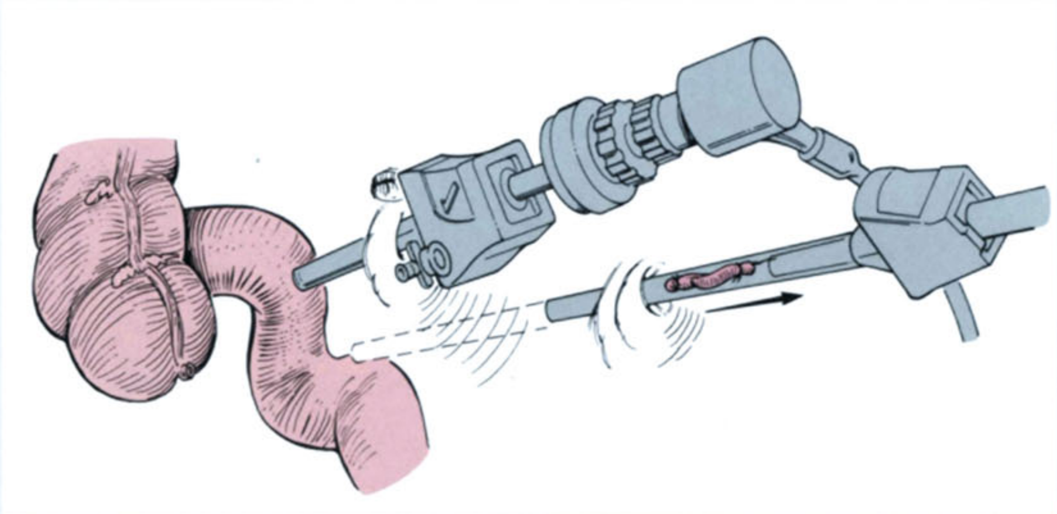


FIGURE 16-17.
The sheath and forceps removed as a unit with the appendix protected inside the sheath.

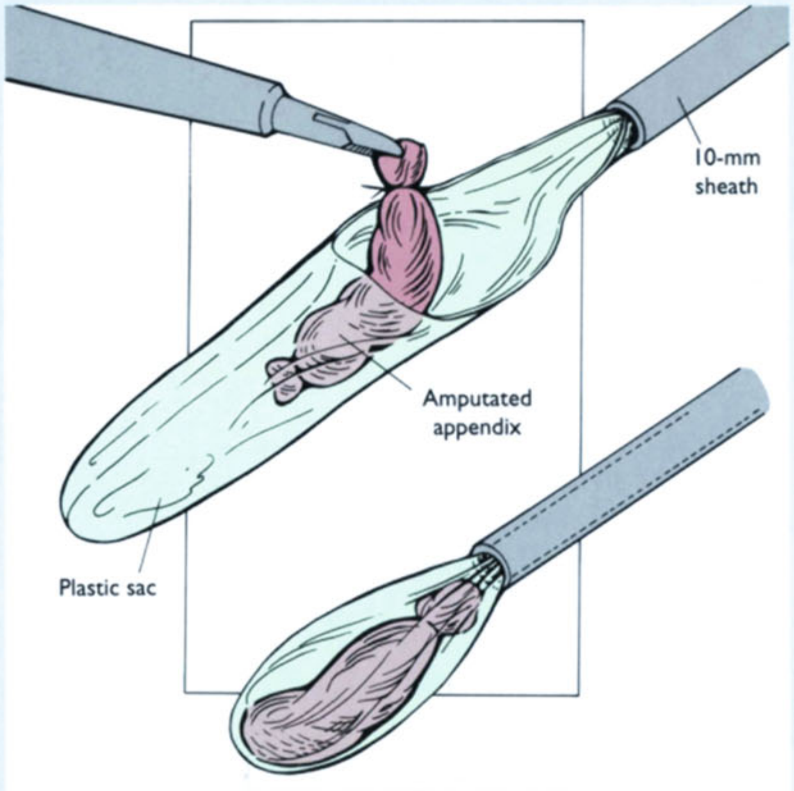


FIGURE 16-18.
If the appendix is large and friable, it may be inserted into a specially designed sterile sac for retrieval. As the sac is partially withdrawn into the 10-mm sheath, it closes around the appendix. The sheath and sac are then removed as a unit.

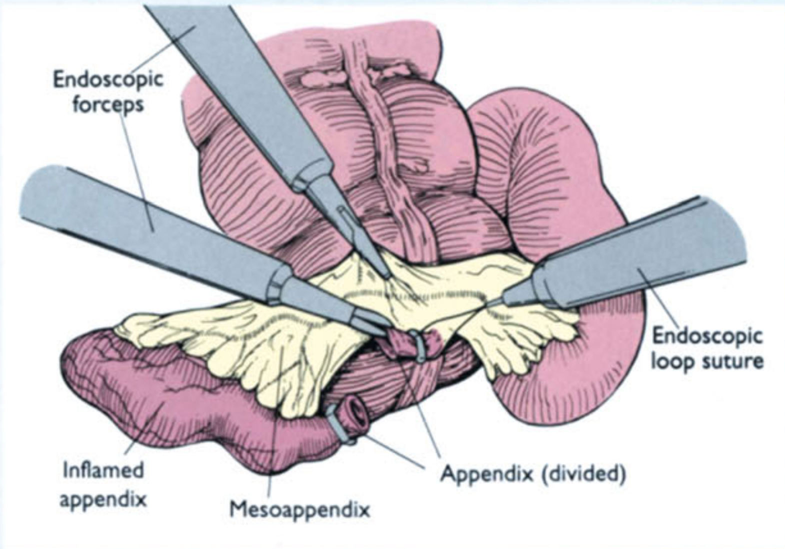


FIGURE 16-19.
Retrograde appendectomy. If the appendiceal tip or body is gangrenous and the base is relatively uninvolved, it may be advantageous to divide the base prior to dissection of the mesoappendix and involved segment. This procedure has been termed "retrograde appendectomy" and may serve to limit soilage of the abdominal cavity and facilitate the dissection. Retrograde appendectomy can be successfully performed via the laparoscope [12,13]. The base is ligated with clips and divided sharply and an endoscopic loop suture is placed on the proximal stump. The mesoappendix is divided as previously described and the appendix removed.

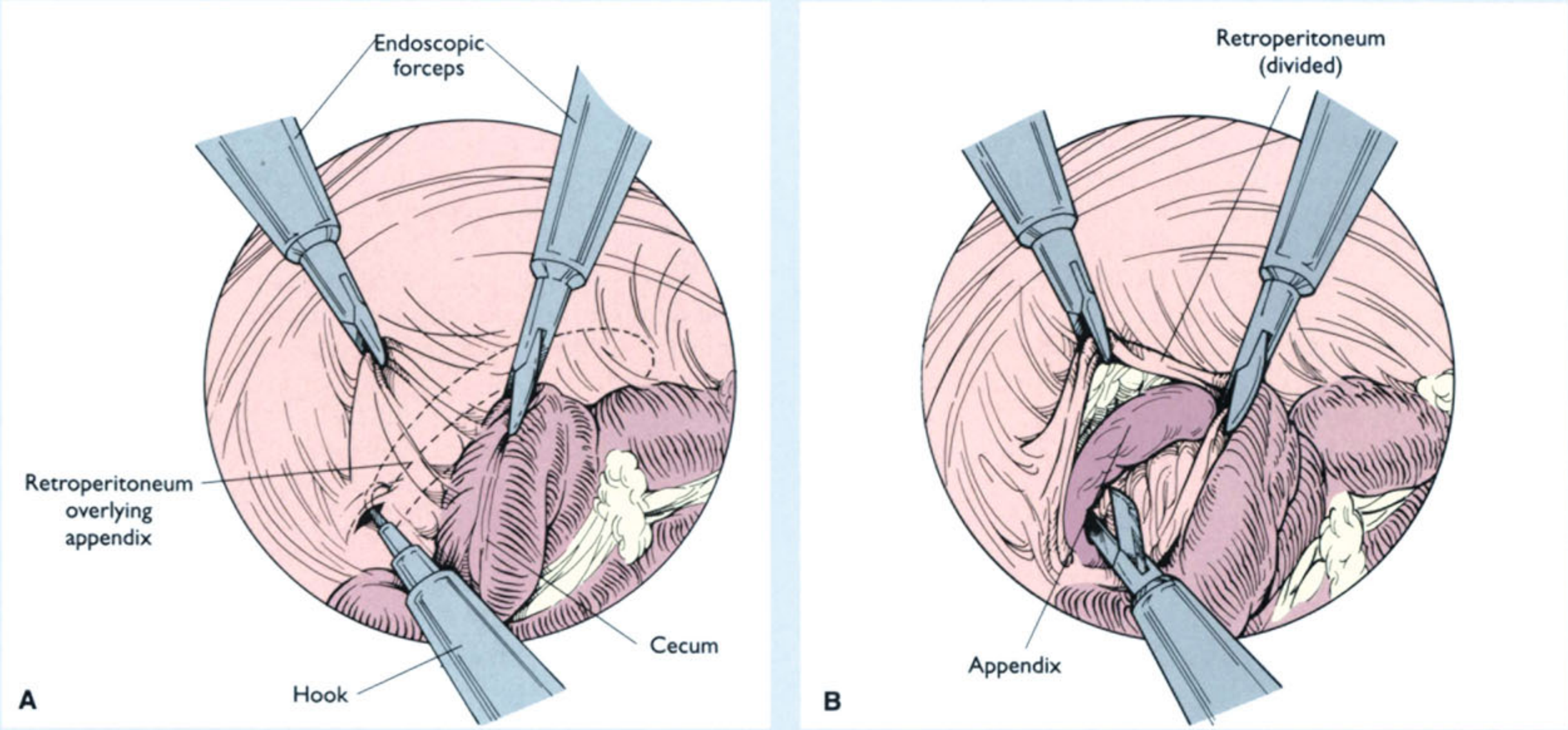


FIGURE 16-20.

Laparoscopic removal of a retrocecal appendix is challenging but successful cases have been reported [14]. **A**, First, the peritoneum overlying the appendix is divided using the hook electrocautery. Care must be taken to avoid injury to the right colon. **B**, Having fully exposed the appendiceal base, appendectomy is performed in a retrograde fashion as previously described.

Results

Over 4000 cases of laparoscopic appendectomy have been reported (Table 16-5). The results have generally been excellent. For the collected series, conversion to open appendectomy was required in about 4% of cases. Wound infection occurred in 1.2% and major complications in 2%. The most common major complication is pelvic abscess, which has become more frequently observed as difficult (*eg*, gangrenous and perforated) appendectomies have been undertaken.

Published reports have taken the form of retrospective reviews [12,14–46], retrospective comparisons [47–58], prospective nonrandomized trials [59–64], and prospective randomized trials [30,65–69]. Safety and efficacy have clearly been demonstrated by retrospective comparisons and nonrandomized trials. However, the superiority of laparoscopic appendectomy over the conventional open technique remains unproven. Some of the prospective trials have demonstrated decreased complications [67] and wound infections [59,61,65–68], improvements in pain and pain control [65–70], shortened hospital stay [59,60,62,65–67,70], and, especially, decreased time to return to full activity [59,60,62,67–69]. Other studies, however, have failed to demonstrate a clear benefit in terms of patient outcome [30,62]. Furthermore, any cost savings realized by the decreased length of stay and convalescence are probably offset by increased expenditures in the operating room [53,59,62–64,70].

In conclusion, laparoscopic appendectomy can be performed safely and reliably and represents an important technique in the armamentarium of the general surgeon. The notion that it has become the procedure of choice in all cases of suspected appendicitis is not supported by the currently available data. It appears to be most beneficial in patients in whom the diagnosis is in question, full visualization of the entire abdominal cavity is critical, or there is compelling need or preference for early return to physical activity. As with most laparoscopic procedures, it be should be applied selectively depending on the clinical setting, hospital environment, and surgeon's experience.

Table 16-5. Reported results of laparoscopic appendectomy between 1987 and 1995 (series reporting ≥ 10 cases)

Study	Cases, *n*	Perforated	Open conversion	Wound infection	Major complications
Gangal and Gangal [46]	73	NR	NR	NR	0
Schreiber [45]	70	0	3	0	1 (stump blowout)
McKernan and Saye [44]	32	NR	NR	0	0
Cristalli *et al.* [40]	12	0	0	0	0
Daniell *et al.* [39]	10	0	0	0	0
Nowzaradan *et al.* [12]	35	3	4	0	0
O'Regan [41]	12	0	0	0	0
Saye *et al.* [43]	109	1	0	0	0
Attwood *et al.* [67]	27	1	2	0	0
Byrne *et al.* [37]	31	0	6	0	2 (ileus, SBO)
Geis *et al* [14]	30	0	0	0	0
Gilchrist *et al.* [59]	14	5	0	0	2 (pneumonia, abscess)
Goh *et al.* [35]	12	NR	0	0	0
McAnena *et al.* [65,66]	29	3	2	1	0
Pelossi and Pelossi [36]	25	0	0	0	0
Scott-Conner *et al.* [34]	16	0	2	0	0
Charoonratana *et al.* [24]	31	NR	NR	0	0
Cox *et al.* [25]	59	4	7	1	4 (ileus in 3, hemorrhage in 1)
Fritts and Orlando [54]	58	0	4	3	1 (vein injury)
Kum *et al.* [68]	52	0	0	0	0
Lansdown *et al.* [51]	48	3	3	0	0
Ludwig *et al.* [31]	29	9	2	1	2 (abscess)
Miller [33]	20	0	0	0	0
Pier and Götz [27–29]	933	15	18	14	5 (abscess in 2, visceral injury in 2, stump blowout in 1)
Richards *et al.* [38]	61	0	7	0	0
Schiffino *et al.* [26]	154	4	10	4	4 (pain/fever in 3, hematoma in 1)
Schirmer *et al.* [50]	62	13	15	4	NR
Schroder *et al.* [53]	96	9	7	2	7 (hemorrhage in 2, ileus in 2, labor in 2, hernia in 1)
Tate *et al.* [52]	51	4	5	1	3 (abscess)
Tate *et al.* [30]	70	12	14	7	4 (ileus in 2, bronchospasm in 1, fluid collection in 1)
Vallina *et al.* [70]	18	2	2	0	1 (abscess)
Bonanni *et al.* [42]	66	NR	3	0	7 (abscess in 5, phlegmon in 1, urinary retention in 1)
Buckley *et al.* [56]	29	9	3	2	1 (abscess)
Corso *et al.* [22]	35	5	5	1	2 (pneumonia, pleural effusion)
Valla *et al.* [17] and el Ghuneimi *et al.* [18]	1379	NR	9	2	15 (SBO in 6, visceral injury in 2, omental evisceration in 2, abscess in 4, fistula in 1)
Frazee *et al.* [69]	38	7	2	1	1 (abscess)
Klaiber *et al.* [15]	40	NR	0	0	0
Kollais *et al.* [60]	87	9	6	3	4 (ileus, pneumonia, hemolytic anemia, infected hydrocele)
Mompean *et al.* [61]	100	12	5	1	6 (SBO in 4, abscess in 2)
Naver *et al.* [55]	21	1	2	0	1 (abscess)
Pruett and Pruett [57]	37	4	0	2	0
Reiertsen *et al.* [62]	72	8	3	NR	3 (abscess in 2, DVT in 1)
Schreiber [19]	78	0	0	0	6 (peritonitis in 4, stump blowout in 1, uterine injury in 1)
Vargas *et al.* [23]	201	14	21	2	6 (abscess in 4, ileus in 1, hemorrhage in 1)
Apelgren *et al.* [63,64]	41	0	0	0	0
Cox *et al.* [16]	73	4	6	1	0
Totals (Weighted percentages)	4576	161 (5.5%)	178 (4.0%)	53 (1.2%)	89 (2.0%)

DVT—deep venous thrombosis; NR—not reported; SBO—small bowel obstruction.

59. Gilchrist BF, Lobe TE, Schropp KP, *et al.* Is there a role for laparoscopic appendectomy in pediatric surgery? *J Pediatr Surg* 1992, 27:209–214.
60. Kollias J, Harries RH, Otto G, Hamilton DW, Cox JS, Gallery RM: Laparoscopic versus open appendicectomy for suspected appendicitis: a prospective study. *Aust N Z J Surg* 1994, 64:830–835.
61. Lujan Mompean JA, Robles Campos R, Parrilla Paricio P, Soria Aledo V, Garcia Ayllon J: Laparoscopic versus open appendicectomy: a prospective assessment. *Br J Surg* 1994, 81:133–135.
62. Reiertsen O, Trondsen E, Bakka A, Andersen OK, Larsen S, Rosseland AR: Prospective nonrandomized study of conventional versus laparoscopic appendectomy. *World J Surg* 1994, 18:411–416.
63. Apelgren KN, Molnar RG, Kisala JM: Laparoscopic is not better than open appendectomy. *Am Surg* 1995, 61:240–243.
64. Apelgren KN, Molnar RG, Kisala JM: Is laparoscopic better than open appendectomy? *Surg Endosc* 1992, 6:298–301.
65. McAnena OJ, Auston O, Hederman WP, Gorey TF, Fitzpatrick J, O'Connell PR: Laparoscopic versus open appendicectomy. *Lancet* 1991, 338:693.
66. McAnena OJ, Austin O, O'Connell PR, Hederman WP, Gorey TF, Fitzpatrick J: Laparoscopic versus open appendicectomy: a prospective evaluation. *Br J Surg* 1992, 79:818–820.
67. Attwood SE, Hill AD, Murphy PG, Thornton J, Stephens RB: A prospective randomized trial of laparoscopic versus open appendectomy. *Surgery* 1992, 112:497–501.
68. Kum CK, Ngoi SS, Goh PM, Tekant Y, Isaac JR: Randomized controlled trial comparing laparoscopic and open appendicectomy. *Br J Surg* 1993, 80:1599–1600.
69. Frazee RC, Roberts JW, Symmonds RE, *et al.*: A prospective randomized trial comparing open versus laparoscopic appendectomy. *Ann Surg* 1994, 219:725–731.
70. Vallina VL, Velasco JM, McCulloch CS: Laparoscopic versus conventional appendectomy. *Ann Surg* 1993, 218:685–692.

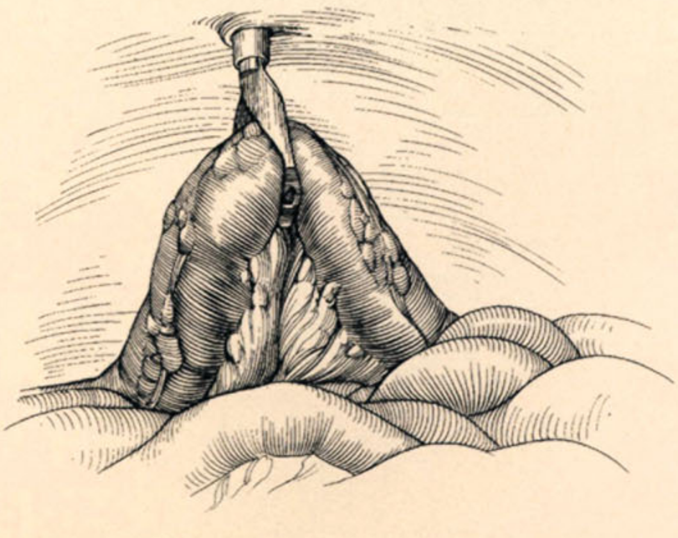
CHAPTER

17

Laparoscopic Enteric Diversion

James R. Mault

H. Kim Lyerly



Enteric diversion procedures are performed in a variety of circumstances leading to intestinal perforation, obstruction, or inflammation (Table 17-1). Standard "open" techniques for the creation of diverting ileostomies or colostomies are safe and effective and can often be performed through minimal laparotomy incisions. However, many patients requiring these procedures may have had a previous abdominal operation or have metastatic disease with peritoneal or mesenteric implants. These circumstances limit the ability of minimal incisions to create a diverting ileostomy or colostomy. Moreover, such procedures are usually complicated by postoperative ileus and longer hospitalization.

Table 17-1. Indications for enteric diversion procedures

Perforation	Volvulus
Diverticulitis	Intussusception
Cancer	Ogilvie's syndrome
Crohn's disease	Inflammatory bowel disease
Ischemia	Crohn's disease
Obstruction	Ulcerative colitis
Unresectable cancer	Toxic megacolon

Table 17-2. Advantages of laparoscopic enteric diversion

- Simple and safe
- Avoids open laparotomy
- Assessment of peritoneal implants
- Identification and takedown of adhesions
- Assessment of torsion or tension on the stoma limbs
- Permits secondary procedure
  - Biopsy
  - Feeding gastrostomy
  - Feeding jejunostomy
- Well tolerated by patients considered high operative risk
- Reduced operative time
- Reduced postoperative discomfort and ileus
- Reduced length of hospital stay

The application of laparoscopic techniques for temporary or permanent enteric diversion is a safe option and offers several distinct advantages that are summarized in Table 17-2. Laparoscopic creation of an ileostomy or colostomy permits thorough inspection of the abdominal cavity for secondary problems that would likely remain undetected using a minimal "open" laparotomy approach. In addition, laparoscopic enteric diversion provides the opportunity to perform additional procedures including diagnostic biopsies, feeding gastrostomy, or feeding jejunostomy. A further technical advantage of laparoscopic diversion is that the proximal and distal intestinal limbs can be examined for torsion and tension after creation of the stoma. As with most laparoscopic procedures, manipulation of the bowel is minimal and intestinal function recovers rapidly, thus allowing patients to begin immediate feedings. A regular diet is well tolerated, the diverting ostomy functions normally, and the patients are discharged 24 or 48 hours postoperatively. Earlier discharge may occur if counseling and training in the care of the stoma are provided prior to admission.

Although a number of minimally invasive techniques for the creation of diverting colostomies and ileostomies exist, the laparoscopic approach is being used more frequently. Diversion can be in the form of a loop, an endostomy alone, or an endostomy with combined mucous fistula. The technical considerations and results of laparoscopic enteric diversion procedures are described in the subsequent text.

Table 17-3. Laparoscopic instruments

Loop enterostomy
- 10-mm video camera
- Trocars and ports: one 10 mm and one 12 mm
- One endoscopic Babcock clamp

End colostomy and mucous fistula
- 10-mm video camera
- Trocars and ports: one 10 mm and two 12 mm
- Two endoscopic Babcock clamps
- One endoscopic stapler with 2–3 loads

Surgical Technique

Set-up

The operative set-up for laparoscopic enteral diversion may vary according to the portion of intestine to be diverted, the location for ostomy creation, the presence of additional findings such as adhesions, and instrumentation for additional procedures such as biopsies or feeding tubes (Table 17-3). For illustrative purposes, the following figures describe the creation of a left, lower-quadrant sigmoid colostomy. These techniques can be easily modified for alternate sites of diversion.

Preoperative considerations

Preoperative considerations are often limited in cases of acute perforation, ischemia, or obstruction, but a minimum should include intravenous antibiotics at induction of anesthesia. Under elective circumstances, both mechanical and antibiotic bowel preparations should be administered on the day prior to operation. In either case, after induction of anesthesia, a urinary bladder catheter and nasogastric tube are essential to decompress the stomach and bladder. In most cases, both tubes can be removed upon completion of the operation.

Figures 17-1 through 17-8 depict the surgical technique for laparoscopic enteric diversion.

Set-up

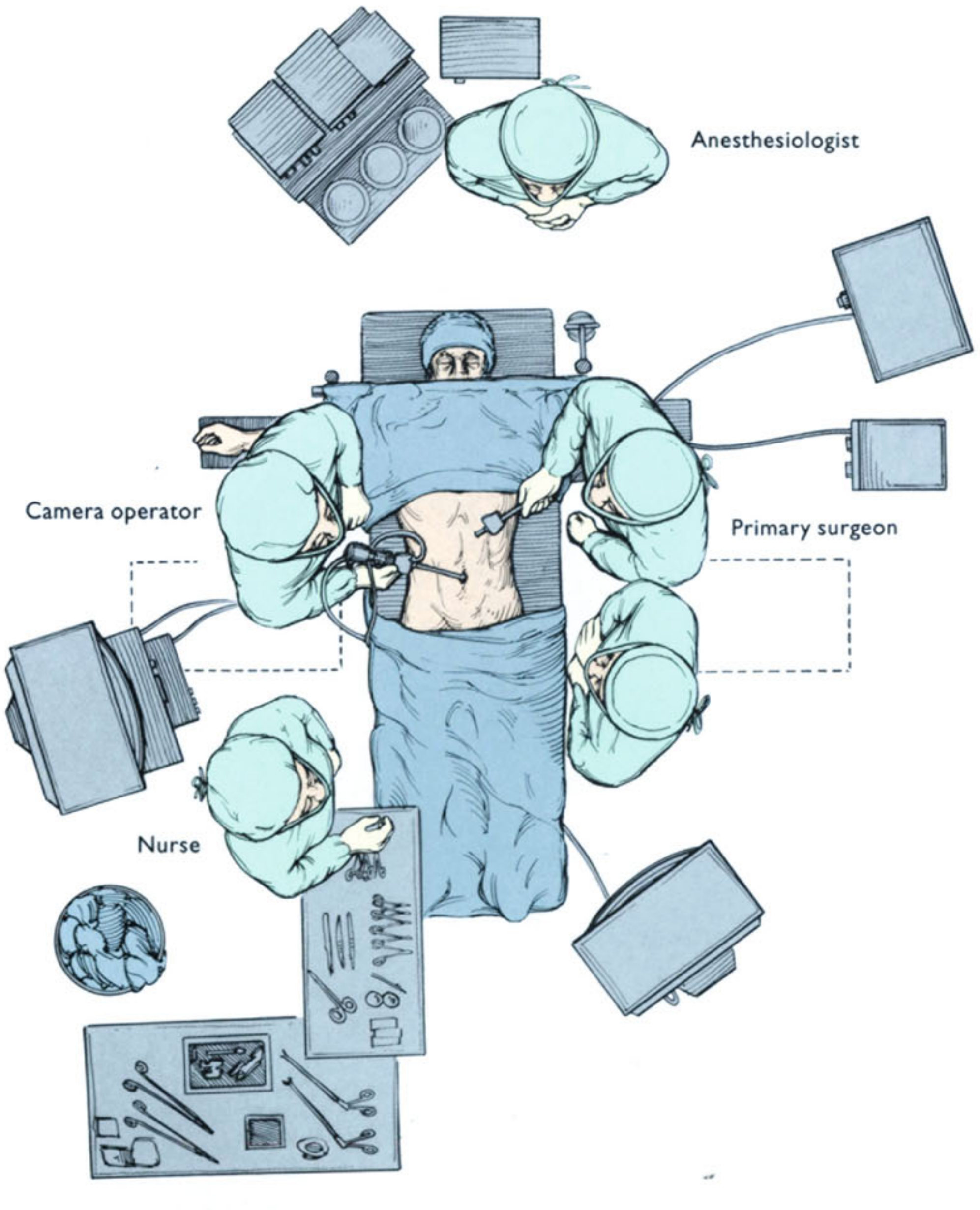


FIGURE 17-1.

Operative set-up for laparoscopic sigmoid colostomy. With the patient in supine position, the entire abdomen is scrubbed and draped widely. The primary surgeon is positioned on the side of the patient where the ostomy is to be located. The camera operator is usually located opposite the primary surgeon. Video monitors are positioned at the foot of both sides of the operating table in direct view of the surgeons. The laparoscopic instruments listed in Table 17-3 should be opened and available on the instrument tray. Additional instruments may be required and include endoscopic scissors and hook electrocautery. After establishing general anesthesia, a carbon dioxide pneumoperitoneum pressurized to 15 mm Hg is achieved at the umbilicus using the closed (Veress needle) or open (Hasson trocar) technique. The laparoscope is then inserted through a 10-mm port and the peritoneal cavity is inspected. The presence of significant adhesions that prevent mobilization of the bowel segment to be diverted may obligate insertion of additional ports in order to provide adequate mobilization. Additional procedures (biopsies, feeding tubes, and so forth) should be performed at this time.

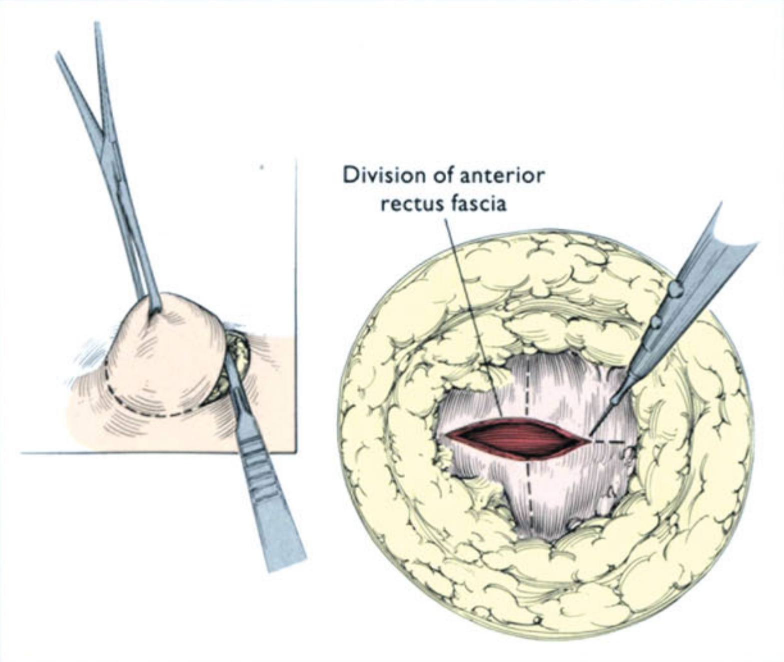


FIGURE 17-2.

Creation of the stoma site. After mobilization of the ileum or colon, a stoma is made on the abdominal wall at a site overlying the segment for diversion, usually in a position that allows the intestine to pass through the rectus muscle. An Allis clamp is used to grasp the skin at the site of the stoma and an ellipse of skin is excised. Following removal of a portion of the subcutaneous fat, a cruciate incision is made through the anterior rectus fascia with an electrocautery. The underlying rectus muscle is split using a Kelly clamp, and the posterior rectus fascia is divided, but the peritoneum is not incised.

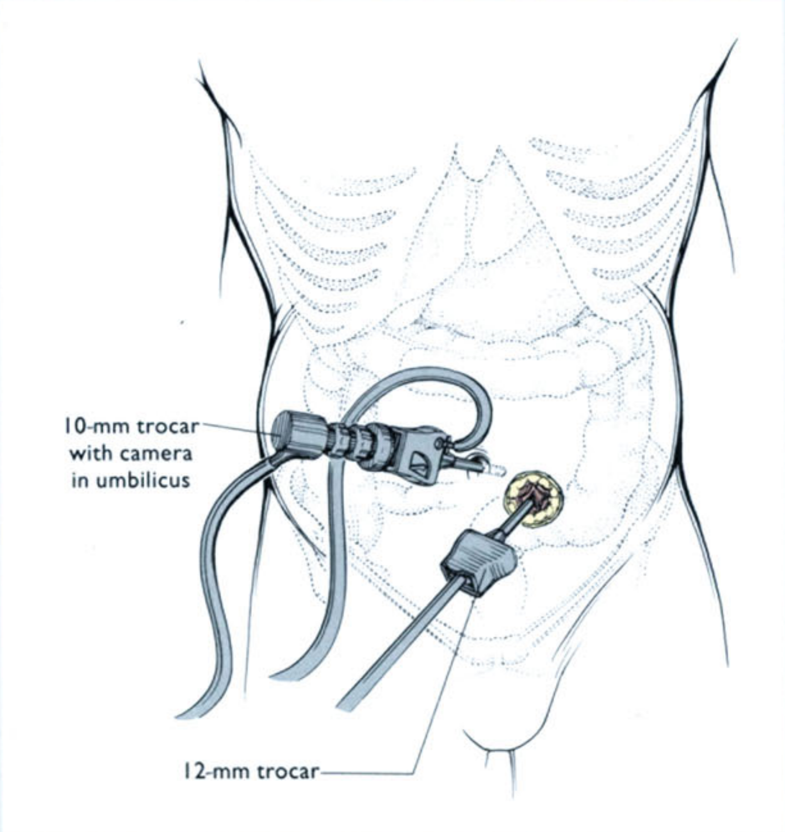


FIGURE 17-3.

Insertion of 12-mm port through the ostomy site. A 10-mm trocar is placed in the periumbilical region, and a laparoscopic camera is placed through the trocar after insufflation of CO_2 into the abdominal cavity. A 12-mm trocar is inserted through the defect created in the skin, rectus fascia, rectus muscle, and through the peritoneum into the peritoneal cavity.

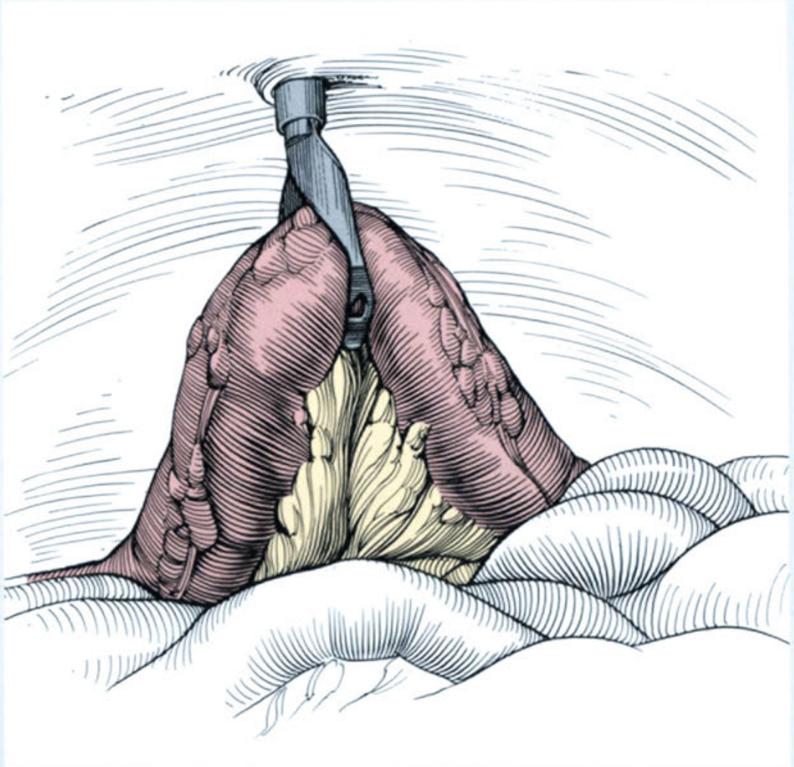


FIGURE 17-4.

A laparoscopic Babcock clamp is used to grasp the antimesenteric border of a mobile segment of the sigmoid colon. This site is selected after demonstrating that it can be drawn to the anterior abdominal wall without tension while maintaining the pneumoperitoneum. At this point, the trocar has been placed through the previously created stoma. The defect in the peritoneum is opened to accommodate the bowel with temporary loss of the pneumoperitoneum. The Babcock clamp is used to withdraw the loop of sigmoid colon through the defect in the anterior abdominal wall with simultaneous removal of the trocar. The loop of sigmoid colon reseals the abdominal cavity, allowing a pneumoperitoneum to be reestablished. Visual inspection of the abdominal cavity and the mesentery of the sigmoid colon is then performed to confirm the absence of tension or torsion on the sigmoid colon.

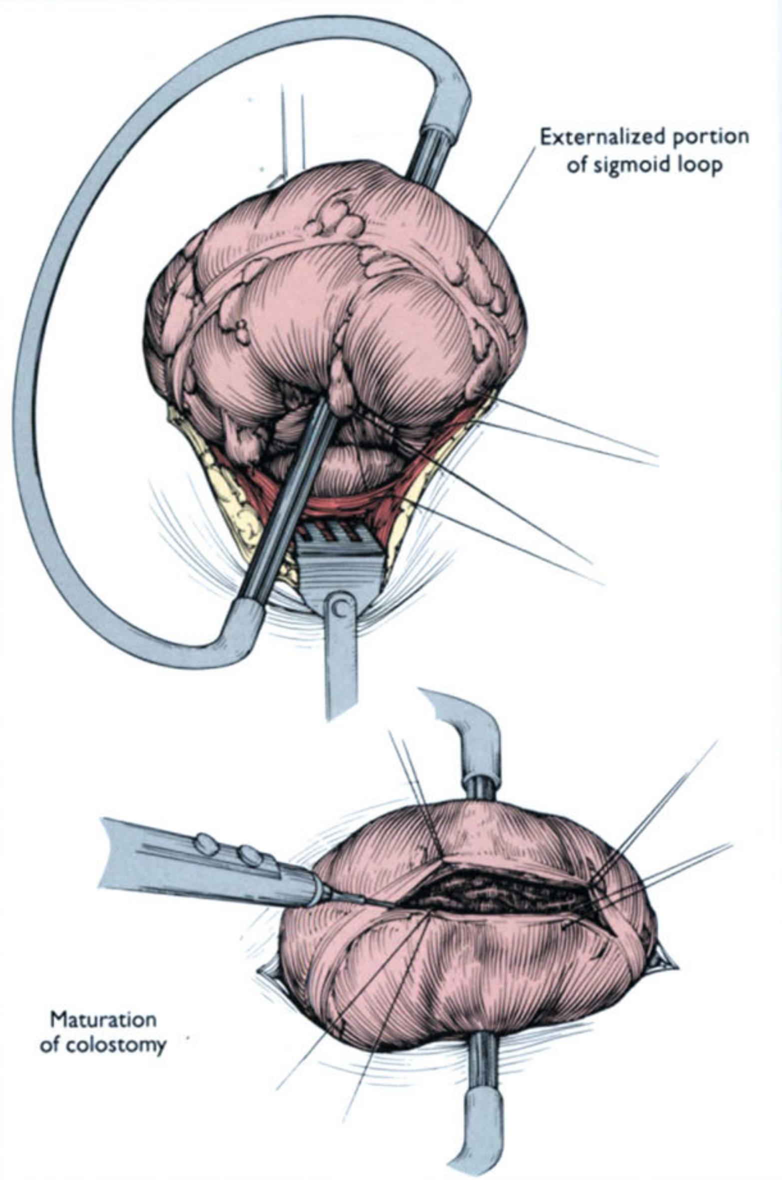


FIGURE 17-5.
Maturing the stoma. Once the sigmoid loop is brought through the site of the stoma, it is matured as a double-barreled loop colostomy as shown here. A red-rubber catheter is passed through the mesentery of the colon and between the colon and the skin to ensure that the colon does not return into the peritoneal cavity. The colostomy is matured by opening the colon along a tenia and placing full-thickness interrupted 3-0 chromic sutures through the colon, approximating the mucosa and the skin.

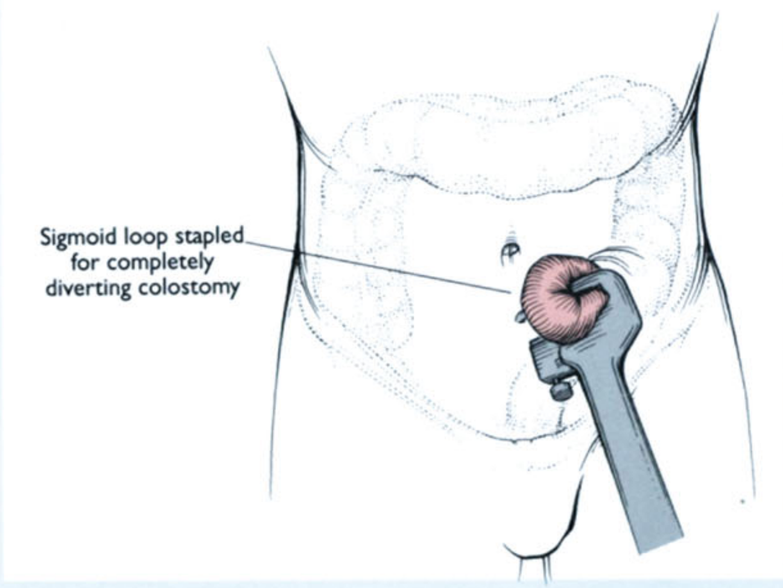


FIGURE 17-6.
Alternatively, a loop of colon brought through the anterior abdominal wall is converted to a completely diverting colostomy by placing a TA-55 staple line across the distal limb. Maturation of the stoma is accomplished by opening the proximal limb along a tenia and placing full-thickness interrupted 3-0 chromic sutures through the colon approximating the mucosa and the skin.

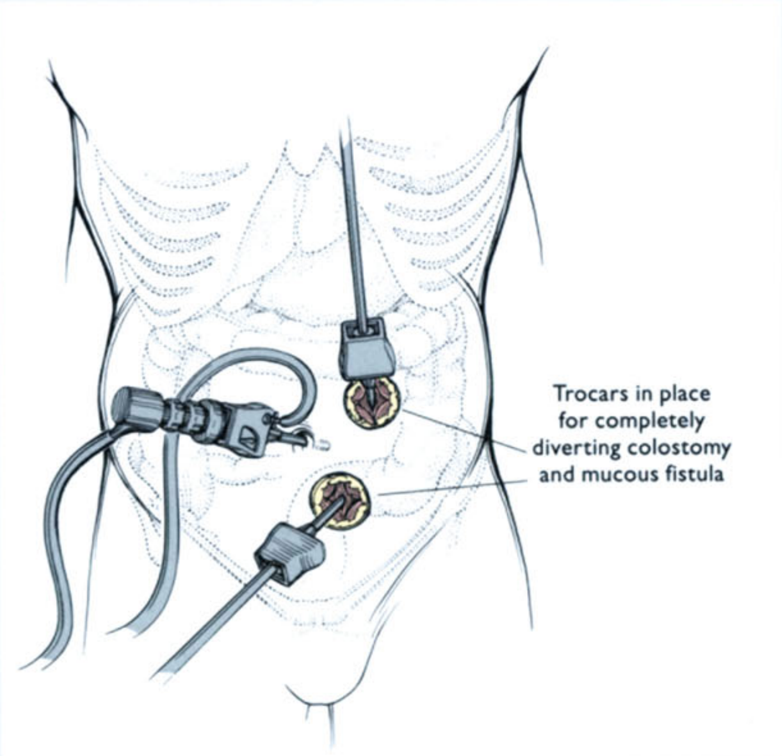


FIGURE 17-7.
Creation of an end-colostomy and mucous fistula. If a distal (defunctionalized) segment of intestine is longer than 10 mm above the peritoneal reflection, a completely diverting colostomy and mucous fistula can be created. In this case, two stoma sites are selected and prepared as previously described.

Duh and Way [3] reported success with a laparoscopic-guided percutaneous cecostomy using T-fasteners to retract and anchor the cecum to the anterior abdominal wall and using a Foley catheter as a cecostomy tube.

The approach to laparoscopic diversion described in this chapter obviates the need for a laparotomy of any kind and can be performed with standard laparoscopic equipment. We have recently reported the first experiences with this technique for laparoscopic ileostomy and colostomy [4]. Since this report, laparoscopic enteric diversion procedures have been successfully performed in over 30 cases without complication. In most cases, postoperative recovery has been prompt with a rapid return of intestinal function and early discharge from the hospital.

References

1. Phillips EH, *et al.*: Laparoscopic colectomy. *Ann Surg* 1992, 216(6):703–707.
2. Lange V, *et al.*: Laparoscopic creation of a loop colostomy. *J Laparoendosc Surg* 1991, 1(5):307–312.
3. Duh QY, Way LW: Diagnostic laparoscopy and laparoscopic cecostomy for colonic pseudo-obstruction. *Dis Colon Rectum* 1993, 36(1):65–70.
4. Lyerly HK, Mault JR: Laparoscopic ileostomy and colostomy. *Ann Surg* 1994, in press.

CHAPTER 18

Laparoscopic-assisted Colectomy and Abdominoperineal Resection

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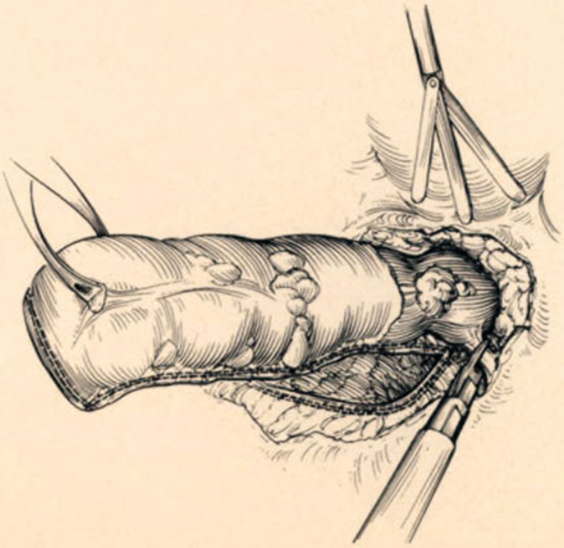
Theodore N. Pappas



Colon resection is a natural extension of laparoscopic techniques that were applied so successfully to cholecystectomy. Preliminary studies have shown the same excellent patient acceptance and accelerated postoperative course as in laparoscopic cholecystectomy [1,2]. The development of laparoscopic-assisted colectomy began with benign lesions on the right side, and as experience increased, the technique was applied to all portions of the colon and rectum. Vascular inflammatory and neoplastic lesions are amenable to the technique, though careful follow-up of laparoscopic-assisted colectomy for malignancy is ongoing to ensure equivalent locoregional clearance of tumor and recurrence rates.

Anatomy

Many aspects of the anatomy of the colon are important when considering a laparoscopic resection (Figure 18-1). The colon has intraperitoneal and retroperitoneal segments. As the ileum enters the cecum in the right lower quadrant, there are intimate associations with vascular and nervous structures as well as the right ureter. The majority of the right colon is retroperitoneal and as the ascending colon approaches the liver, there are associations with the gallbladder, duodenum, pancreas, and potentially the common bile duct. The transverse colon overlies the body of the pancreas and is attached to the stomach by the omentum. The descending colon begins at the left colic flexure where the tail of the pancreas and the spleen lie in close proximity. The descending colon is retroperitoneal and the associations of the descending and sigmoid colon with the ureter, iliac vessels, and femoral and lateral femorocutaneous nerves lie in the left iliac fossa. The rectum is in proximity to the ureters at the pelvic brim, and to the fallopian tubes and ovaries in females. Within the male pelvis, the rectum contacts the prostate and bladder, and in the female approximates the vagina.

The colon itself is easily distinguished from the small intestine by its sacculations, or haustra coli, taeniae, and appendices epiploica. Moreover, the greater omentum is attached to the transverse colon and the small intestine itself is surrounded by the colon in the supine position.

The major vascular supply of the colon and terminal ileum includes the ileocolic and right colic arteries that supply the ileum to the hepatic flexure. The middle colic branch of the superior mesenteric artery supplies the hepatic flexure to the splenic flexure. At this point, the inferior mesenteric artery supplies the descending and sigmoid colon and the proximal rectum. The important but variable marginal artery of Drummond forms a rich anastomotic network allowing for great flexibility in resectional strategy.

The venous drainage follows the arterial supply with the proximal and transverse colon draining into the superior mesenteric vein, and the descending and sigmoid draining predominantly into the inferior mesenteric vein. Similarly, the lymphatic drainage of the colon follows the major arterial channels first through the epicolic lymph nodes near the colonic wall. The second level of nodal structures are pericolic lymph nodes in the mesentery along the branches of the supplying arteries. The third level of lymph nodes is at the base of the colonic mesentery near the inferior or superior mesenteric arteries. Finally, terminal nodes at the base of the colic vessels anastomose with periaortic lymph channels.

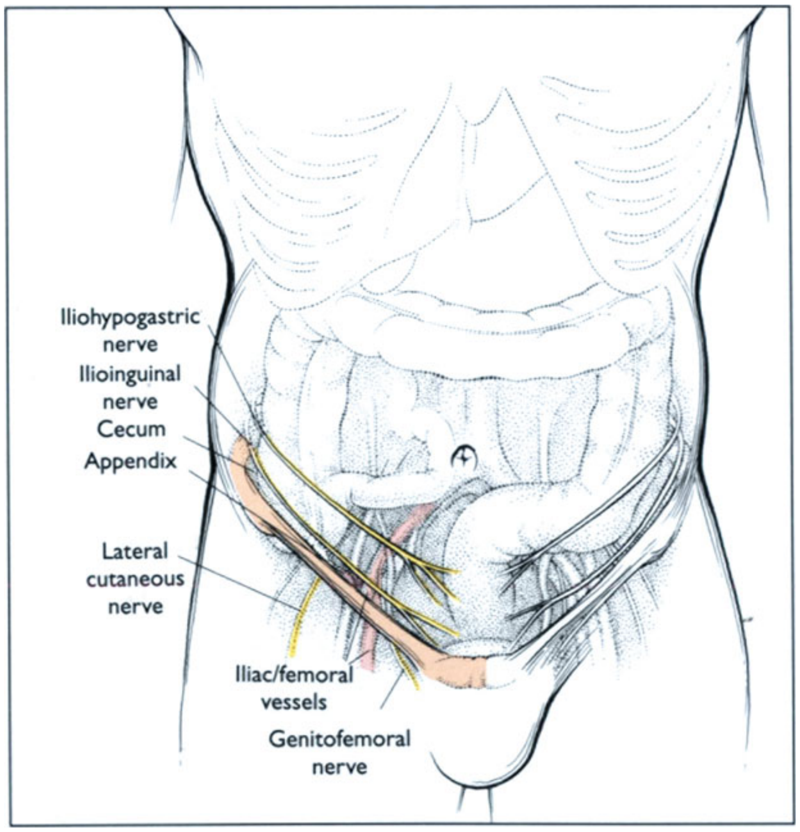


FIGURE 18-1.
Anatomy of the colon.

Surgical Technique

Right Colectomy

Figures 18-2 through 18-11 depict the surgical technique for right colectomy.

Set-up

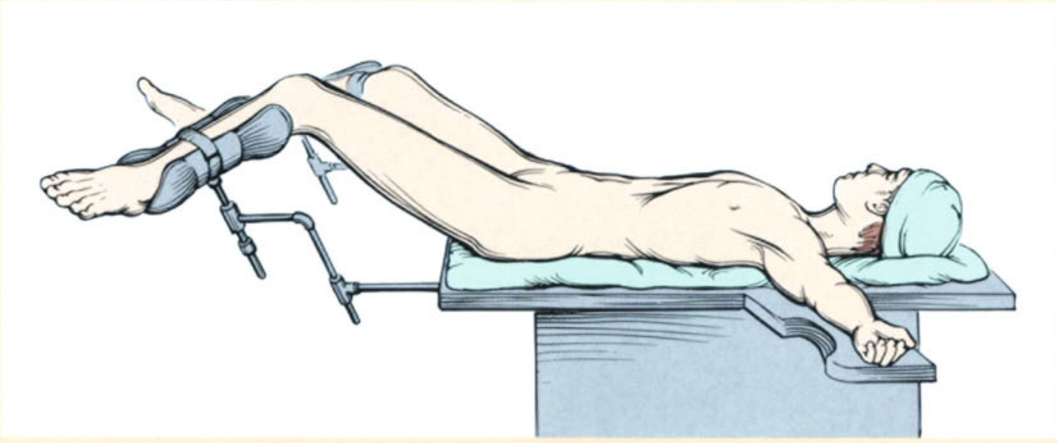


FIGURE 18-2.

The patient may be placed in a modified lithotomy or supine position. Trendelenburg or reverse Trendelenburg will be used variously throughout the procedure. The patient is prepped and draped so that the laparoscopic or an open procedure may be performed.

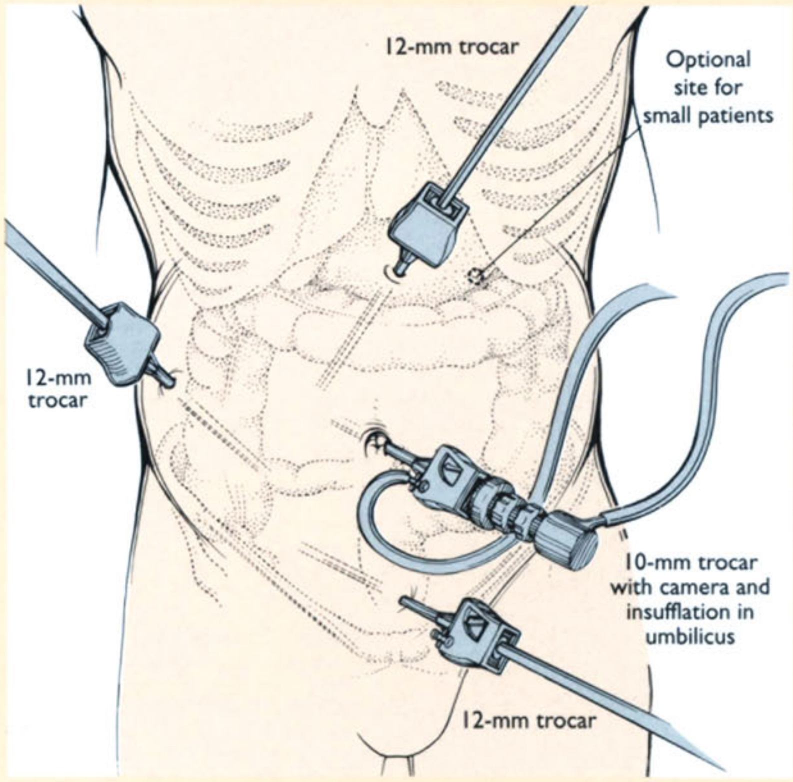


FIGURE 18-3.

Standard techniques of either closed or open insufflation and umbilical trocar placement are performed and a 10- to 11-mm trocar inserted at the umbilicus. After careful visual exploration of the abdominal cavity for unsuspected pathology, 12- or 15-mm trocars are placed in the suprapubic region in the right mid-to-upper abdomen and supraumbilically either in the midline or slightly to the left. Most right colectomies can be performed with these four trocar sites, though an additional left lower quadrant trocar may be used instead of the right paramedian site. For the right colectomy, the assistant and the surgeon stand on the left side of the patient or one between the patient's legs and the other on the patient's left. It is critical to maintain meticulous hemostasis throughout the procedure, especially if intracorporeal suturing techniques are to be used. Moreover, it is important that high-flow insufflation be used to maintain intra-abdominal pressure at 15 mm Hg mercury. It is helpful to have a 30° scope available for use in mobilization, especially at the hepatic flexure.

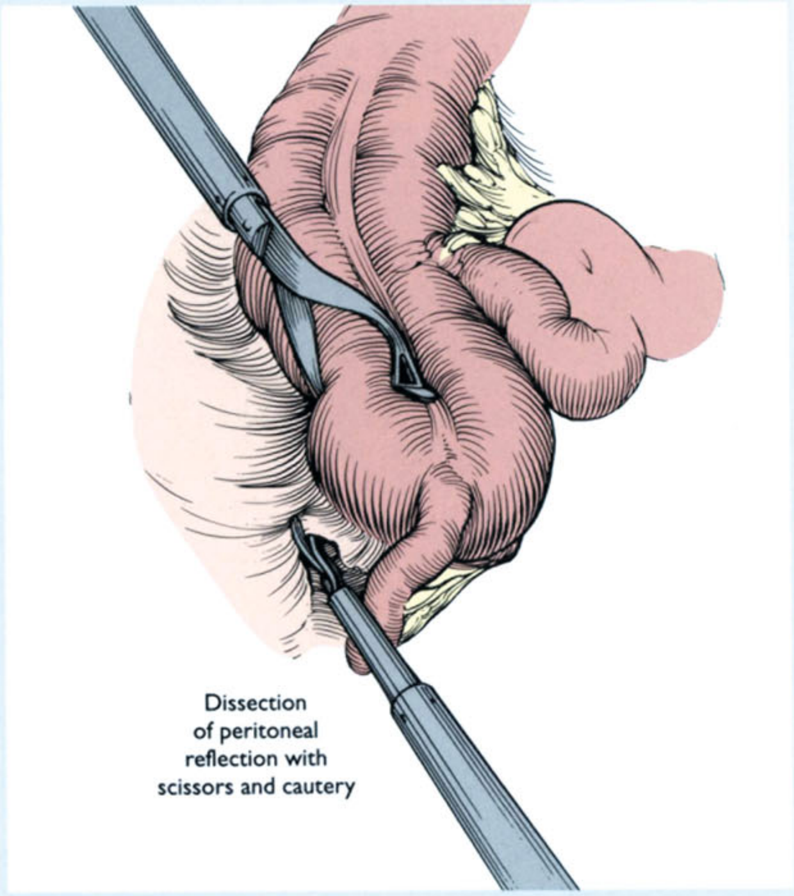


FIGURE 18-4.
The dissection is begun by cephalad and medial retraction of the ileocecal area and division of the lateral peritoneal attachments (the white line of Toldt) using scissor electrocautery.

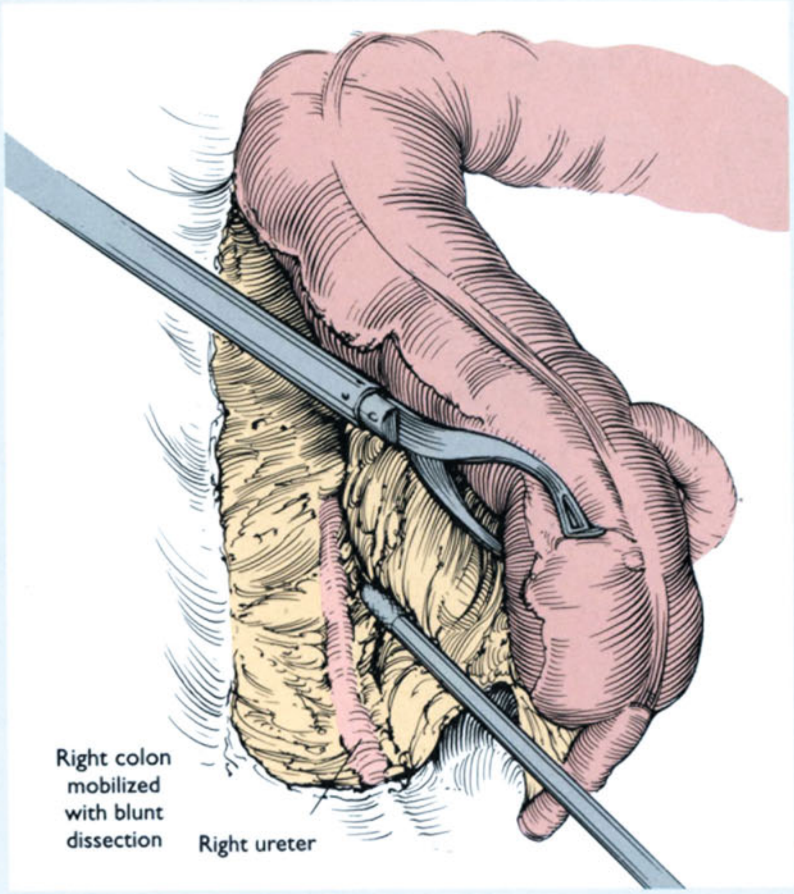


FIGURE 18-5.
After division of the peritoneal lining, a Kitner or other blunt dissector is used to elevate the cecum and right colon medially. At this point, the right ureter is readily identifiable in its retroperitoneal position.

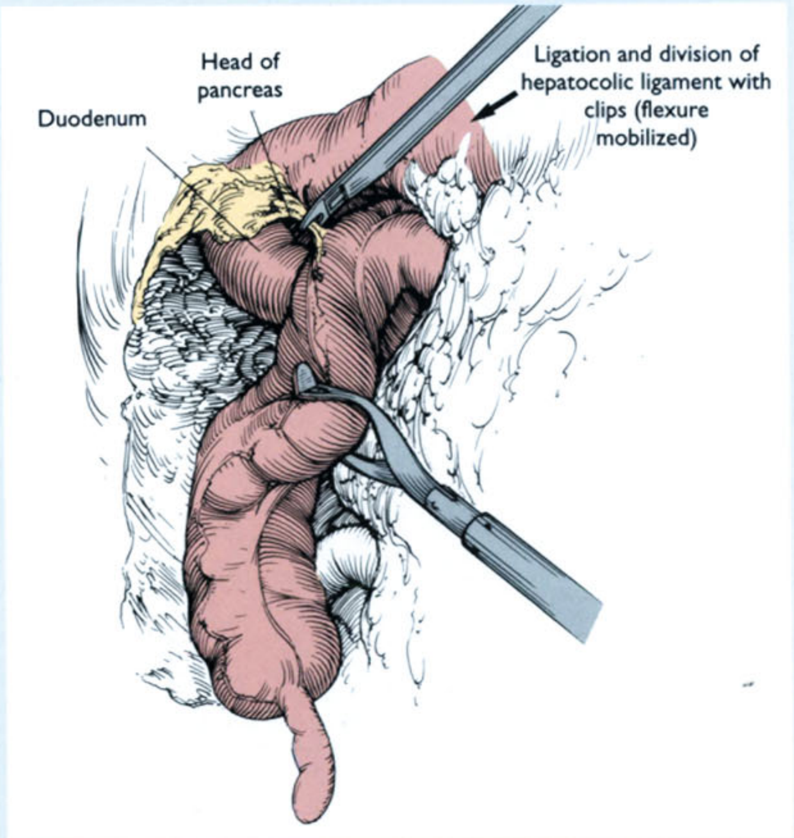


FIGURE 18-6.
As dissection continues up the right pericolic gutter, the retraction on the colon is changed to a caudad and medial direction, and reverse Trendelenburg instituted to better visualize the peritoneal attachments toward the hepatic flexure and duodenum. As the hepatic flexure is approached, the scissor electrocautery will be adequate for most hemostasis but some clipping of small vessels may be judicious. The gastrocolic attachments are approached; larger vessels should be clipped before division. Once the cecum and right colon have been freed around the hepatic flexure, the ileal peritoneal attachment is incised and the terminal ileum elevated in the cephalomedial direction. At this point in the dissection, the ileum, right colon, and hepatic flexure are usually extremely mobile and several choices are available for identification and control of the mesenteric vessels.

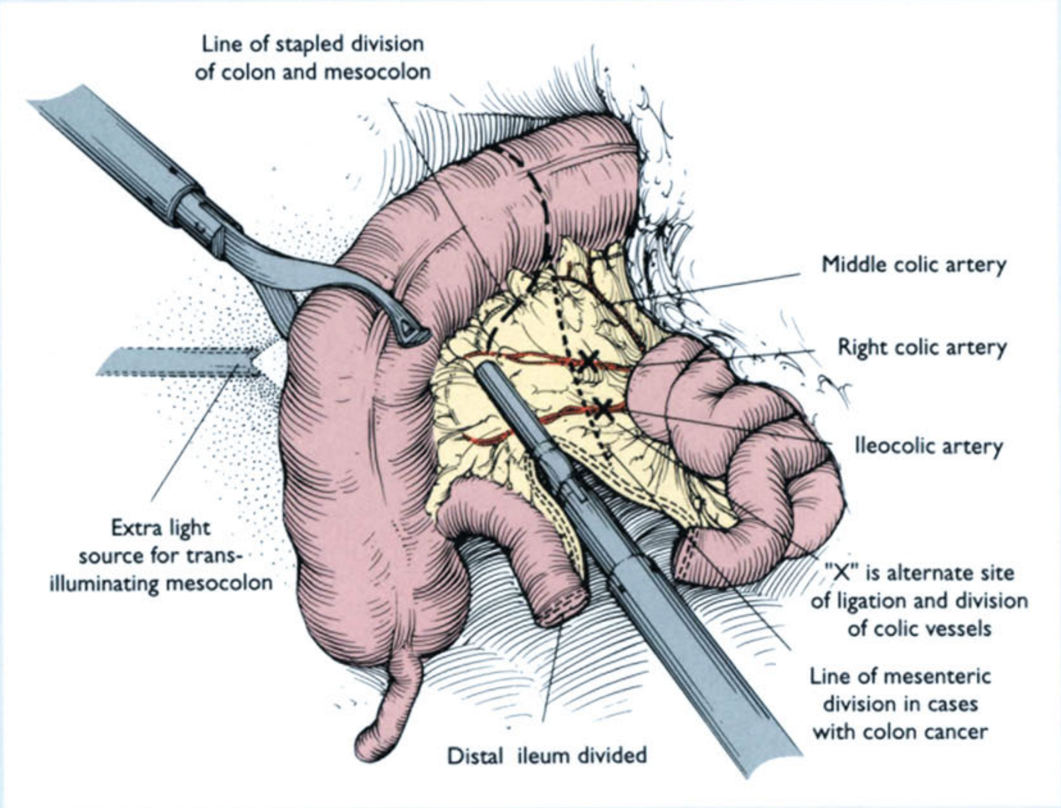


FIGURE 18-7.

In a procedure done for malignancy, the mesenteric vessels are approached near their junction with the superior mesenteric artery, as in an open procedure. In thin patients with relatively little fat in their mesenteric substance, the vessels may be easily identified with the camera either in the medial or lateral position. However, in the obese patient, it may be necessary to insert a lateral light source for translumination of the mesentery to easily identify and dissect the mesenteric vessels. Once the vessels are identified, blunt and sharp dissection with scissors and forceps can be used to isolate them. They may then either be multiply clipped and divided, suture ligated with intracorporeal suturing techniques, or the mesentery may be divided using a linear laparoscopic stapling instrument.

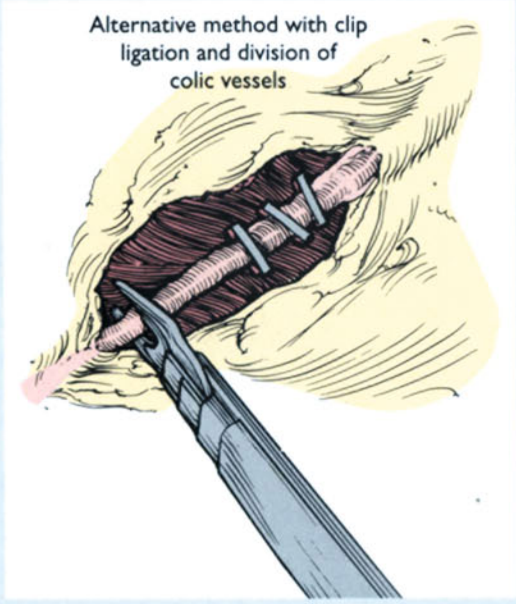


FIGURE 18-8.

For mesenteric stapling, the stapler is inserted through the suprapubic trocar site. A small window is made in the peritoneum to allow both tips of the instrument to be seen. Two or three firings of the instrument may be necessary to completely ligate and divide the mesentery and its vessels. The same instrument is then used to divide the ileum and the transverse colon completing the resection.

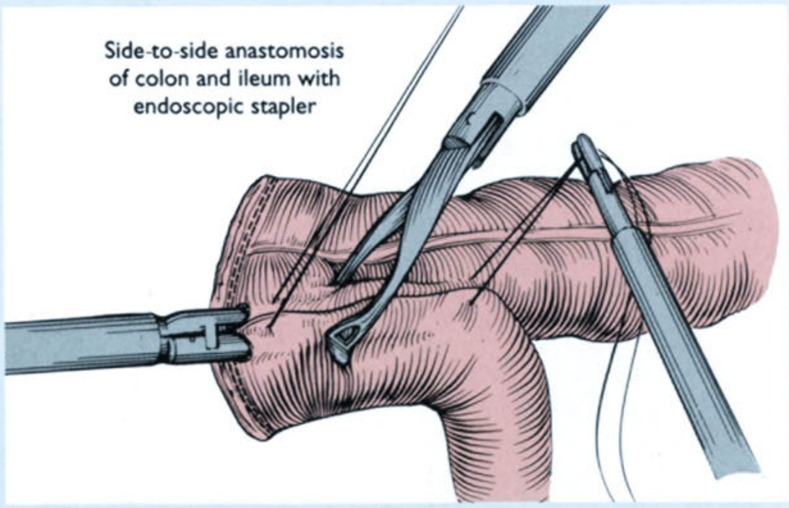


FIGURE 18-9.

Reanastomosis may be accomplished by one of two methods. Intracorporeal reanastomosis is accomplished by approximating the terminal ileum and transverse colon in a side-to-side manner using endosurgical suturing techniques. Small openings are then made in the bowel walls adjacent to the staple lines and a stapler inserted through the lateral or suprapubic trocar. The limbs of the stapler are inserted into the lumina of the small and large bowel and fired sequentially either two or three times forming a widely patent anastomosis. The remaining defect may be closed using suture or the linear stapler.

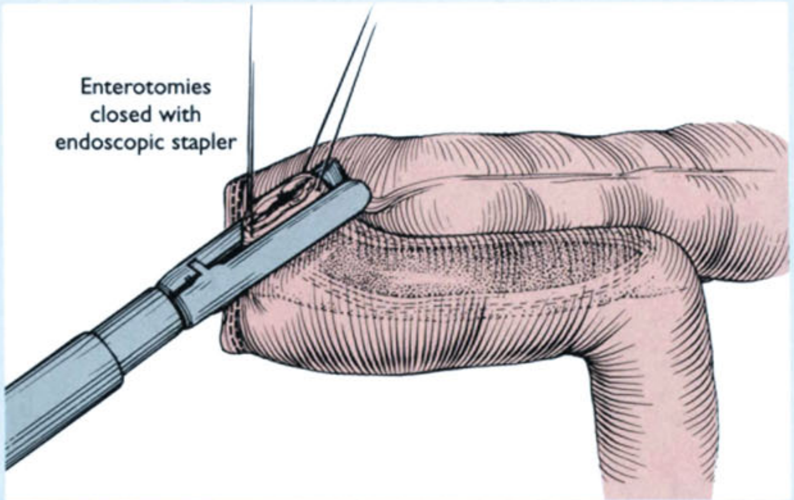


FIGURE 18-10.

The camera is reinserted, insufflation reestablished, and the mesenteric defect closed intracorporeally using either suture or clips.

Procedure

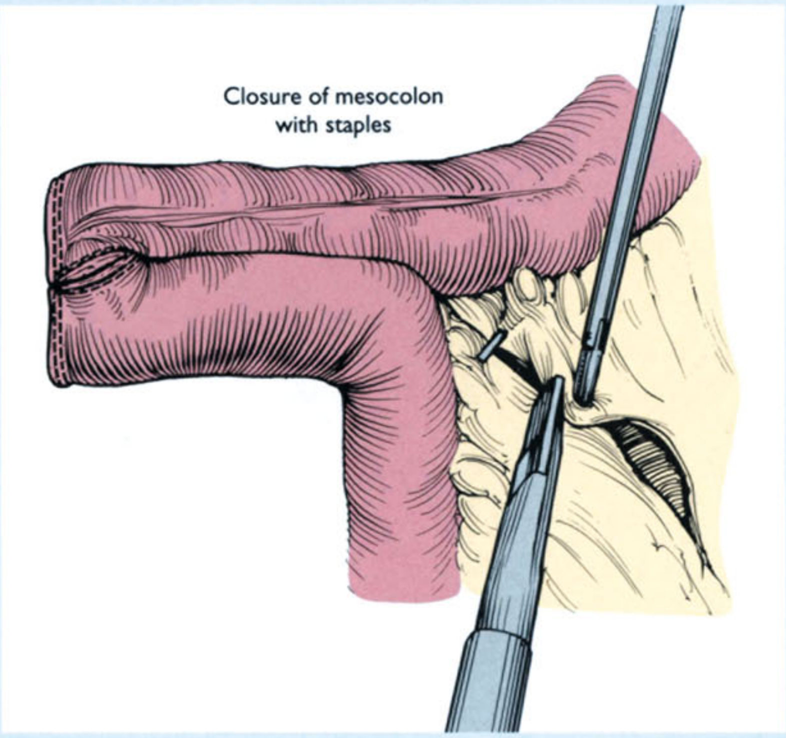


FIGURE 18-11.
The peritoneal cavity is then copiously irrigated with saline solution and the abdomen carefully examined to exclude residual hemorrhage. Once this is assured, the trocars are removed and the puncture sites closed using standard methods.

Left Colectomy, Sigmoid Colectomy, and Low Anterior Anastomosis

Figures 18-12 through 18-19 depict the surgical technique for left colectomy, sigmoid colectomy, and low anterior anastomosis.

The procedure may be accomplished completely intracorporeally by proximal transection using the stapling device and distal transection using scissor electrocautery. The specimen may then be removed transanally after mild dilation of the anus. The stapling device may then be introduced transrectally with the anvil placed in the proximal segment via an enterotomy. The mesenteric defect is closed as previously described.

Set-up

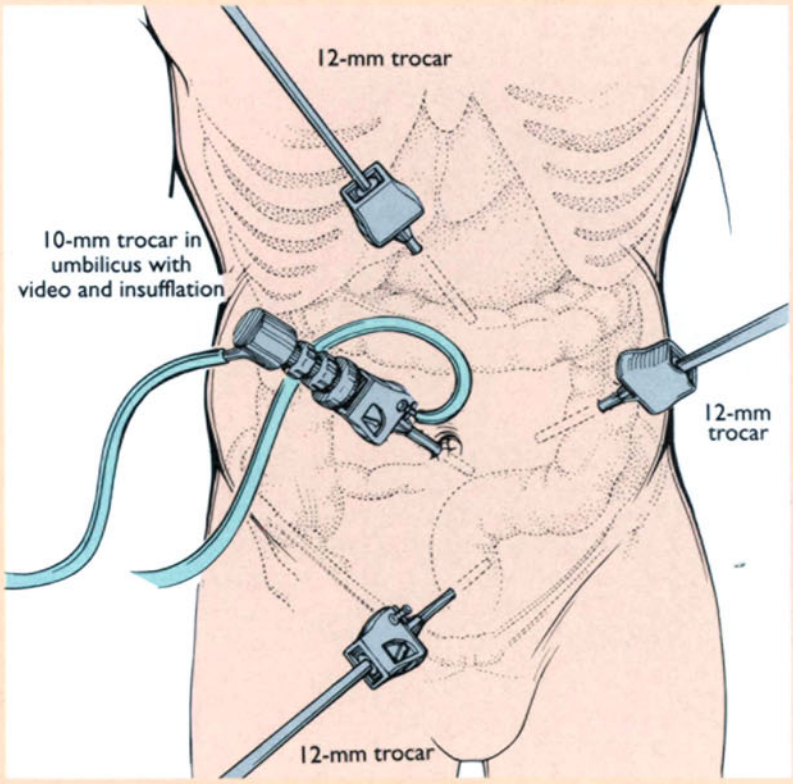


FIGURE 18-12.
For operations on the left or sigmoid colon, the patient is once again placed in the modified lithotomy position. The surgeon and assistant are on the patient's right side or one surgeon is between the patient's legs. The trocar sites are essentially mirror images of the right-sided dissection with a 10- to 11-mm umbilical trocar, a larger suprapubic trocar, and right upper quadrant trocar and a left lateral trocar. A caveat for this left lateral position is that it should be placed in a premarked site for colostomy formation should this be necessary. For adequate mobilization and visualization of the splenic flexure, additional trocars may be necessary in the subcostal position on the left so that the camera may be passed from the umbilical site to this subcostal trocar site. Dissection is begun with cephalad and medial retraction of the sigmoid colon.

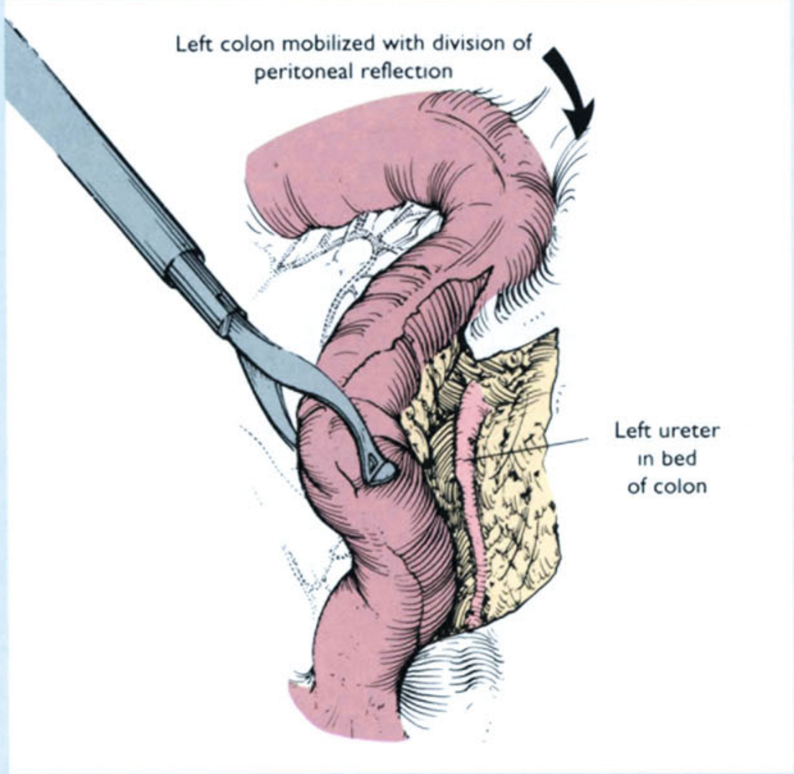


FIGURE 18-13.
The lateral peritoneal flexion is divided using scissor electrocautery. Blunt dissection is then used to elevate the colon medially and the left ureter is usually identified without difficulty. As the splenic flexure is approached, extreme caution must be used as in open colectomy.

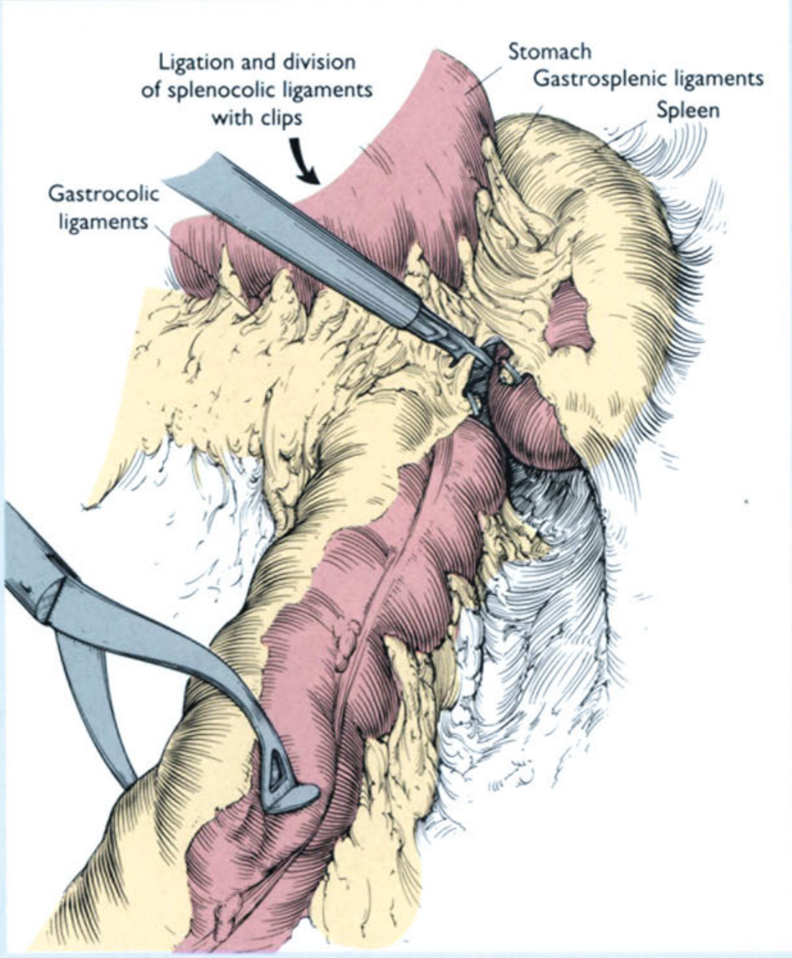


FIGURE 18-14.
Gentle caudad retraction using a Babcock forceps is applied and splenocolic attachments are carefully identified, clipped, and divided using scissors. It is critical that excessive traction not be applied to the colon as splenic capsular disruption can occur with its attendant bleeding, obscuring the operative field. Continuing the caudad retraction of the colon, the gastrocolic attachments are identified and vessels clipped and divided in continuity. Once these vascular attachments have been divided, blunt dissection can be used to mobilize the splenic flexure and proximal descending colon inferomedially. When enough mobility is obtained for adequate resection and tension-free reanastomosis, the techniques previously described for the right colon may be used to divide the mesenteric vessels and fat on the left side. Translumination is extremely useful in the thicker sigmoid mesentery. Isolated sigmoid resections are usually accomplished extracorporeally because of the redundant nature of this portion of the colon.

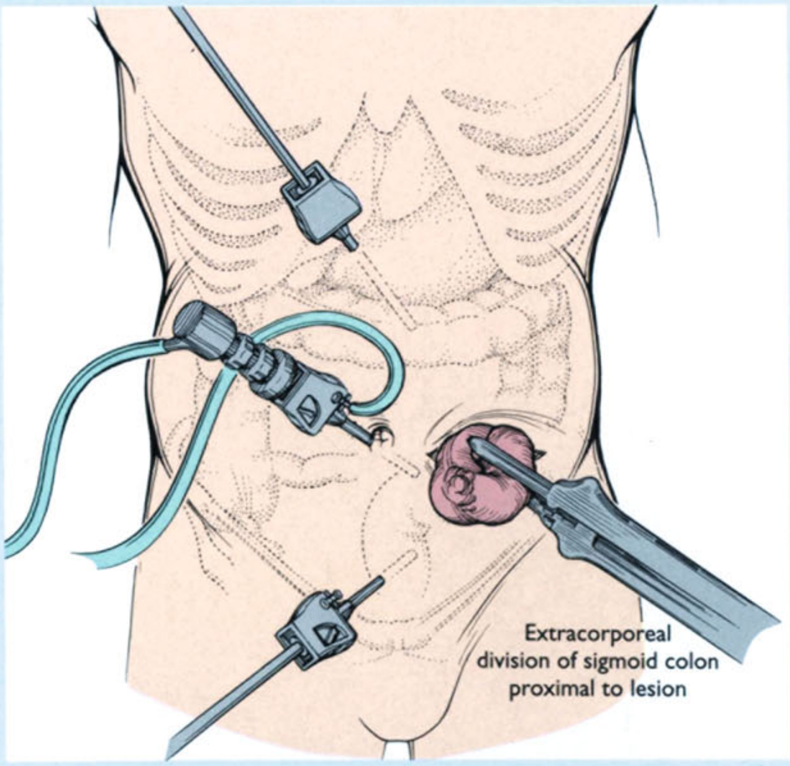


FIGURE 18-15.
Depending on the extent of dissection necessary and the site of transection of the sigmoid colon and rectum, the rectosigmoid mesentery is easily controlled and divided using a linear stapler inserted via the left midabdominal trocar.

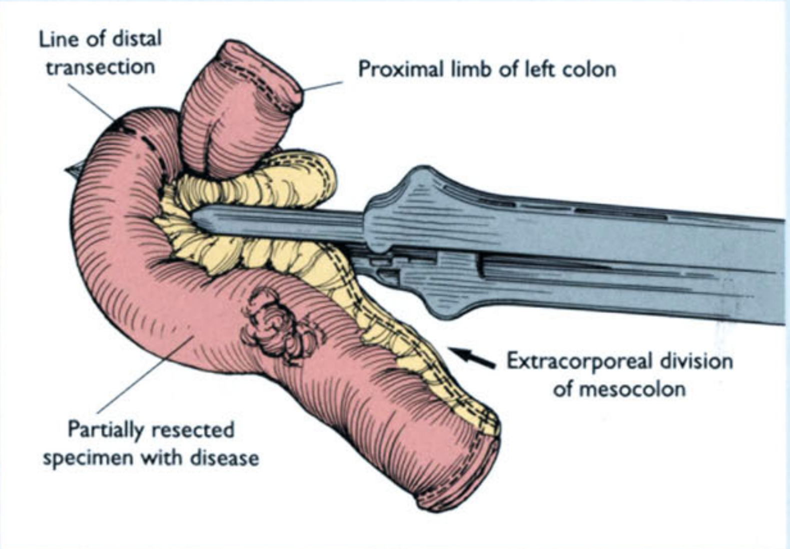


FIGURE 18-16.
In benign disease, the stapler is passed close to the bowel wall. In operations for cancer, the inferior mesenteric artery is controlled near its junction with the aorta, allowing for adequate resection of the nodal basin. There are several options for specimen removal, although the easiest in a segmental resection is extension of the left lateral trocar site with extracorporeal division and hand sewn or stapled reanastomosis.

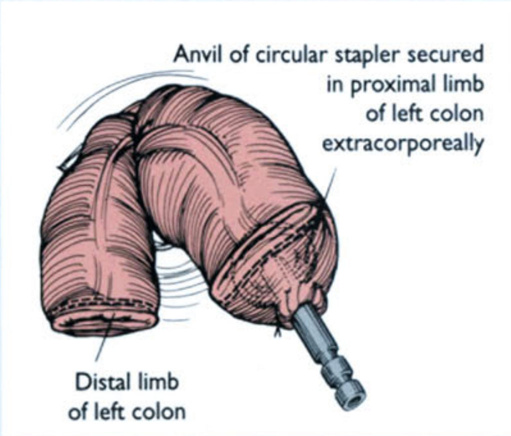


FIGURE 18-17.
If a lower anterior anastomosis is necessary because of distal resection of the rectosigmoid, the lateral or umbilical trocar site incision is extended medially and laterally and the proximal colonic transection accomplished extracorporeally. The anvil of a circular stapler is then inserted and secured with a purse-string suture. The anvil is then returned to the abdomen and the abdominal incision closed in an air- and water-tight fashion. The abdomen is reinsufflated and a circular stapler introduced via the anus. The device is opened, puncturing the rectal wall. A special grasping device or large forceps can be used to remove the puncturing device and insert the anvil.

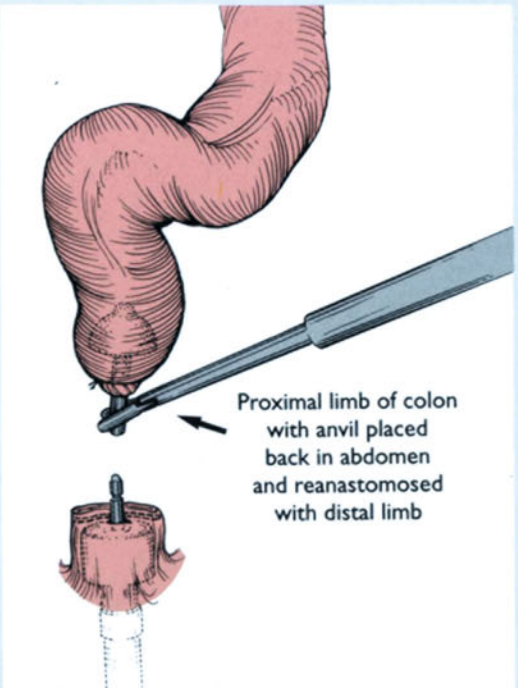


FIGURE 18-18.
The stapler is then closed and fired in the usual manner. The specimen is examined for two complete donuts.

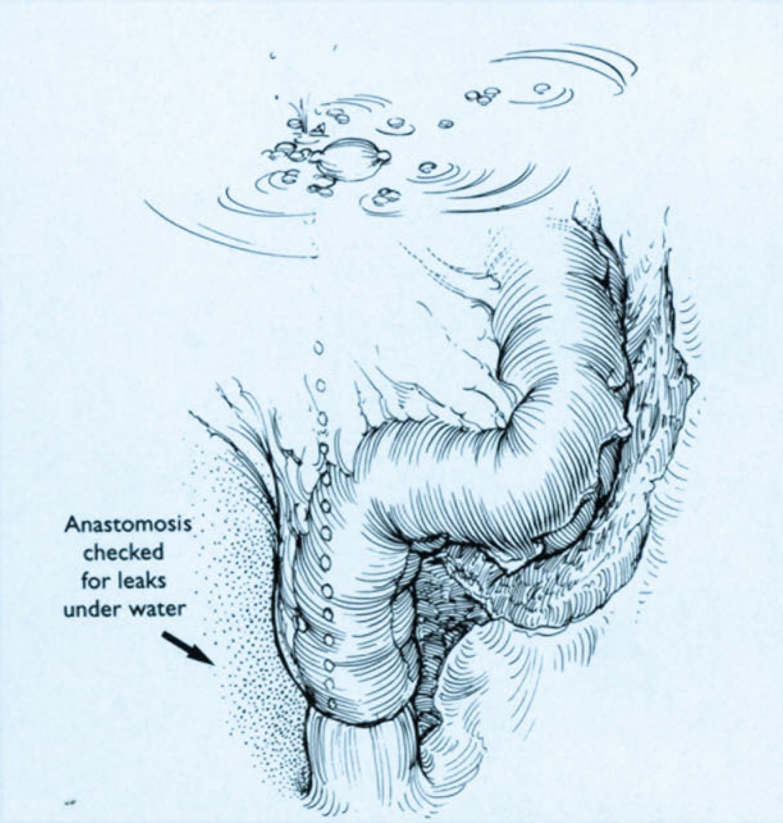


FIGURE 18-19.
The pelvis is then filled with saline and air insufflated via the rectum to assure an air-tight anastomosis. The mesenteric defect is then closed using clips or intracorporeal suturing techniques.

Abdominoperineal resection

Figures 18–20 through 18–21 depict the surgical technique for abdominoperineal resection.

Procedure

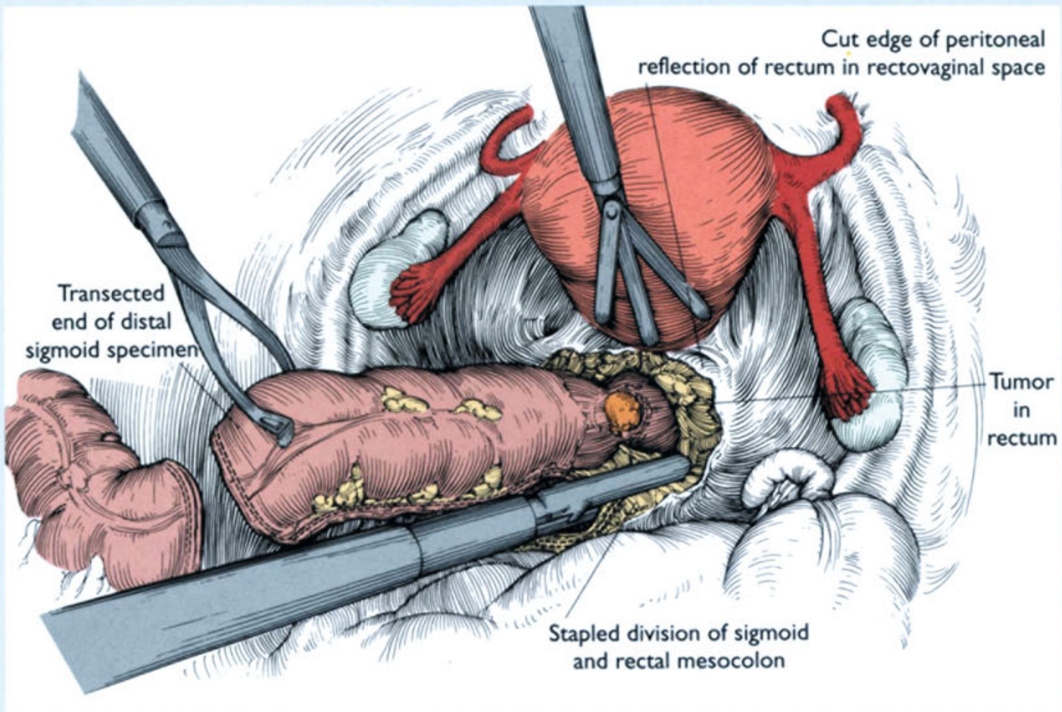


FIGURE 18-20.

Positioning and trocar placement for abdominoperineal resection is identical to that for descending and sigmoid colectomy, with the caveat that the left lateral trocar position must be carefully placed at the colostomy site. The sigmoid and colonic mobilization is as previously described. Once this has been accomplished, the pelvic peritoneum is divided using cautery scissors and the bladder dissected bluntly away from the rectum anteriorly. It will be necessary in females to retract the uterus and right adnexa anteriorly, and this can be accomplished most easily using a fan retractor or by a traction suture on the fundus of the uterus. With the patient in slight Trendelenburg, sharp and blunt dissection reveals the superior and middle hemorrhoidal attachments that can be clipped and divided individually or transected using the linear stapler. Likewise, the lateral attachments of the rectum to the side wall are easily exposed with blunt dissection and divided between clips.

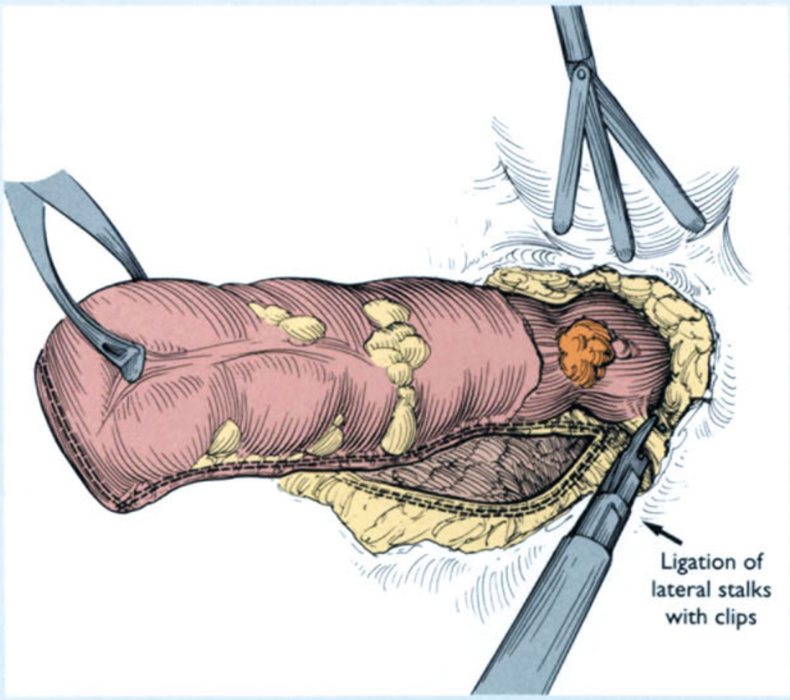


FIGURE 18-21.

This process can be continued down to the anal verge at which point the proximal transection site is chosen. The bowel is transected using a linear stapler and brought through the abdominal trocar site for colostomy formation. Mobilization of the rectum and division of its lateral attachments can be facilitated by the insertion of a proctoscope for rectal traction and translumination. Once the mobilization and proximal transection are complete, the perineal portion of the operation may proceed. The perineal portion of the procedure is difficult to perform while the superior dissection is ongoing. Specifically, if the perineal cavity is entered from below it is impossible to maintain insufflation. For this reason, the combined approach used in the traditional abdominoperineal resection is impractical, though as advances in gasless laparoscopic techniques improve, the combined approach may become routine. Once the perineal portion of the procedure has been performed and the specimen removed, the perineal incision is closed and pneumoperitoneum reestablished. The perineum is closed and the pelvis irrigated copiously with normal saline solution. The trocars are removed and sites closed in the usual fashion, and the colostomy matured.

Discussion

Laparoscopic colon resection has proven feasible and safe when performed by well-trained surgeons [1–4]. Most groups who have performed laparoscopic colectomy began doing so on benign processes in the right colon. Once experience was gained, the procedure was extended to malignant and inflammatory disease throughout the colon and rectum. Concerns with the procedure include the intraoperative identification of the site of pathology and the adequacy of nodal clearance in cases performed for malignancy. Finally, patients are routinely discharged on days 3 to 5 following routine laparoscopic colectomies, raising the possibility that complications arising on days 5 to 7 or later could go unrecognized.

The lack of tactile feedback during laparoscopic colectomy necessitates accurate pre- and intraoperative identification of disease prior to performing a resection. Several methods may be used. Obviously, a large percentage of cancers are externally evident on the colonic or rectal surfaces. For lesions that are small or intraluminal, preoperative barium enema will disclose the precise anatomic location in the majority of cases. It is perilous when laparoscopic dissection is performed to rely solely on an endoscopist's report, especially if the endoscopist is not the operating surgeon. If a lesion has been removed preoperatively (*ie*, polypectomy), endoscopic identification and marking of the polypectomy site with sterile India ink (or as a last resort intraoperative colonoscopy) may be necessary. It is imperative that upon removal of the operative specimen it must be opened to assure the presence of the pathologic lesion.

The issue of adequacy of lymph node dissection in operations for cancer is under review. The adequacy of lymph node harvest was studied in 66 patients in a multi-institutional study and compared with historical controls. In sigmoid and right colectomy specimens for carcinoma, there was no statistically significant difference in the number of lymph nodes removed. Similar results were seen in a study of 24 patients in which the lymph node yield from right and sigmoid colectomies was equivalent to that of open operations [1].

Recent reports indicate that the postoperative stay is significantly shorter for patients undergoing laparoscopically assisted colectomy [4,5]. In addition, though the operative times are significantly longer, there is earlier return of bowel function. Preliminary reports indicate that patients return to normal activity at an earlier date than those undergoing traditional colectomy.

The traditional "leak day" of colonic anastomoses is day 6 or 7. The vast majority of patients undergoing laparoscopic colonic resections have returned to their homes by this time. We had one patient develop a devastating leak on postoperative day 7 and now routinely have patients return to the clinic on postoperative day 7 or 8 for examination and follow-up. This is especially true of patients who do not have easy access to a phone or a local physician.

One study of cost-benefit analysis revealed no difference in hospital costs when comparing laparoscopically assisted with traditional colon resection [4]. It is significantly more expensive both in terms of operating room costs and hospital costs, however, when a laparoscopically assisted procedure is converted to an open procedure. It remains to be seen whether there is overall cost benefit from the earlier patient mobilization and return to work.

The most critical long-term issue is whether in most surgeons hands local control and survival are equivalent in open versus laparoscopic resections performed for malignancy. Intense scrutiny and long-term follow-up will be needed to answer this critical question.

Postoperative complications in several series have been comparable to those encountered in traditional colectomy. Complication rates of 13% in 24 patients with no wound or anastomotic complications have been reported by Peters and Bartels [1]. Falk and coworkers [4] reported only two (3%) major complications and 11 (28%) minor complications in a series of 39 patients. The minor complications included predominantly urinary tract infection, diarrhea, and two wound complications. A large series of 114 bowel cases sited a 7% major complication rate, including three abscesses and only two clinical anastomotic leaks. Though larger studies are needed, these complication rates are comparable to open procedures.

References

1. Peters WR, Bartels TL: Minimally invasive colectomy: are the potential benefits realized? *Dis Colon Rectum* 1993, 36:751–756.
2. Scoggin SD, Frazee RC, Snyder SK, *et al.*: Laparoscopic-assisted bowel surgery. *Dis Colon Rectum* 1993, 36:747–749.
3. Phillips EH, Franklin M, Carroll BJ, *et al.*: Laparoscopic colectomy. *Ann Surg* 1992, 216:703–707.
4. Falk PM, Beart RW Jr, Wexner SD, *et al.*: Laparoscopic colectomy: a critical appraisal. *Dis Colon Rectum* 1993, 36:28–34.
5. Monson JRT, Darzi A, Carey PD, Guillou PJ: Prospective evaluation of laparoscopic-assisted colectomy in an unselected group of patients. *Lancet* 1992, 340:831–833.

CHAPTER

19

Laparoscopic Inguinal Herniorrhaphy

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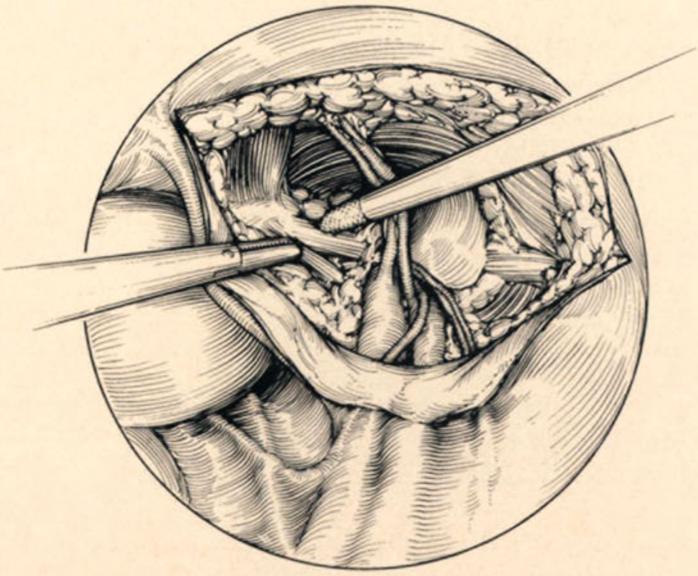
Lewis B. Schwartz
Steve Eubanks



Inguinal herniorrhaphy is an operation with a rich history, almost as old as surgery itself (Table 19-1). It is the second most common general surgical procedure performed in the United States, with over 500,000 annual cases [1]. Yet, until recently, few advances had been made in the treatment of inguinal hernia. Recurrence rates in population-based series average about 10% [2] and morbidity, including incisional pain and convalescence, continues to be significant. With the widespread acceptance of laparoscopic cholecystectomy as the preferred approach to gallbladder disease, it was, perhaps, inevitable that laparoscopic techniques would be applied to the treatment of inguinal hernia (Table 19-2). At least six conceptually different techniques have been described to date. The purpose of this chapter is to describe in detail two laparoscopic mesh repairs, the transabdominal preperitoneal (TAPP) placement, and the totally preperitoneal (TOPP) placement.

Table 19-1. The abbreviated history of hernia surgery

Year	Investigator and study	Location	Contribution
			Anatomic era
1556	Pierre Franco [35]	France	First recorded description of an operation for strangulated hernia
1756	Percival Pott [4]	England	Published treatise on hernia including the first description of the congenital nature of indirect hernias
1778	August Gottlieb Richter [36]	Germany	First description of hernia with partial enterocele ("Richter's hernia")
1793	Arbos Gimbernat [37]	Spain	Described lacunar ligament ("Gimbernat's ligament")
1804	Sir Astley Paston Cooper [38,39]	England	Described superior pubic ligament, transversalis fascia, and shutter mechanism of internal oblique and transversus abdominis
1806	Franz Caspar Hesselbach [40,41]	Germany	Described iliopubic tract and "Hesselbach's triangle"
1809	Antonio Scarpa [42,43]	Italy	Published classic treatises on cremasteric fascia ("Scarpa's fascia") and sliding hernia
			Early surgical repairs
1871	Henry O. Marcy [44,45]	Boston	Stressed importance of ligation of the hernia sac with internal ring repair as well as introduced antiseptic ligatures
1884	Edoardo Bassini [46]	Italy	Described reconstruction of the inguinal floor by approximation of the transversalis fascia and inguinal ligament ("Bassini repair")
1889	William S. Halsted [47]	Baltimore	Described reconstruction of inguinal floor with transposition of the spermatic cord ("Halsted I Procedure")
1898	Georg Lothaissen [48]	Austria	Described Cooper's ligament repair
1942	Chester B. McVay [49,50]	South Dakota	Reintroduced and popularized Cooper's ligament repair ("McVay repair")
			Preperitoneal repair
1920	Sir George Lenthal Cheatle [51]	England	Introduced preperitoneal repair
1936	Arnold Kirkpatrick Henry [52]	Chicago	Rediscovered preperitoneal repair
1960s	Lloyd Nyhus [27,29]	Seattle, Chicago	Popularized iliopubic tract preperitoneal repair
1975	Rene E. Stoppa [30,53]	Dublin, Cairo	Reported "giant prosthetic repair"
			Contemporary repairs
1969	Edwin W. Shearburn and Richard N. Myers [54]	Canada	Described continuous, multilayer repair of inguinal floor ("Shouldice repair")
1970	Irving L. Lichtenstein [55]	Los Angeles	Popularized ambulatory hernia surgery
1989	Irving L. Lichtenstein [56]	Los Angeles	Introduced "tension-free" primary mesh repair

Table 19-2. History of laparoscopic inguinal herniorrhaphy

Year	Study	Contribution
1990	Ger and coworkers [5]	Reported laparoscopic closure of indirect hernia sac in dogs
1990	Schultz and coworkers [7]	Described "plug and patch" laparoscopic inguinal herniorrhaphy
1991	Spaw and coworkers [57]	Described detailed anatomy with respect to laparoscopic approach
1991	Toy and Smoot [13]	Described intra-abdominal onlay patch technique
1992	Gazayerli [15]	Described laparoscopic "anatomic repair" and patch technique
1992	Dion and Morin [16]	Described transabdominal preperitoneal patch (TAPP) technique
1992	McKernan [31,58,59]	Described totally preperitoneal patch (TOPP) technique
1993	MacFayden and coworkers [6]	First large review of complications and results
1995	Fitzgibbons and coworkers [22]	Multicenter trial comparing TAPP, TOPP, and onlay mesh techniques

Anatomy

Figures 19-1 and 19-2 depict the anatomy of the groin.

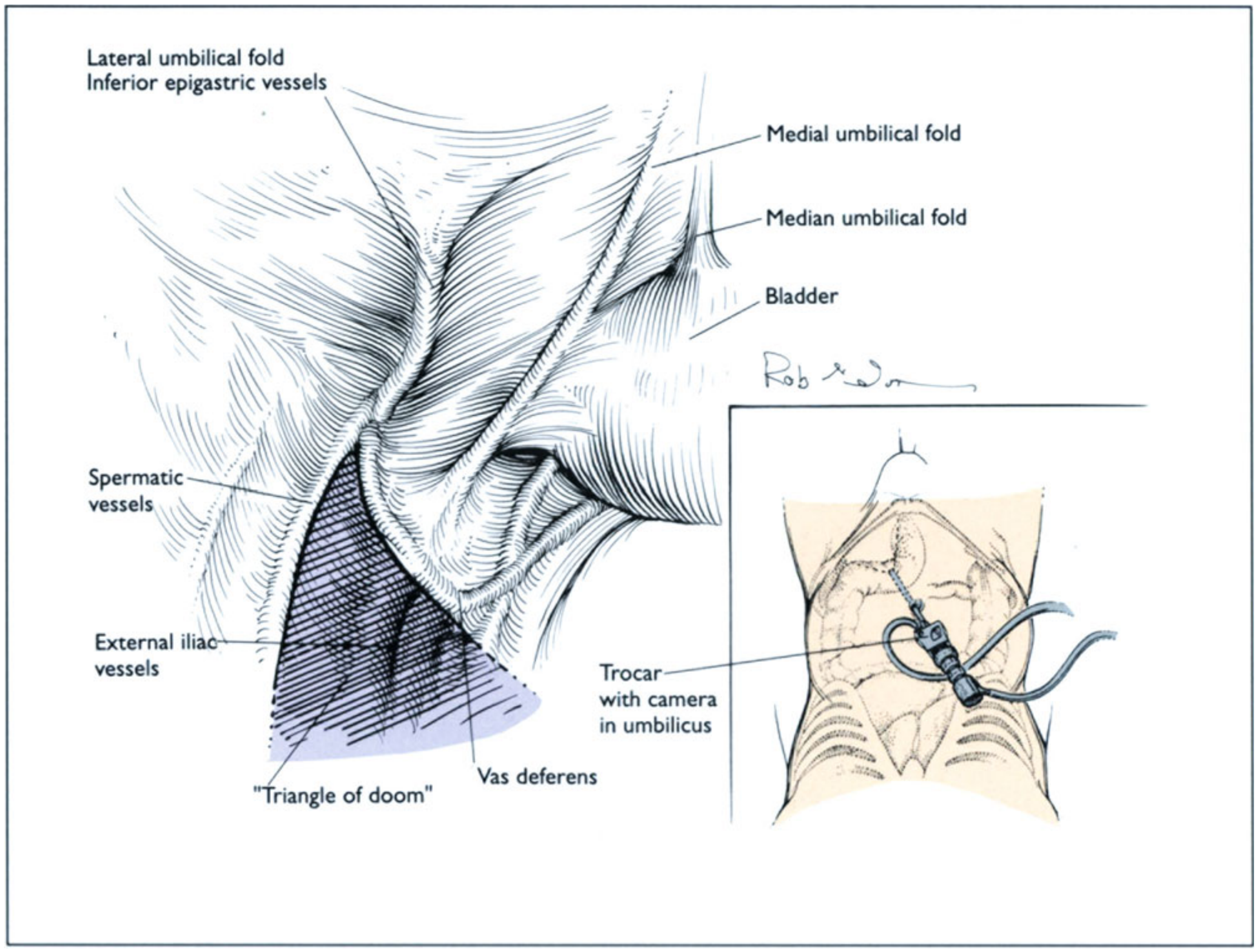


FIGURE 19-1. Laparoscopic view of the left male groin with intact peritoneum. The laparoscope offers the surgeon a new perspective on the anatomy of the groin. On initial inspection of the left male groin with the peritoneum intact, the following landmarks are identified: 1) the bladder and median umbilical fold (urachus remnant) defining the midline; 2) the medial umbilical fold; 3) the lateral umbilical fold identifying the location of the inferior epigastric vessels; 4) the spermatic vessels; and 5) the vas deferens. The so-called "triangle of doom" is bounded by the spermatic vessels and vas deferens and identifies the area under which lie the external iliac vessels and femoral nerve [3].

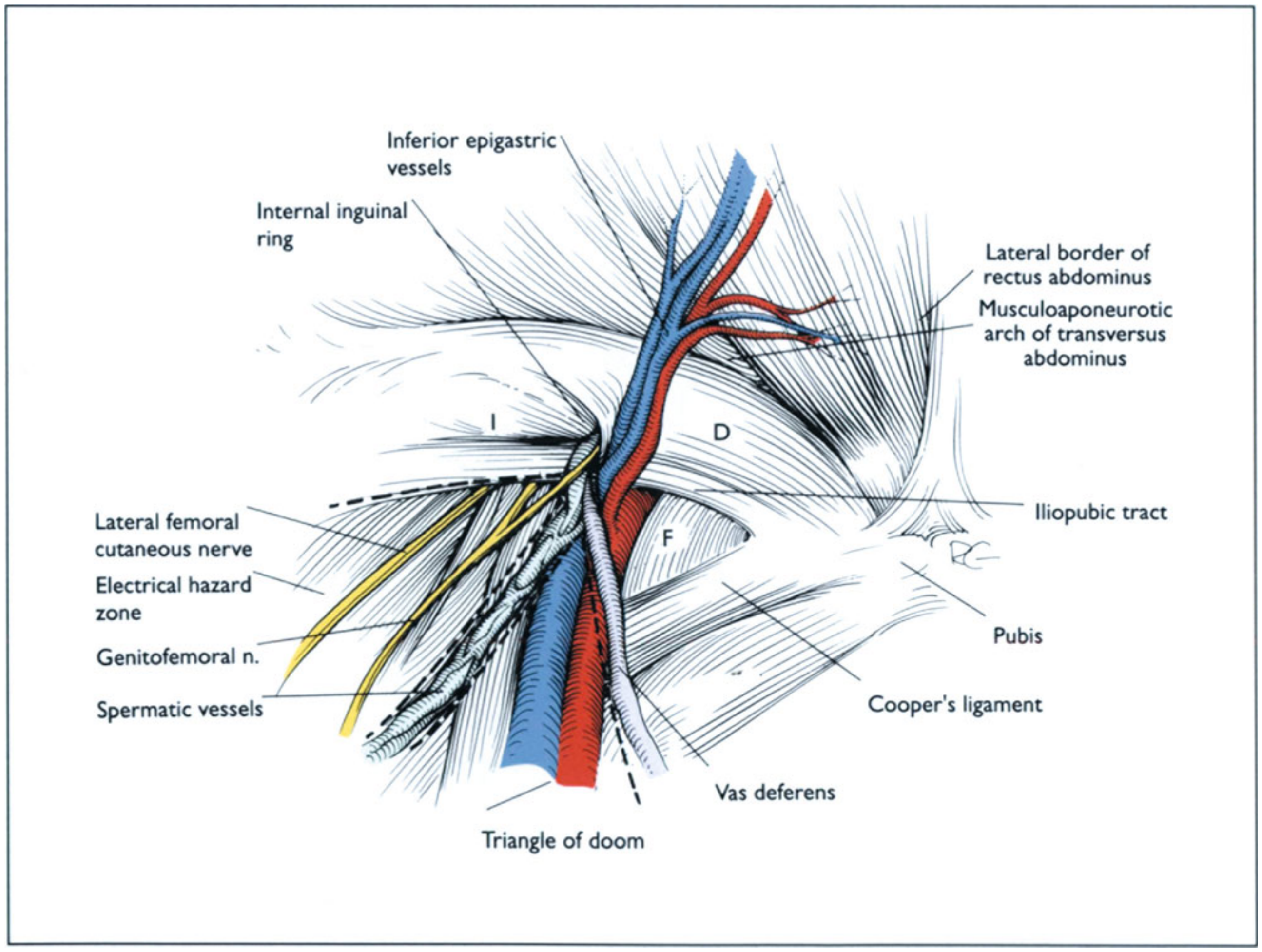


FIGURE 19-2. Laparoscopic view of the left male groin with peritoneum removed. With the peritoneum removed, the topographical anatomy is more clearly apparent. The following structures are important: 1) Cooper's ligament, pubis, lateral border of rectus abdominis, and musculoaponeurotic arch of the transversus abdominis, the structures to which mesh is affixed during hernia repair; 2) the iliopubic tract, a thickening of the transversus abdominis aponeurosis that lies immediately posterior to the inguinal ligament; 3) the inferior epigastric vessels, the last branches of the external iliac artery and vein prior to its passing beneath the inguinal ligament; 4) the spermatic vessels and vas deferens; and 5) the so-called "electrical hazard zone" that contains the lateral femoral cutaneous nerve and the genital and femoral branches of the genitofemoral nerve. The locations of the various hernia types can now be readily identified and include the indirect (*I*), direct (*D*), and femoral (*F*) variants.

Pathophysiology, Presentation, and Differential Diagnosis

The pathophysiology of groin hernia has been debated since the time of Percival Pott [4]. It now appears clear that direct hernias are a result of a primary defect in the inguinal floor, the deepest layer of abdominal fascia composed of the transversus abdominis aponeurosis and transversalis fascia. Although these hernias may arise from a congenitally high-riding aponeurotic arch or weak transversalis fascia, it is believed that most direct hernias are acquired through the normal aging process and aggravated by intermittent intra-abdominal straining as occurs with coughing, constipation, prostatic hypertrophy, and obesity.

Indirect inguinal hernias occur as a result of herniation through the internal ring through which the gonadal vessels and vas deferens course (or round ligament in females). After testicular descent during fetal development, the testes are normally covered by a rim of peritoneum (tunica albuginea) in continuity with the abdomen proper via the processus vaginalis. Normally, the processus vaginalis involutes separating the peritoneum from the scrotum. An indirect hernia will result if the processus vaginalis remains patent and, with increased intra-abdominal pressure, slips through the internal inguinal ring and enters the scrotum. Therefore, most internal inguinal hernias are felt to be congenital in origin.

Femoral hernias arise from defects in the floor beneath the inguinal ligament alongside the femoral vessels and should therefore be classified separately from direct and indirect hernias. Their pathogenesis is probably similar to the direct variant and involves weakness of the reflected fibers of the iliopubic tract where the femoral vessels penetrate the fascia.

Inguinal hernias usually present as an intermittent or persistent bulge with or without localized pain. These complaints are often precipitated or exacerbated by standing or physical activity. The complete history should include a discussion of contributing factors such as chronic obstructive pulmonary disease, constipation or other forms of low-grade bowel obstruction, bladder outlet obstruction, and cirrhosis with ascites. Alleviation of these conditions will be important to ensure the durability of the repair.

Physical examination will usually reveal the diagnosis. The patient should be examined initially while standing and then supine. The groin is visually inspected for a mass. The testes and spermatic cord are inspected and palpated in order to reveal the presence of herniated viscera and/or tenderness. The inguinal floor is palpated during Valsalva in order to identify a direct component. Elicitation of pain on straining suggests the diagnosis but is not confirmatory. Many conditions cause pain and/or a mass in the groin and should be investigated if the symptoms or findings are atypical (Table 19-3). In selected cases, exploration may be performed in the absence of physical findings when the history is strongly suggestive.

Surgical Technique

At least six conceptually different approaches to the laparoscopic repair of inguinal hernia have been reported. The initial method involved simple clip plication of the indirect hernia sac and internal ring. Results in an experimental model were first reported by Ger and colleagues [5] in 1990 and early clinical experience was described as part of a multi-institutional review in 1993 [6]. This technique did not include a floor repair and its application in adults has been limited.

The second approach, the "plug and patch" technique, was first described by Schultz and colleagues [7] in 1990 and subsequently by a number of other clinicians [8–11]. Although each author's method varies slightly, all include placement of one or more mesh plugs (usually polypropylene) directly into the hernia followed by coverage of the orifice with one or more mesh patches. Because of the fairly high early recurrence rate (approximately 7% after 8 months) [6], occasional plug migration, and plug-related pain, this technique has largely been abandoned.

The third method involves the intra-abdominal placement of an onlay polytetrafluoroethylene (PTFE) patch over the deep ring and inguinal floor without peritoneal dissection and was first described by Toy and Smoot [12,13] in 1991. This technique has the advantage of simplicity and short operative time, but it is believed that its limited identification of detailed groin anatomy will lead to a high early recurrence rate and intraperitoneal mesh placement may cause adhesive complications [14]. Various modifications of this method are still in use.

The fourth method or "anatomic repair" consists of floor repair via laparoscopic suturing and reinforcement with mesh and was first described by Gazayerli [15] in 1992. Although theoretically attractive, the procedure is technically difficult and has not gained widespread acceptance.

The most widely used technique as of this writing is the laparoscopic TAPP placement of prosthetic mesh first

Table 19-3. Differential diagnosis of inguinal hernia

Hydrocele (communicating or noncommunicating)	Epididymitis
Varicocele	Epidermal cyst
Cord lipoma	Hidradenitis suppurativa
Musculoskeletal pain ("groin pull")	Perirectal abscess
Athletic pubalgia	Gastroenteritis
Urinary tract infection	Diverticulitis
Prostatitis	Intra-abdominal abscess
Femoral aneurysm or pseudoaneurysm	Colorectal carcinoma
Inguinal adenopathy	Tubal pregnancy
Hematoma/seroma from previous exploration	Pelvic inflammatory disease
Appendicitis	Psoas abscess
Testicular carcinoma	Rectus sheath hematoma
	Ovarian torsion

described by Dion and Morin [16] in 1992 and preferred by a number of institutions including our own [6,17–22]. This procedure is the laparoscopic equivalent of the open anterior preperitoneal mesh repair described extensively by Nyhus [23–29]. The results with open preperitoneal mesh repair over the past two decades have been excellent, with recurrence rates in large series ranging from 1.4% to 1.7% [23,30]. Furthermore, these experiences have revealed that the often talked about risk of mesh infection and/or migration is rare (<1%). Thus, these studies appear to provide a precedent for the laparoscopic preperitoneal repair.

Finally, the sixth approach, the extraperitoneal or TOPP placement of mesh, was first described by McKernan and Laws [31] in 1992 and, more recently, by other groups [32–34]. It is essentially identical to the TAPP procedure with the exception that the procedure is performed entirely in the preperitoneal space and with the theoretical advantage of not entering the peritoneum proper. Because these last two methods, the TAPP and TOPP, have become the most routinely performed laparoscopic repairs, their detailed descriptions follow.

Figures 19-3 through 19-23 depict the surgical technique for inguinal herniorrhaphy.

Set-up

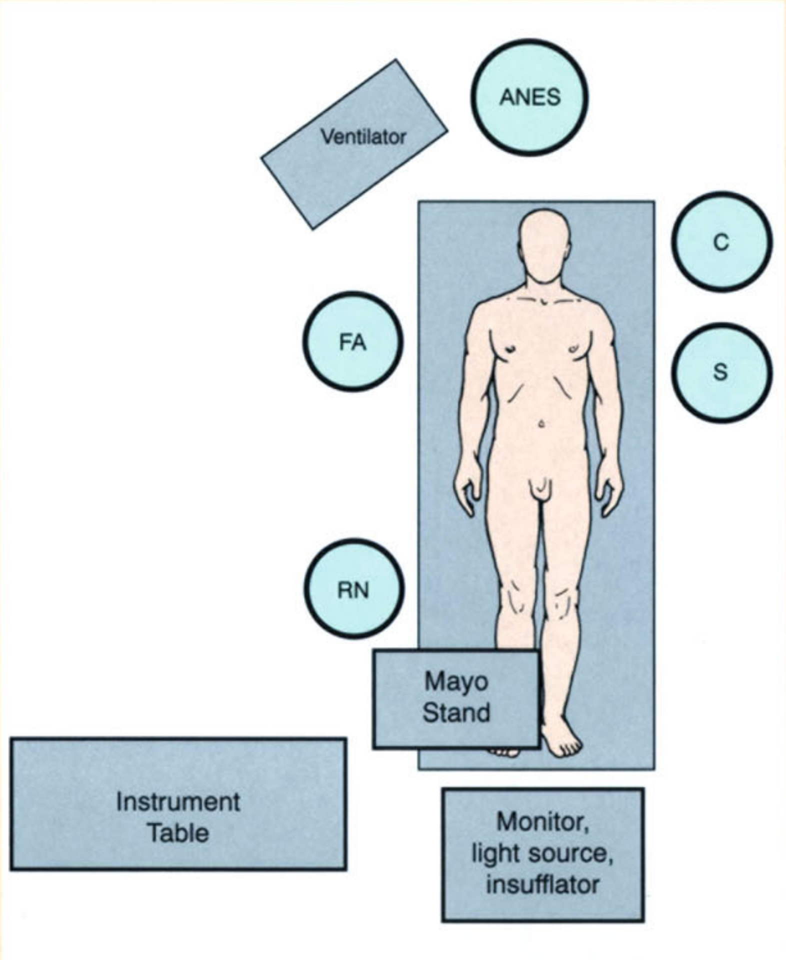


FIGURE 19-3.
Operative set-up for laparoscopic right inguinal herniorrhaphy. A single dose of antibiotic is administered preoperatively. General anesthesia is preferred for comfort during pneumoperitoneum, although spinal anesthesia and the use of an abdominal wall lifting device (Laprolift; Origin Medsystems, Menlo Park, CA) can be utilized. Urinary and orogastric catheters are placed for decompression. The arms are tucked. Both the camera operator (C) and operating surgeon (S) stand opposite the hernia side while the optional first assistant (FA) stands on the ipsilateral side (the camera may also be operated by the FA if desirable). This sidedness is a matter of personal preference, however, and there is no need to switch positions to repair the second side of a bilateral hernia. Only one video monitor is required and it should be placed at the foot.

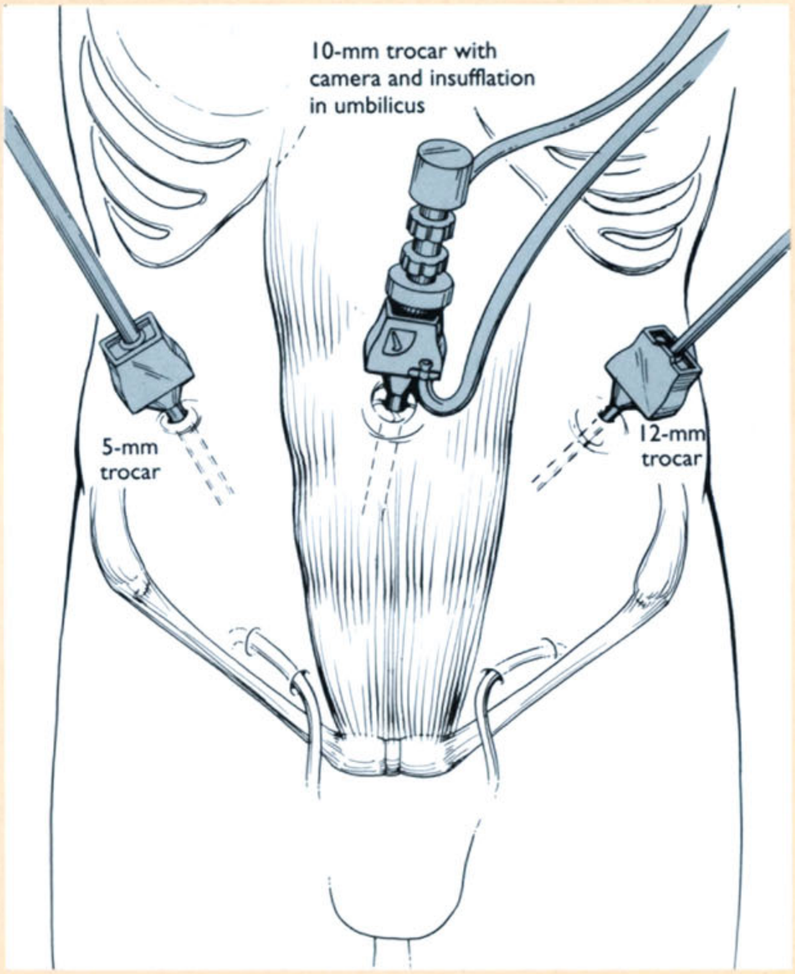


FIGURE 19-4.
Trocar and sheath placement for laparoscopic right inguinal herniorrhaphy. Three trocars are used although additional trocars may be inserted if the dissection is difficult. The camera is placed via a 10-mm midline sheath at the umbilicus. A 5-mm trocar is placed on the hernia side and a 12-mm trocar on the contralateral side, both lateral to the rectus at the level of the umbilicus. Care is taken to avoid the epigastric vessels. Obviously the 5/12-mm trocar combination should be converted to 12/12 mm if bilateral herniorrhaphy is planned.

Set-up

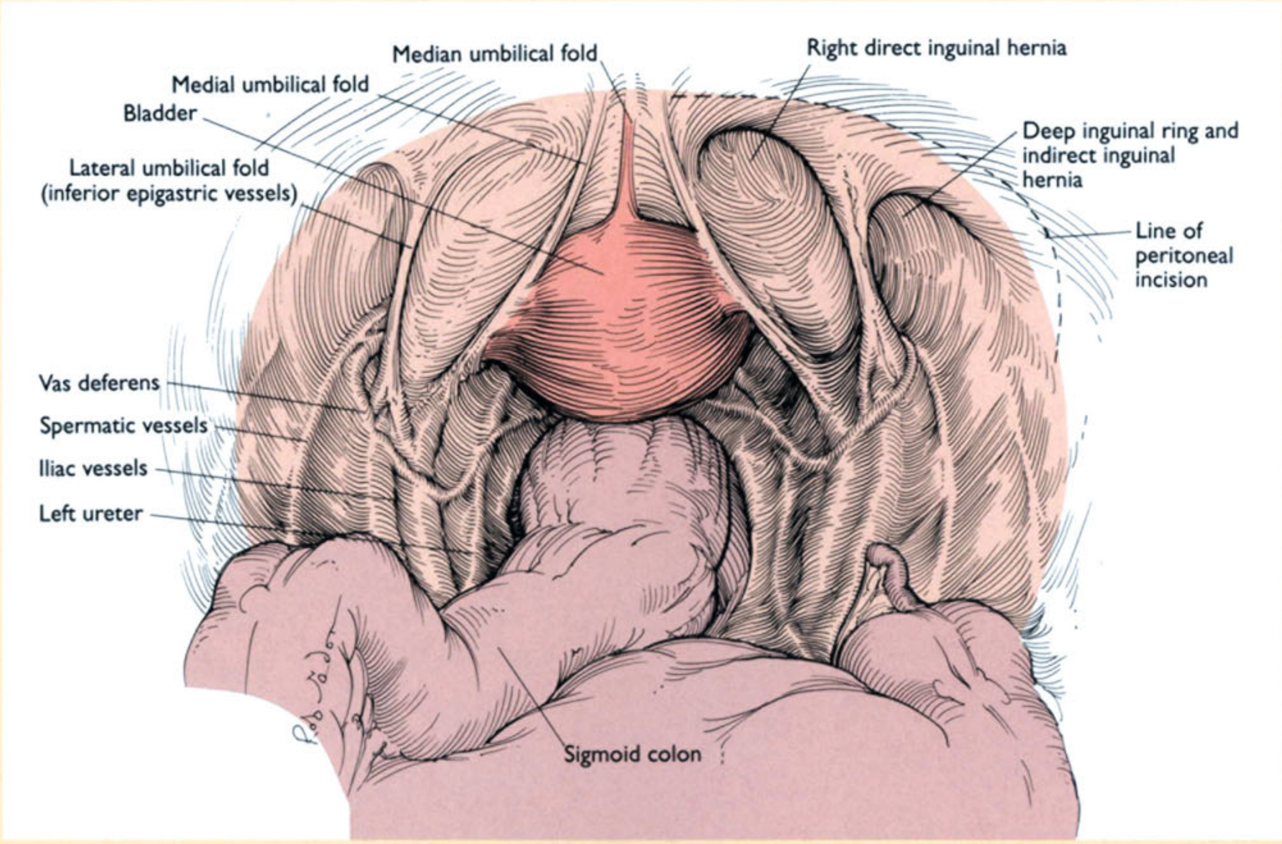


FIGURE 19-5.

Initial view after laparoscopic insertion. The following structures should be identified: median and medial umbilical folds, bladder, lateral umbilical fold (overlying epigastric vessels), vas deferens, spermatic vessels, iliac vessels, direct and indirect inguinal hernias. The *dashed line* represents the planned peritoneal incision.

Procedure

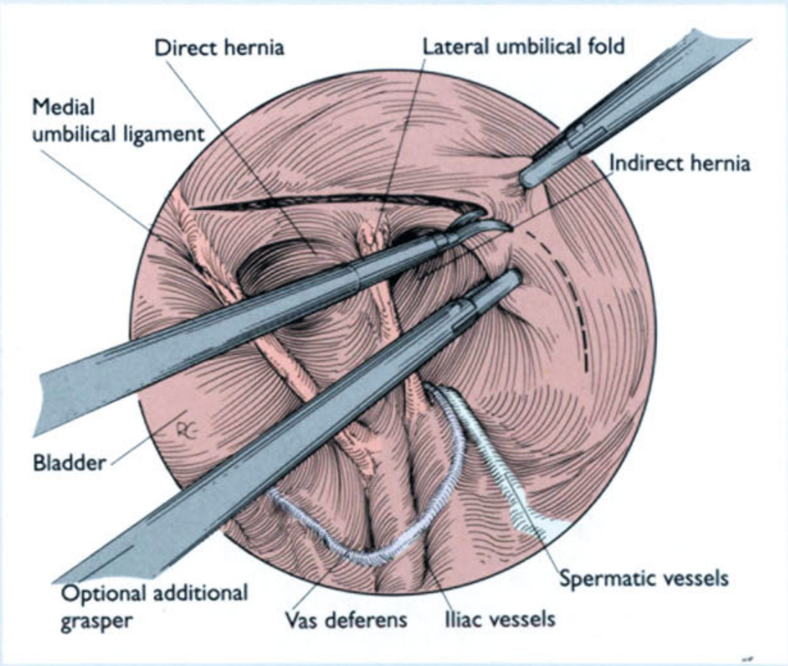


FIGURE 19-6.

Incision of peritoneum. The incision is begun at, but not medial to, the medial umbilical fold, and extended laterally past the lateral umbilical fold on the arch of the transversus abdominis toward the anterior superior iliac spine.

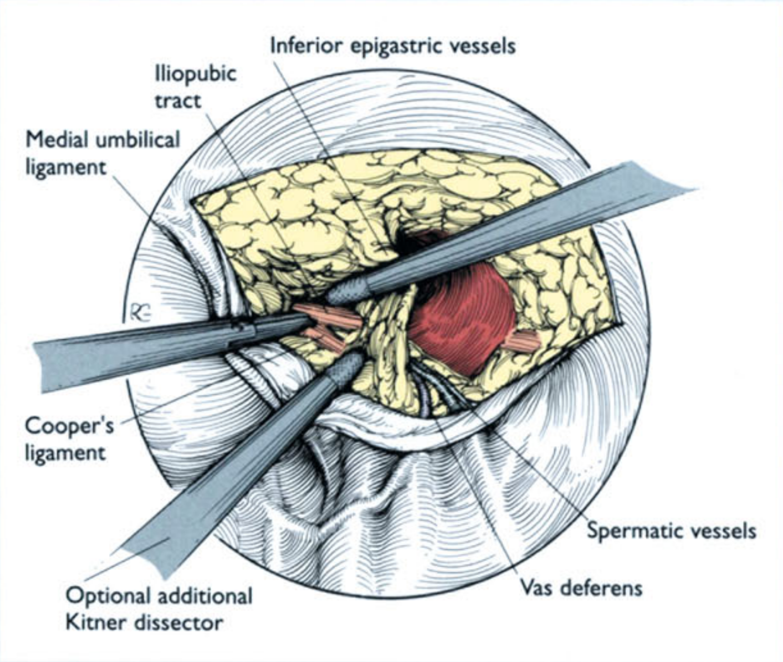


FIGURE 19-7.
Dissection of the inguinal floor. Following peritoneal incision and reduction of the hernia sacs, further dissection is required to mobilize the peritoneal flap and identify the floor and relevant structures. Most, if not all, of this dissection should be performed bluntly. As in open herniorrhaphy, the cord should be skeletonized in order to completely identify and reduce any indirect component. Cooper's ligament should be cleaned of its overlying preperitoneal fat for complete identification. Laterally, the dissection is continued along the musculoaponeurotic arch of the transversus abdominis to the level of the anterior superior iliac spine. Occasionally, the dissection of the hernia sacs and related structures may be facilitated by external manipulation.

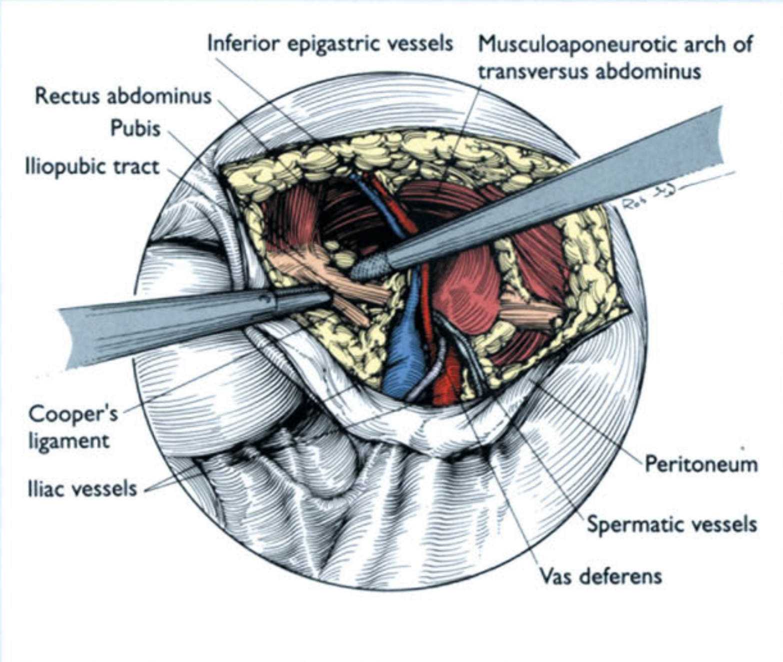


FIGURE 19-8.
Completed dissection of the inguinal floor prior to mesh insertion. Note the complete dissection of pubis and Cooper's ligament as well as musculoaponeurotic arch of transversus abdominis a full 2 cm above and lateral to the internal inguinal ring.

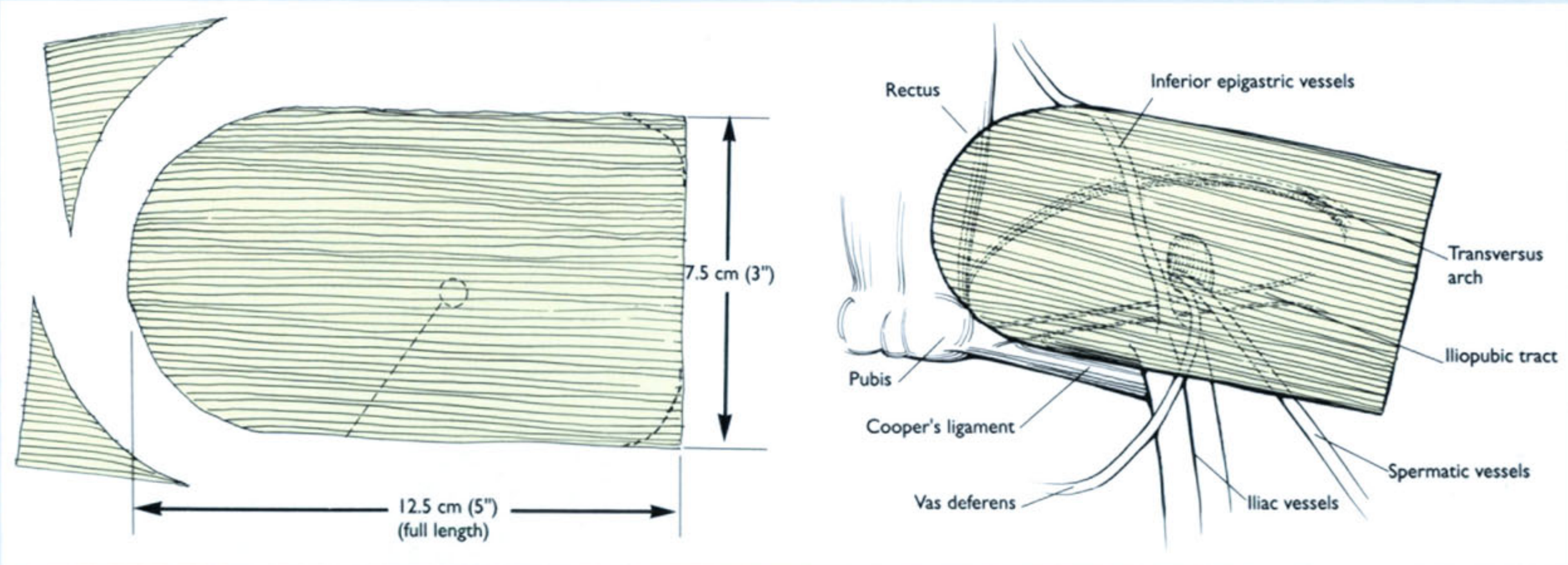


FIGURE 19-9.
Preparation of mesh. A 3 X 5 inch (7.6 X 12.7 cm) size polypropylene mesh is delivered to the field and modified as shown. The only required modification is rounding of the medial corners to facilitate positioning. Rounding of the lateral corners and/or creation of a "buttonhole" for the cord structures are optional modifications (*dashed lines*).

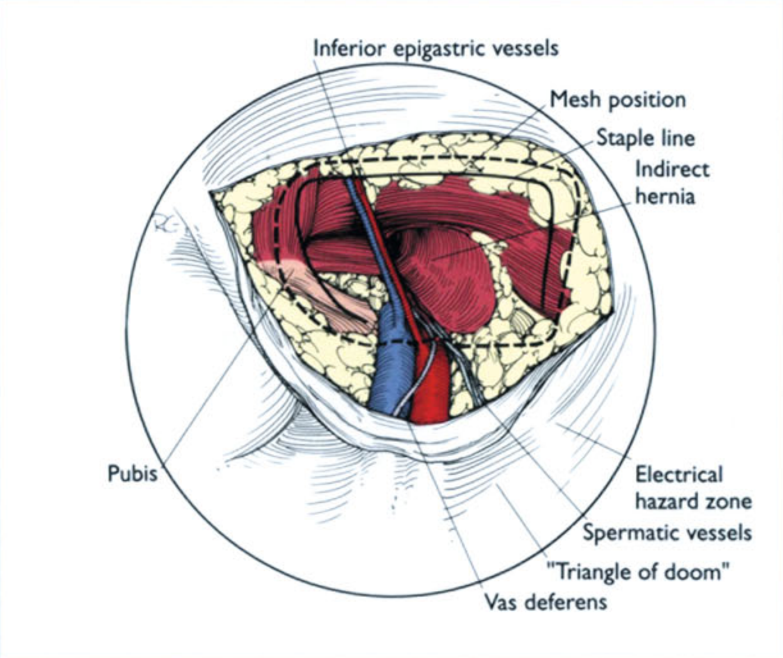


FIGURE 19-10.

Planned location of mesh and staple line. The mesh will cover the defects of any or all of direct, indirect, and femoral hernias. The staple line courses counterclockwise from the 7 o'clock to the 4 o'clock position on the mesh. Leaving the inferolateral portion of the mesh unstapled avoids injury to the triangle of doom and electrical hazard zone.

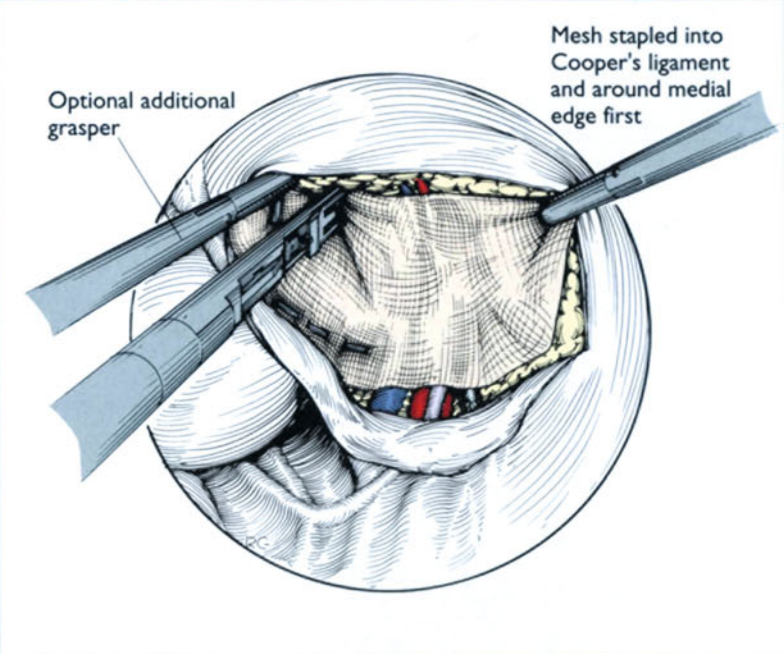


FIGURE 19-11.

Fixation of mesh to inguinal floor. The mesh is rolled from squared edge to rounded edge, delivered through the 12-mm sheath, placed near Cooper's ligament, and unrolled laterally. Stapling is begun medially using an endoscopic stapling device (Multifire Endohernia Stapler; Autosuture, Norwalk, CT). The usual progression of stapling is counterclockwise: Cooper's ligament, pubis, lateral edge of rectus, medial musculoaponeurotic arch, and lateral musculoaponeurotic arch. As the mesh covers the epigastric vessels, care must be exercised to avoid their injury during stapling.

FIGURE 19-12.

Endoscopic stapling. Stapling of the mesh is facilitated by hooking the mesh with one spike of a partially delivered staple, delivering the mesh to the desired location, applying adequate pressure, and firing.

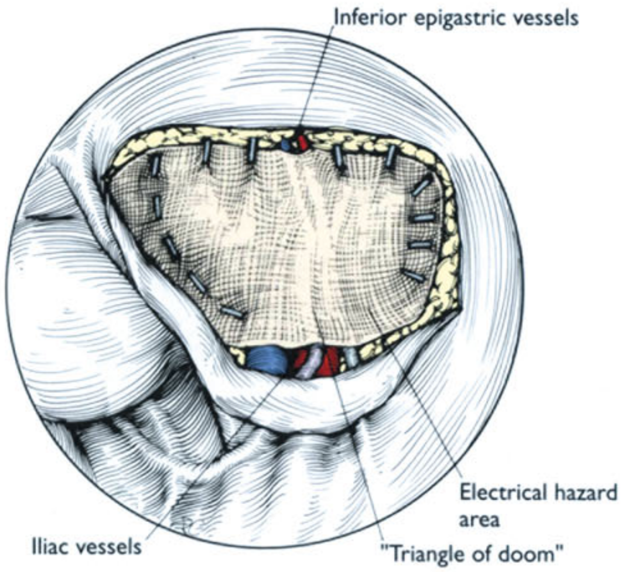


FIGURE 19-13.

Completed hernia repair. Note the absence of staples inferolaterally in the area of the triangle of doom and electrical hazard zone.

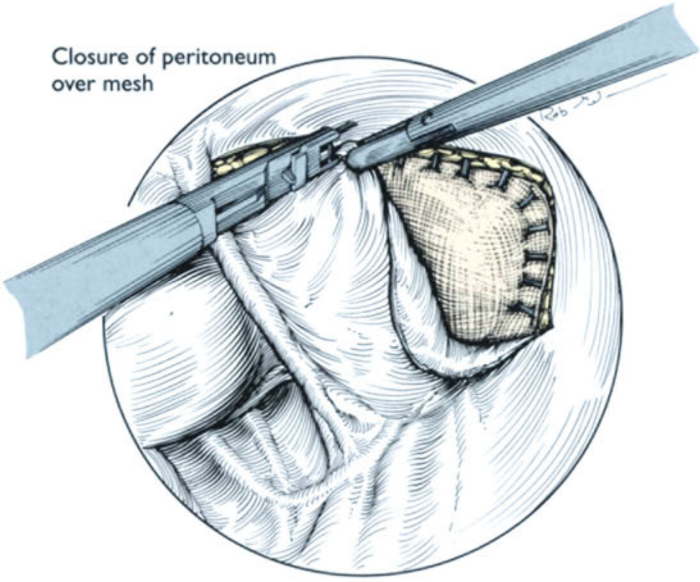


FIGURE 19-14.

Closure of the peritoneal flap. Following irrigation and checks for hemostasis, the peritoneum is closed over the mesh with staples. Approximately eight staples are required. For bilateral repairs, this is obviously deferred until completion of both repairs.

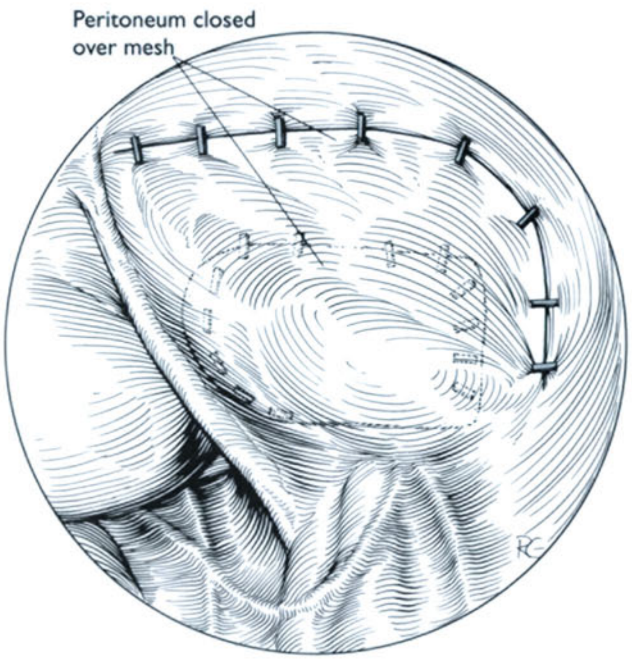


FIGURE 19-15.

Completed peritoneal flap closure.

Alternative Procedure

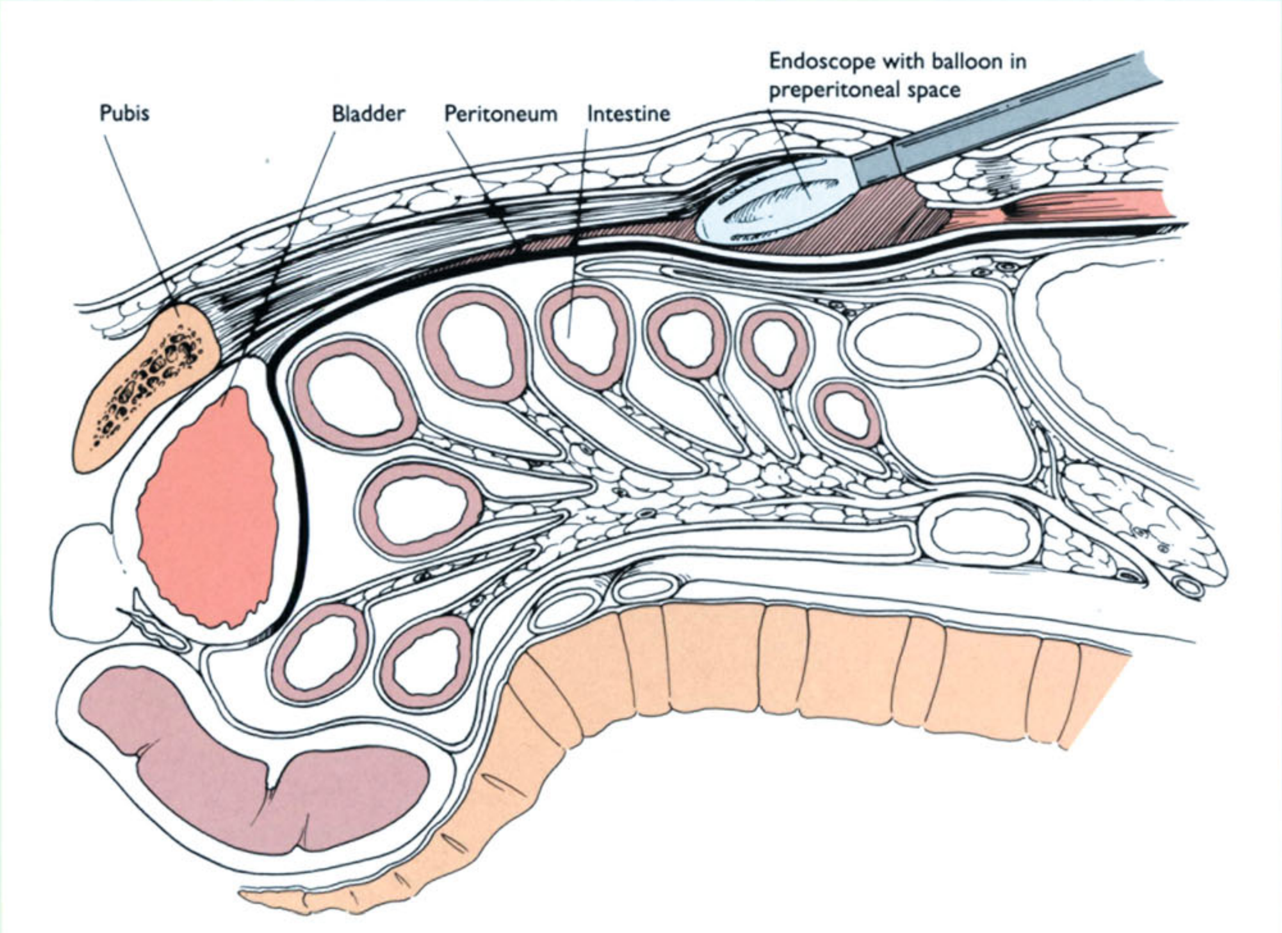


FIGURE 19-16.
Alternative technique: the totally preperitoneal (TOPP) placement repair. Some surgeons have advocated laparoscopic inguinal herniorrhaphy performed entirely within the preperitoneal space without entrance into the peritoneum. A specially designed laparoscope–cannula system with a blunt tip and inflatable balloon device (Origin Medsystems, Inc., Menlo Park, CA; and General Surgical Innovations, Portola Valley, CA) is inserted preperitoneally in the midline at the umbilicus as seen in this sagittal section.

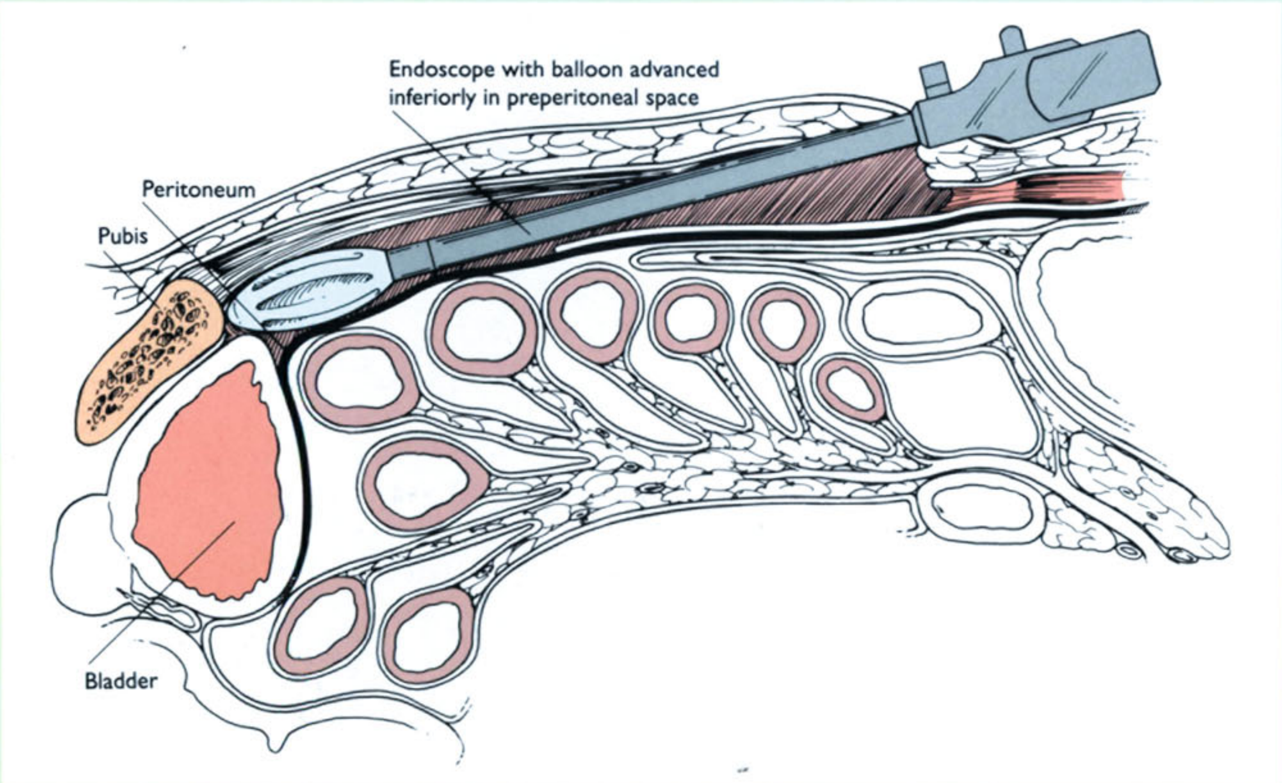


FIGURE 19-17.
Advancement of the blunt tip to the pubis. The blunt tip trocar is advanced in the preperitoneal space to the level of the pubis.

Alternative Procedure

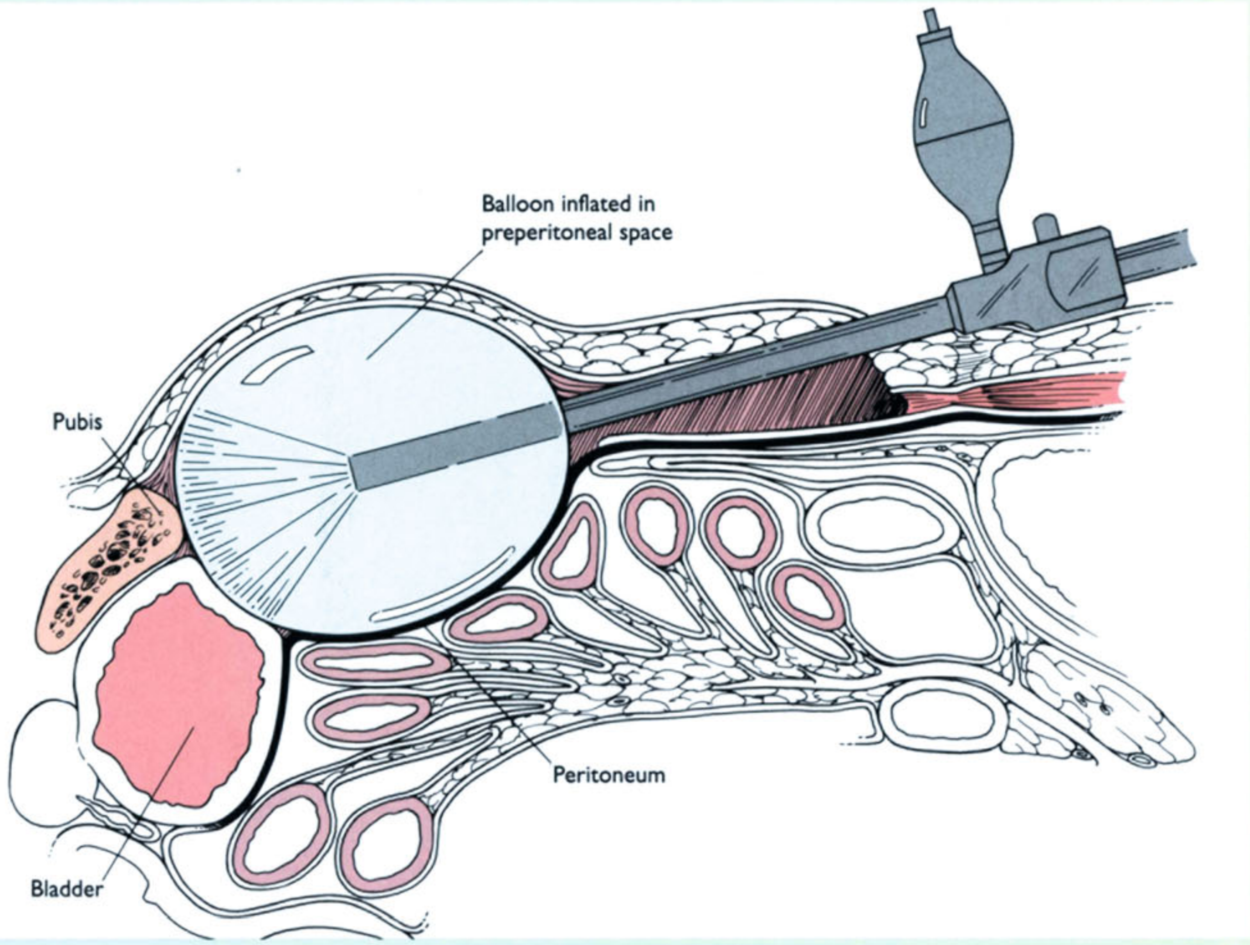


FIGURE 19-18.
Inflation of the preperitoneal balloon. Under laparoscopic visualization, the balloon is insufflated with air, creating an operative field from the potential preperitoneal space.

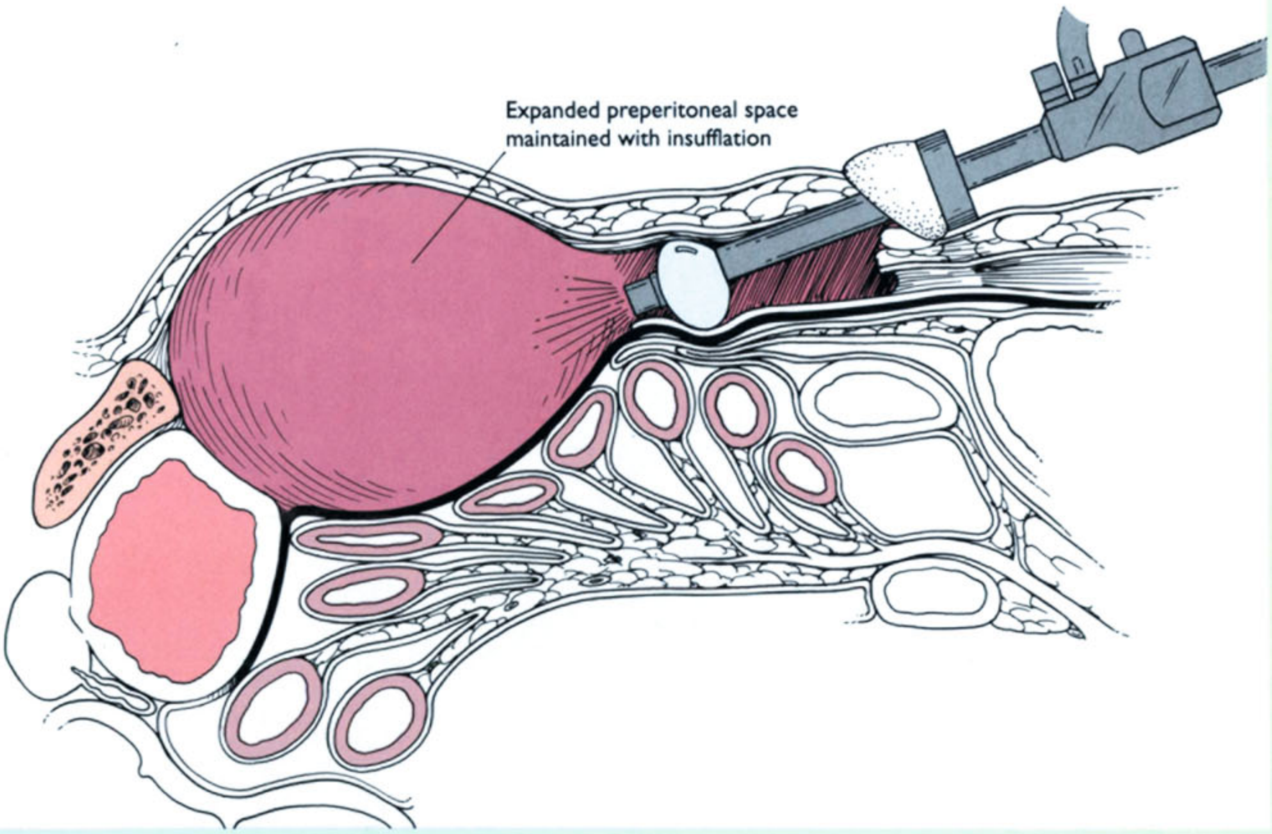


FIGURE 19-19.
The preperitoneal operative field. Deflation of the balloon and exchange of trocars leaving an operative field for herniorrhaphy.

Alternative Procedure

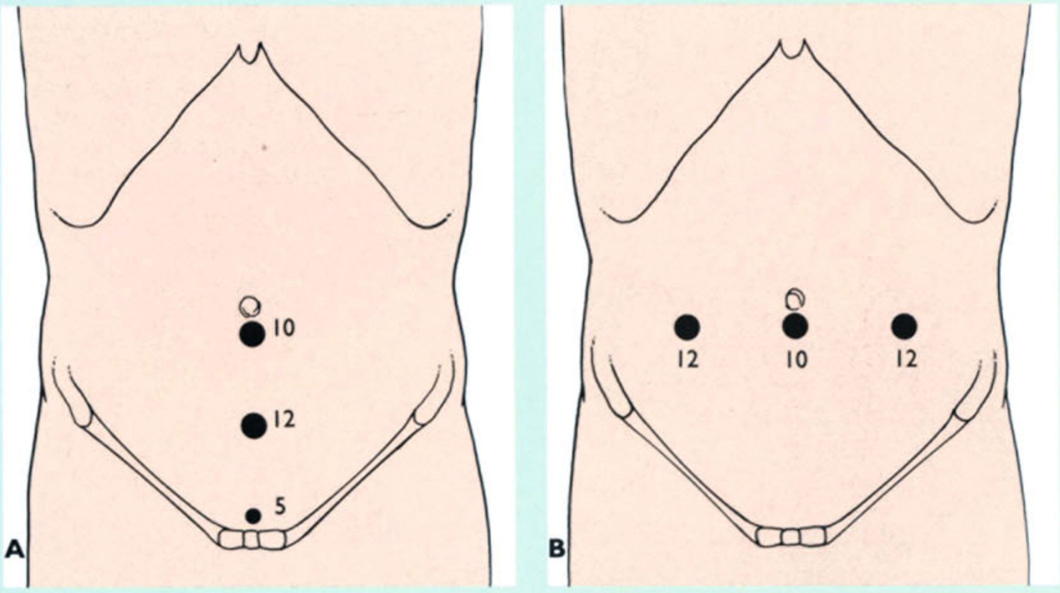


FIGURE 19-20.
Trocar placement. **A** and **B**, The remaining trocars can be placed in two configurations as shown. The authors prefer configuration B, if possible, although this can only be accomplished with favorable anatomy and the creation of a large preperitoneal operative field.

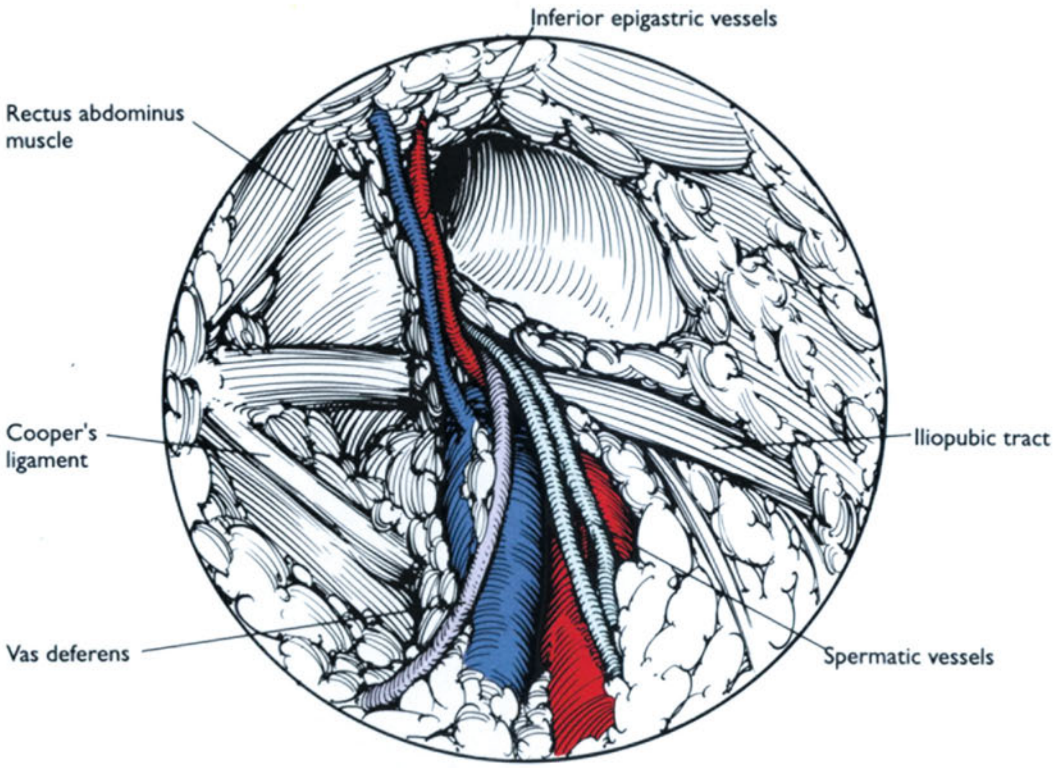


FIGURE 19-21.
The operative field. After additional trocar placement and blunt dissection, the operative field should be identical to that seen with trans-abdominal approach.

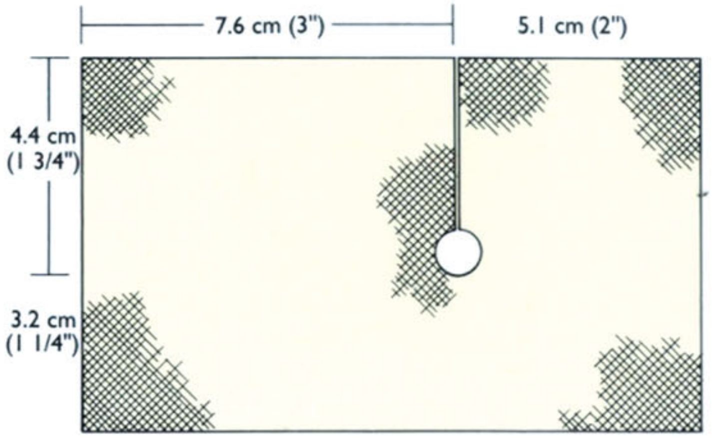


FIGURE 19-22.
Preparation of the mesh. The mesh is delivered to the field and prepared as shown. For this approach, it is helpful to create a buttonhole for the spermatic cord to traverse since there is limited operative space inferiorly.

Alternative Procedure

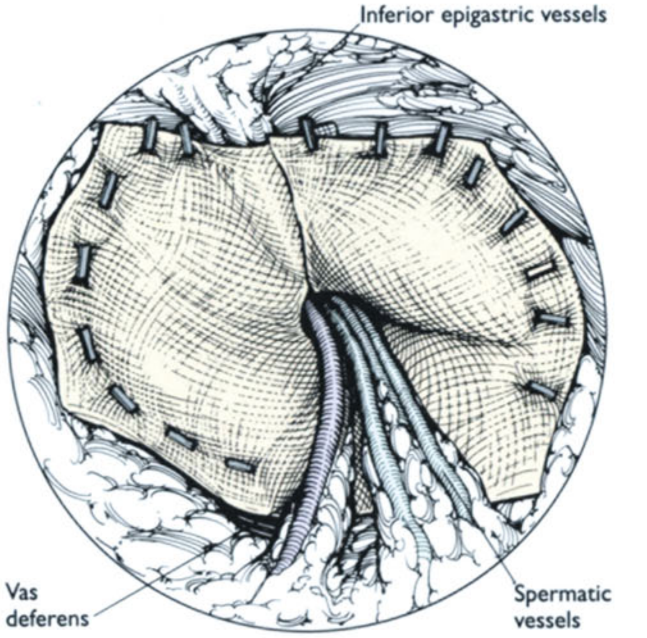


FIGURE 19-23.

Completed repair. The position of the mesh is identical to the transabdominal preperitoneal (TAPP) placement approach.

Results

Most patients undergoing laparoscopic inguinal herniorrhaphy can do so on an outpatient basis and return to full activity in 7 to 10 days. There is minimal discomfort and narcotics are often avoided. Although lengthy follow-up for this new procedure is not available, the initial experience with laparoscopic inguinal herniorrhaphy has been encouraging. The results of a multicenter trial describing repair of 869 hernias using either the TAPP, TOPP, or onlay mesh technique yielded an overall recurrence rate of 4.5% with minimum follow-up of 15 months [22]. Major and minor complications related to laparoscopy (bleeding, abdominal wall hematomas, bowel/bladder injury) occurred in 5.4%, and patient complications (urinary retention, ileus, pneumonia, adhesions) occurred in 6.7%. There was one mortality (0.1%) from postoperative myocardial infarction. In summary, laparoscopic inguinal herniorrhaphy is a safe and effective procedure. Establishment of its superiority over contemporary open techniques awaits further controlled comparison.

References

1. Vayda E, Mindell WR, Rutkow IM: A decade of surgery in Canada, England, and the United States. *Arch Surg* 1982, 117:846–853.
2. Rand Corp.: Conceptualization and measurement of physiologic health for adults. Santa Monica: RAND Corp; 1983:3–120.
3. Colborn GL, Brick WG, Gadacz TR, Skandalakis JE: Inguinal anatomy for laparoscopic herniorrhaphy, part I: the normal anatomy. *Surg Rounds* 1995, May:189–198.
4. Pott PA, ed.: *A Treatise on Ruptures.* London: C. Hitch and L. Hawes; 1756.
5. Ger R, Monroe K, Duvivier R, Mishrick A: Management of indirect inguinal hernias by laparoscopic closure of the neck of the sac. *Am J Surg* 1990, 159:370–373.
6. MacFayden BV Jr, Arregui ME, Corbitt JD Jr, *et al.*: Complications of laparoscopic herniorrhaphy. *Surg Endosc* 1993, 7:155–158.
7. Schultz L, Graber J, Pietrafitta J, Hickok D: Laser laparoscopic herniorrhaphy: a clinical trial preliminary results. *J Laparoendosc Surg* 1990, 1:41–45.
8. Hawasli A: Laparoscopic inguinal herniorrhaphy: classification and 1 year experience. *J Laparoendosc Surg* 1992, 2:137–143.
9. Nolen M, Melichar R, Jennings WC, McGee JM: Use of a Marlex fan in the repair of direct and indirect hernias by laparoscopy. *J Laparoendosc Surg* 1992, 2:61–64.
10. Hawasli A: Laparoscopic inguinal herniorrhaphy: the mushroom plug repair. *Surg Laparosc Endosc* 1992, 2:111–116.
11. Seid AS, Deutsch H, Jacobson A: Laparoscopic herniorrhaphy. *Surg Laparosc Endosc* 1992, 2:59–60.
12. Toy FK, Smoot RT Jr: Laparoscopic hernioplasty update. *J Laparoendosc Surg* 1992, 2:197–205.
13. Toy FK, Smoot RT Jr: Toy-Smoot laparoscopic hernioplasty. *Surg Laparosc Endosc* 1991, 1:151–155.
14. Fitzgibbons RJ Jr, Salerno GM, Filipi CJ, *et al.*: A laparoscopic intraperitoneal onlay mesh technique for the repair of an indirect inguinal hernia. *Ann Surg* 1994, 219:144–156.
15. Gazayerli MM: Anatomical laparoscopic hernia repair of direct or indirect inguinal hernias using the transversalis fascia and iliopubic tract. *Surg Laparosc Endosc* 1992, 2:49—52.
16. Dion YM, Morin J: Laparoscopic inguinal herniorrhaphy. *Can J Surg* 1992; 35:209–212.
17. Winchester DJ, Dawes LG, Modelski DD, *et al.*: Laparoscopic inguinal hernia repair. A preliminary experience. *Arch Surg* 1993, 128:781–784.
18. Stoker DL, Spiegelhalter DJ, Singh R, Wellwood JM: Laparoscopic versus open inguinal hernia repair: randomized prospective trial. *Lancet* 1994, 343:1243–1245.

19. Soper NJ, Brunt LM, Kerbl K: Laparoscopic general surgery. *N Engl J Med* 1994, 330:409–419.
20. Dion YM: Laparoscopic inguinal herniorrhaphy: an individualized approach. *Surg Laparosc Endosc* 1993, 3:451–455.
21. Corbitt JD Jr: Transabdominal preperitoneal herniorrhaphy. *Surg Laparosc Endosc* 1993, 3:328–332.
22. Fitzgibbons RJ, Camps J, Coronet DA, *et al.*: Laparoscopic inguinal herniorrhaphy: results of a multicenter trial. *Ann Surg* 1995, 221:3–13.
23. Nyhus LM, Pollak R, Bombeck CT, Donahue PE: The preperitoneal approach and prosthetic buttress repair for recurrent hernia: the evolution of a technique. *Ann Surg* 1988, 208:733–737.
24. Nyhus LM, Klein MS, Rogers FB: Inguinal hernia. *Curr Probl Surg* 1991, 28:401–450.
25. Nyhus LM: Iliopubic tract repair of inguinal and femoral hernia: the posterior (preperitoneal) approach. *Surg Clin North Am* 1993, 73:487–499.
26. Nyhus LM, Klein MS, Rogers FB, Kowalczyk S: Inguinal hernia repairs: types, patient care. *Association of Operating Room Nurses Journal* 1990, 52:292–304.
27. Nyhus LM, Couden RE, Harkins HN: Clinical experiences with preperitoneal hernial repair for all types of hernia of the groin. *Am J Surg* 1960, 100:234.
28. Nyhus LM: The recurrent groin hernia: therapeutic solutions. *World J Surg* 1989, 13:541–544.
29. Nyhus LM: An anatomical reappraisal of the posterior inguinal wall: special consideration of the iliopubic tract and its relation to groin hernia. *Surg Clin North Am* 1964, 44:1305–1312.
30. Stoppa RE, Warlaumont CR: The preperitoneal approach and prosthetic repair of groin hernia. In *Hernia*, 3rd ed. Edited by Nyhus LM, Condon RE. Philadelphia: J.B. Lippincott; 1989:199.
31. McKernan JB, Laws HL: Laparoscopic preperitoneal prosthetic repair of inguinal hernias. *Surg Rounds* 1992, July:597–607.
32. Fromont G, Leroy J: Laparoskopischer Leistenhernienerschluss durch subperitoneale Protheseneinlage (Operation nach Stoppa) [in German]. (Laparoscopic repair of inguinal hernia by subperitoneal prosthesis implantation [Stoppa operation]). *Chirurg* 1993, 64:338–340.
33. Ferzli GS, Massad A, Albert P: Extraperitoneal endoscopic inguinal hernia repair. *J Laparoendosc Surg* 1992, 2:281–286.
34. Voeller GR, Mangiante EC Jr, Wilson C: Totally preperitoneal laparoscopic inguinal herniorrhaphy using balloon dissection. *Surg Rounds* 1995, March:107–112.
35. Franco P, ed.: *Petit Traitée Contenant une des Parties Principalles de Chirurgie, Laquelle les Chirurgiens Herniéeres Excercent* [in French]. Lyon: Antoine Vincent; 1556.
36. Richter AG, ed.: *Abhandlung von den Brüuchen* [in German]. Göttingen: J.C. Dieterich; 1778.
37. Gimbernat A, ed.: *Nuevo Méetodo de Operar en la Hernia Crural* [in Spanish]. Madrid: vda. Ibarra; 1793.
38. Cooper AP, ed.: *The Anatomy and Surgical Treatment of Inguinal and Congenital Hernia.* London: Cox; 1804.
39. Cooper AP, ed.: *The Anatomy and Surgical Treatment of Crural and Umbilical Hernia.* London: Longman; 1807.
40. Hesselbach FK, ed.: *Nueste anatomisch-pathologische Untersuchungen über den Ursprung und das Fortschreiten der Leisten-und Schenkel-br\üche* [in German]. Würzburg:Baumgärtner; 1814.
41. Hesselbach FK, ed.: *Anatomisch-Chirurgische Abhandlung über den Ursprung der Leistenbrüche* [in German]. Würzburg: Baumgärtner; 1806.
42. Scarpa A, ed.: *Sull'ernia del revineo.* Pavia: P. Bizzoni; 1821.
43. Scarpa A: *A Treatise on Hernia.* Translated by John Henry Wishart. Edinburgh: Longman, Hurst, Rees *et al*; 1814.
44. Marcy HO: A new use of carbolized catgut ligatures. *Boston Med Surg J* 1871, 85:315.
45. Marcy HO: The radical cure of hernia by the antiseptic use of the carbolized catgut ligature. *Trans Am Med Assoc* 1878, 29:295–305.
46. Bassini E: Nuovo metodo per la cura radicale dell'ernia. *Atti Cong Assoc Med Ital* 1889, 2:179.
47. Halsted WS: The radical cure of hernia. *Bull Johns Hopkins Hosp* 1889, 1:12.
48. Lothaissen G. Zur radikaloperation der schenkelhernien. *Zentralbl Chir* 1898, 25:548.
49. Anson BJ, McVay CB: The anatomy of the inguinal and hypogastric regions of the abdominal wall. *Anat Rec* 1938, 70:211–225.
50. McVay CB: Inguinal and femoral hernioplasty: anatomic repair. *Arch Surg* 1948, 57:524–530.
51. Cheatle GI: An operation for the radical cure of inguinal and femoral hernia. *BMJ* 1920, 2:68–69.
52. Henry AK: Operation for femoral hernia by a midline extraperitoneal approach; with a preliminary note on the use of this route for reducible inguinal hernia. *Lancet* 1936, 1:531–533.
53. Stoppa R, Petit J, Henry X: Unsutured Dacron prosthesis in groin hernias. *Int Surg* 1975, 60:411–412.
54. Shearburn EW, Myers RN: Shouldice repair for inguinal hernia. *Surgery* 1969, 66:450–459.
55. Lichtenstein IL, ed.: *Hernia Repair Without Disability.* St. Louis: C.V. Mosby; 1970.
56. Lichtenstein IL, Shulman AG, Amid PK, Montllor MM: The tension-free hernioplasty. *Am J Surg* 1989, 157:188–193.
57. Spaw AT, Ennis BW, Spaw LP: Laparoscopic hernia repair: the anatomic basis. *J Laparoendosc Surg* 1991, 1:269–277.
58. McKernan JB: Laparoscopic extraperitoneal repair of inguinofemoral herniation. *Endosc Surg Allied Technol* 1993, 1:198–203.
59. McKernan JB: Laparoscopic extraperitoneal inguinal hernia repair. *Curr Tech Gen Surg* 1994, 3:1–7.

CHAPTER 20

Laparoscopic Evaluation in Abdominal Trauma

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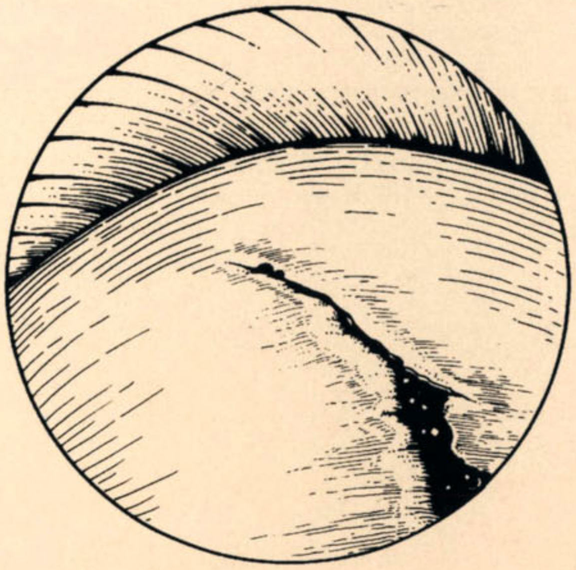
R. Lawrence Reed II



Background

Trauma is the leading cause of death in the United States among individuals between the ages of 1 and 44 years. It accounts for approximately 150,000 deaths annually, at a cost of $180,000 per year [1]. Fifty-seven million people were accidentally injured in 1985. There is an annual injury incidence of once for every four people [2]. Today's politically motivated environment dictates that cost-effective, dependable diagnostic modalities be employed for the evaluation of the trauma patient. Finding these tools is a prime challenge for the trauma surgeon.

The introduction of diagnostic peritoneal lavage (DPL) in 1965 by Root and colleagues [3] revolutionized the approach to abdominal trauma. It has proved to be a safe and accurate technique, with an accuracy of greater than 95%. The procedure is easily mastered, can be performed on a patient within minutes of arrival to the emergency department, and gives immediate results. Although the DPL has become a gold standard, its high sensitivity rate coupled with a low specificity rate is recognized as a drawback. It is apparent that a substantial number of nontherapeutic laparotomies have been performed for insignificant injuries, such as nonbleeding splenic or liver lacerations. The incidence of nontherapeutic laparotomies following a positive DPL is reported to be 5% to 14% for blunt trauma and as high as 50% for penetrating injuries [4].

Over the past two decades, reports of computed tomography's (CT) use in the diagnosis of abdominal trauma has flooded the literature [5–7]. With the development of more sophisticated scanners, many trauma surgeons are more comfortable with nonoperative management of stable patients with solid organ injuries. CT scanning provides a good evaluation of retroperitoneal injuries, which are invaluable by DPL. CT also provides an excellent way to more precisely identify a source of bleeding. Yet, there are concerns over the use of CT in trauma. When applied within the first few hours of blunt injury, abdominal CT may miss as many as 50% of visceral injuries, particularly pancreatic injuries. Scanning is time consuming, although the newer generation scanners have become much faster. Many argue that taking a potentially unstable patient away from a controlled environment is dangerous. Finally, the routine use of CT scanning produces a tremendous financial burden, with an average cost of $1000 per study.

With the evolution of laparoscopic technique and equipment, the examination of abdominal injuries with laparoscopy provides not only an accurate and inexpensive diagnostic tool; it is also effective in avoiding nontherapeutic laparotomies [8,9]. Laparoscopic inspection of the abdominal cavity following trauma was initially advocated by Gazzaniga and coworkers [10] and Carnevale and coworkers [11]. Carnevale and coworkers reviewed 20 individuals who were evaluated with laparoscopy prior to exploratory laparotomy. Laparotomy was avoided in 12 of the 20 patients who had sustained abdominal trauma. Several other reviews have recently appeared in the literature (Table 20-1).

With the advent of more sophisticated equipment and increasing experience by general surgeons, laparoscopy is increasingly used as a modality to evaluate both penetrating and blunt abdominal trauma (Tables 20-2 and 20-3). Although commonly performed in the operating room, laparoscopic evaluation may be accomplished in the emergency department.

Table 20-1. Laparoscopy in abdominal trauma

Study	Year	Patients, n	Type of trauma
Gazzaniga and coworkers [10]	1976	37	Mixed*
Carnevale and coworkers [11]	1977	20	Mixed*
Berci and coworkers [12]	1991	150	Blunt
Sosa and coworkers [15]	1992	8	Penetrating
Livingston and coworkers [14]	1993	39	Mixed*
Salvino and coworkers [16]	1993	75	Mixed*
Fabian and coworkers [17]	1993	182	Mixed*
Ivatury and coworkers [13]	1993	100	Penetrating

*Combination of blunt and penetrating injury.

Table 20-2. Frequency of organ injury in penetrating abdominal trauma*

Organ	Occurrence, %
Liver	37
Small bowel	26
Stomach	19
Colon	17
Major vascular	13
Retroperitoneal	10
Mesentery	10
Spleen	7
Diaphragm	5
Kidney	4
Pancreas	4
Duodenum	2
Biliary system	1
Other	1

**From* Greenfield and coworkers [18]; with permission.

Table 20-3. Frequency of organ injury in blunt abdominal trauma*	
Organ	**Occurrence, %**
Spleen	25
Intestine	15
Liver	15
Retroperitoneal	13
Kidney	12
Urinary bladder	6
Mesentery	5
Pancreas	3
Diaphragm	2
Urethra	2
Vascular	2

*From Greenfield and coworkers [18]; with permission.

There are several potential complications associated with the use of laparoscopy for trauma. Several series have reported tension pneumothoraces associated with diaphragmatic injuries and pneumoperitoneum, although no adverse outcomes have been reported [12]. Gas embolization is also a theoretically possible complication, although this has not been reported in the recent literature. The three major limitations of laparoscopy in evaluation of abdominal trauma are 1) failure to visualize the spleen; 2) inability to reliably evacuate blood clots; and 3) inability to fully examine the small bowel [13].

Surgical Technique

Figures 20-1 through 20-20 depict the surgical technique for laparoscopic evaluation in abdominal trauma.

Set-up

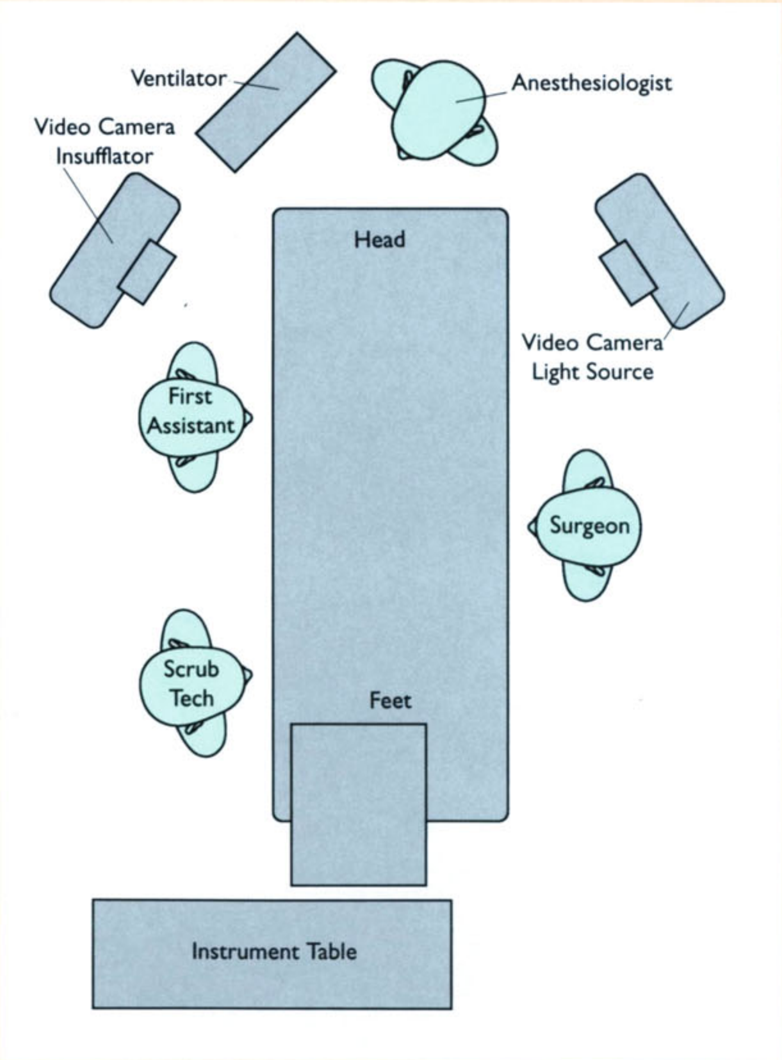


FIGURE 20-1.
Initial operating room set-up for laparoscopic exploration for abdominal trauma. Preoperative antibiotics are generally administered in the emergency department. Nasogastric and Foley catheters should also be placed in the emergency department. The initial positioning of the surgeon is similar to that for laparoscopic cholecystectomy. The surgeon must be sure that the patient is placed on an operating table that is easily and reliably moveable by the anesthesiologist. The first assistant must be prepared to take control of the camera as the exploration progresses. Both the operating room staff and the operating surgeon must keep in mind that flexibility in positioning the patient and equipment is critical during such exploration.

Set-up

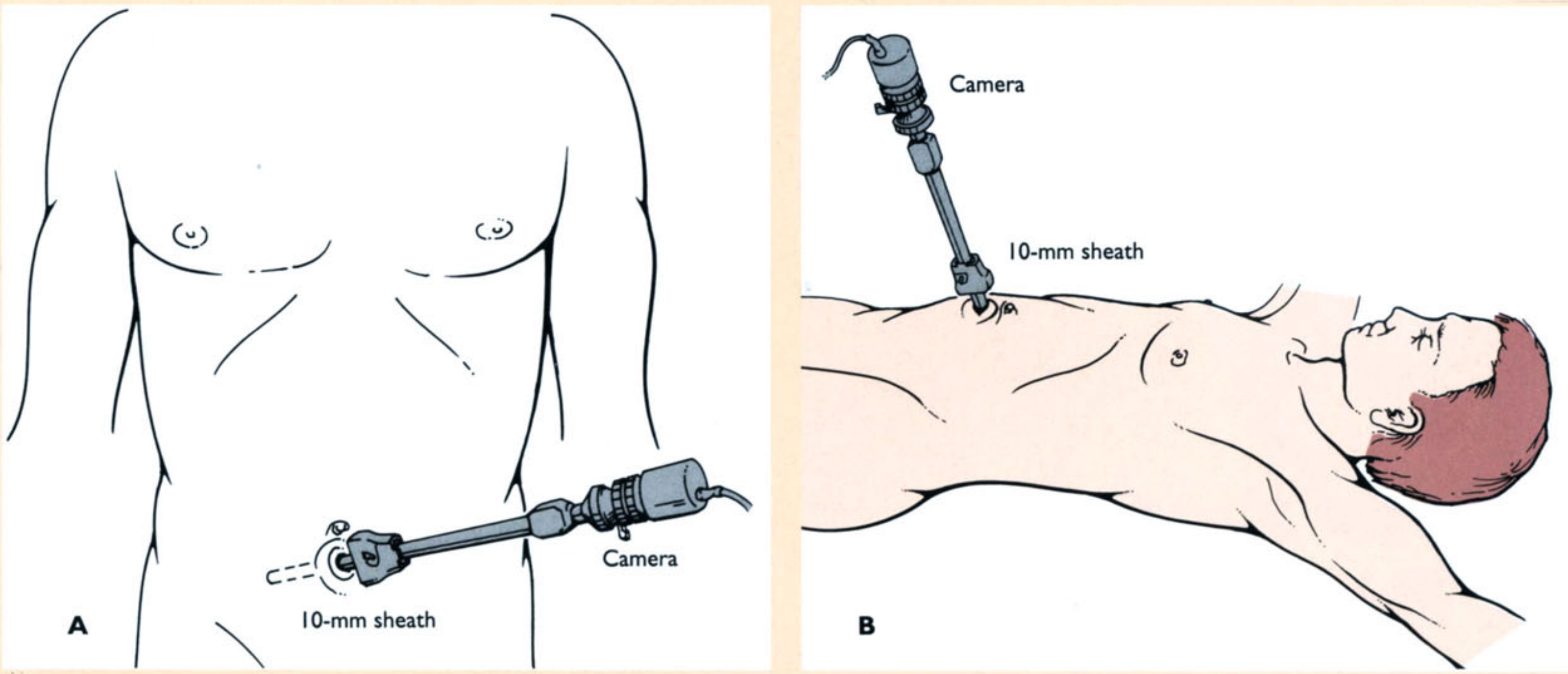


FIGURE 20-2.

A and **B**, The patient is initially positioned with the head down by 30° with the arm extended at the side. Access to the peritoneal cavity is gained infraumbilically using a 10-mm sheath via a closed (Veress needle) or open (Hasson trocar) technique. Following insufflation with either carbon dioxide or nitrous oxide to a pressure of 15 to 20 mm Hg, the laparoscope is inserted via the 10-mm sheath. At this point, thorough inspection of the peritoneal cavity is undertaken, with special attention to areas of known or possible peritoneal violation.

Procedure

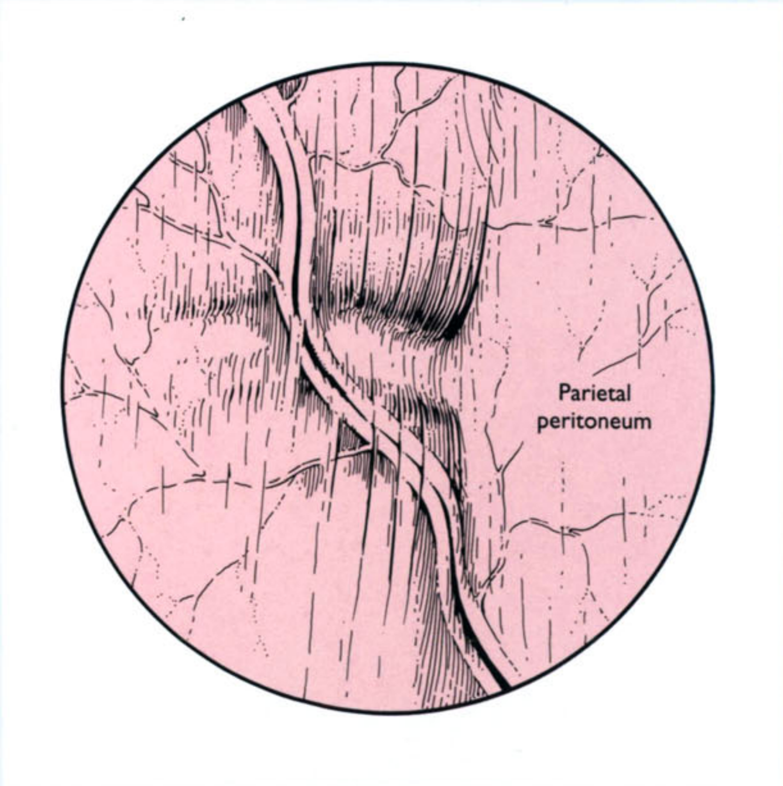


FIGURE 20-3.

Initial exploration consists of a complete evaluation of the parietal peritoneal surface of the anterior abdominal wall. This should be accomplished with the operating table flat. Particular attention is paid to known sites of external injury (penetrating entrance wounds).

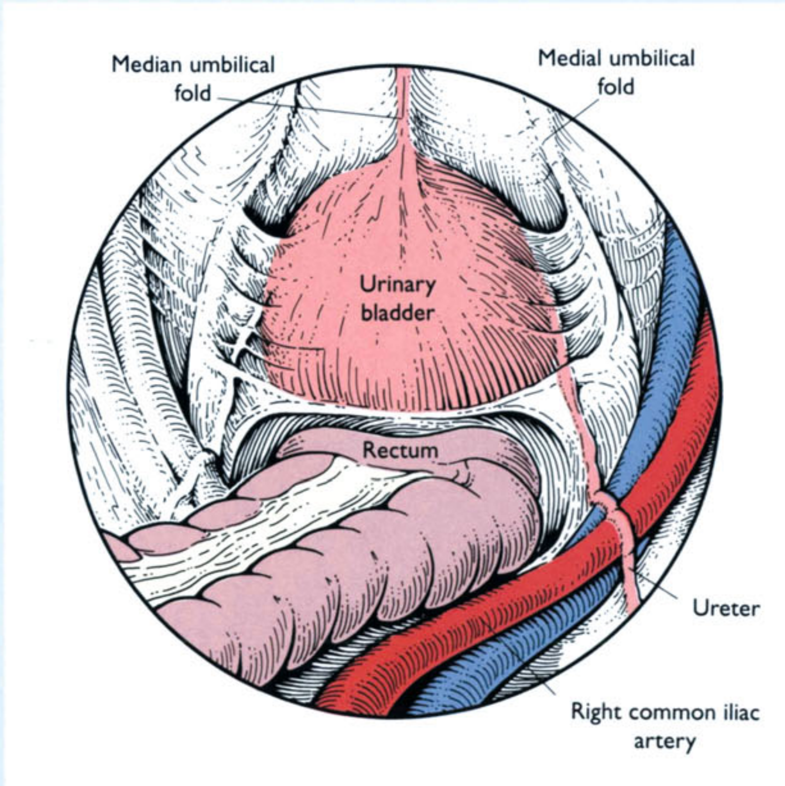


FIGURE 20-4.

Once the inspection of the parietal peritoneal surface has been completed, the surgeon begins a systematic and complete exploration of the abdominal cavity. This technical description will begin with viewing the pelvis. The surgeon should first give special attention to the presence of free fluid in the pelvis. The patient should be placed with the head down by 30°, allowing the small bowel to fall cephalad.

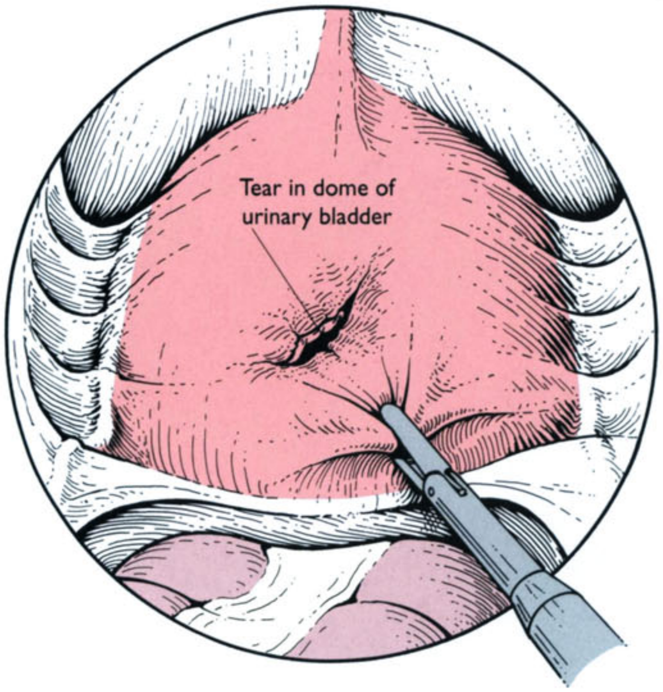


FIGURE 20-5.
The bladder is inspected for penetration by looking for ecchymosis of the bladder wall or the free flow of urine. At this point, a 5-mm trocar may be placed in the right upper quadrant. A fine grasper is placed through the sheath. This will allow the surgeon to place traction on the bladder for a better evaluation of the pelvis.

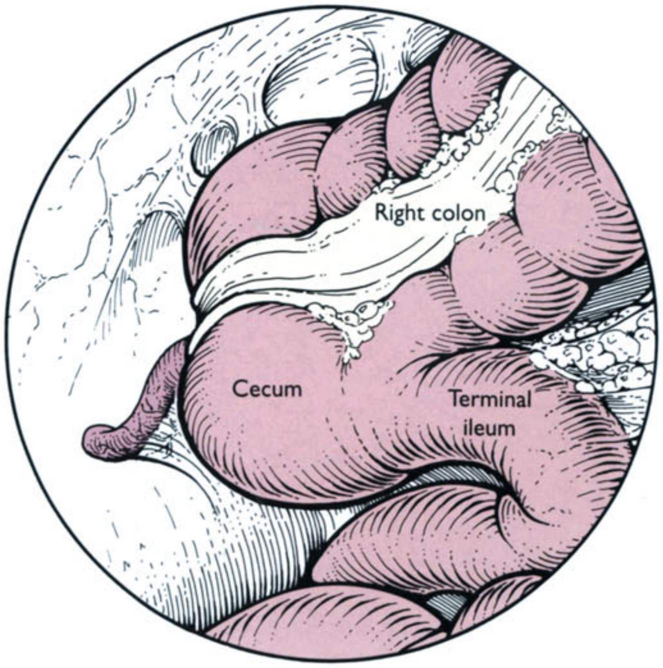


FIGURE 20-6.
The exploration is continued by examining the right lower quadrant. The patient is kept in 30° of Trendelenburg, but the table is rotated in the long axis 30° to the left. This allows better exposure to the right lower quadrant. The surgeon now pays special attention to the cecum and right (ascending) colon. Penetrating injuries to the anterior surface of the colon are evaluated. Bleeding, extravasation of bowel contents, and ecchymosis all indicate injury to the colon.

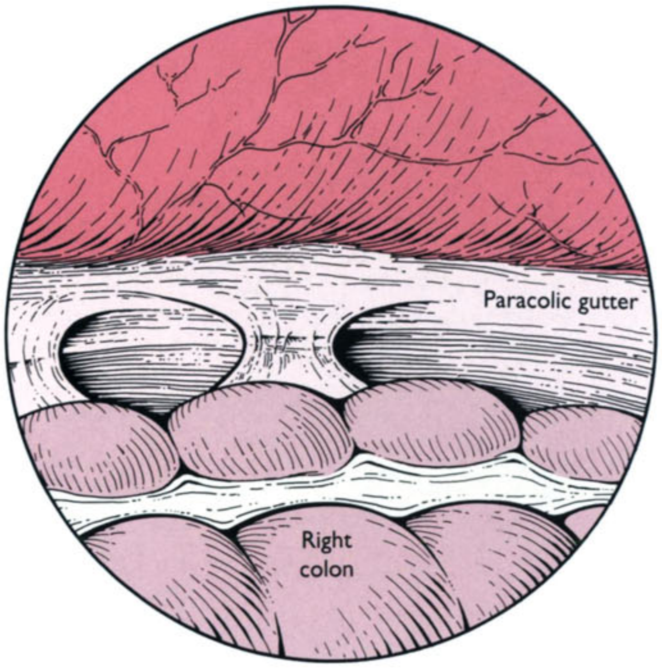


FIGURE 20-7.
The right paracolic gutter is evaluated for evidence of retroperitoneal injury. Ecchymosis is an important clue to injury in this region. If retroperitoneal injury is anticipated (which is suggested from knowledge of the entry wound), freeing up of the retroperitoneal portion of the ascending colon is recommended.

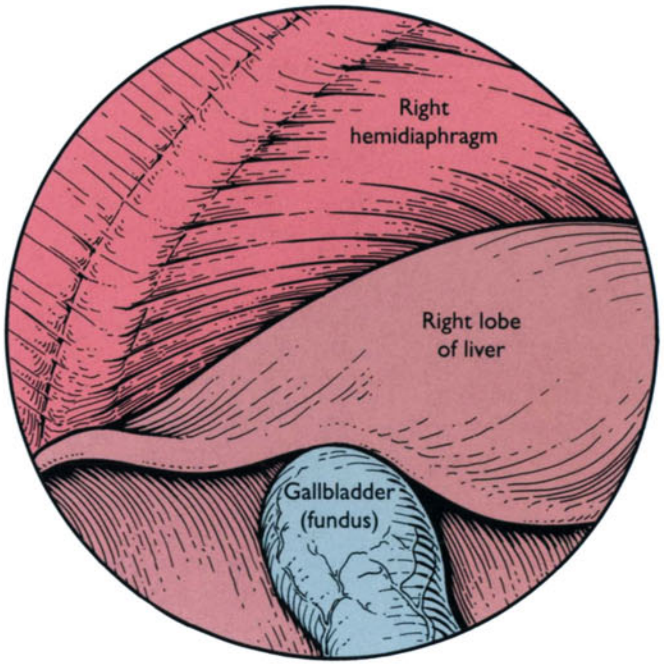


FIGURE 20-8.
The liver and contents of the right upper quadrant are now evaluated. The operating table should be flattened. The liver can best be evaluated with the aid of the grasper. The anterior and lateral surfaces of the right lobe may be easily explored with minimal effort.

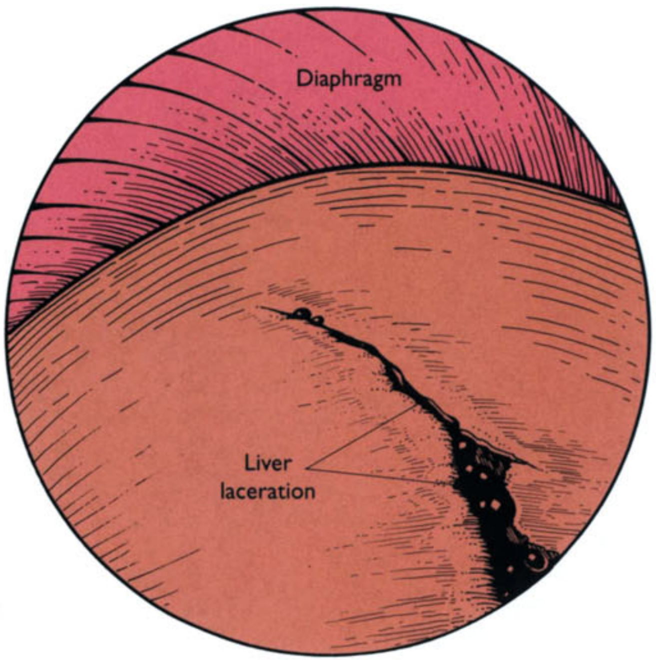


FIGURE 20-9.
Penetrating injuries (lacerations) and parenchymal fractures to the surface of the liver can be evaluated for active bleeding. Cauterization of bleeding sites may be attempted; if initial attempts fail, the procedure should be converted to open laparotomy.

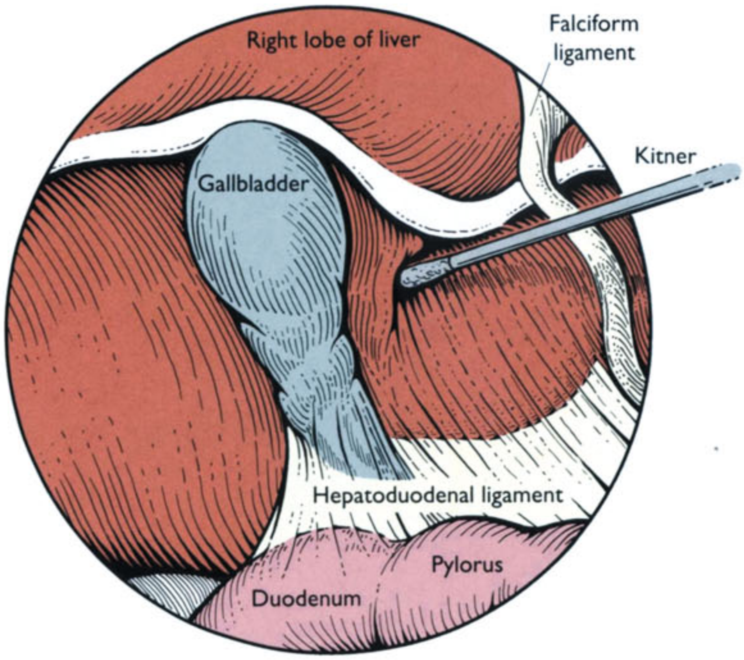


FIGURE 20-10.
The inferior surface of the right lobe of the liver and gallbladder are next evaluated. This is accomplished by simply elevating the right lobe with an endoscopic Kitner probe. One must be aware that isolated injury to the inferior surface of the liver is uncommon. Thus, the surgeon should reevaluate the liver for additional injuries if a laceration is found on the inferior surface.

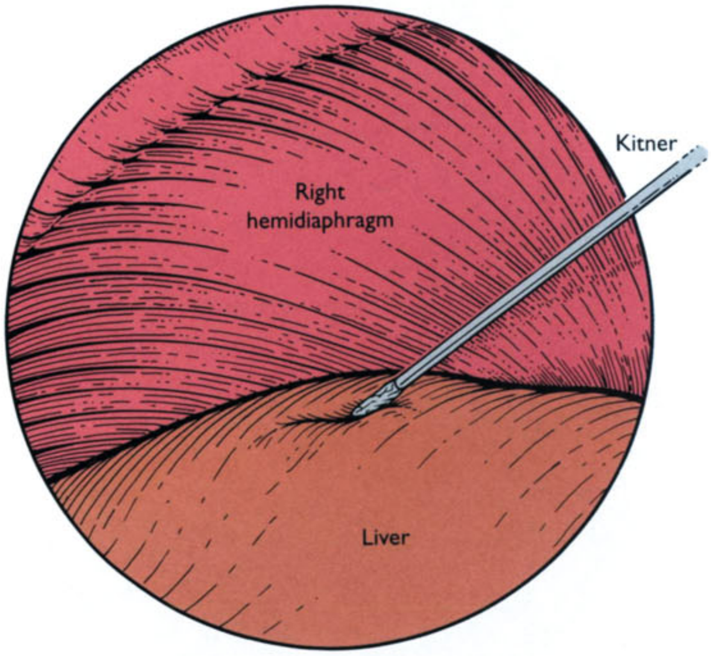


FIGURE 20-11.
Once the right lobe has been completely evaluated, the exploration can then be continued by examining the right hemidiaphragm. The operating table is now placed with the feet down 30°, leaving it rotated to the left. A grasper may be used to shift the liver medially. The anterior and central portions of the diaphragm can be explored without difficulty. The surgeon must be aware that a thorough evaluation of the posterior portion of the diaphragm using laparoscopy is difficult.

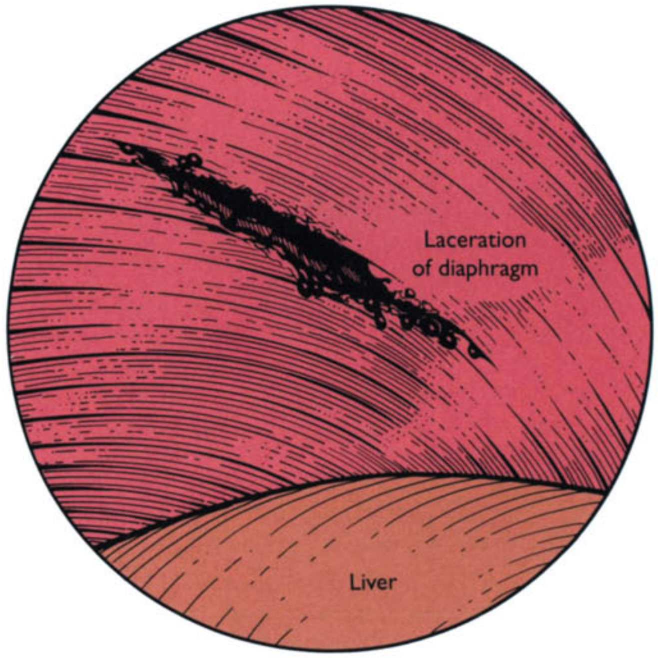


FIGURE 20-12.
Lacerations to the diaphragm can be seen without difficulty, especially in the anterior and central portions.

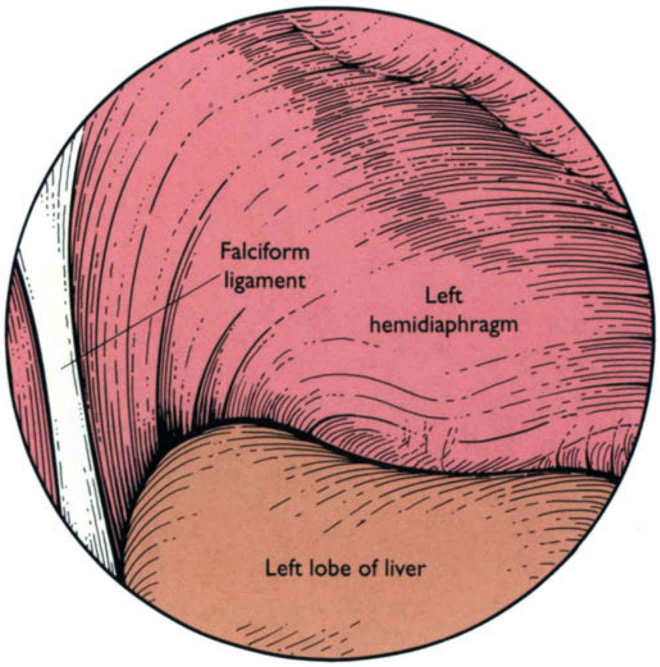


FIGURE 20-13.
The left upper quadrant is now examined. The operating table is rotated 30° in the long axis to the right, leaving the patient's feet down. The left lobe of the liver and left hemidiaphragm are evaluated.

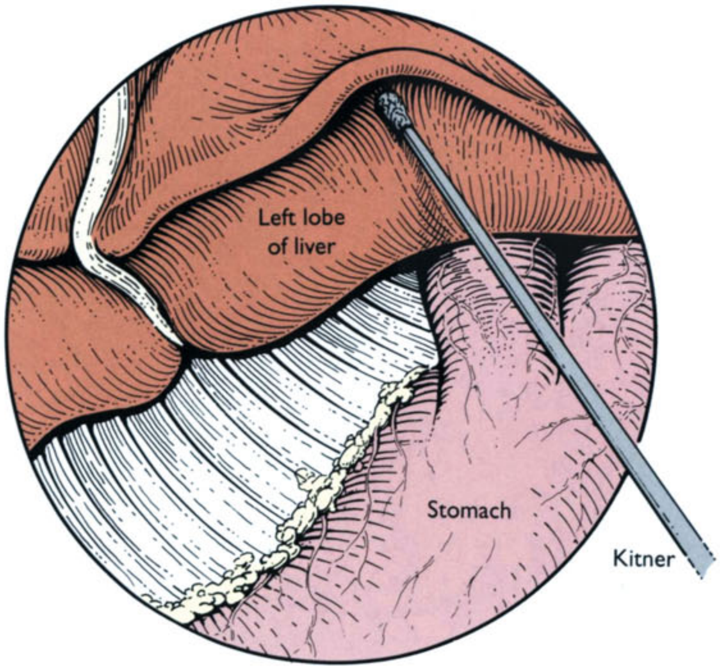


FIGURE 20-14.
A grasper may be used to elevate the liver to view its inferior surface. The anterior surface of the stomach is also explored at this time.

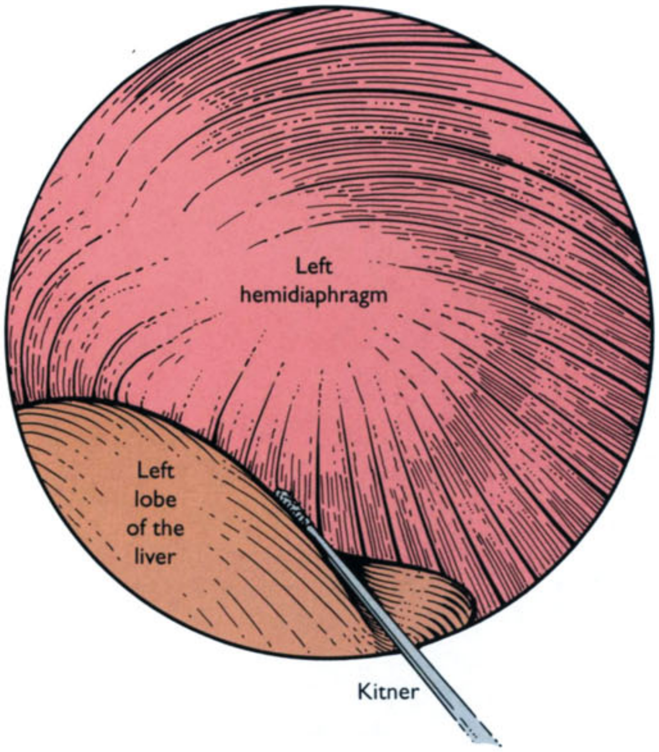


FIGURE 20-15.
The left hemidiaphragm is viewed as before. The grasper is used to shift the left lobe of the liver to the right.

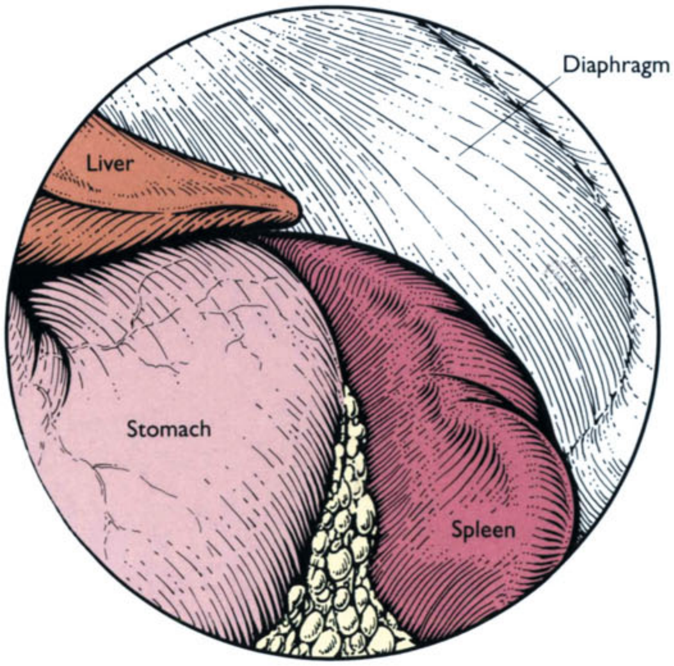


FIGURE 20-16.
The spleen is next evaluated for injuries. It is impossible to visualize the entire spleen because of its posterior position. The anterior aspect of the inferior portion of the spleen is inspected.

References

1. Rice DP, Mackenzie EJ, *et al.*, eds.: *Cost of Injury in the United States: A Report to Congress.* Atlanta: Centers for Disease Control; 1989.
2. Baker CC, Oppenheiner L, Stephens B, *et al.*: Epidemiology of trauma death. *Am J Surg* 1980, 140:144–150.
3. Root HO, Hauser CW, McKinley CR, *et al.*: Diagnostic peritoneal lavage. *Surgery* 1965, 57:633–637.
4. Oreskovich MR, Carrico CJ: Stab wounds of the anterior abdomen. *Ann Surg* 1983, 4:411–419.
5. Matsubara TK, Fong HMT, Burns CM: Computed tomography of the abdomen in the management of blunt abdominal trauma. *J Trauma* 1986, 26:585–592.
6. Sorkey AJ, Farnell MB, *et al.*: The complementary roles of diagnostic peritoneal lavage and computed tomography in the evaluation of blunt abdominal trauma. *Surgery* 1989, 106:794–800.
7. Meyer DM, Thal ER, *et al.*: Evaluation of computed tomography and diagnostic peritoneal lavage in blunt abdominal trauma. *J Trauma* 1989, 29:1168–1172.
8. Kelling G: Uber Oesophagoskopie, Gastroskopie und Koelioskopie. *Munch Med Wochenschr* 1901, 49:21. In *Surg Clin North Am* 1992, 72:997–1002.
9. Jacobaeus HC: Kurze Ubersicht Uber meine Erfahrunger mit der Laparothorakoskopie. *Munch Med Wochenschr* 1911, 57:2017. In *Surg Clin North Am* 1992, 72:997–1002.
10. Gazzaniga AB, Stanton WW, Barlett RH: Laparoscopy in the diagnosis of blunt and penetrating injuries to the abdomen. *Am J Surg* 1976, 131:315–318.
11. Carnevale N, Baron N, Delany HM: Peritoneoscopy as an aid in the diagnosis of abdominal trauma: a preliminary report. *J Trauma* 1977, 17:634–641.
12. Berci G, Sackier JM, Paz-Partlow M: Emergency laparoscopy. *Am J Surg* 1991, 161:332–335.
13. Ivatury RR, Simon RJ, Stahl WM: A critical evaluation of laparoscopy in penetrating abdominal trauma. *J Trauma* 1993, 24:822–827.
14. Livingston DH, Tortella BJ, Blackwood J, *et al.*: The role of laparoscopy in abdominal trauma. *J Trauma* 1992, 33:471–475.
15. Sosa JL, Sim D, *et al.*: Laparoscopic evaluation of tangential gunshot wounds. *Arch Surg* 1992, 127:109–110.
16. Salvino CK, Esposito TJ, *et al.*: The role of diagnostic laparoscopy in the management of trauma patients: a preliminary assessment. *J Trauma* 1993, 34:506–515.
17. Fabian TC, Croce MA, Stewart RM, *et al.*: A prospective analysis of diagnostic laparoscopy in trauma. *Ann Surg* 1993, 127:557–565.
18. Greenfield LJ, Mulholland MW, Oldham KT, Zelenock GB, eds.: *Surgery: Scientific Principles and Practice.* Philadelphia: J.B. Lippincott; 1993.

CHAPTER 21

Pediatric Endosurgery

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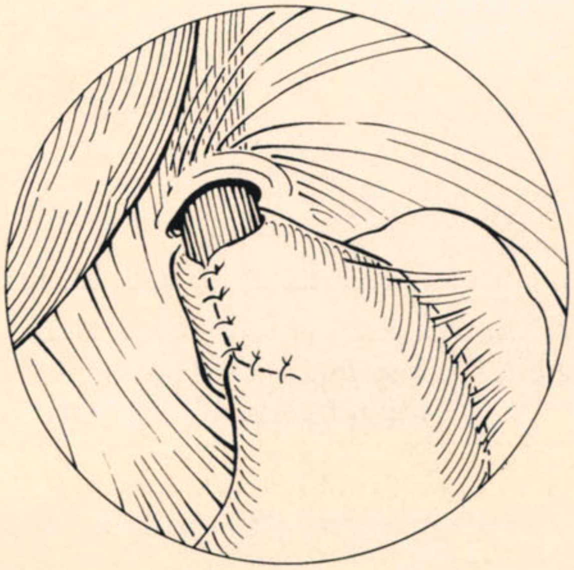


Minimally invasive surgical procedures have been enthusiastically received in adult patients. This enthusiasm has been driven by the appeal of shortened hospitalization, decreased perioperative pain, a more rapid convalescence, and an earlier return to work for the patients. Many of the same considerations make minimally invasive techniques appealing in pediatric patients (Table 21-1), especially the potential to decrease perioperative apprehension, discomfort, and respiratory complications, particularly in infants and children who have underlying respiratory conditions. Although pediatric peritoneoscopy and thoracoscopy were advocated in the 1970s [1–3], recent technical advances in imaging and downsizing of instrumentation in the past 5 years have made widespread use of these procedures feasible even in small patients. As a result, the use of these techniques has expanded dramatically, and imaginative new approaches to clinical problems are developing at a rapid pace (Table 21-2).

A word of caution is in order, however. "Endoscopic" is not necessarily equivalent to "better." Many conventional procedures in pediatric surgery are already "minimally invasive," resulting in minimal morbidity and satisfactory cosmetic outcomes. The corresponding endoscopic procedures may be more lengthy and considerably more expensive. Under such circumstances, it may be difficult or impossible to demonstrate any advantage of endoscopic procedure over conventional techniques.

Special Considerations

Technical Considerations

Several modifications of the general technique for laparoscopy as performed in adults are listed in Table 21-3. The open technique of trocar sheath insertion is advocated for laparoscopy in children smaller than 15 kilograms. Because of their small size, the proximity of the very elastic anterior abdominal wall to the abdominal viscera and fixed retroperitoneal structures, and because the dome of the bladder is intraperitoneal, it is our impression that open trocar insertion is safer in infants and small children. In addition, the potential for an umbilical hernia that may contain bowel adherent to the peritoneal lining makes the open technique more appealing. These hernias are repaired by fascial closure upon removal of the trocar. Routine decompression of the urinary bladder and stomach is recommended to reduce the risk of trocar injury.

Table 21-1. Potential benefits of an endosurgical approach in pediatric patients

Improved cosmesis
Smaller incision
Decreased postoperative pain
Shorter hospital stay
Shorter convalescence
Decreased incidence of adhesive bowel obstruction*
Better intraoperative visualization
Fewer postoperative pulmonary complications*

*Not well-documented.

Table 21-2. Laparoscopic operations in pediatric surgery

Appendectomy	Pyloromyotomy
Meckel's diverticulectomy	Hirschsprung's disease
Adnexal detorsion	Biopsy
Nissen fundoplication	Colostomy
Inguinal exploration	Pullthrough
Cholecystectomy	Gonadectomy
Splenectomy	Orchiopexy
Diagnostic laparoscopy	Nephrectomy
Chronic pain	Varicocelectomy
Trauma	Ureterolysis
Hepatobiliary disease	Ureteral repair
Cancer diagnosis and staging	

Table 21-3. Modifications for pediatric patients

Smaller camera instruments and trocars
Wider spacing of trocar sites
Trocar placement at greater distances from operative site margin
Lower insufflation pressures
Smaller volumes for pneumoperitoneum
More frequent use of Hasson trocar
Foley and nasogastric catheter decompression

Table 21-4. Anesthetic considerations in pediatric endosurgery

Pneumoperitoneum/increased intra-abdominal pressure
Decreased functional residual capacity
Increased peak airway pressure
Decreased systemic venous return
Impaired return from lower extremity intravenous lines
Impaired splanchnic blood flow
Carbon dioxide insufflation
Increased $PaCO_2$
CO_2 gas embolus
Intraluminal gas
Expands with N_2O
Single lung ventilation

Trocar sheath placement is generally similar to that used for corresponding operations in adult patients. However, shorter trocars are used, and if possible these sites are placed more widely apart and further from the operating field to prevent overlapping ("dueling") of instruments within the peritoneal cavity. The relatively large size of the liver, which may extend well below the right costal margin, demands great care when inserting trocars in the right upper quadrant in infants and small children.

The great elasticity of the abdominal wall in children generally means that a satisfactory pneumoperitoneum can be achieved with lower insufflation pressures than in adults. In general, only 5 to 10 mm Hg is required in infants weighing up to 15 kilograms. The use of higher pressures can result in significant hemodynamic compromise or hypercarbia, and the operator is advised therefore to use the minimum insufflation pressure required to maintain adequate visualization of the peritoneal cavity.

Equipment

Perhaps the most significant technological advance leading to the widespread use of minimally invasive techniques is improved imaging. High-resolution monitors, true-color imaging, and high-sensitivity cameras (including the newer three-chip designs) allowed manufacturers to scale down telescopes to a size that is appropriate for infants and small children. Several companies are now introducing instruments designed specifically for pediatric patients. However, a prohibitive problem remains with stapling devices, which are often too large to fit within the limited space presented by the thoracic and abdominal cavities of infants and small children. Downsized stapling devices are not yet available.

Anesthesia

Major anesthetic considerations unique to endoscopic procedures are outlined in Table 21-4. These are related primarily to the mechanical effects of pneumoperitoneum and the requirement for single lung ventilation during thoracoscopic procedures, which may be accentuated in infants and children compared with adults. Monitoring can be performed adequately by standard, noninvasive measurement of hemodynamics, airway pressure, ventilation, end-tidal carbon dioxide partial pressure, and intra-abdominal pressure.

Experimental models using piglets and neonatal lambs demonstrate decreased cardiac index and impaired perfusion of the kidneys, liver, and intestine when intra-abdominal pressures exceed 15 mm Hg [4,5]. Although children usually compensate well, they should be adequately volume resuscitated prior to laparoscopy, and intra-abdominal pressures should be maintained at the minimum level needed to safely visualize the operative field.

Elevation of the diaphragm by the pneumoperitoneum may decrease lung compliance, thereby adversely affecting minute ventilation. The resulting hypercapnia may be further accentuated by absorption of carbon dioxide across the peritoneum. These effects are usually manageable by modest increases in minute ventilation. During upper abdominal operations, accidental egress of carbon dioxide from the peritoneal cavity into the pleural space resulting in a pneumothorax may result in acute changes in ventilatory requirements. This complication mandates termination of the laparoscopic procedure, and may require placement of a tube thoracostomy.

Thoracoscopic procedures may be performed under general or regional anesthesia with intravenous sedation. Regional techniques such as a four-rib intercostal block are potentially attractive for patients undergoing biopsy of mediastinal masses resulting in tracheal compression, where the risk of general anesthesia may be prohibitive. Single lung ventilation is preferred for optimal thoracic exploration, and may be achieved by use of the dual lumen endotracheal tube in larger patients, or selective bronchial intubation in smaller patients. This is usually well tolerated when the lung is intrinsically normal. During biopsies for interstitial lung disease (viral or fungal pneumonias, bleomycin toxicity, and so forth), gas exchange may not be adequate during single lung ventilation, and the thoracoscopic approach may not be feasible.

Endosurgical Procedures

Cholecystectomy

Laparoscopic cholecystectomy is the most widely reported and universally accepted indication for minimally invasive surgery in children. Cholelithiasis associated with hematologic disease is the most common indication for cholecystectomy, followed by calculus and acalculus cholecystitis, parenteral nutrition, induced cholestasis, gallbladder dysfunction, and ileal resection.

The details of the operative procedure are nearly identical to those described for adults (*see* Chapter 9). As illustrated in Figure 21-1, trocar placement should emphasize wide separation to avoid overlap of instruments at the operative site. This is an issue of major technical importance. In smaller children this may necessitate placing the second right subcostal trocar in the right lower quadrant and the epigastric trocar in a left subcostal position. The 5-mm laparoscope can be used in infants. Intraoperative cholangiography should be used selectively, but may be particularly useful when there is difficulty defining the anatomy, particularly the junction of the cystic duct with the common bile duct. Published results have uniformly been excellent, confirming shortened hospital stay and earlier return to school and normal activities [6–10].

Appendectomy

Appendectomy is the most common emergency intra-abdominal operation performed in children. The first laparoscopic appendectomy was performed by Semm in 1982 [11]. Subsequent reports describe successful application of the minimally invasive technique in children [12–14].

In both of these reports only two trocars, one in each of the lower quadrants, were used in addition to the camera port. An additional trocar may be placed in the left lower quadrant, through which a grasper may be placed for better retraction and exposure of the mesoappendix, particularly if acute periappendiceal inflammation is present (Figure 21-2). Placement of this trocar in the left lower quadrant in children will help avoid overlapping trocars and promote facile manipulation of the appendix. Dissection of the mesoappendix and appendiceal base (Figure 21-3) proceeds as in adults (*see* Chapter 16). The base of the appendix can be secured with either endoscopic loops or staples.

Suspected perforation is not considered a contraindication to laparoscopic appendectomy. In fact, laparoscopy may permit better visualization of the right lower quadrant and pelvis with more thorough irrigation and aspiration of necrotic material. The laparoscopic approach also provides excellent visualization of abdominal and pelvic organs that must be investigated when the appendix is normal. This may be the primary advantage of the endosurgical approach compared with the open technique. Many of these other pathologic conditions can be managed laparoscopically, *eg*, adnexal torsion or Meckel's diverticulitis.

Early observations suggest that patients undergoing laparoscopic appendectomy may have shorter hospital stays and shorter convalescence than those undergoing a traditional open approach. This observation, and the hidden economic advantage of lost time for the parents of these children, might compensate for the increased cost of the laparoscopic procedure. However, the role of laparoscopic approaches in pediatric patients is not at all clear at present. Both open and laparoscopic appendectomies are effective with limited morbidity that is roughly equivalent in current reports. As noted, an important argument for a laparoscopic approach is in the patient without a clear clinical diagnosis.

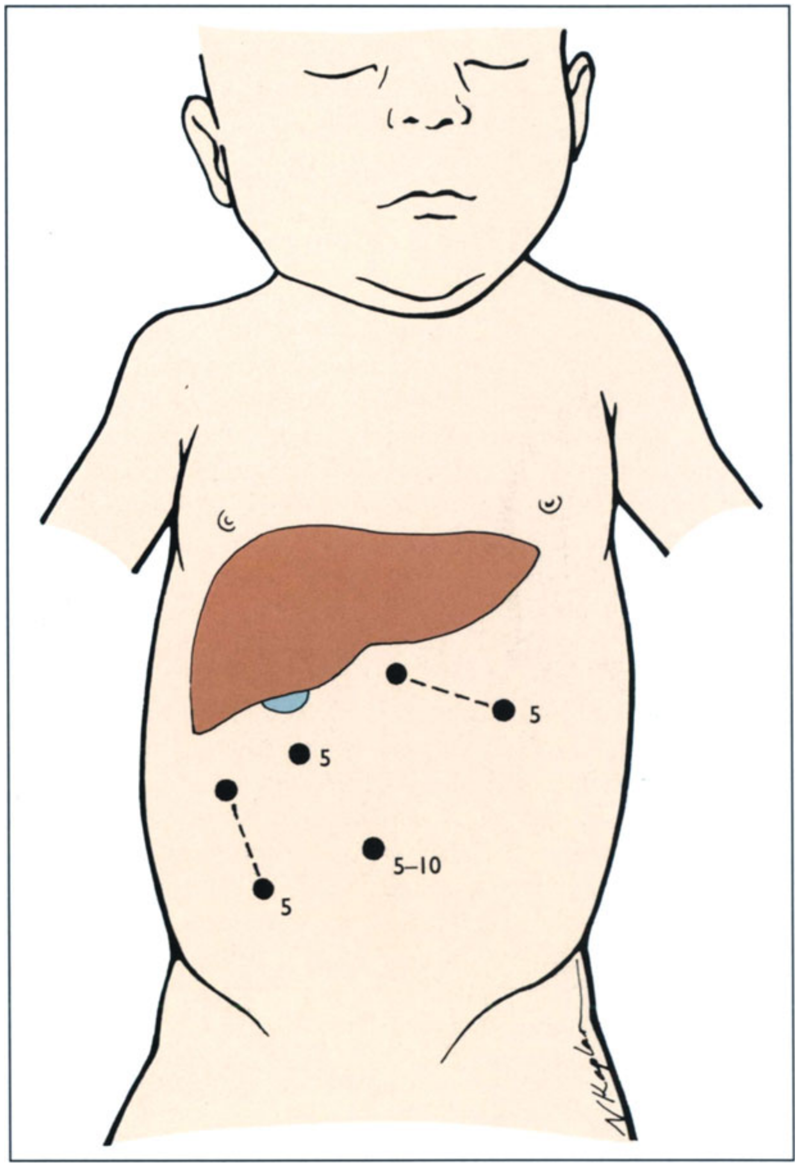


FIGURE 21-1.

Trocar placement for laparoscopic cholecystectomy. Note the inferior placement of the right upper quadrant trocars in order to avoid the liver and the wide spacing of the trocars for smaller children. The second 5-mm, right-sided trocar may even be in the right lower quadrant skin crease. A 5- or 10-mm umbilical port may be used depending on camera size availability.

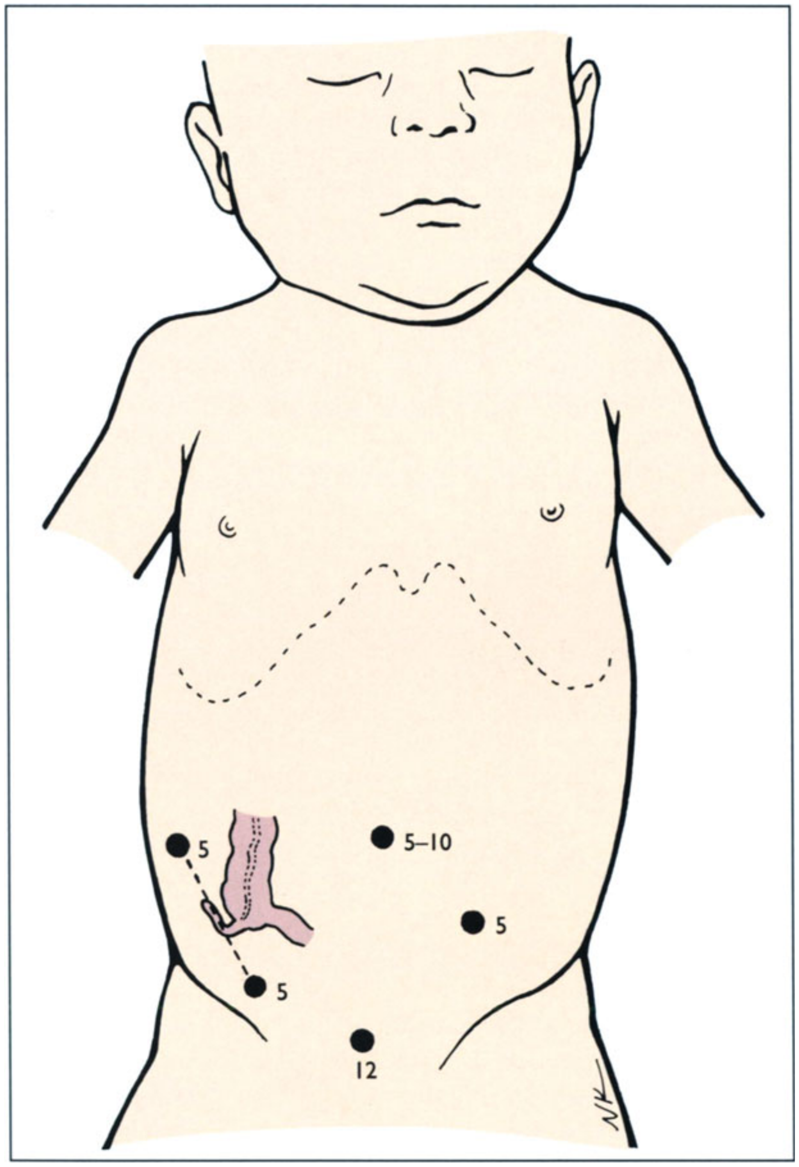


FIGURE 21-2.

Trocar placement for appendectomy. Adequate visualization can be achieved with either a right lower quadrant or suprapubic trocar through which a retractor is placed. However, use of both ports frequently provides superior retraction. The 10-mm trocar, through which the stapler is passed, can be placed in the suprapubic position, which is more easily hidden below the hairline, rather than in the left lower quadrant.

Antireflux Procedures

Gastroesophageal reflux is a common problem in infants and children, particularly those with impaired neurologic function. Antireflux procedures are unequivocally indicated for the management of complications of gastroesophageal reflux, which are summarized in Table 21-5. A more difficult management decision is required in the neurologically impaired infant or child who requires placement of gastrostomy for nutritional support. The authors generally advocate a selective approach to fundoplication in these patients, based upon the outcome of upper gastrointestinal contrast studies and extended (24-hour) esophageal pH monitoring. It should be noted, however, that a significant number of these patients without demonstrable gastroesophageal reflux preoperatively develop symptoms attributable to reflux after fixation of the gastric wall to the anterior abdominal wall for gastrostomy placement [15].

The minimally invasive approach is particularly attractive in the neurologically impaired population, simplifying perioperative pain management and the management of other medications, particularly anticonvulsants. Neurologically impaired patients and other patient populations with compromised pulmonary function due to recurrent aspiration or frequent pneumonias potentially benefit by avoiding an upper abdominal incision. The theoretical possibility that the laparoscopic approach minimizes the development of adhesions and the potential for future intestinal obstruction is also very appealing, although unproven.

Many minor technical differences exist among surgeons on the particular details of fundoplication (Table 21-6). However, the laparoscopic fundoplication can be performed in essentially the same manner as any conventional open approach, allowing for subtle differences in technique.

A nasogastric tube should be placed after endotracheal intubation to assure gastric decompression for safe trocar insertion and visualization of the left upper quadrant. It is particularly important to leave the nasogastric tube in place if a percutaneous endoscopic gastrostomy is to be placed

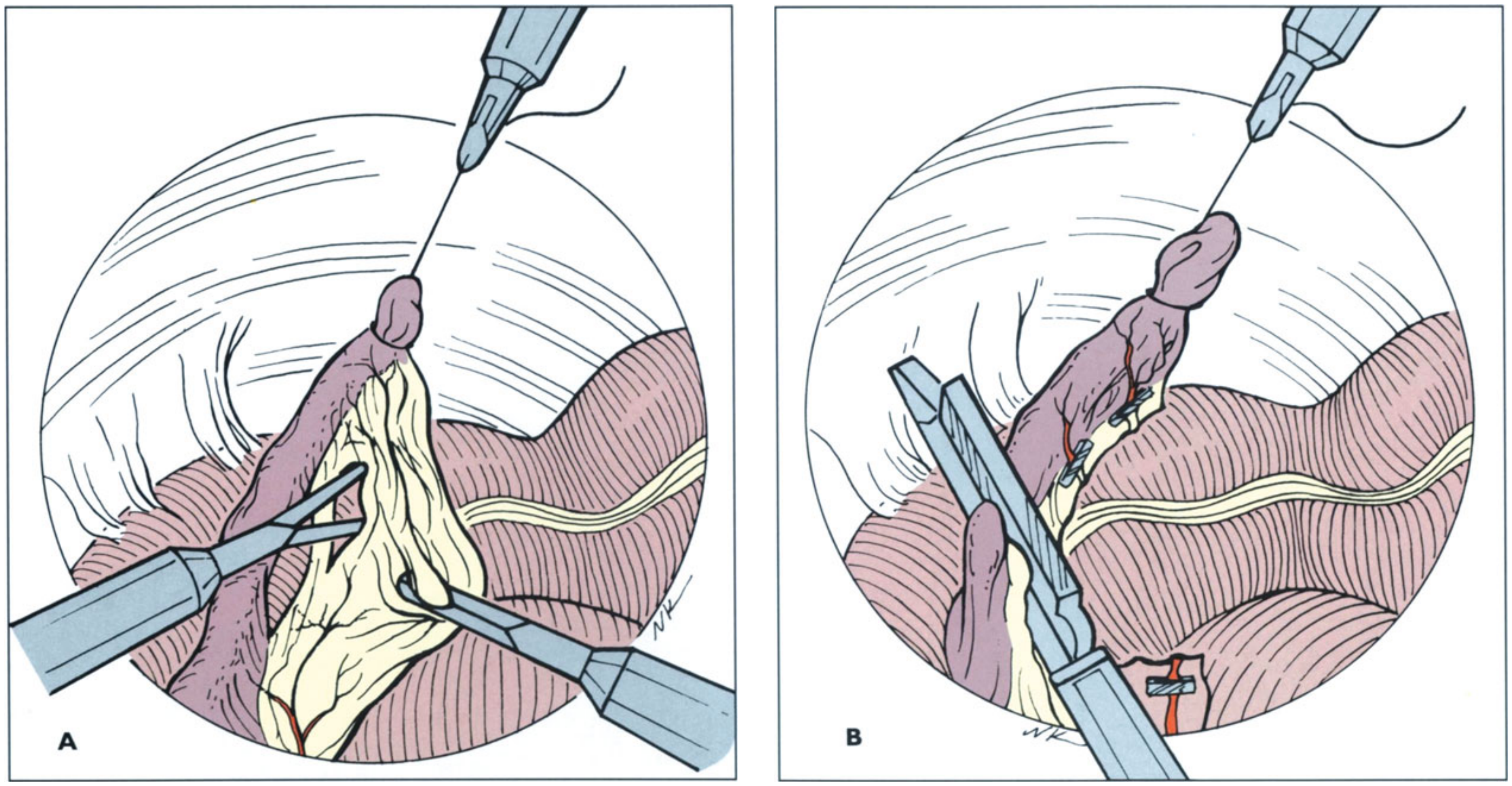


FIGURE 21-3.
A, Dissection of the mesoappendix is performed with blunt-tipped forceps. The mesoappendix can be secured with either endoscopic clips or an endoscopic stapler. **B**, The base of the appendix can be divided with an endoscopic stapler or between endoscopic loop sutures.

Table 21-5. Indications for an antireflux procedure

Aspiration pneumonia
Refractory vomiting
Failure to thrive
Apnea or "near miss" sudden infant death syndrome
Reactive airway disease and temporally related reflux
Severe esophagitis or its complications (hemorrhage, stricture)
Failure of medical therapy

Table 21-6. Variations in Nissen fundoplication

Tightness of wrap (Bougie diameter)
Length of wrap (number of sutures)
Use of pledgets
Incorporating diaphragm with uppermost suture
Plication of crura
Division of short gastric vessels

after fundoplication. Distention of the fundic wrap during insufflation may preclude passage of the endoscope into the stomach if it is not decompressed via the nasogastric tube. Prior to dissection of the esophageal hiatus, an appropriate sized esophageal bougie is placed transorally into the stomach. This is used to calibrate the esophagus and the esophageal hiatus as well as to plan suture placement. It is withdrawn when the sutures are actually tied to facilitate tension-free tissue apposition. A loose, circumferential fundic wrap is the objective of the Nissen fundoplication; it is relatively easy to produce obstruction of the esophagus in an infant or small child, or a patient who has underlying esophageal dysmotility.

Trocar placement for Nissen fundoplication is illustrated in Figure 21-4. Again, we prefer an open technique for placement of the infraumbilical trocar, which is used for camera insertion and insufflation. The remaining ports are placed under direct vision. In general, an isosceles triangle is designed with the working ports inferior and the apex at the operative site (the esophageal hiatus). Again, in small children it is important to place the working ports far enough from the hiatus to allow facile manipulation. The remainder of the procedure is quite similar to that described for adults in Chapter 2. The completed Nissen fundoplication is seen in Figure 21-5.

Most infants and children require a gastrostomy. We prefer a conventional percutaneous endoscopic gastrostomy. Once again, it is important to avoid insufflation of the stomach without a nasogastric tube present to avoid esophageal compression by the wrap that may preclude passage of the endoscope.

Other antireflux procedures can be performed using minimally invasive techniques, including the posterior gastropexy and anterior fundoplication. We have some experience with the anterior fundoplication described by Thal and used extensively by Ashcraft and coworkers [16]. This technique uses a partial fundic wrap, which appears to produce less symptomatic esophageal obstruction. This technique is useful in small infants where the size of the fundus may be inadequate to perform a circumferential wrap, and in patients with significant esophageal dysmotility.

Long-term efficacy of the endoscopic technique has not yet been documented. It should be noted that perioperative complications are reported in up to one-half of the patients undergoing conventional open fundoplication [17,18]. These include postoperative pulmonary compromise in approximately 15%, small bowel obstruction in 8% to 10%, and disruption of the fundic wrap in approximately 10%. Approximately one-fourth of the infants and chil-

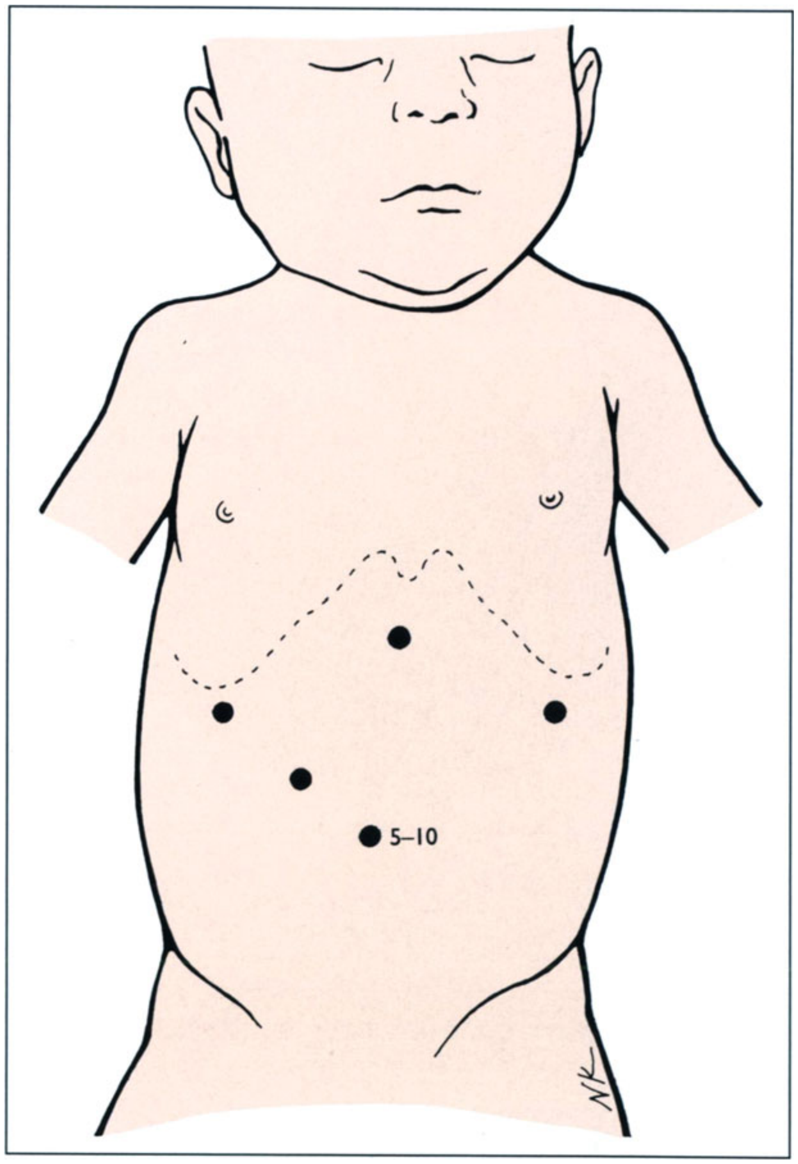


FIGURE 21-4.

Trocar placement for laparoscopic Nissen fundoplication. Emphasis is placed on wide separation of trocar sites to permit dexterous manipulation of the instruments and mobilization of the esophagus. In particular, the right flank trocar should be placed as far laterally as possible.

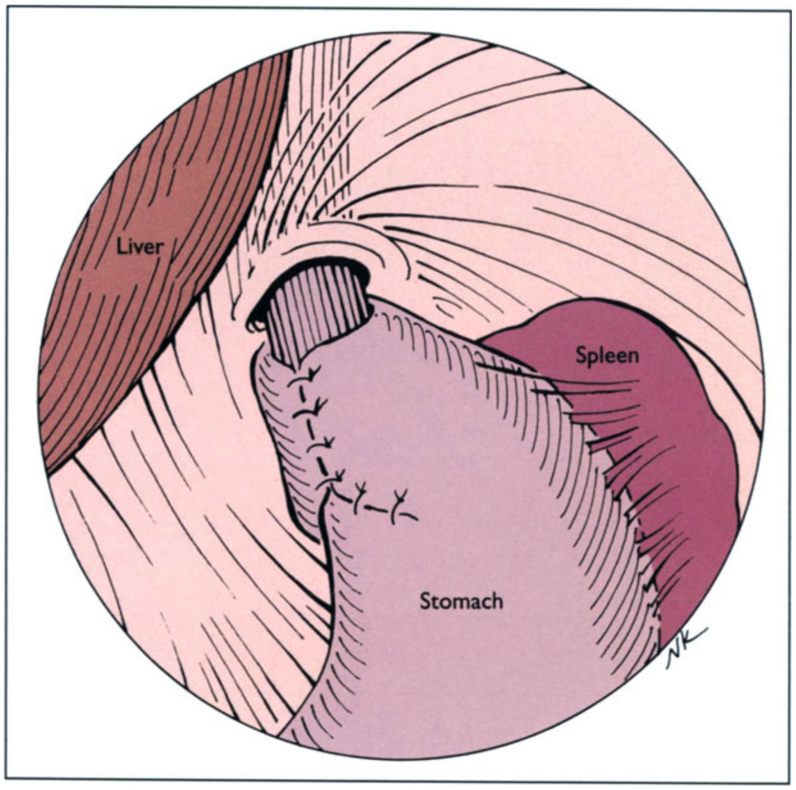


FIGURE 21-5.

Videoscopic appearance of a completed Nissen fundoplication.

dren who require surgery for gastroesophageal reflux die from other causes within 5 years of their operation. Therefore, a minimally invasive technique that decreases this perioperative morbidity with equivalent safety and efficacy is particularly desirable.

Pyloromyotomy

Some have advocated the use of the endosurgical approach for management of infantile hypertrophic pyloric stenosis [19]. It is the authors' opinion that the traditional open technique results in minimal morbidity. The patients are almost uniformly discharged from the hospital within 24 hours, and the cosmetic result is quite satisfactory. The endosurgical approach offers little if any advantage over the traditional open technique.

Inguinal Herniorrhaphy

Inguinal herniorrhaphy is the most common surgical procedure performed in children. The conventional open technique, which is essentially a high ligation of the hernia sac, is rapidly accomplished on an outpatient basis, with a small incision, minimal morbidity, and a satisfactory cosmetic result. The potential risks to trocar placement and foreign body (mesh) placement likely outweigh any possible benefit. Not surprisingly, there are currently no reports of laparoscopic hernia repair in infants and young children.

An ongoing controversy exists over the necessity for contralateral groin exploration in infants with a unilateral hernia. The risk of a missed hernia in the asymptomatic groin normal to examination (approximately 10%) and the requirement for a second anesthetic must be weighed against the morbidity of a potentially unnecessary inguinal exploration, which may result in injury to the testicular vessels or vas deferens. Lobe and Schropp [20] have described their experience of laparoscopic contralateral inguinal exploration in pediatric patients undergoing conventional inguinal herniorrhaphy. In this technique, a 2-mm endoscope is passed through a 3-mm trocar after pneumoperitoneum has been established. Both internal rings are then examined (Figure 21-6). Standard open groin exploration is then performed in patients in whom a contralateral hernia is identified. Others have suggested passing the laparoscope into the peritoneum through the open hernia sac in the symptomatic groin. This approach is more appealing as it minimizes the possible risks.

Abdominal Exploration

Diagnostic laparoscopy with or without biopsy can be easily performed in children, and may spare the patient the need for open laparotomy. Examples include cases of trauma [21], hepatobiliary disease [22], or chronic pain of unclear etiology [23]. Heloury and coworkers [24] have reported their experience with 28 children ranging in age from 8 to 16 years. Thirty diagnostic and therapeutic procedures were performed, including evaluation of adnexal pathology, reduction of adnexal torsion, ovarian transposition before radiotherapy, gonadal ablation in cases of sexual ambiguity, drainage or biopsy of ovarian cysts, and evaluation of appendiceal pathology.

Laparoscopic techniques have been used for cancer diagnosis and staging. Spinelli and coworkers [25] reported an extensive experience in pediatric patients aged 2 to 16 years. The primary indication for the laparoscopic procedure was staging of known neoplastic disease, particularly Hodgkin's. The laparoscopic examinations were accomplished with minimal morbidity (1.2%). There were some false-negative laparoscopic examinations, but in most cases the clinical and radiologic follow-up confirmed the reliability of the laparoscopic examination.

Splenectomy has also been described in children [26]. The technical aspects of this procedure are described in detail in Chapter 12.

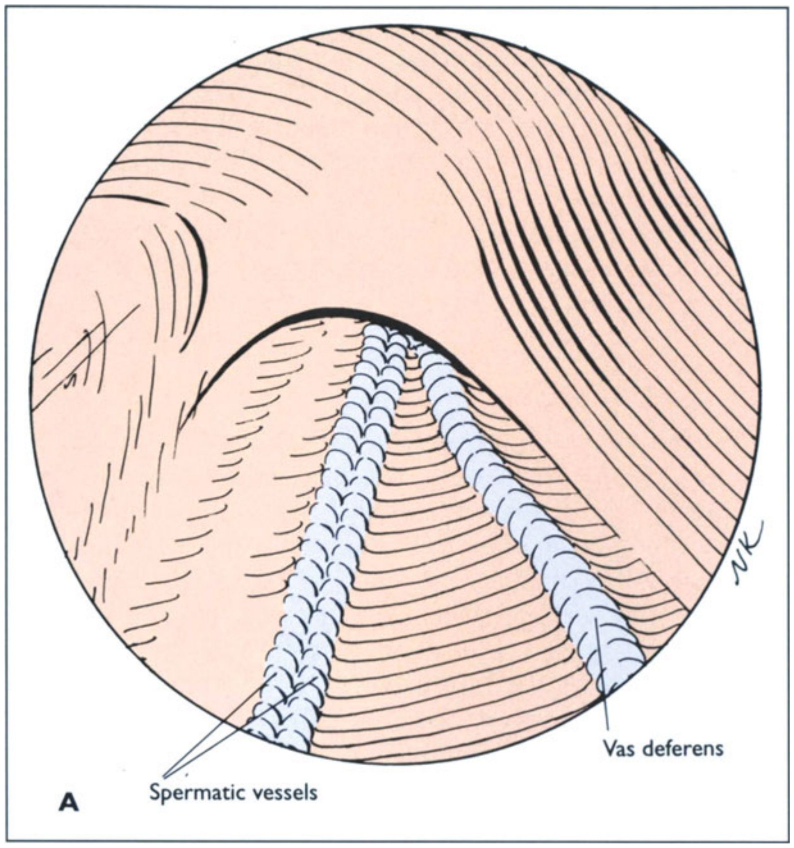
Urologic Procedures

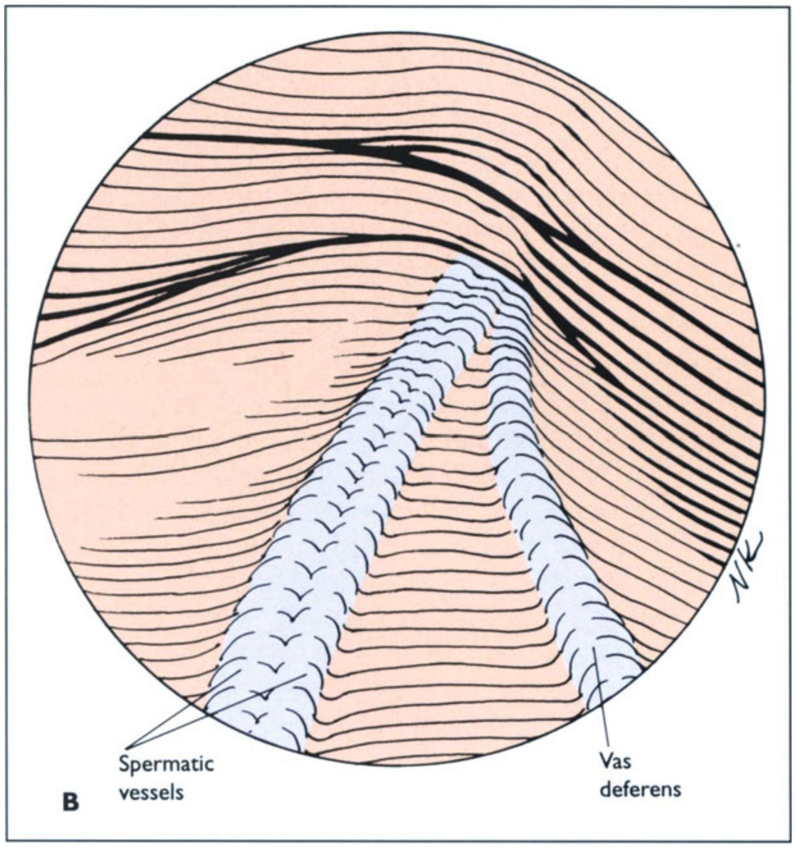
Evaluation of the child with cryptorchidism is a common problem in pediatric surgical practice with impalpable testes comprising about one-fifth of the cases. This condition is one in which evaluation and treatment using a laparoscopic approach is becoming increasingly popular. In 1976 Cortesi and coworkers [27] published the first description of the use of laparoscopy for localization of the undescended testis, and Scott [28] subsequently reported the use of this approach in a series of pediatric patients. Figure 21-7 outlines an algorithm for managing patients with impalpable testes in which laparoscopy plays a prominent role as the initial diagnostic modality. This permits minimally invasive assessment of the presence, location, and size of an undescended testes, and the length and position of the vas deferens and gonadal vessels.

The testes are most reliably identified by locating their blood supply. After placing the laparoscope into the peritoneal cavity, a systematic exploration of the abdominal cavity should be performed, as outlined in Figure 21-8. Patients found to have a normal vas and gonadal vessels entering the internal ring (*see* Figure 21-6), or blind ending or absent gonadal vessels (Figure 21-9), are spared a laparotomy (or retroperitoneal dissection).

The laparoscopic approach can also be used as an important therapeutic modality. A small, atrophic testis with a normal contralateral gonad can be excised as illustrated in Figure 21-10*A*, thereby precluding the need for laparotomy. Two additional trocars are required for orchiectomy. These should be placed appropriately after locating the testis to form the base of an isosceles triangle with its apex at the site of the gonad. The first stage of Ransley's modification of the Fowler-Stephens procedure, in which short testicular vessels supplying a high intra-abdominal testes are divided, can also be performed laparoscopically (Figure 21-10*B*). This follows a similar approach as orchiectomy in identifying the testis and dividing the testicular artery, but the vas deferens and testis are left untouched. This avoids laparotomy or extensive retroperitoneal dissection and accomplishes the goals of the first stage of the modified Fowler-Stephens procedure with minimal manipulation of the testis and better preservation of the important collateral blood supply. Based on the early observations of Clatworthy and coworkers [29], a more favorable outcome would be predicted for patients whose testes have been subjected to minimal manipulation. With the development of collateral blood flow to the testis through the vas deferens and gubernacular attachments, delayed orchiopexy can then be performed in the standard fashion.

Several case reports have been published detailing the use of the laparoscopic approach for other pediatric urologic procedures including nephrectomy [30,31], varicocele management [32], ureterolysis [33], or extravesical ureteral repair for vesicoureteral reflux [34].





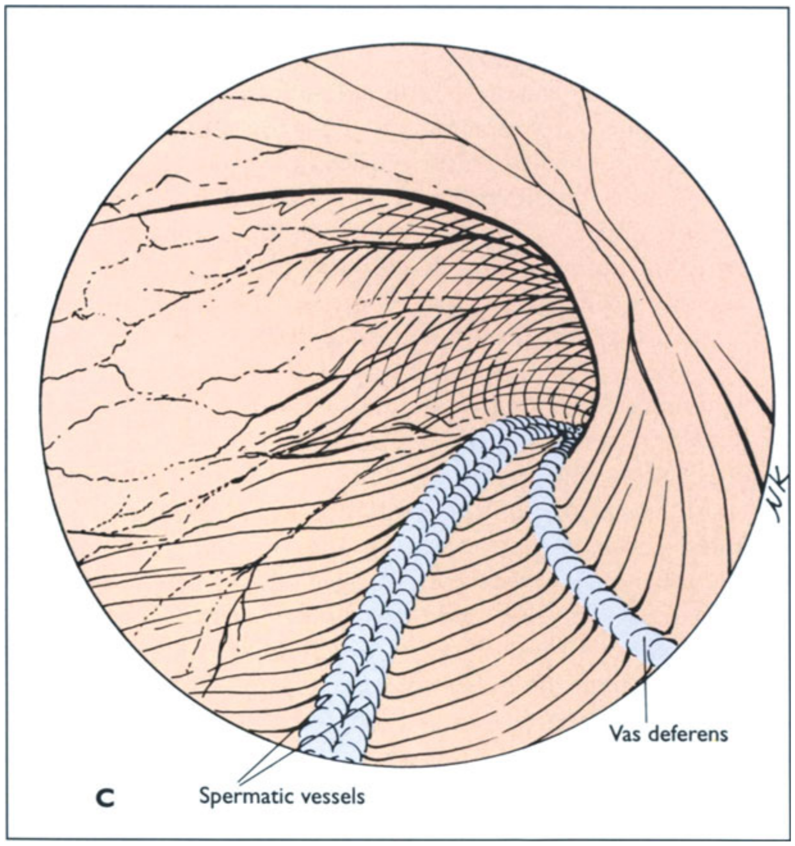


FIGURE 21-6.

Videoscopic appearance of the internal ring. **A**, A normal ring without a patent processus vaginalis. **B**, An internal ring with a patent processus vaginalis covered by a veil of peritoneum. **C**, A ring through which a large indirect hernia sac passes. Note the retroperitoneal vas deferens and spermatic vessels at the medial aspect of the ring.

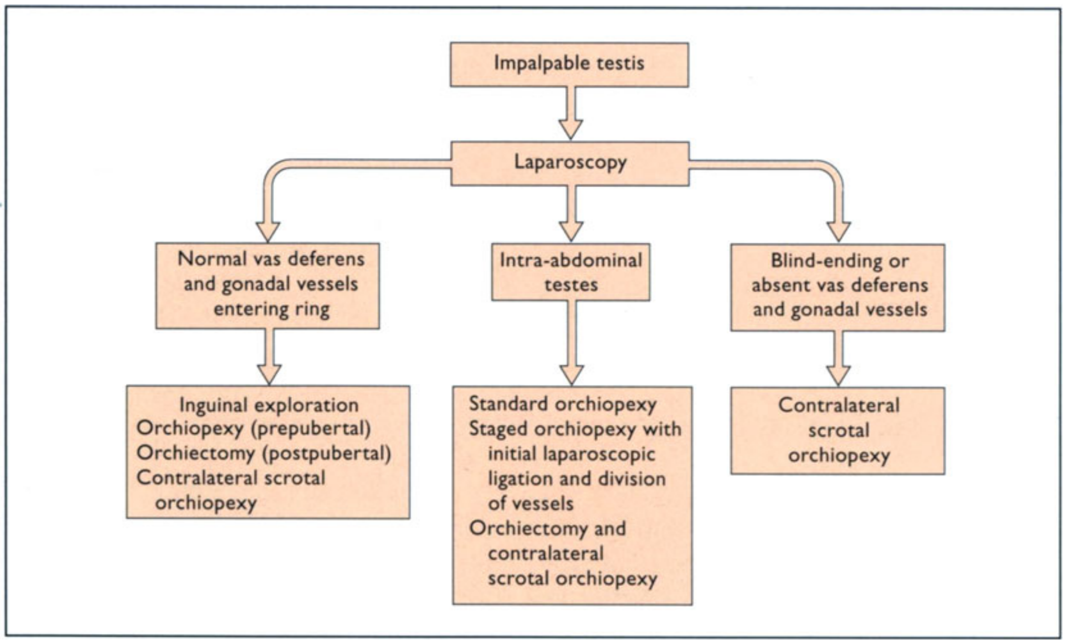


FIGURE 21-7.
Algorithm for initial laparoscopic evaluation and management of undescended testes.

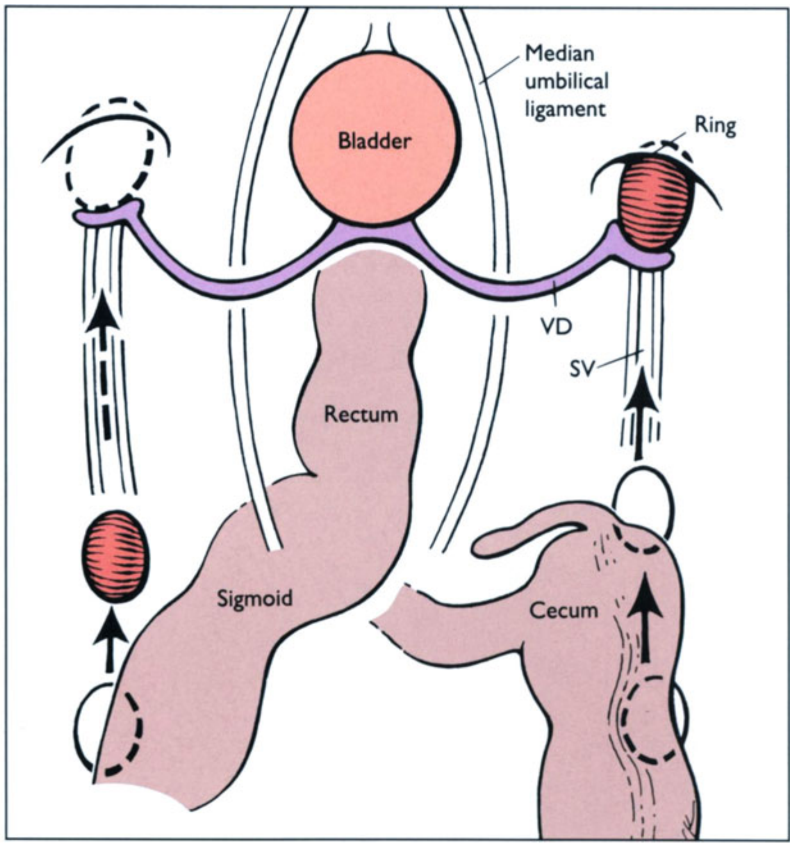


FIGURE 21-8.
Laparoscopic exploration for impalpable testes. After placing an infraumbilical trocar through which the laparoscope is passed, the normal, contralateral side and then the abnormal side is inspected. The median umbilical ligament and internal ring are identified and the vas deferens and spermatic vessels are sought. If they do not course into the internal ring, a systematic search is begun along the lateral paracolic gutter. This may require incising the lateral peritoneal attachments to the right or left colon by placing a suprapubic trocar for scissors and a contralateral lower quadrant trocar for a retractor, as in colectomy (see Chapter 18).

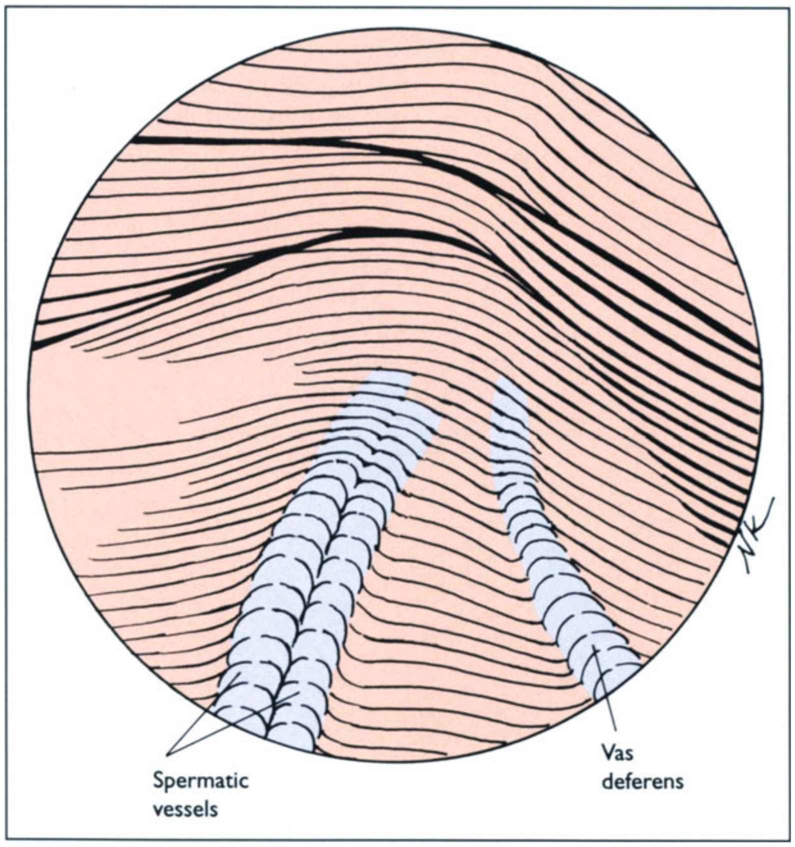


FIGURE 21-9.
Videoscopic appearance of internal ring with a blind-ending vas deferens and gonadal vessels.

Thoracoscopic Procedures

Although thoracoscopy was first performed in 1910 by Jacobaeus, a significant series of thoracoscopic procedures in pediatric patients was not published until 1976 [35]. Since then, enthusiasm for the thoracoscopic approach to chest surgery in children has increased substantially as experience has been gained. A current list of indications for thoracoscopic surgery in children is outlined in Table 21-7. "Minimally invasive" surgery of the chest is especially appealing for the pediatric population because the pain and respiratory complications associated with a thoracotomy incision can be avoided, particularly when there is severe underlying lung disease.

Diagnostic thoracoscopy can be performed easily with a patient in a lateral decubitus position. Slight variations in patient positioning may be helpful when evaluating particular regions of the thorax such as the apices or mediastinum (Figure 21-11). The trocar for the thoracoscope is generally placed in the sixth intercostal space. A small skin incision is made at the selected site and the subcutaneous tissue and muscles are dissected bluntly until the parietal pleura is reached. Unlike the approach for standard tube thoracostomy, a tunnel through the subcutaneous tissue should not be created; a direct approach will help protect against injury to the visceral pleura that may be quite close in small patients and permits greater instrument mobility during the subsequent procedure. After pneumothorax has been created (in rare cases of noncompliant lungs this may require minimal CO_2 insufflation) the trocars may be carefully placed. Additional trocars are placed in a similar fashion under direct vision as required. At the conclusion of a procedure, trocars are removed and sites are closed. A chest tube may be placed through one of the trocar sites to monitor drainage or if an air leak is anticipated. In situations where these are not concerns, many surgeons simply evacuate the pneumothorax and cover thoracostomy sites with occlusive dressings without placing a chest tube.

Thoracoscopy has been shown to be effective in the diagnosis, evaluation, and management of intrathoracic lesions involving the lung parenchyma, pleura, and mediastinum in children [35–37]. Assistance in the evaluation of undiagnosed localized or diffuse pulmonary disease, especially in immunocompromised children, is frequently requested of pediatric surgeons, as is the diagnosis and staging of intrathoracic malignancy. Thoracoscopic lung biopsy is sensitive, specific, and easily performed. A second trocar is placed over the area to be biopsied, through which a grasping instrument is passed, while a third trocar (12 mm) is placed as far away from the biopsy site as possible to allow complete entry of a linear stapler into the thoracic cavity (Figure 21-12). In very small patients the stapler may not fit; biopsies are then taken directly through the trocar overlying the lesion with cup biopsy forceps. Coagulation of the lung parenchyma should be performed following deep biopsies. Thoracoscopic lobectomy has been reported in adults. The technique is described elsewhere in this text.

The differential diagnosis of a mediastinal mass is extensive and varied, as outlined in Table 21-8. Thoracoscopy can be used both for diagnosis and treatment. Patient and trocar positioning for anterior and posterior mediastinal masses are shown in Figure 21-11. It is again important to place the operating trocar as far away from the lesion as possible in order to optimize mobility.

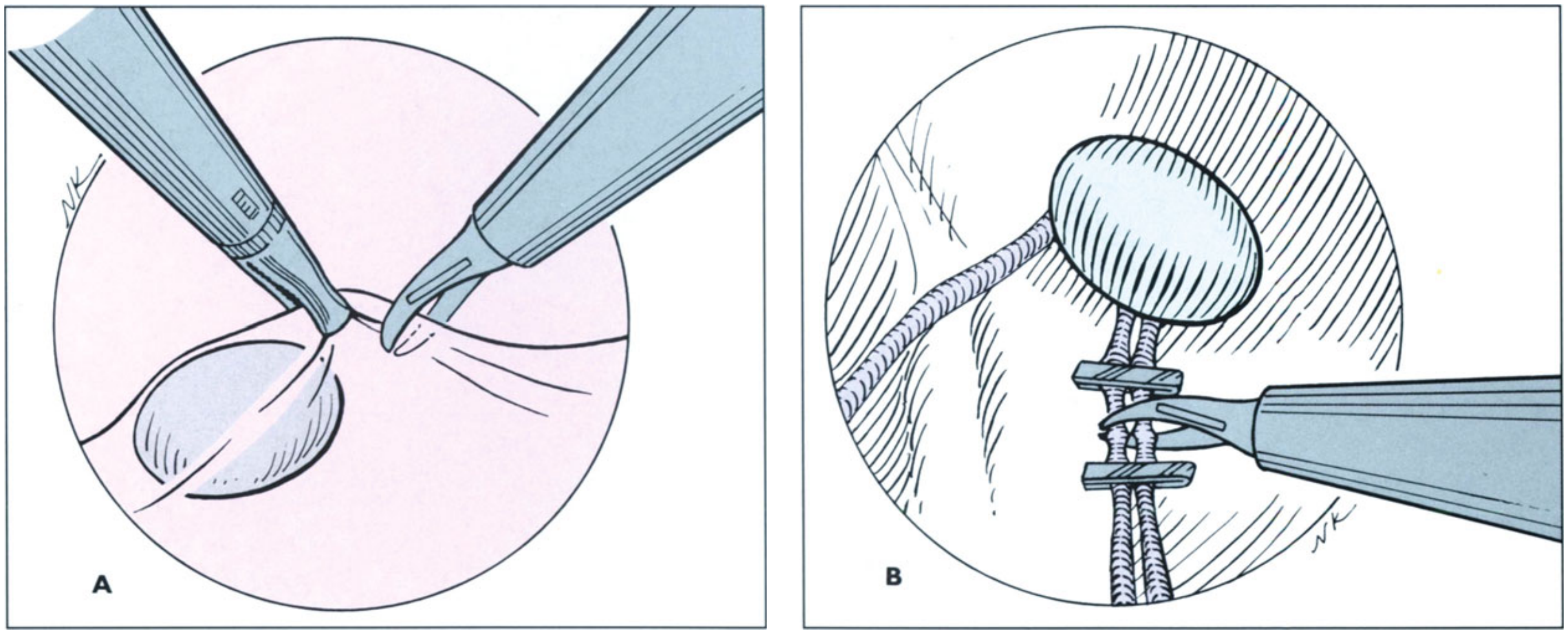


FIGURE 21-10.

Identification of intra-abdominal testes. **A**, Excision of atrophic intra-abdominal testis. The overlying peritoneum is incised and the testis is removed, usually by sharp dissection and electrocautery, as the blood supply is usually minimal. **B**, Ligation and division of testicular vessels. Placement of the two operating ports is based on localization of testes. The port for the instrument used to grasp the peritoneum is placed in the suprapubic region while the second port for the dissecting instrument is placed as far away as possible in the contralateral lower quadrant. This trocar may need to be 10 mm to accommodate the clipping device.

Dissection of the overlying pleura can be performed with either scissor or hook cautery (Figure 21-13). As with mediastinoscopy, lesions should be aspirated prior to biopsy if there is a possibility that they are vascular structures.

Finally, there are reports of the successful use of thoracoscopy for the management of pleural disease in children, such as for effusions, empyema, and pneumothorax [38–40]. The techniques for pleural drainage, decortication, and pleurodesis (with or without bleb resection) are described elsewhere in this text.

Table 21-7. Common indications for thoracoscopic surgery in children

Diagnostic thoracoscopy
Lung biopsy
Evaluation and excision of mediastinal mass
Excision of bronchogenic cyst
Pleurodesis and bleb resection
Treatment of pleural effusion/empyema
Diagnosis and staging of cancer
Evaluation of chest wall and diaphragm

Conclusions

The relatively small but rapidly expanding experience with pediatric laparoscopy and thoracoscopy is confirming the safety and efficacy of "minimally invasive" surgery in children. The potential benefits of improved visualization at the time of operation, decreased pain and ileus after surgery, shortened hospitalization, and improved cosmesis are especially attractive for the pediatric population. The specific indications and the operations best performed by an endosurgical approach are being evaluated. There should be a clearly demonstrated benefit of an endosurgical approach to an operation over the conventional, time-tested open technique. In addition, the risks of laparoscopy, such as trocar placement and pneumoperitoneum, as well as the loss of tactile sensation so important in the performance of many operations, should be carefully considered. There is no doubt that the role of these new approaches will undergo considerable evolution in the coming years.

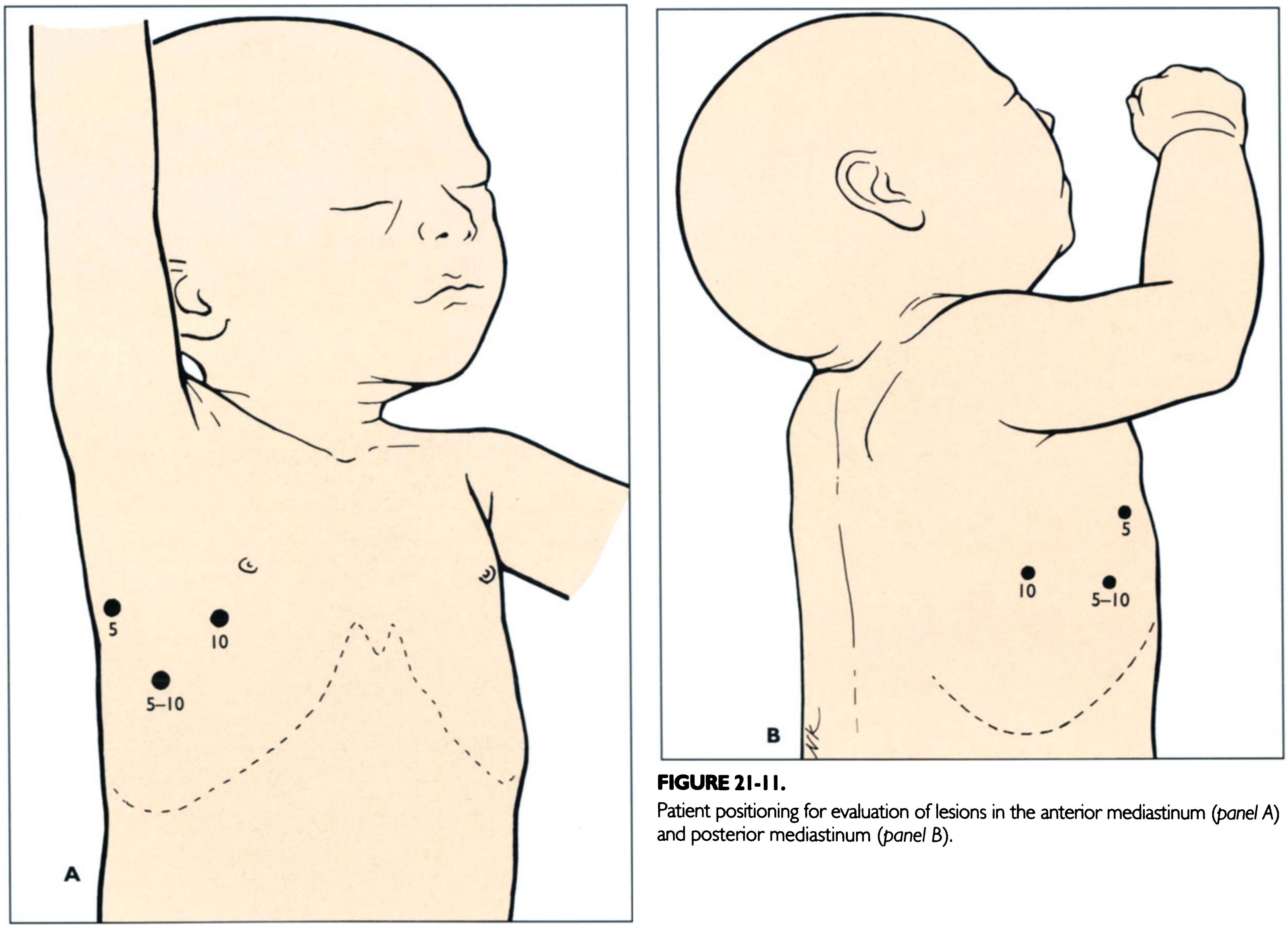


FIGURE 21-11.
Patient positioning for evaluation of lesions in the anterior mediastinum (*panel A*) and posterior mediastinum (*panel B*).

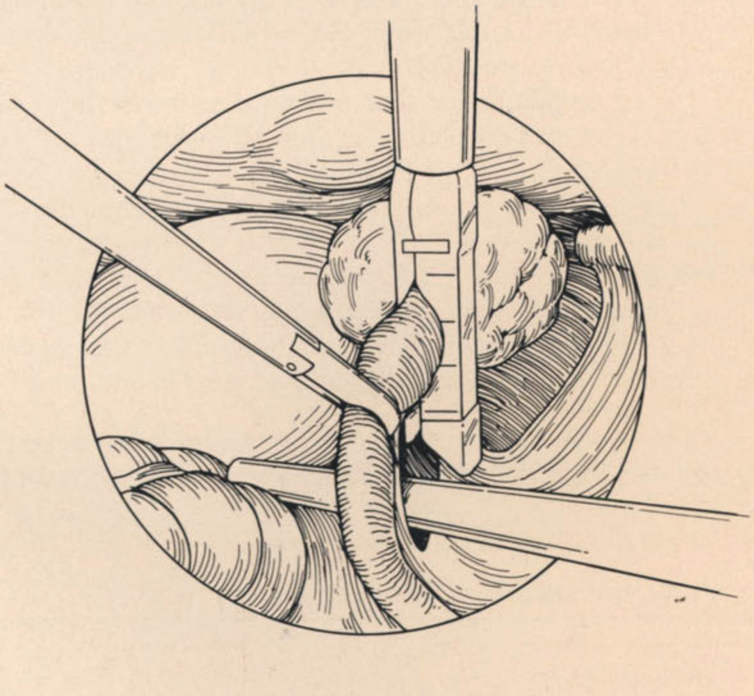
References

1. Gans SL, Berci G: Advances in endoscopy of infants and children. *J Pediatr Surg* 1971, 6:199–234.
2. Gans SL, Berci G: Peritoneoscopy in infants and children. *J Pediatr Surg* 1973, 8:399–405.
3. Rodgers BM, Talbert JL: Thoracoscopy for diagnosis of intrathoracic lesions in children. *J Pediatr Surg* 1976, 11:703–708.
4. Lynch FP, Ochi T, Scully M, *et al.*: Cardiovascular effects of increased intra-abdominal pressure in newborn piglets. *J Pediatr Surg* 1974, 9:621–626.
5. Masey SA, Koehler RC, Buck JR, *et al.*: Effect of abdominal distention on central and regional hemodynamics in neonatal lambs. *Pediatr Res* 1985, 19:1244–1249.
6. Holcomb GW, Olsen DO, Sharp KW: Laparoscopic cholecystectomy in the pediatric patient. *J Pediatr Surg* 1991, 26:1186–1190.
7. Sigman HA, Laberge JM, Croitoru D, *et al.*: Laparoscopic cholecystectomy: a treatment option for gallbladder disease in children. *J Pediatr Surg* 1991, 26:1181–1183.
8. Newman KD, Marman LM, Attori R, *et al.*: Laparoscopic cholecystectomy in pediatric patients. *J Pediatr Surg* 1991, 26:1184–1185.
9. Moir CR, Donahoe JH, VanHeerden JA: Laparoscopic cholecystectomy in children: initial experience and recommendations. *J Pediatr Surg* 1992, 27:1066–1070.
10. Davidoff AM, Branum GD, Murray EA, *et al.*: The technique of laparoscopic cholecystectomy in children. *Ann Surg* 1992, 215:186–191.
11. Semm K: Endoscopic appendectomy. *Endoscopy* 1983, 15:59.
12. Valla JS, Limonne V, Valla V, Montupet P: Laparoscopic appendectomy in children: report of 465 cases. *Surg Laparosc Endosc* 1991, 166–172.
13. Ure BM, Spangenberg W, Hebebrand D, *et al.*: Laparoscopic surgery in children and adolescents with suspected appendicitis: results of medical technology assessment. *Eur J Pediatr Surg* 1992, 2:336–340.
14. Gilchrist BF, Lobe TE, Schropp KP, *et al.*: Is there a role for laparoscopic appendectomy in pediatric surgery? *J Pediatr Surg* 1992, 27:209–214.
15. Papaila JG, Vane DW, Colville C, *et al.*: The effect of various types of gastrostomy on the lower esophageal sphincter. *J Pediatr Surg* 1987, 22:1198–1202.
16. Ashcraft KW, Holder TM, *et al.*: The Thal fundoplication for gastroesophageal reflux. *J Pediatr Surg* 1984, 19:480–483.
17. Dedinsky GK, Vane DW, *et al.*: Complications and reoperation after Nissen fundoplication in childhood. *Am J Surg* 1987, 153:177–183.
18. Turnage RH, Oldham KT, Coran AG, Blane CE: Late results of fundoplication for gastroesophageal reflux in infants and children. *Surgery* 1989, 105:457–464.
19. Alain JL, Grousseau D, Terrier G: Extramucosal pylorotomy by laparoscopy. *J Pediatr Surg* 1991, 26:1191–1192.
20. Lobe TE, Schropp KP: Inguinal hernias in pediatrics: initial experience with laparoscopic inguinal exploration of the asymptomatic contralateral side. *J Laparoendosc Surg* 1992, 2:135–140.
21. Fabian TC, Croce MA, Stewart RM, *et al.*: A prospective analysis of diagnostic laparoscopy in trauma. *Ann Surg* 1993, 217:557–565.
22. Reich H, McGlynn F, De Caprio J, *et al.*: Laparoscopic excision of benign liver lesions. *Obstet Gynecol* 1991, 78:956–958.
23. Goldstein DP: Acute and chronic pelvic pain. *Pediatr Clin North Am* 1989, 36:573–580.
24. Heloury Y, Guiberteau V, Sagot P, *et al.*: Laparoscopy in adnexal pathology in the child: a study of 28 cases. *Eur J Pediatr Surg* 1993, 3:75–78.
25. Spinelli P, Pizzetti P, Lo Gullo C, *et al.*: Laparoscopy in oncological pediatrics. *Pediatr Med Chir* 1988, 10:99–101.
26. Tulman S, Holcomb GW III, Karamanoukian HL, Reynhout J: Pediatric laparoscopic splenectomy. *J Pediatr Surg* 1993, 28:689–692.
27. Cortesi N, Ferrari P, Zambarda E, *et al.*: Diagnosis of bilateral abdominal cryptorchidism by laparoscopy. *Endoscopy* 1976, 8:33–34.
28. Scott JES: Laparoscopy as an aid in the diagnosis and management of impalpable testis. *J Pediatr Surg* 1982, 17:14–16.
29. Clatworthy H Jr, Hollanbaugh R, Grosfeld J: The "long loop vas" orchiopexy for high undescended testis. *Am Surg* 1972, 38:69–73.
30. Clayman RV, Soper N, Kavoussi LR, *et al.*: Laparoscopic nephrectomy: laboratory and clinical experience. *J Urol* 1991, 145:421–425.
31. Koyle MA, Woo HH, Kavoussi LR: Laparoscopic nephrectomy in the first year of life. *J Pediatr Surg* 1993, 28:693–695.
32. Matsuda T, *et al.*: Laparoscopic varicocelectomy: a simple technique for clip ligation of the spermatic vessels. *J Urol* 1992, 147:636–638.
33. Kavoussi LR, Clayman RV, Brunt LM, Soper NJ: Laparoscopic ureterolysis. *J Urol* 1992, 147:426–429.
34. Peters CA: Laparoscopy in pediatric urology. *Urology* 1993, 41[suppl]:33–37.
35. Rodgers BM, Talbert JL: Thoracoscopy for the diagnosis of intrathoracic lesions in children. *J Pediatr Surg* 1976, 11:703–707.
36. Ryckman FC, Rodgers BM: Thoracoscopy for intrathoracic neoplasia in children. *J Pediatr Surg* 1982, 17:521–524.
37. Rogers DA, Lobe TE, Schropp KP: Video-assisted thoracoscopic surgery in the pediatric patient. *Chest Surg Clin North Am* 1993, 3:325–335.
38. Vanderschueren RG: The role of thoracoscopy in the evaluation and management of pneumothorax. *Lung* 1990, 168[suppl]:1122–1125.
39. Daniel TM, Tribble CG, Rodgers BM: Thoracoscopy and talc poudrage for pneumothoraces and effusions. *Ann Thorac Surg* 1990, 50:186–189.
40. Kern JA, Rodgers BM: Thoracoscopy in the management of empyema in children. *J Pediatr Surg* 1993, 28:1128–1132.

CHAPTER 22

Laparoscopic-assisted Vaginal Hysterectomy With or Without Removal of the Adnexae

John T. Soper



Although vaginal hysterectomies were described before the 18th century, it was not until the middle 19th century that the first successful abdominal hysterectomy was reported with survival of the patient [1]. Until the late 19th century, abdominal hysterectomy was rarely performed and remained an extremely morbid procedure until the principles of sterile technique, ligature of vascular pedicles for hemostasis, and basic anesthesia were widely applied in the 1890s and early 20th century. Initially, vaginal hysterectomy was more frequently performed than abdominal hysterectomy, but improvements in anesthetic techniques, antibiotics, and blood transfusion services in the mid-20th century along with changing indications for hysterectomy have resulted in a relative increase in the number of abdominal hysterectomies compared with vaginal hysterectomies. Thompson [1] has compiled an excellent review of the historical aspect of these procedures.

Laparoscopy has been widely used by obstetricians and gynecologists in the United States since the late 1960s for diagnostic purposes and for tubal sterilizations [2]. Until the development of videolaparoscopy, however, surgical procedures were generally limited to lysis of pelvic adhesions, fulguration of endometriosis, and simple procedures on adnexal structures.

Reich and coworkers [3] described the first laparoscopically assisted vaginal hysterectomy (LAVH) in 1989. Since this initial report, many anecdotal reports of LAVH have appeared using various techniques and instrumentation. It is only recently that series of patients have been reported rather than case reports; however, LAVH was widely embraced by gynecologists before the procedure was subjected to critical analysis in the literature. The use of laparoscopy along with a vaginal removal of the uterus would seem to yield many of the benefits of an abdominal approach without the morbidity of an abdominal incision and preserve the advantages of a vaginal approach. The purported benefits of LAVH are presented in Table 22-1.

Anatomy

The gynecologic anatomy pertinent to performance of the laparoscopic portion of LAVH will be considered; detailed gynecologic anatomy is presented elsewhere. Figure 22-1 depicts the gynecologic organs as viewed through the laparoscope. The uterus is situated between the bladder (anterior) and the rectosigmoid (posterior). The parietal peritoneum is applied directly to the uterus, fallopian tubes, and ovaries with little intervening adventitia. It reflects anteriorly over the bladder forming the anterior cul de sac, and posteriorly over the upper vagina onto the rectosigmoid forming the posterior cul de sac. Within loose areolar tissues along the endopelvic fascial planes are the potential vesicovaginal and rectovaginal spaces.

Lateral reflections of the visceral peritoneum applied to the adnexae and round ligaments bilaterally form the broad ligament. Condensations of perivascular fascia form the round ligaments. These pass anterolaterally from the anterior uterine cornu to exit the pelvis through the internal iliac rings. Sampson's artery, an anastomotic vessel arising from the uterine vasculature, accompanies the round ligament, and must be controlled when the round ligament is divided.

The anterior leaf of the broad ligament is the flat expanse of peritoneum extending from the round ligament to the bladder. The middle leaf of the broad ligament is the triangular portion of peritoneum bound by the round ligament anteriorly, the tube and infundibulopelvic ligament medially, and the pelvic sidewall laterally. When the anterior and middle leaves of the broad ligament are opened, the underlying loose areolar tissue can be easily dissected to expose the pelvic sidewall and retroperitoneal structures. The medial leaf of the broad ligament extends posterior to the fallopian tube, ovary, and infundibulopelvic ligament. In Figure 22-1, the peritoneum of the medial leaf of the left broad ligament has been removed to illustrate the relationships of the ureter, infundibulopelvic ligament, and uterine artery. The ureter is loosely adherent to the medial leaf of the broad ligament throughout its course through the pelvis and can be readily visualized through the peritoneum by the laparoscope. The posterior boundary of the medial leaf is formed by the uterosacral ligaments, which extend posterior from the lateral cervix, lateral to the rectum, to insert into the sacrum as the posterior rectal pillars.

The dominant uterine blood supply is from the uterine arteries that are anterior branches of the hypogastric (internal iliac) arteries. Each uterine artery rises and courses anteromedially, crossing anterior to the ureter approximately 2-cm lateral to the cervix. It divides into ascending branches, which supply the uterine fundus and anastomose

Table 22-1. Purported advantages of laparoscopically assisted vaginal hysterectomy versus abdominal or vaginal hysterectomy

LAVH vs. vaginal hysterectomy	LAVH vs. abdominal hysterectomy
Superior visualization of abdominal contents	Abdominal incision avoided
Reliable removal of adnexae	Reduced ileus
Can surgically approach adhesions, endometriosis, and adnexal pathology	Reduced infectious morbidity
	Reduced postoperative adhesions
	Concomitant repair of vaginal relaxation
	Reduced hospital stay and convalescence

with vessels from the mesosalpinx, and descending cervicovaginal branches. The uterine veins coalesce and descend as a plexus that drain into the hypogastric vein.

The vascular adventitia of the uterine vessels condense to form the cardinal ligament, which traverses laterally and provides major lateral support to the uterine cervix. The ureter passes posterior to the uterine artery within the ureteric tunnel through the cardinal ligament (Figure 22-1).

The ovarian blood supply descends into the pelvis within the infundibulopelvic ligament. The ovarian arteries are direct branches from the aorta. The right ovarian vein drains into the inferior vena cava, while the left ovarian vein drains into the left renal vein. The ovarian artery continues medially forming the arcade of the mesosalpinx and terminates in anastomoses with ascending branches of the uterine artery adjacent to the uterine cornu. The ovaries are supported medially by the utero-ovarian ligaments.

The ureter enters the pelvis at approximately the level of the bifurcation of the common iliac artery in close proximity to the infundibulopelvic ligament. The pelvic ureter courses anterior and medial in a shallow arc. It is applied loosely to the medial leaf of the broad ligament and enters the ureteric tunnel under the uterine artery as previously described (Figure 22-1). The most common sites of injury to the ureter during hysterectomy are at the level of the uterine artery and at the level of the infundibulopelvic ligament. It is imperative that the ureter be isolated and visualized at all times during ligation of these structures.

Indications

A variety of disease processes are amenable to this hysterectomy [1]. It is beyond the scope of this chapter to discuss the pathophysiology of each of these. However, as in the use of any surgical technique, it is imperative that the surgeon be thoroughly familiar with the disease processes that might constitute indications for LAVH and have a thorough knowledge of the therapeutic options. It should be emphasized that it is inappropriate to use LAVH when a simple vaginal hysterectomy is indicated [4]. The major advantage to the use of LAVH lies in the potential to convert procedures that might otherwise be performed by laparotomy into vaginal procedures. A partial listing of both cervicouterine and adnexal diseases that might be approached with this technique appears in Table 22-2.

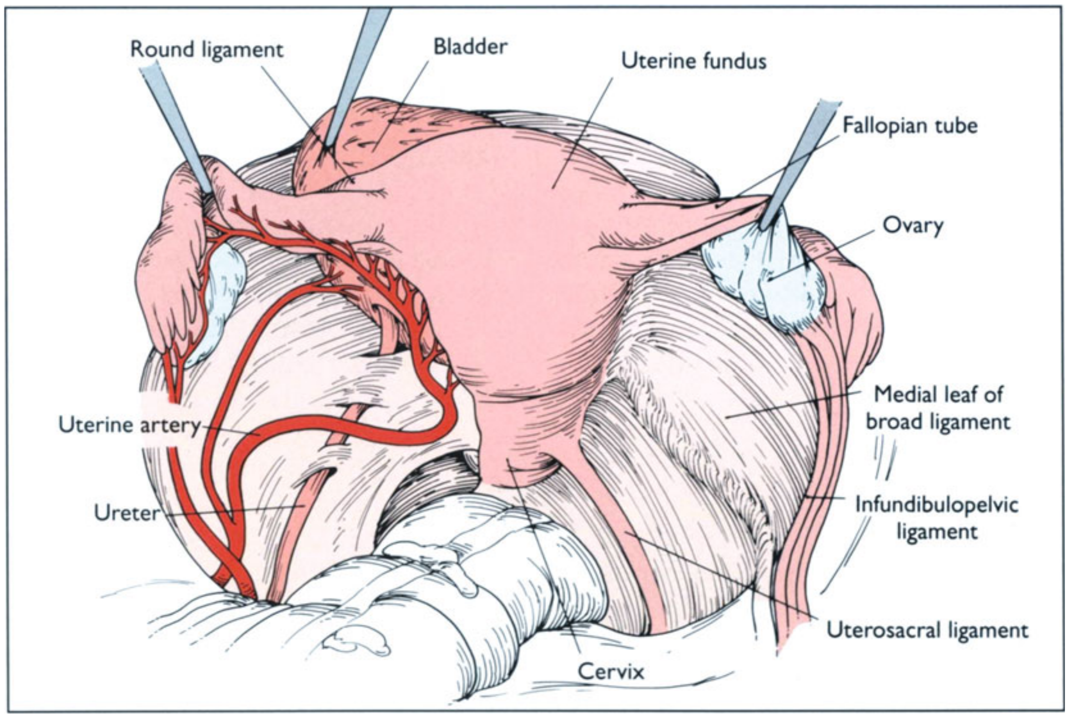


FIGURE 22-1.

Idealized laparoscopic view of the gynecologic pelvis. The medial leaf of the broad ligament has been removed to illustrate the relationships of the ureter, infundibulopelvic ligament, and uterine artery.

Table 22-2. Partial listing of indications for laparoscopically assisted vaginal hysterectomy

Refractory dysfunctional uterine bleeding	Endometriosis
Adenomyosis	Refractory cervical dysplasia
Uterine leiomyomas	Endometrial adenomatous hyperplasia
Chronic pelvic inflammatory disease	Benign adnexal masses and ovarian neoplasms

A normal uterus is often removed in conjunction with removal of adnexal pathology, particularly in women who do not desire to retain fertility or who are perimenopausal [1]. Conversely, elective removal of normal fallopian tubes and ovaries is often performed in conjunction with hysterectomy in perimenopausal women. In general, the lifetime risk of developing ovarian cancer in a retained ovary is approximately 1.5% at age 40 and increases threefold in women with a family history of ovarian cancer, but rare families may have a much higher risk for ovarian cancer among women. This risk and the risk of subsequent surgery for benign disease in a retained adnexum must be weighed against the risk of surgical castration of the patient and the need for estrogen replacement therapy in premenopausal women [1].

Relative contraindications for LAVH including the following: 1) Invasive cervical cancer: in these patients radical surgery or radiation is appropriate, while simple hysterectomy of any type is generally inadequate therapy [1,5]. 2) Endometrial cancer: although endometrial cancer is usually treated with hysterectomy, this disease is surgically staged [5]. While the efficacy of laparoscopic staging of endometrial cancer is currently being evaluated [6], it often includes performance of pelvic and para-aortic lymphadenectomy, procedures that are beyond the capabilities of most laparoscopic surgeons. 3) Pelvic masses that are suspicious for ovarian cancer or are larger than approximately 6 to 8 cm in diameter: similar to patients with endometrial cancer, patients with early ovarian cancers usually require comprehensive staging laparatomies, including pelvic and para-aortic lymphadenectomies [5]. Furthermore, intra-abdominal rupture of an early ovarian malignancy increases the stage and may adversely affect survival [5]. Finally, management of advanced ovarian cancer is based on the principle of maximal tumor debulking at primary surgery [5]. Table 22-3 provides criteria that may aid in the identification of benign pelvic masses.

Surgical Technique

Several types of LAVH techniques have been reported, ranging in scope from simply using laparoscopy to confirm the feasibility of vaginal hysterectomy, to procedures that use laparoscopic ligation of all vascular pedicles and ligaments, development of the bladder flap, and entry into the vagina, leaving only removal of the uterus for the vaginal portion of the procedure [7]. We teach and use a modified LAVH technique: laparoscopic dissection is used to lyse adhesions, control the round ligaments, open the pelvic sidewall and control the infundibulopelvic ligament or utero-ovarian ligament and tube, and partially develop the bladder flap. The procedure is then converted to a standard vaginal hysterectomy with ligation of the uterosacral ligaments, cardinal ligaments, and uterine vessels vaginally. We believe that this is the safest technique to learn and teach to physicians who do not have advanced laparoscopic skills. It avoids the potential for ureteral injury caused when endoscopic staplers or electrocautery are used for laparoscopic control of the uterine vessels [8].

Patients receive a mechanical bowel prep with clear liquids, magnesium citrate for 2 days prior to surgery, and perioperative prophylactic antibiotics. The patient is positioned in a modified lithotomy position using the candy-cane stirrups with the hips flexed 30° to 45°. The arms are tucked at the patient's sides. The vagina and perineum are sterilely prepped and draped but excluded from the abdominal field. A Foley catheter and uterine manipulator are placed. Figure 22-2 illustrates the operating room set-up that we use for LAVH. We usually use two lateral video monitors so that both the surgeon and assistant have an unobstructed view of the operation. An alternative placement of a single monitor at the foot of the operating table is also illustrated.

Peritoneal access is performed with a 10-mm sheath placed infraumbilically using closed (direct insertion and Veress needle) or open (Hasson trocar) techniques (Figure 22-3). CO_2 is insufflated with a high-flow (> 3 L/min) insufflator at pressures < 15 mm Hg. The laparoscope is inserted and upper abdominal contents are visualized. The patient is placed in 20° to 30° Trendelenburg position for visualization of the pelvic structures.

Additional sheaths are placed under laparoscopic guidance with transabdominal illumination and avoidance of the major vessels at the sites indicated in Figure 22-3. Two 5-mm sheaths are placed approximately 3 to 4 cm medial to and slightly above the level of the anterior superior iliac crests. The inferior epigastric vessels should be avoided when placing these sheaths. A 12-mm sheath is usually placed in the suprapubic location if endoscopic staplers or clips are to be used.

If additional exposure is required or a large uterus is encountered, the 12-mm trocar may be placed either above or below the umbilicus or an additional sheath may be placed at these sites (Figure 22-3). If these placements are used, the sheaths should be placed just off the midline

Table 22-3. Preoperative criteria suggesting benign pelvic mass

Diameter < 7 cm	No evidence of ascites
Unilocular, simple cyst on ultrasound	Serum CA 125, < 35 μ/mL
Unilateral lesion	

to avoid interference between the instruments and the laparoscope.

The bowel is manipulated out of the pelvis with atraumatic forceps and the probe. Adhesions are taken down sharply (Figure 22-4) with endoscopic scissors. Electrocautery should not be used on adhesions involving the bowel. The course of each pelvic ureter should be visualized through the medial leaf of the broad ligament, and its relative position should be verified during each portion of the procedure.

The uterus is placed on lateral traction, and the round ligament on each side is elevated and divided with the endoscopic scissors using monopolar electrocautery (Figure 22-5) or divided after bipolar cautery with the Kleppinger forceps. The principles of traction-countertraction are used throughout the procedure. Although one operator can serve as the primary surgeon and the other as the camera operator/assistant, it is often easier for the two to alternate functions and serve as the primary surgeon for procedures on the opposite side of the pelvis.

The peritoneum of the broad ligament is opened lateral to the fallopian tube and infundibulopelvic ligament (Figure 22-6). Medial traction on the utero-ovarian ligament or ovary using atraumatic graspers and the use of endoscopic scissors with monopolar cautery expedite the dissection. The peritoneal incision parallels the tube and is lateral to the ovarian vessels. If salpingo-oophorectomy is to be performed, the peritoneal incision is extended cephalad, parallel to the infundibulopelvic ligament. The loose areolar tissue within the broad ligament and the pelvic sidewall are opened using blunt dissection. Occasional small perforators can be controlled with electrocautery. The ureter will remain adherent to the middle leaf of the broad ligament.

When salpingo-oophorectomy is performed, a window is created with endoscopic scissors above the level of the ureter in the middle leaf of the broad ligament (Figure 22-7). This extends from the infundibulopelvic ligament to approximately the uterine vessels. Electrocautery may be required to control bleeding from small vessels.

Ligation of the infundibulopelvic ligament can be performed with the endoscopic stapler using the vascular staples. The instrument is placed through the 12-mm suprapubic port (Figure 22-8). The open stapler is advanced across the infundibulopelvic ligament though the window in the broad ligament. By closing the stapler and gently lifting the infundibulopelvic ligament before firing the stapler, the surgeon can ensure that the tips of the stapler are free, and the ureter is isolated from the pedicle (Figure 22-8).

An alternative technique using electrocautery with the bipolar Kleppinger forceps is illustrated in Figures 22-9A through 22-9C. The infundibulopelvic ligament is divided with endoscopic scissors after electrodesiccation (Figures 22-9A, 22-9B). Care must be taken to ensure that the ureter is at least 2 to 3 cm from the point of cautery. Additional assurance of hemostasis can be obtained by grasping the infundibulopelvic ligament through an open endoscopic loop suture (Figure 22-9B) as it is being divided. The endoscopic loop suture is then secured around the proximal pedicle (Figure 22-9C).

If the adnexae are to be preserved, the endoscopic stapler is passed through the suprapubic sheath and used to divide the utero-ovarian ligament and tube (Figure 22-10) using either the vascular or the tissue cartridge. The round ligament should be excluded from this pedicle and a tissue sizer used to determine the correct cartridge.

The fallopian tube/utero-ovarian ligament pedicle can also be divided after bipolar electrodesiccation with the Kleppinger forceps (Figure 22-11). The ureter is less likely to be damaged at this location than when the infundibulopelvic ligament is being divided.

The peritoneum and loose areolar tissues of the anterior leaf of the broad ligament and anterior peritoneal reflection of the uterus are opened with the endoscopic scissors using monopolar electrocautery for hemostasis (Figures 22-12 and 22-13). The bladder is reflected anteriorly with atraumatic forceps, and the bladder flap is developed with sharp dissection using monopolar electrocautery for hemostasis (Figure 22-13). Extensive mobilization of the bladder is not required, because this will be completed during the vaginal phase of the procedure. The uterus should be elevated and directed toward the posterior pelvis during dissection of the bladder flap.

The instruments are removed from the sheaths and the patient repositioned in the lithotomy position with the hips flexed 45°. The uterine manipulator is removed. Hysterectomy is completed with a standard vaginal hysterectomy technique [1] and the vaginal cuff is closed. After completion of the hysterectomy, the peritoneal cavity is insufflated with CO_2 and the laparoscope reinserted to inspect all pedicles for hemostasis. The large fascial defects caused by 10- to 12-mm trocars should be closed to prevent hernia formation. The skin incisions are closed with subcuticular sutures of absorbable material.

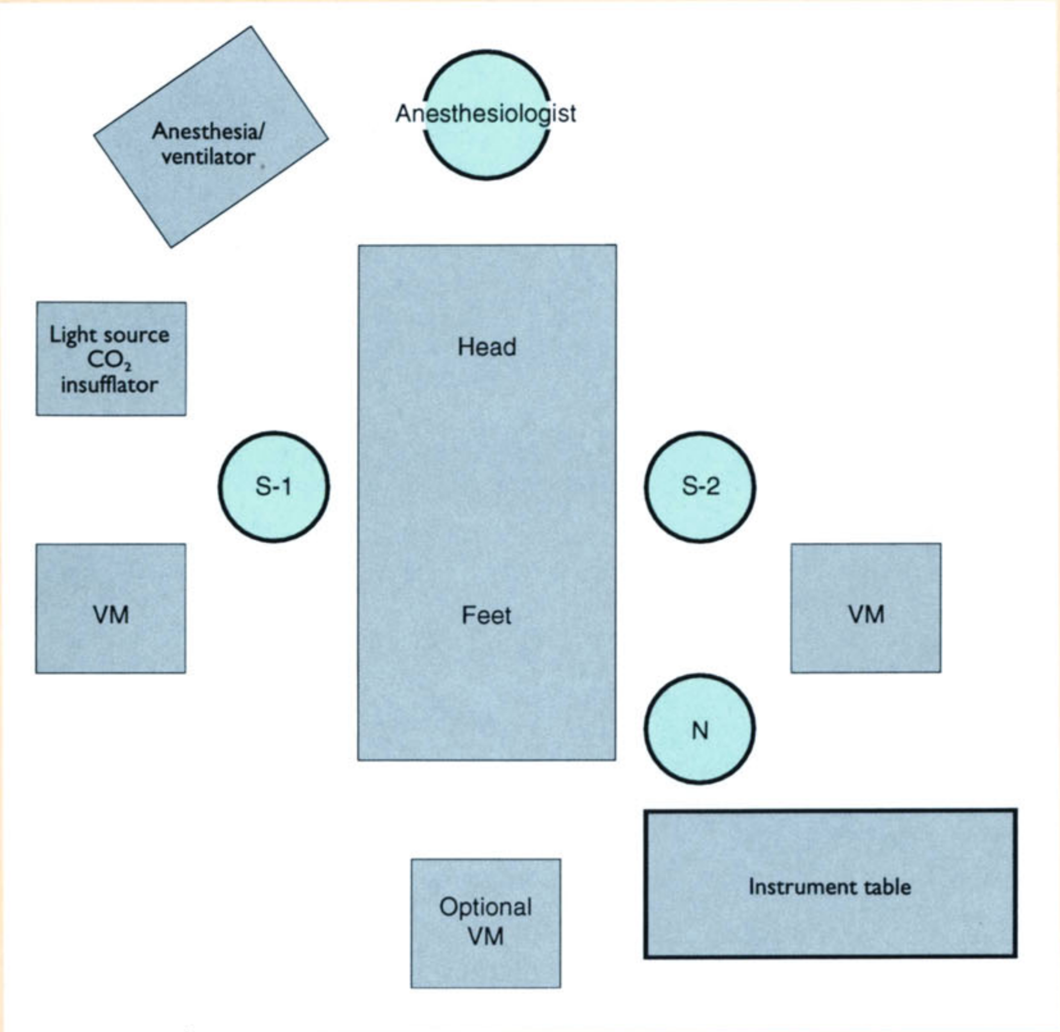


FIGURE 22-2.

Operating room set-up for laparoscopic-assisted vaginal hysterectomy. S-1—primary surgeon; S-2—surgical assistant; VM—video monitor; N—scrub nurse.

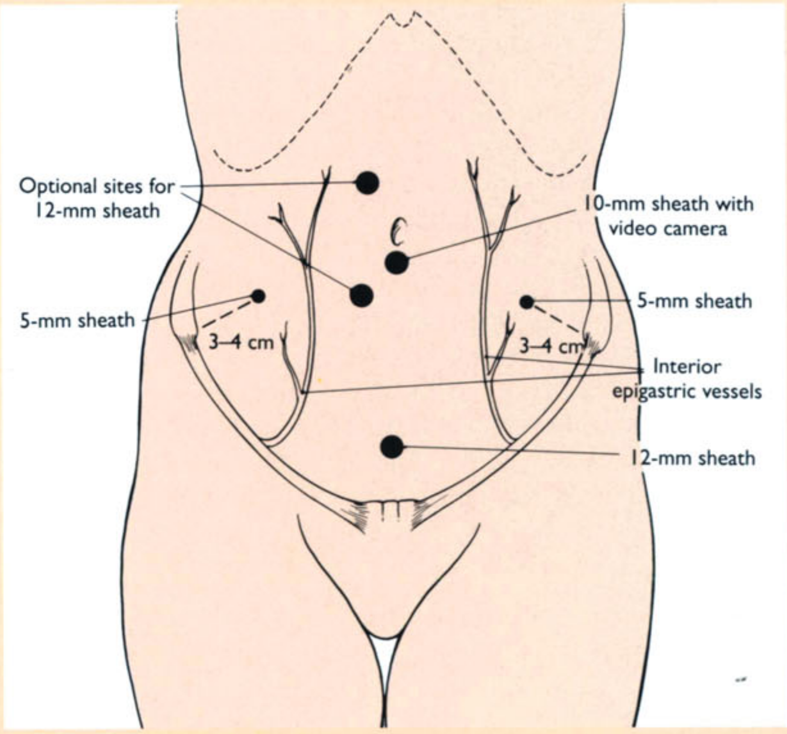


FIGURE 22-3.

Sites for placement of laparoscopic sheaths. If additional or superior placement of a 12-mm sheath is required, it should be positioned lateral to the midline to avoid interference with the laparoscope.

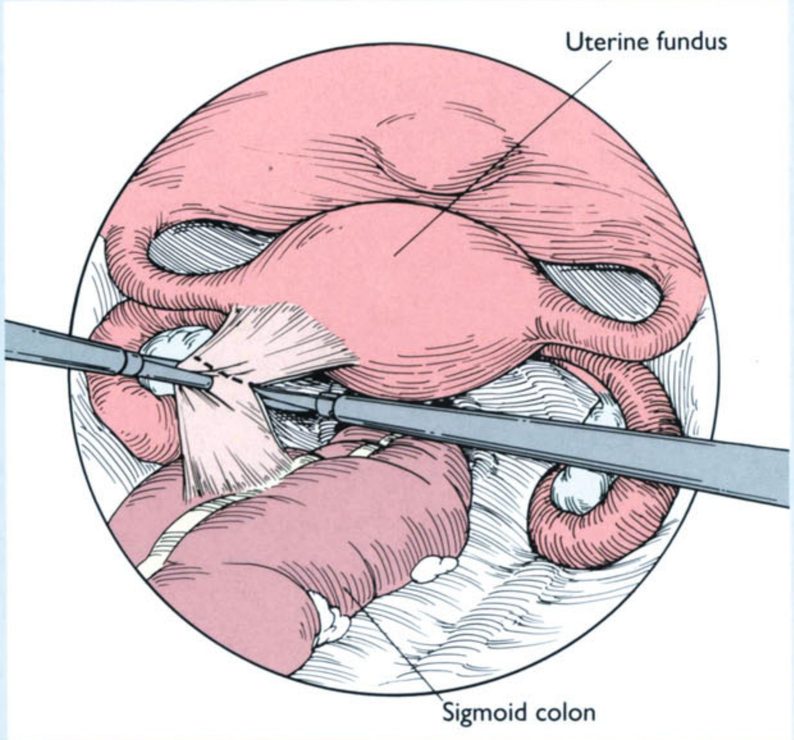


FIGURE 22-4.
Adhesions involving pelvic structures are frequently encountered. Adhesions involving the bowel should be taken down with sharp dissection, avoiding electrocautery.

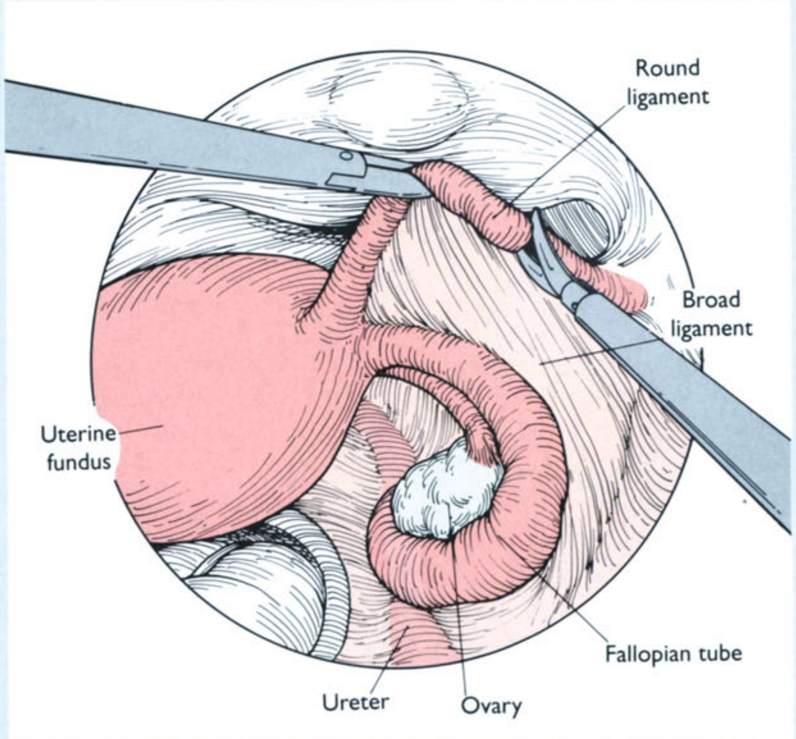


FIGURE 22-5.
Division of the round ligament using monopolar electrocautery and endoscopic scissors.

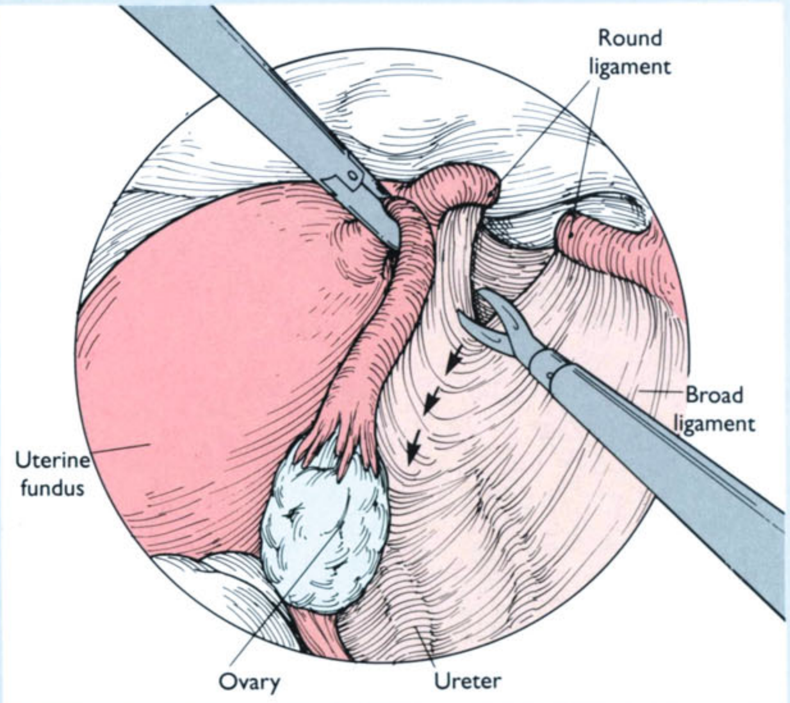


FIGURE 22-6.
Opening the peritoneum of the broad ligament lateral to fallopian tubes and infundibulopelvic ligament with endoscopic scissors.

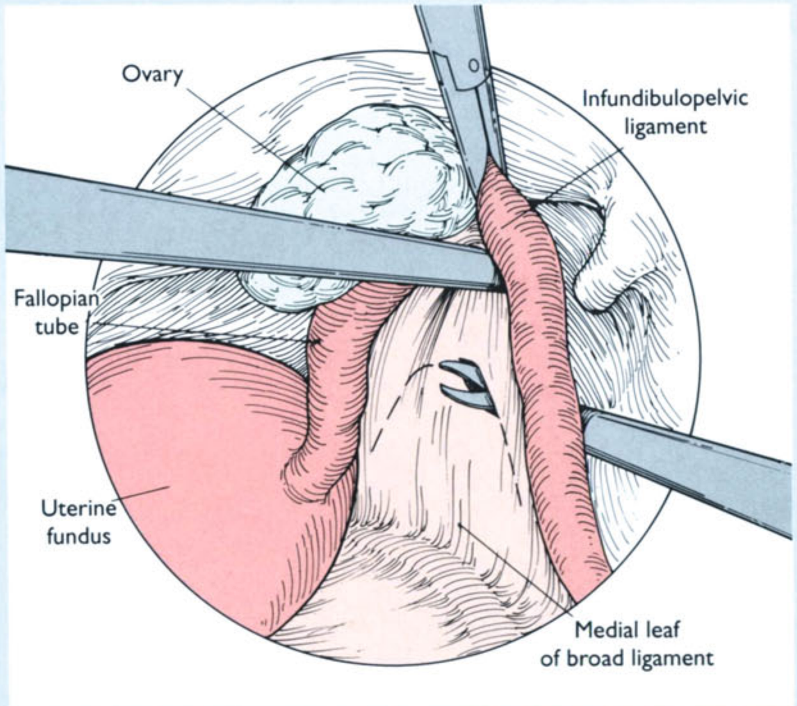


FIGURE 22-7.
Creating a window in the medial leaf of the broad ligament above the level of the ureter with endoscopic scissors. The peritoneal incision can be initiated with either a lateral approach, as shown, or with a medial approach and incising the peritoneum. In either case, the window is created only after visualizing the pelvic ureter. The peritoneal incision is extended from the infundibulopelvic ligament to the uterine arteries.

Procedure

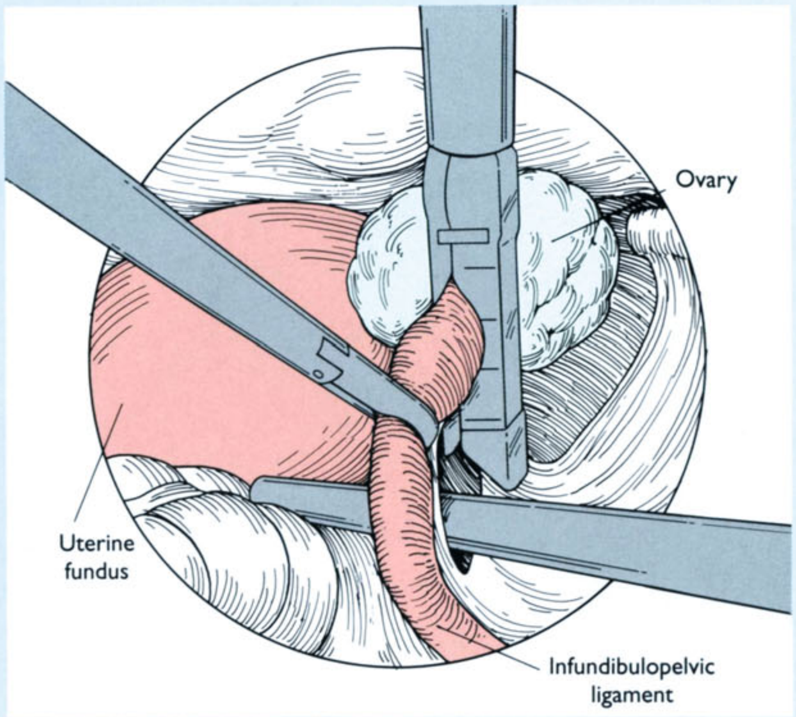


FIGURE 22-8.

Ligation and division of the infundibulopelvic ligament with an endoscopic stapler. A vascular cartridge is required in almost all cases when this technique is used. Illustration is of the right side.

Alternative Procedure

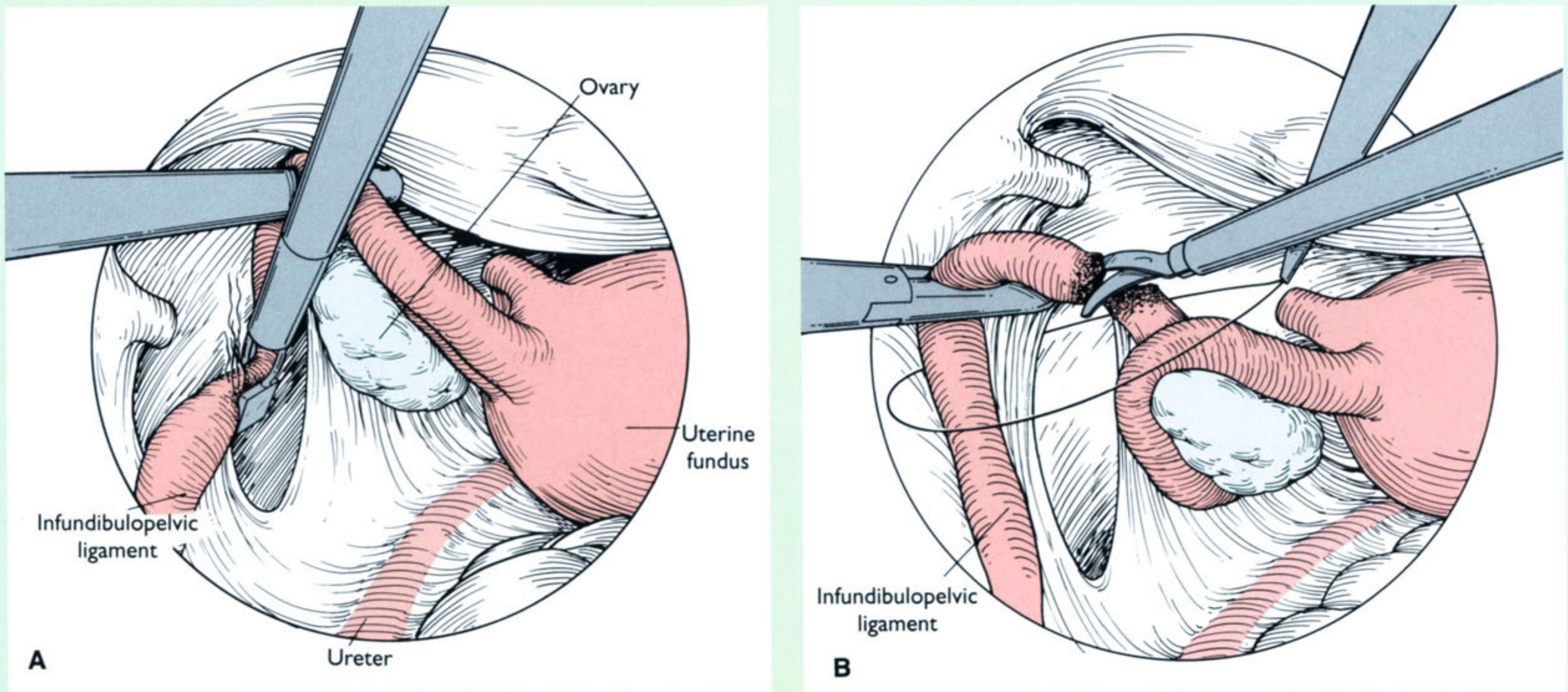


FIGURE 22-9.

Alternative technique using electrodesiccation with bipolar Kleppinger forceps (*panel A*) and division of the infundibulopelvic ligament with endoscopic scissors (*panel B*). Additional hemostasis may be obtained with an endoscopic loop suture applied to the proximal pedicle (*panels B* and *C*). (*Continued*)

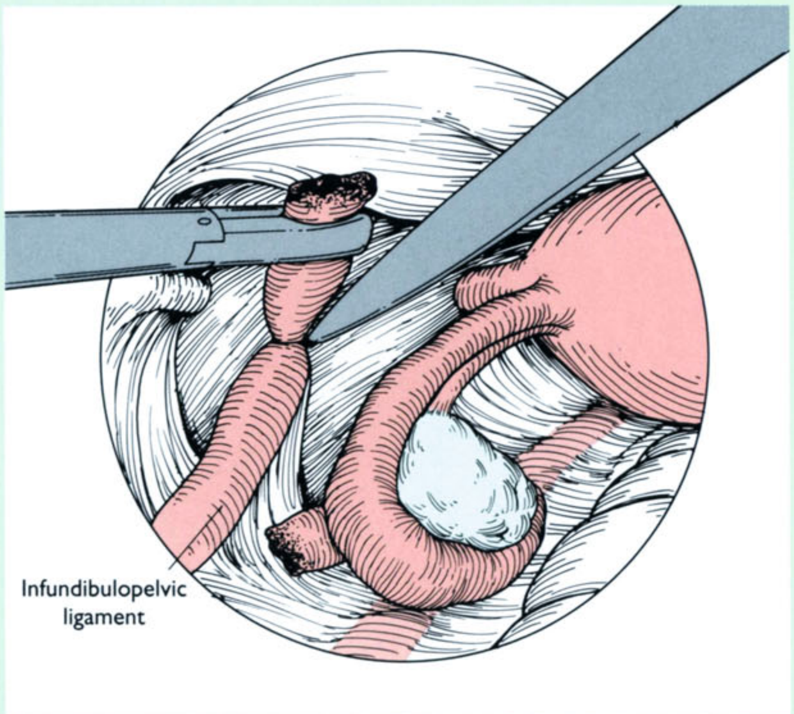


FIGURE 22-9. *(Continued)*
Illustration is of the left side.

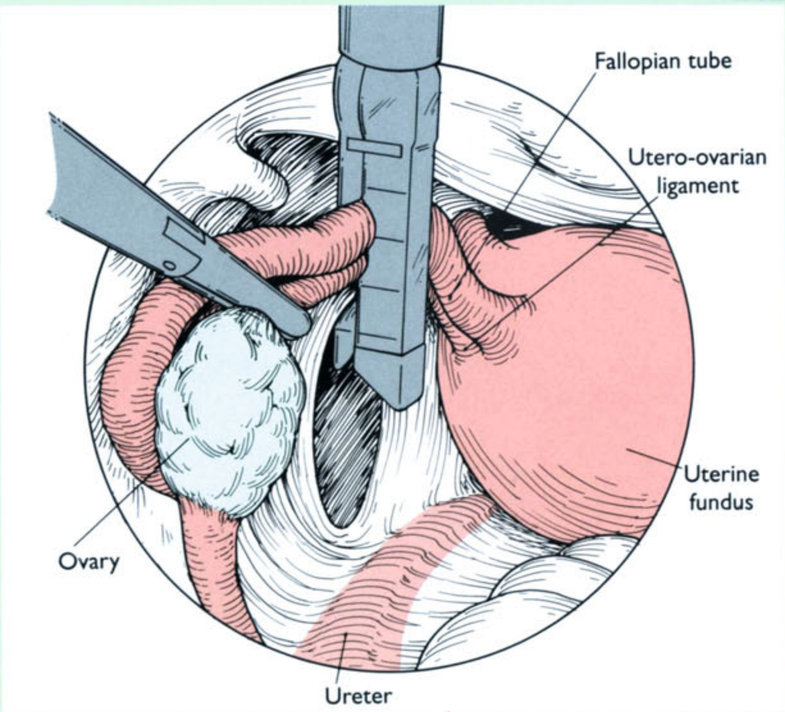


FIGURE 22-10.
Ligation and division of the tube and utero-ovarian ligament with an endoscopic stapler in patient desiring preservation of ovaries. The tissue sizer should be used to select the proper cartridge size.

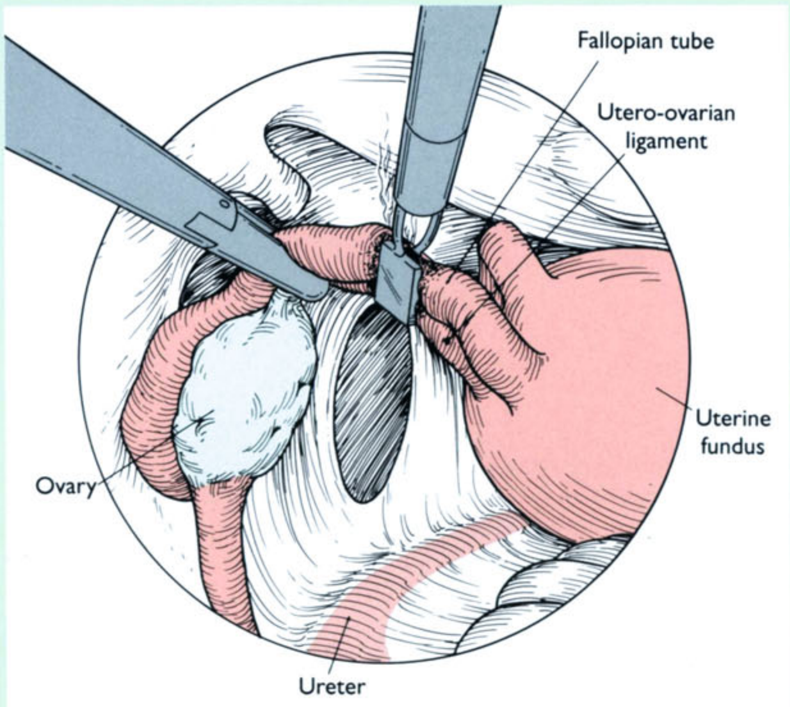


FIGURE 22-11.
Alternative use of bipolar electrocautery to control the fallopian tube and utero-ovarian ligament. These tissues are divided with endoscopic scissors after complete electrodesiccation.

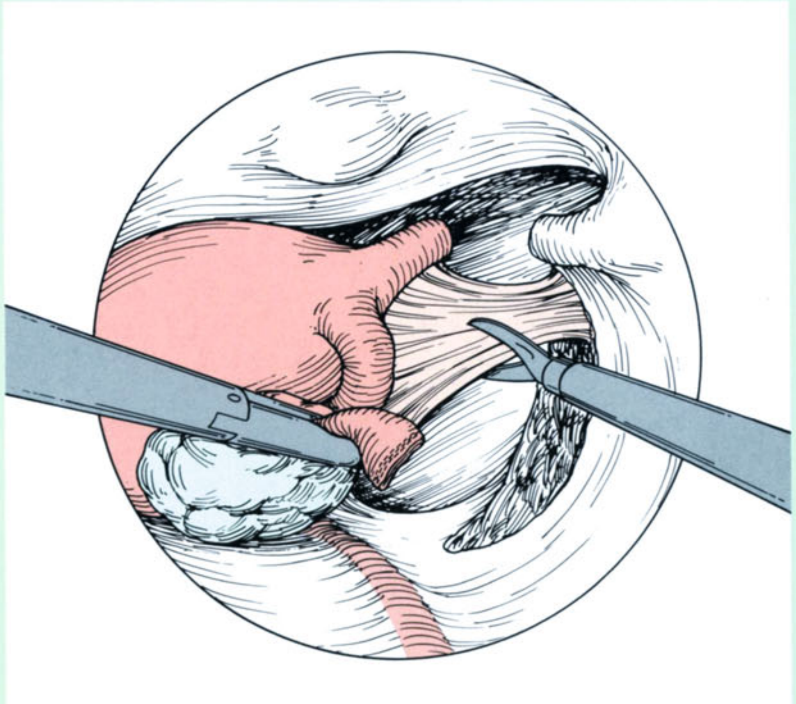


FIGURE 22-12.
Opening of the peritoneum and loose areolar tissue of the anterior leaf of the broad ligament using endoscopic scissors.

had one or more prior abdominal procedures. Despite this atypical patient population, 32 (86%) LAVH procedures were successfully completed. Reasons for aborting LAVH included hemorrhage in two patients early in the series and interligamentous fibroid, metastatic carcinoma, and suspected metastatic endometrial cancer in one patient each. Perioperative morbidity consisted of four postoperative transfusions, three asymptomatic flank hematomas, one partial small bowel obstruction that resolved with conservative management, and one small cystotomy that was repaired by laparoscopic suture techniques.

Notably, a recent randomized series reported by Summitt and coworkers [4] compared vaginal hysterectomy with LAVH. Patients in both groups had similar rates of estimated blood loss and length of hospital stay. However, patients undergoing LAVH had a longer operative procedure and higher cost for the procedure; therefore, LAVH should not be used when vaginal hysterectomy is the appropriate procedure.

References

1. Thompson JD: Hysterectomy. In *TeLinde's Operative Gynecology,* 7th ed. Edited by Thompson JD, Rock JA. Philadelphia: JB Lippincott Co; 1992:663–738.
2. Murphy AA: Diagnostic and operative laparoscopy. In *TeLinde's Operative Gynecology,* 7th ed. Edited by Thompson JD, Rock JA. Philadelphia: JB Lippincott Co; 1992:361–409.
3. Reich H, Decaprio J, McGlynn F: Laparoscopic hysterectomy. *J Gynecol Surg* 1989, 5:213–216.
4. Summitt RL Jr, Stovall TG, Lipscomb GH, Ling FW: Randomized comparison of laparoscopy-assisted vaginal hysterectomy with standard vaginal hysterectomy in an outpatient setting. *Obstet Gynecol* 1992, 80:895–901.
5. Disaia PJ, Creasman WT, eds.: *Clinical Gynecologic Oncology.* St. Louis: CB Mosby Co.; 1992.
6. Childers JM, Surwit EA: Combined laparoscopic and vaginal surgery for the management of stage I endometrial cancer. *Gynecol Oncol* 1992; 45:46–51.
7. Canis M, Mage G, Chapron C, *et al.*: Laparoscopic hysterectomy: a preliminary study. *Surg Endosc* 1993, 7:42–45.
8. Woodland MB: Ureter injury during laparoscopy-assisted vaginal hysterectomy with the endoscopic linear stapler. *Am J Obstet Gynecol* 1992, 167:756–757.
9. Minelli L, Angiolillo M, Caione C, Palmara V: Laparoscopically-assisted vaginal hysterectomy. *Endoscopy* 1991, 23:64–66.
10. Nezhat F, Nezhat C, Gordon S, Wilkins E: Laparoscopic assisted hysterectomy. *J Reprod Med* 1992, 37:247–250.
11. Maher PJ, Wood EC, Hill DJ, Lolatgis NA: Laparoscopically assisted hysterectomy. *Med J Aust* 1992, 156:316–318.
12. Liu CY: Laparoscopic hysterectomy: a review of 72 cases. *J Reprod Med* 1992, 37:351–354.
13. Lee CL, Soony YK: Laparoscopic hysterectomy: preliminary report of 24 cases. *J Formos Med Assoc* 1992, 91:712–715.
14. Langebrekke A, Skar OJ, Urnes A: Laparoscopic hysterectomy: initial experience. *Acta Obstet Gynecol Scand* 1992, 71:226–229.
15. Nezhat C, Nezhat F, Pennington E: Laparoscopic therapy of infiltrative rectosigmoid colon and rectovaginal septum endometriosis by the technique of videolaparoscopy and the CO_2 laser. *Br J Obstet Gynaecol* 1992, 99:664–667.
16. Hershlag A, Loy RA, Levy G, DeCherney AH: Femoral neuropathy after laparoscopy: a case report. *J Reprod Med* 1990, 35:575–633.

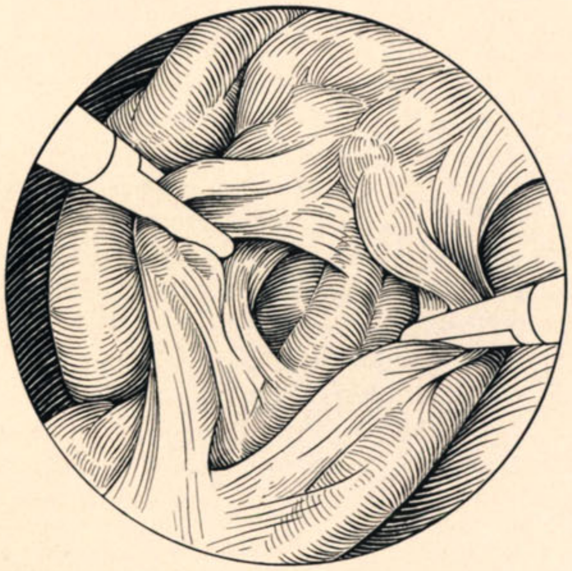
CHAPTER

23

Laparoscopic Staging Pelvic Lymphadenectomy for Prostate Cancer

David T. Price

Cary N. Robertson



While laparoscopic techniques in urology have developed at a slower pace than in other surgical disciplines, it is interesting to note that the initial description of endoscopic inspection of the peritoneal cavity in 1901 by Kelling made use of a Nitze cystoscope; therefore, the earliest reports of laparoscopy used urologic instruments [1]. However, the true pioneering efforts in the field of laparoscopy must be credited to the gynecologists [2]. Recently, the application of laparoscopic techniques for cholecystectomy by the general surgeon has greatly facilitated the widespread use of laparoscopy [3]. Until recently, the major applications for laparoscopy in urology were evaluation of the undescended testis and occasional biopsy of an abdominal or pelvic mass [4,5]. However, with laparoscopic training now being instituted into most surgical training programs and widespread accessibility to laparoscopic training courses, the number of reported laparoscopic urologic procedures has increased (Table 23-1).

The most common urologic laparoscopic procedure to date is laparoscopic pelvic lymph node dissection. Pelvic lymphadenectomy is indicated in the preoperative staging of certain pelvic malignancies. For instance, in the case of prostate cancer, regional lymph node metastasis occurs early in progression of disease and is a negative prognostic indicator [6–9]. Open pelvic lymphadenectomy has been demonstrated to be an effective means of evaluating the regional nodal status prior to initiating definitive therapy [10,11]. However, open pelvic lymphadenectomy is not without morbidity [12]. In an attempt to decrease the morbidity and hospital stay associated with staging pelvic lymphadenectomy, Schuessler and coworkers [13] are credited with developing the laparoscopic pelvic lymphadenectomy as a minimally invasive technique for staging patients prior to external radiotherapy or brachytherapy [13]. This technique has been demonstrated to be both safe and effective in the preoperative assessment of the regional nodal status in patients with localized prostate cancer. This chapter will discuss technique, results, and indications for staging laparoscopic pelvic lymph node dissection in the management of prostate cancer.

Table 23-1. Laparoscopic urologic procedures

Bladder neck suspension	Pelvic lymphadenectomy
Cystectomy	Radical prostatectomy
Nephrectomy	Ureterolysis
Nephroureterectomy	Varicocelectomy

Anatomy

The lymphatic drainage of the prostate occurs via the ileopelvic lymph nodes that can be divided into three main groups: external iliac, internal iliac, and common iliac. The medial chain of the external iliac lymph nodes are referred to as the obturator nodes because of the close association with the obturator nerve, artery, and vein. This package of nodal tissue has been demonstrated to be the site for early and frequent metastasis from prostate cancer [10]. The obturator nodes are confined within the retroperitoneal obturator fossa, the borders of which are the iliac vessels laterally, the medial umbilical ligament medially, the pubic ramus caudally, the bifurcation of the common iliac vessels cranially, and the obturator nerve posteriorly. Additional structures that have an intimate relationship with the area of dissection include the bladder and ureter. The bladder is medial to the medial umbilical ligament while the ureter has a cranial relationship with the obturator fossa coursing retroperitoneally over the common iliac vessels before turning medial to intersect with the bladder at the ureteral trigone. When performing a standard lymph node dissection, the borders for the dissection are the borders of the obturator fossa (Figure 23-1).

Pathophysiology, Presentation, and Differential Diagnosis

With 160,000 new cases diagnosed and an alarming 30,000 cancer-related deaths reported in 1993, prostate cancer now reigns as the principal cancer affecting men in the United States and is second only to lung cancer in cancer-related deaths. The etiology of prostate cancer remains largely unknown; however, a variety of environmental factors including heavy metals, dietary fats, and possible viral agents have been proposed, and evidence exists for both hereditary and familial forms of prostate cancer. Nevertheless, the only definitive factors associated with the development of prostate cancer are the presence of an intact hypothalamic-pituitary-gonadal axis, and advancing age.

Prostate cancer usually does not present with clinical symptoms until metastasis has occurred, at which time patients will often present with symptoms of low back or hip pain, hematuria, or abdominal pain. A more routine way in which prostate cancer is diagnosed is during routine physical examination, at which time a digital rectal examination reveals an indurated mass. The differential diagnosis of an indurated mass in the prostate is listed in

Table 23-2. Transrectal biopsy is then indicated to obtain a histologic diagnosis. More recently, prostate-specific antigen (PSA), a serine protease, has been shown to be elevated in patients with prostate cancer. However, other conditions can cause elevations of PSA (Table 23-3). Nevertheless, an elevated serum PSA often leads to a transrectal ultrasound to investigate the possibility of a nonpalpable localized prostate cancer not detected by digital rectal examination. If a localized lesion is detected by transrectal ultrasound, it is biopsied under ultrasound guidance. In the event of a negative transrectal ultrasound, multiple transrectal prostatic biopsies are indicated to rule out localized prostate cancer.

Once histologic confirmation of prostate cancer is established, the patient is worked up to identify whether the tumor is localized to the prostate gland or if it has metastasized. Prostate cancer can metastasize via direct extension, lymphatic, or hematogenous routes. Since prostate cancer has a propensity to metastasize to bone, part of the work-up includes radiographs as indicated and a bone scan to rule out bone metastasis. Imaging studies, such as lymphangiograms and pelvic computed tomography scans, are unreliable methods for evaluation of pelvic lymph nodes. The current stand for evaluation of pelvic lymph node status is pelvic lymphadenectomy.

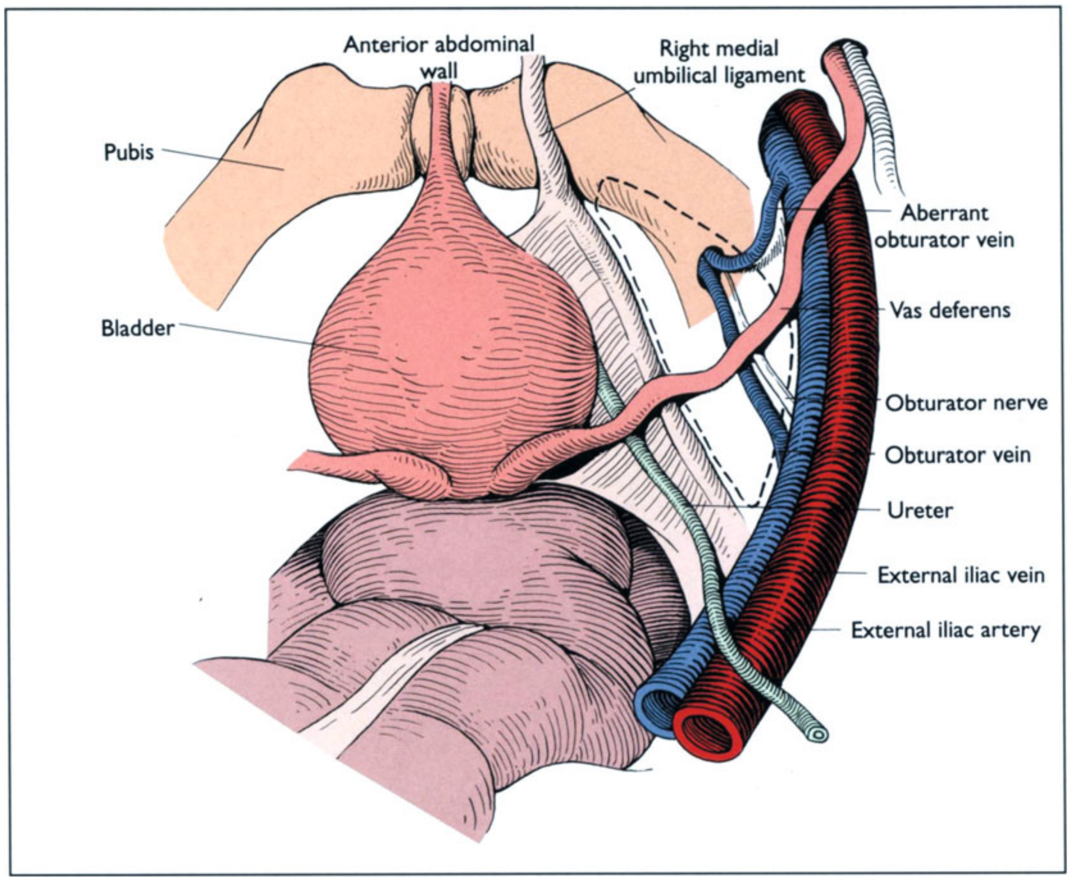


FIGURE 23-1.
Pelvic anatomy and borders of the obturator fossa.

Table 23-2. Differential diagnosis of an indurated prostatic mass

Prostate cancer	Granulomatous prostatitis
Benign prostatic hyperplasia	Tuberculosis
Prostatic infarct	Prostatic calculi

Table 23.3 Differential diagnosis of an elevated prostate-specific antigen

Prostate cancer	Prostatic abscess
Benign prostatic hyperplasia	Prostatitis
Prostatic infarction	

Surgical Technique

Figures 23-2 through 23-23 depict the surgical technique for laparoscopic pelvic lymphadenectomy.

Set-up

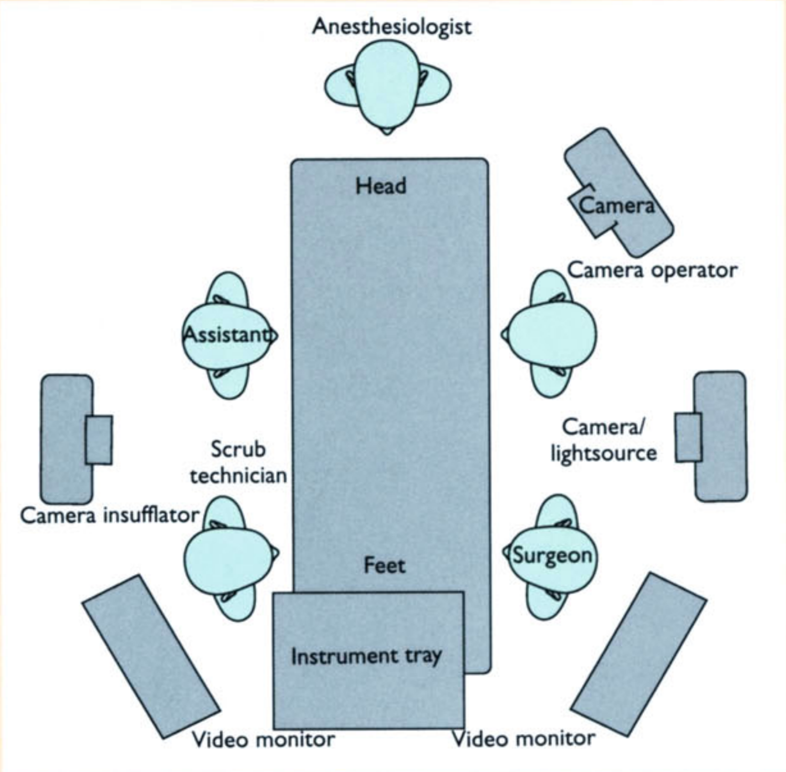


FIGURE 23-2.
Operative set-up for laparoscopic pelvic lymphadenectomy. Two video monitors are positioned on the sides of the table, or alternatively a single monitor is positioned directly at the foot of the table in plain view for both the surgeon and assistant.

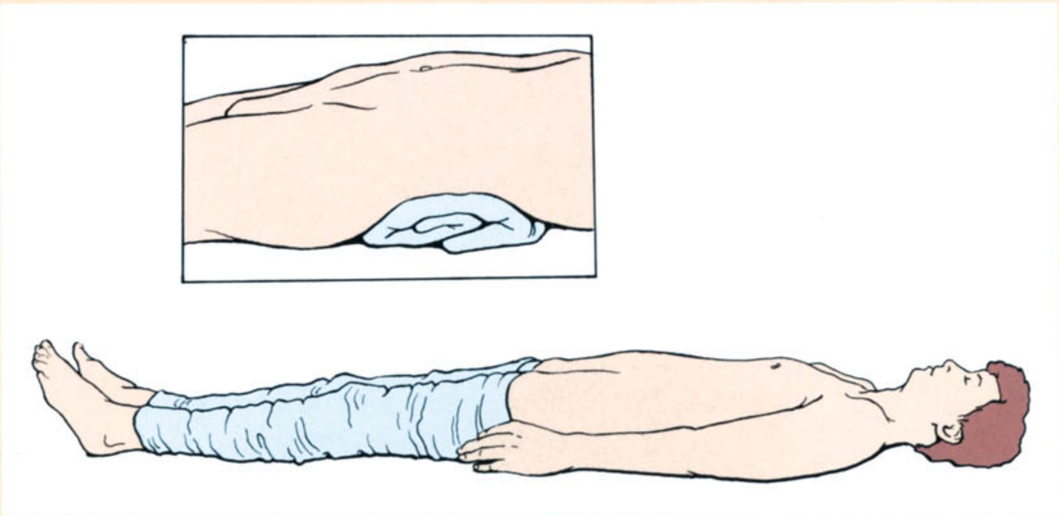


FIGURE 23-3.
A mechanical and antibiotic bowel preparation is administered the day prior to surgery on an outpatient basis. A preoperative dose of an antibiotic is administered prior to initiating the procedure, and both a nasogastric tube and Foley catheter are inserted following induction of general anesthesia. The patient is placed in a supine position. Intermittent pneumatic leg compression devices may be employed to prevent venous stasis and thereby lessen the risk of deep venous thrombosis. A towel is rolled and placed beneath the lower back (*inset*) and the patient is secured to the operating table with the arms placed along the side of the patient. The table is then placed in a 30° Trendelenburg position and rolled toward the surgeon to help gain better exposure to the area of dissection.

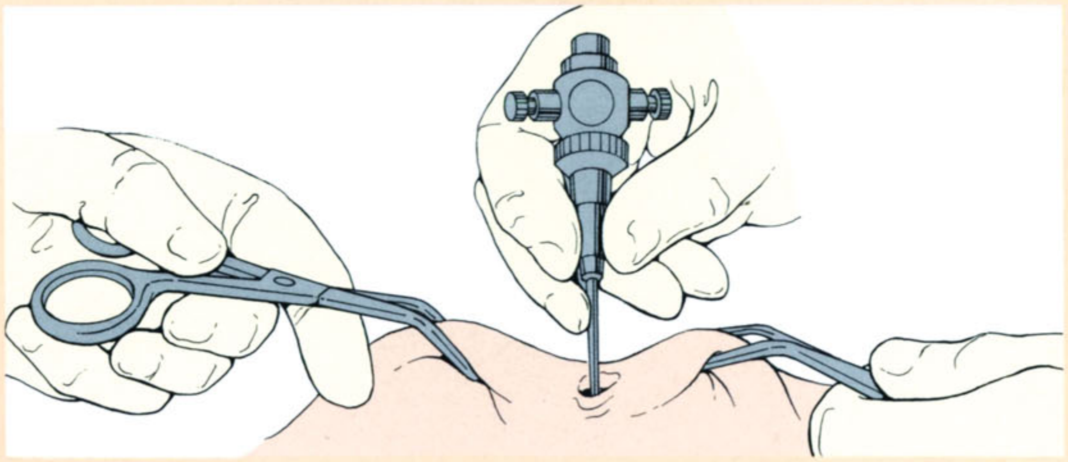


FIGURE 23-4.
Pneumoperitoneum is established by either the closed (Veress needle) or open (Hasson trocar) technique. The Veress needle is inserted through a small incision at the umbilicus at a 45° angle to the abdominal wall and directed toward the sacral

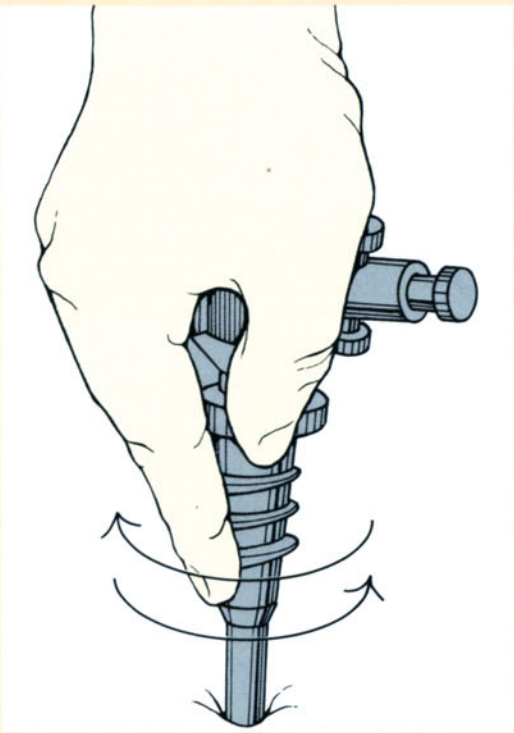


FIGURE 23-5.
After pneumoperitoneum is established with carbon dioxide insufflation to 15 mm Hg, the initial trocar should be placed at the umbilicus as shown. The trocar is held securely in the surgeon's hand with the index finger extended, and with controlled downward pressure and a twisting motion the trocar is forced through the abdominal wall. It is extremely important to have control of the trocar at all times to prevent injury to intraperitoneal structures. An alternative to the Veress needle technique for establishing pneumoperitoneum is the Hasson trocar technique. This technique is extremely useful for patients who have had previous abdominal surgery since it allows the surgeon to place the initial trocar into the peritoneal cavity under direct vision, thereby decreasing the chance of significant injury that can occur with both the Veress needle and the initial trocar placement.

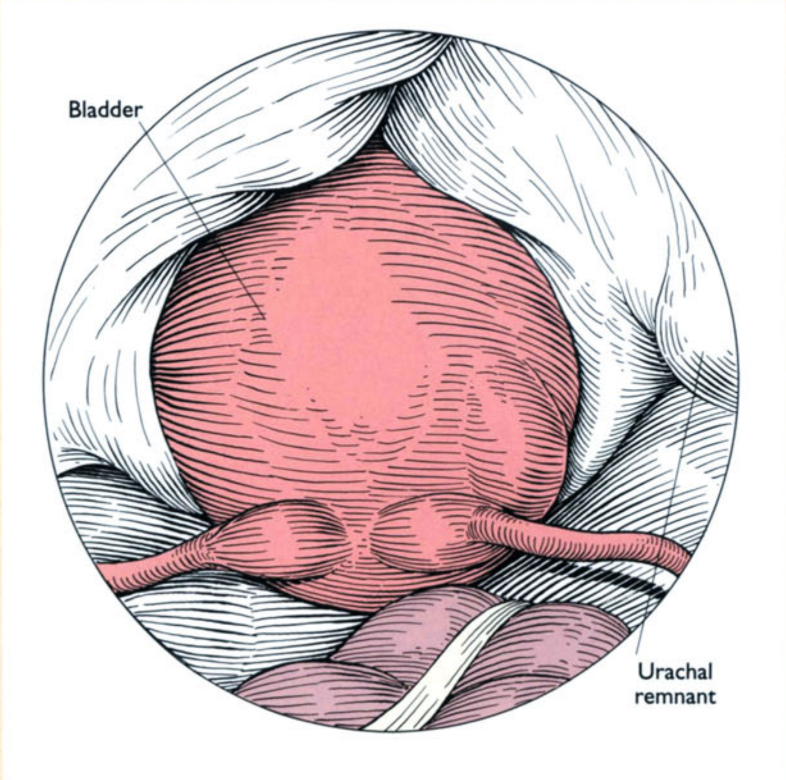


FIGURE 23-6.
The laparoscope is then inserted through the initial port and the peritoneal cavity is inspected for evidence of metastatic disease or iatrogenic injury.

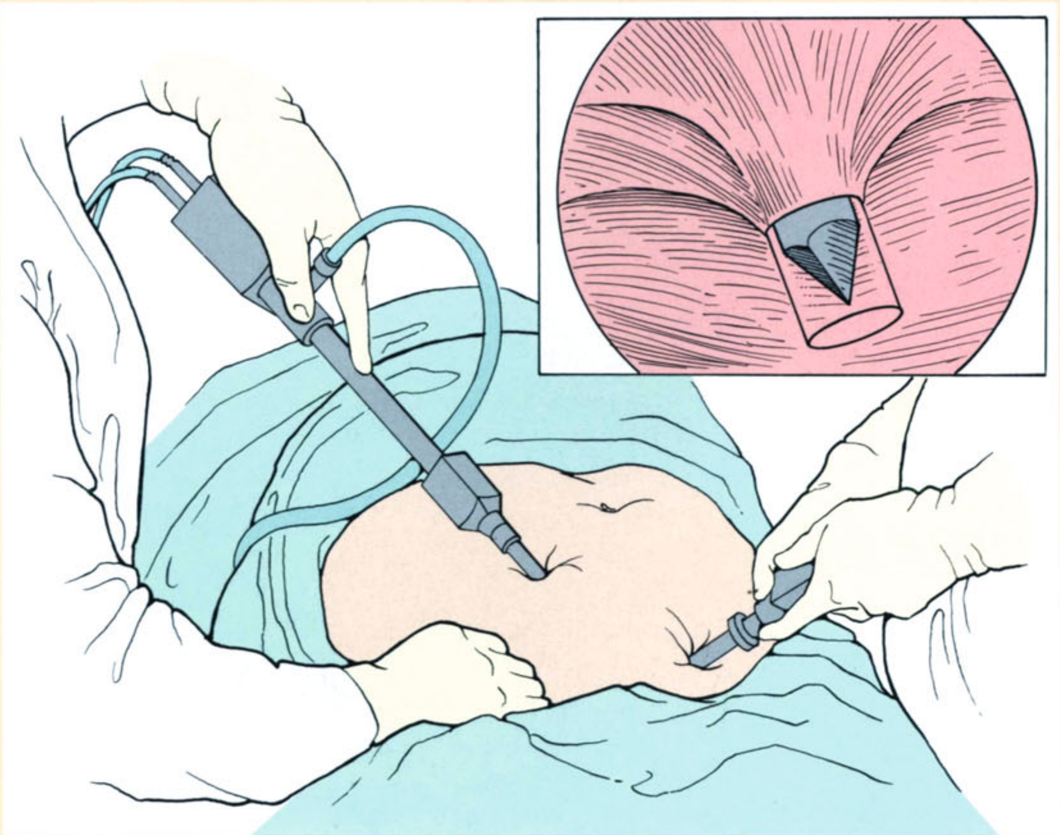


FIGURE 23-7.
Additional trocars and ports are placed under direct laparoscopic vision to avoid injuring intra-abdominal organs with the trocar. The laparoscope can also be used to transluminate the abdominal wall to identify the inferior epigastric vessels (*inset*).

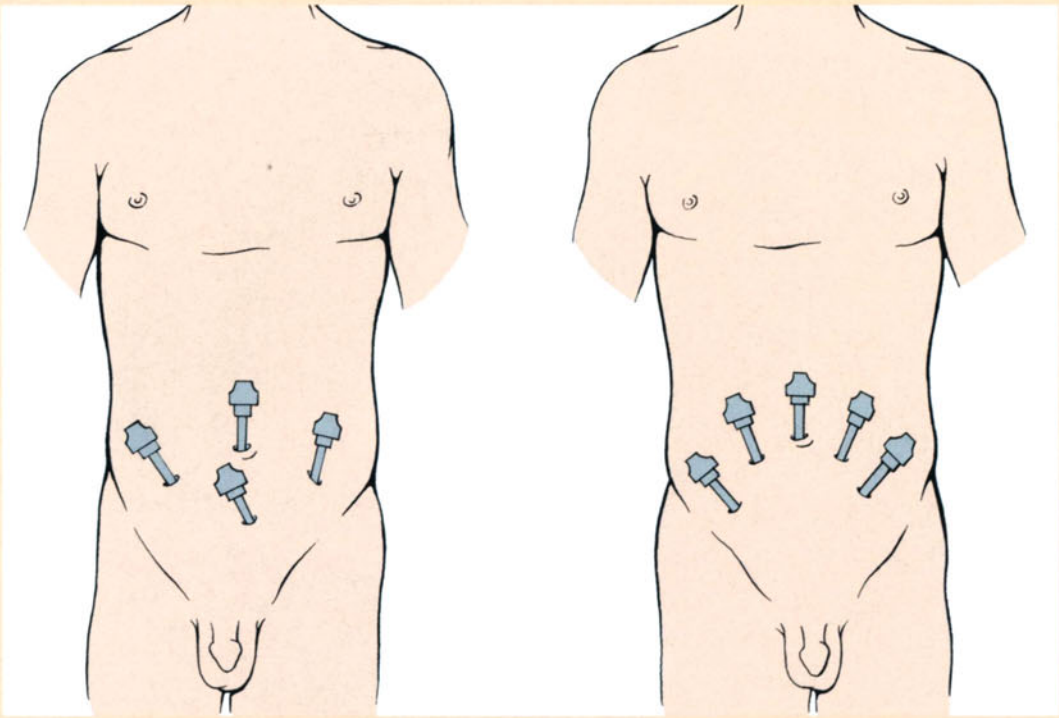


FIGURE 23-8.

The two most commonly used patterns of trocar/port placement for this procedure are the diamond (*left*) and fan (*right*) arrangement. In the diamond pattern four ports are placed: one 11-mm port at the umbilicus, one 11-mm port in the midline half way between the umbilicus and the symphysis pubis, and two 5-mm ports, one on each side mid-way between the umbilicus and the anterosuperior iliac spine. In the fan configuration five ports are placed: an 11-mm port at the umbilicus, a 10-mm port on each side at the level of the anterosuperior iliac spine, and a 10-mm port on each side half way between the anterosuperior iliac spine and the umbilicus. At our institution the fan arrangement is favored because it allows both the surgeon and assistant to use both hands to operate and assist during the procedure.

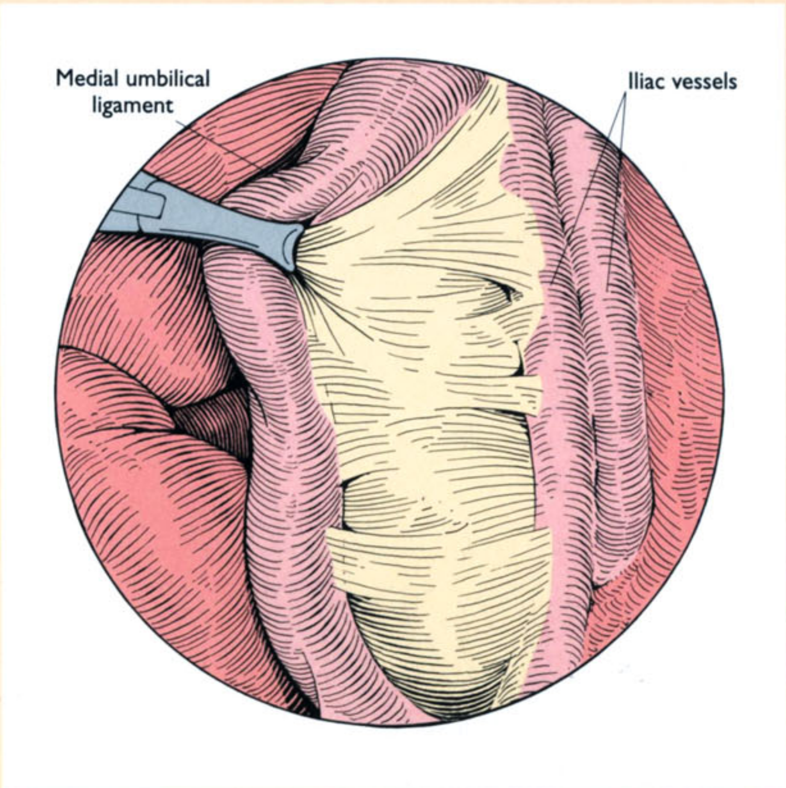


FIGURE 23-9.

Anatomical landmarks of importance that should be identified prior to initiating the procedure include the bladder, medial umbilical ligament, and iliac vessels. The vas deferens may be visualized coursing medially beneath the peritoneum in some cases.

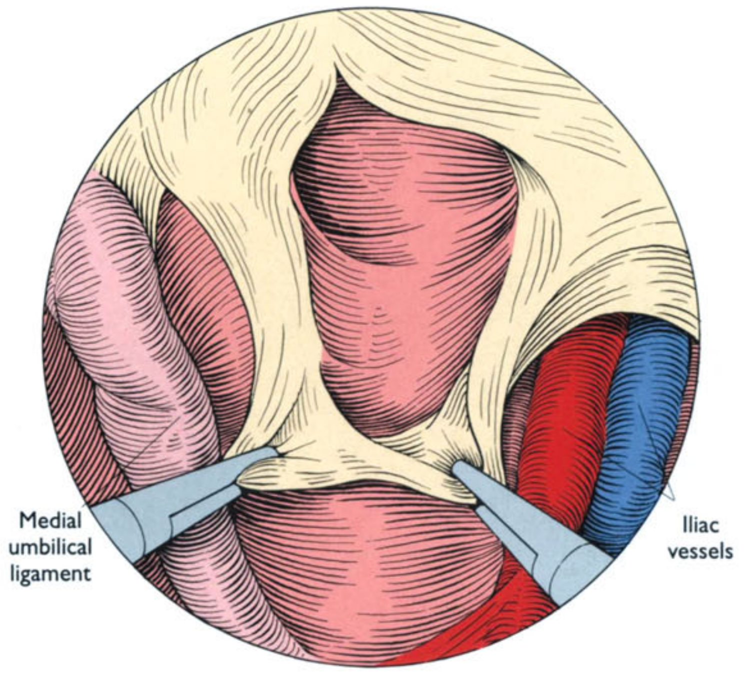


FIGURE 23-10.
The dissection begins over the obturator fossa on the surgeon's contralateral side. The right side should be investigated first unless there is a high suspicion of finding a positive node on the left since it is usually simpler to perform because of the redundancy of the sigmoid colon on the left. The peritoneum is grasped and lifted anteriorly using an endoscopic dissector, creating a tent in the peritoneum just anterior to the vas deferens. An incision in the peritoneum is made lateral to the medial umbilical ligament extending from the point shown to the pubic ramus using endoscopic scissors.

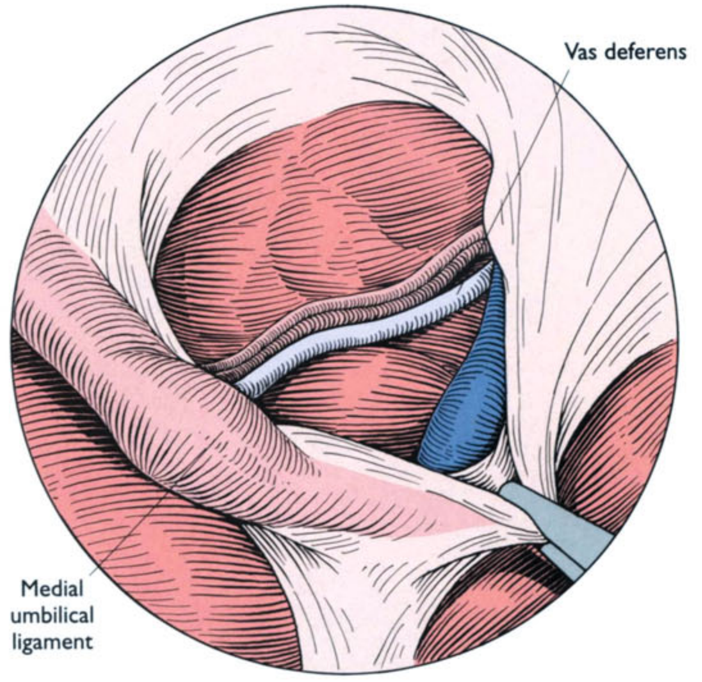


FIGURE 23-11.
A combination of sharp and blunt dissection is used to identify the vas deferens medial to the iliac vessels and lateral to the umbilical ligament.

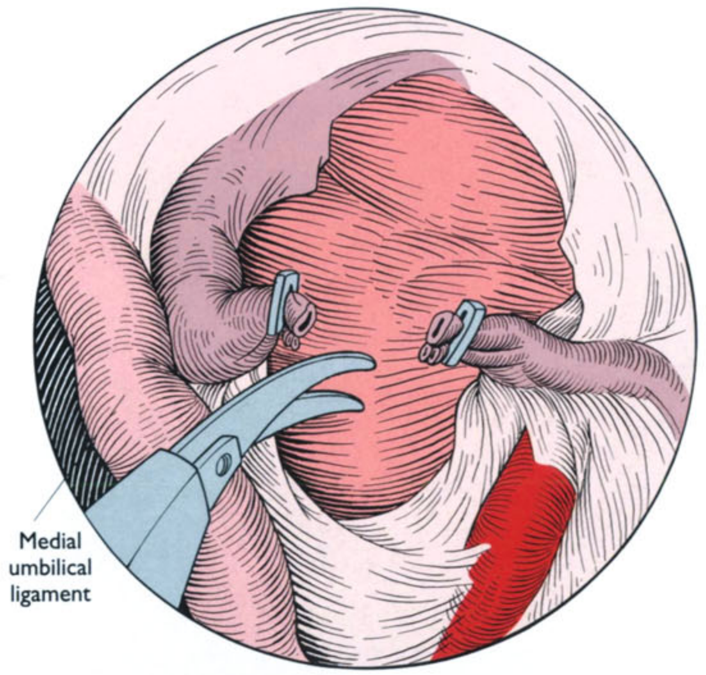


FIGURE 23-12.
The vas deferens is dissected from the surrounding tissues and clipped before dividing with endoscopic scissors.

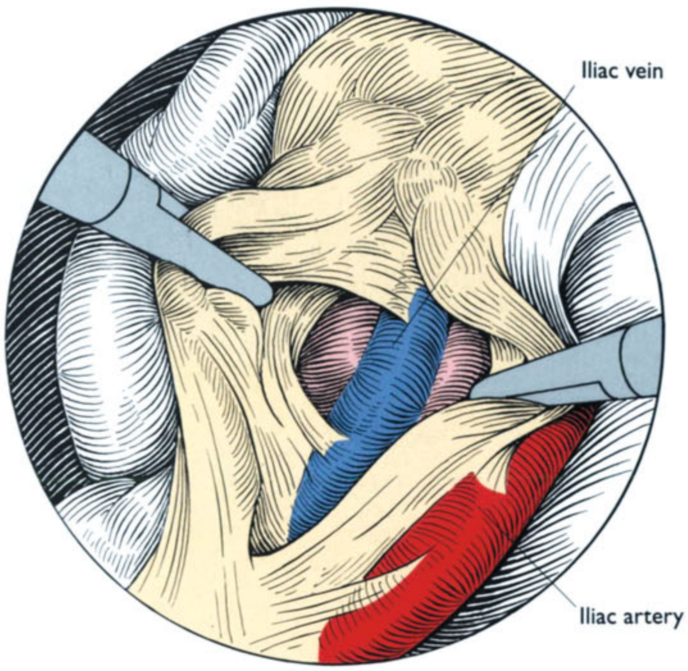


FIGURE 23-13.
The fat and nodal tissue is carefully retracted in a medial direction while blunt dissection is used to identify the medial surface of the external iliac vein.

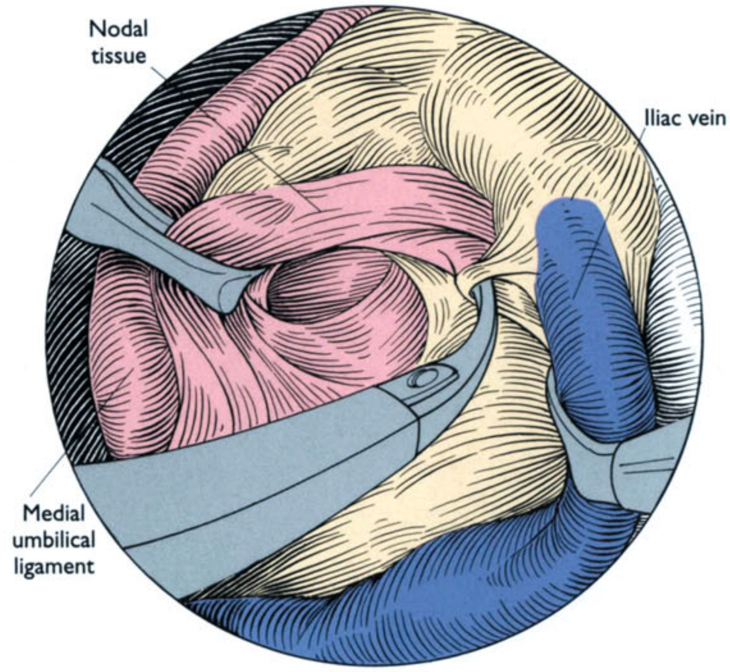


FIGURE 23-14.
After the external iliac vein is identified, a laparoscopic vein retractor can be used by the assistant to retract the vein laterally while the surgeon pulls the nodal package medially and dissects the nodal package off the medial surface of the vein and pelvic side wall. This dissection is continued caudally to the pubic ramus.

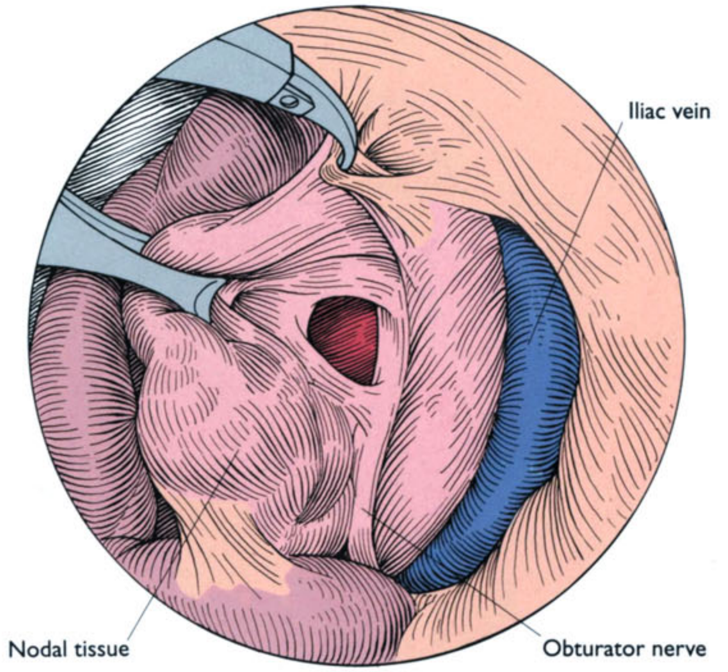


FIGURE 23-15.
The dissection continues caudally toward the pubic ramus and posteriorly down the pelvic side wall using a combination of sharp and blunt dissection to identify the obturator nerve that is the limit of the posterior dissection. The use of cautery and sharp dissection in this region should be limited to avoid injury to the obturator nerve and vessels.

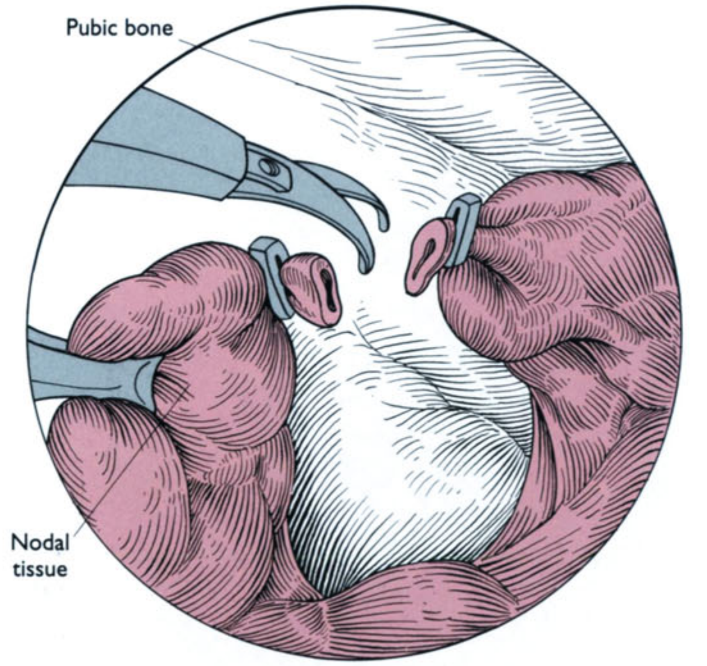


FIGURE 23-16.
The nodal tissue is then bluntly dissected from the pubic ramus and divided between clips. Care should be taken in this region to avoid injury of the aberrant obturator vein.

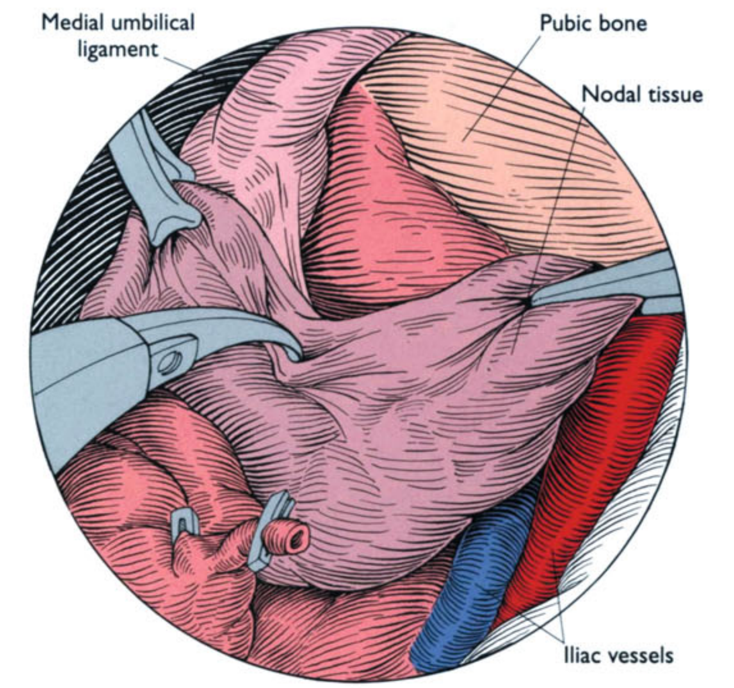


FIGURE 23-17.
The nodal package is then grasped by the assistant and pulled laterally while the surgeon develops the medial limits of the dissection that is just lateral to the medial umbilical ligament.

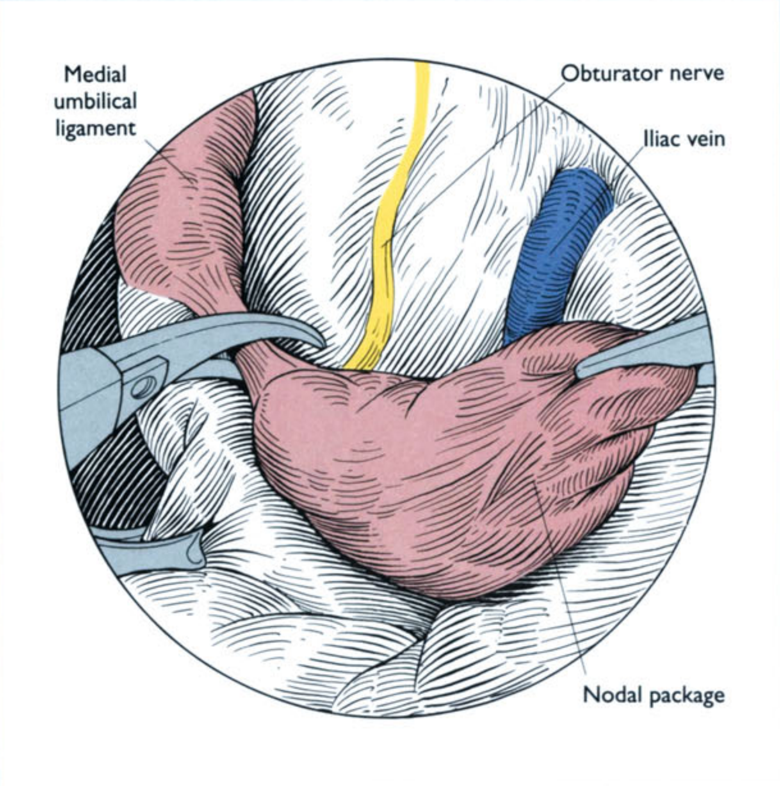


FIGURE 23-18.
The nodal package is bluntly dissected from the medial umbilical ligament and obturator nerve in a cephalad direction using a gentle sweeping motion by the surgeon as the assistant holds traction in the lateral and cephalad direction. The cephalad limit of the dissection is the bifurcation of the common iliac vessels.

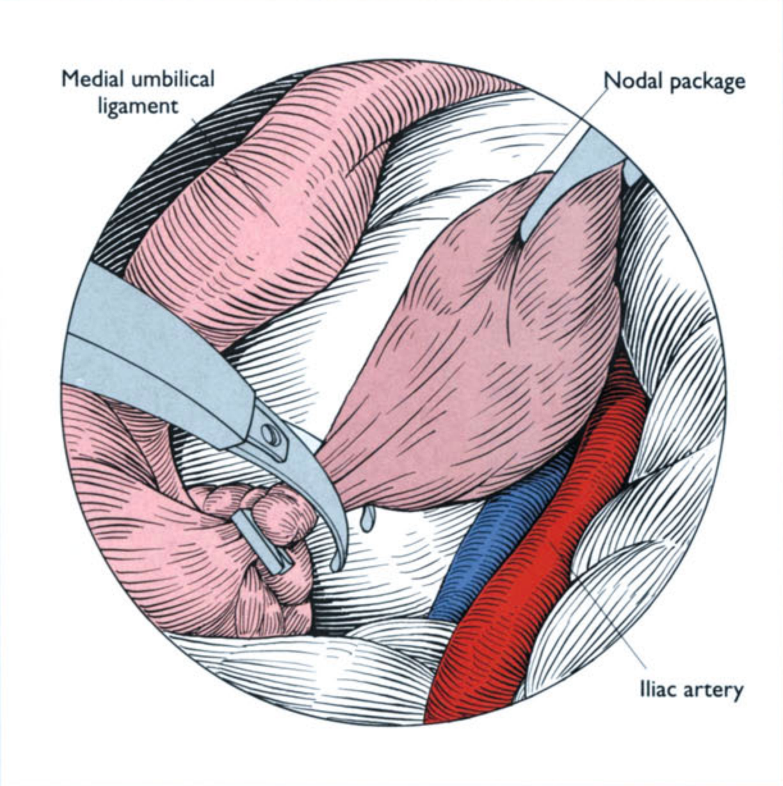


FIGURE 23-19.
Once the cephalad limit of the dissection is reached, the nodal package is divided above a clip. Care should be exercised in this region due to the proximity of the ureter.

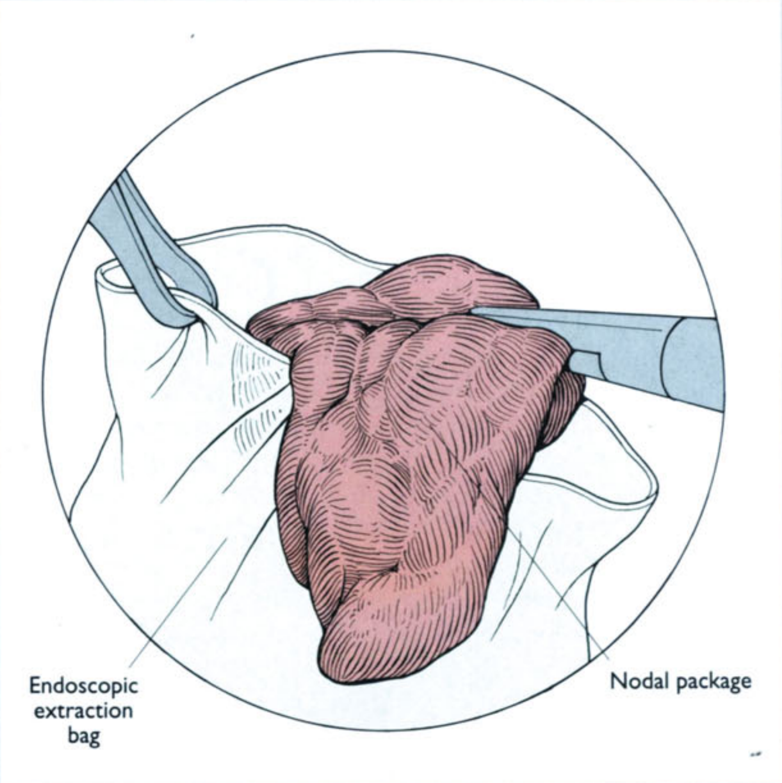


FIGURE 23-20.
The nodal package is then placed in an endoscopic extraction bag as shown before removing from the abdomen, or an alternative method of removing the specimen is to use spring-loaded, self-locking, 10-mm spoon forceps to remove the specimen through an 11-mm port.

FIGURE 23-21.
The nodal package contained in an endoscopic extraction bag is removed under laparoscopic vision through a port site.

my in patients with either an elevated PSA > 40 ng/dL or Gleason score > 7 associated with a PSA > 15 ng/mL; 2) those with evidence by either computed tomography or clinical exam suggesting local extension of disease; and 3) prior to a retropubic prostatectomy in patients in whom there is a high likelihood of identifying a positive pelvic node that would preclude them from definitive surgical therapy.

In summary, laparoscopic lymphadenectomy is a viable alternative to traditional open lymphadenectomy. The benefits of decreased postoperative pain and rapid convalescence must be weighed against increased operative time and perhaps increased medical costs. Furthermore, the well described surgical learning curve associated with the procedure warrants caution, and the procedure should be practiced in animal models until the surgeon has gained sufficient experience with laparoscopic techniques. After completion of training in animal models, the surgeon should seek the experience and guidance of an experienced laparoscopic surgeon to proctor his initial attempts at the procedure in patients. However, with adequate training and supervision, laparoscopic lymphadenectomy can be performed safely and effectively.

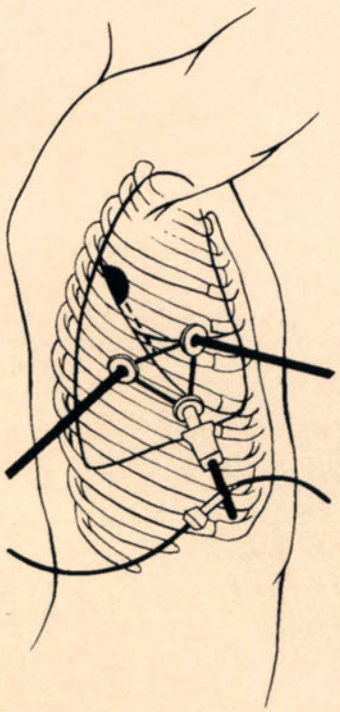
References

1. Gunning JE: History of laparoscopy. In *Laparoscopy*. Edited by Phillips JM. Baltimore: Williams & Wilkins; 1977:6–16.
2. Semm K: *Atlas of Gynecologic Laparoscopy and Hysteroscopy*. Philadelphia: W.B. Saunders Co.; 1977.
3. Muhe E: Die erste Cholecystektome durch das Laparoskop. *Langenbecks Arch Chir* 1986, 369:804.
4. Cortesi N, Ferrari P, Zambarda E, *et al.*: Diagnosis of bilateral abdominal cryptorchidism by laparoscopy. *Endoscopy* 1976, 8:33.
5. Das S, Amar AD: The impact of laparoscopy on modern urologic practice. *Urol Clin North Am* 1988, 15:537–540.
6. Arnheim FK: Carcinoma of the prostate: a study of the postmortem findings in one hundred and seventy-six cases. *J Urol* 1948, 60:599–603.
7. Arduino LJ, Glucksman MA: Lymph node metastases in early carcinoma of the prostate. *J Urol* 1962, 88:91–93.
8. Prout GR Jr, Heaney JA, Griffin PP: Nodal involvement as a prognostic indicator in patients with prostatic carcinoma. *J Urol* 1980, 124:226–231.
9. Gervasi LA, Mata J, Easley JD, *et al.*: Prognostic significance of lymph nodal metastases in prostate cancer. *J Urol* 1989, 142:332–336.
10. McLaughlin AP, Saltztein SL, McCullough DL, Gittes RF: Prostate carcinoma: incidence and localization of unsuspected lymphatic metastases. *J Urol* 1976, 115:89–94.
11. Brendler CB, Cleeve LK, Anderson EE, Paulson DF: Staging pelvic lymphadenectomy for carcinoma of the prostate: risk versus benefit. *J Urol* 1980, 124:849–850.
12. Paul DB, Loening SA, Narayana AS, Culp DA: Morbidity from pelvic lymphadenectomy in staging carcinoma of the prostate. *J Urol* 1983, 129:1141–1144.
13. Schuessler WW, Vancaillie TG, Reich H, Griffith DP: Transperitoneal endosurgical lymphadenectomy in patients with localized prostate cancer. *J Urol* 1991, 145:988–991.
14. Kerbl K, Clayman RV, Petros JA, *et al.*: Staging pelvic lymphadenectomy for prostate cancer: a comparison of laparoscopic and open techniques. *J Urol* 1993, 150:396–399.
15. Schuessler WW, Pharand D, Vancaillie TG: Laparoscopic standard pelvic node dissection for carcinoma of the prostate: is it accurate? *J Urol* 1993, 150:898–901.
16. Parra RO, Andrus C, Boulliler J: Staging laparoscopic pelvic lymph node dissection: comparison of results with open pelvic lymphadenectomy. *J Urol* 1992, 147:875–878.
17. Kavoussi LR, Sosa E, Chandhoke P, *et al.*: Complications of laparoscopic pelvic lymph node dissection. *J Urol* 1993, 149:322–325.
18. Petros JA, Catalona WJ: Lower incidence of unsuspected lymph node metastases in 521 consecutive patients with clinically localized prostate cancer. *J Urol* 1992, 147:1574–1575.
19. Danella JF, DeKernion JB, Smith RB, Steckel J: The contemporary incidence of lymph node metastases in prostate cancer: implications for laparoscopic lymph node dissection. *J Urol* 1993, 149:1488–1491.

CHAPTER 24

Diagnostic Thoracoscopy

Scott H. Johnson
James M. Douglas, Jr



Thoracoscopy, like laparoscopy, was first reported in 1910 by Hans Christian Jacobaeus who used a cystoscope to evaluate the pleural cavity [1]. Jacobaeus used thoracoscopy to divide pleural adhesions in order to complete induced pneumothorax in the treatment of tuberculosis. This technique was adopted with enthusiasm in the United States and Europe. Day and coworkers [2] in 1948 reported 1000 consecutive cases with low operative mortality. The development of effective chemotherapy for tuberculosis ended the widespread use of this technique and by 1980 only a few centers performed thoracoscopy regularly. The recent development of video-assisted endosurgical equipment has increased interest in thoracoscopy as a minimally invasive technique to evaluate intrathoracic pathology.

The pleural space, lung parenchyma, and mediastinum are accessible to evaluation by thoracoscopy. The etiology of pleural effusions, diffuse lung disease, solitary pulmonary nodules, and mediastinal masses can be ascertained with a high diagnostic yield. In many instances, effective therapy such as pleurodesis, wedge resection, and cyst excision can be performed simultaneously. However, current limitations in equipment, loss of tactile sensation, and loss of three-dimensional vision limit the effectiveness of this procedure where vascular control is necessary and in specific anatomic locations. The pulmonary hilum, the deep pulmonary parenchyma, and the parenchyma adjacent to the superior mediastinum and paravertebral space are difficult to assess with current technology (Table 24-1). Careful preoperative evaluation of the patient and radiologic studies are needed to determine whether a thoracoscopic approach is warranted (Figure 24-1) [3].

Potential advantages of thoracoscopy include the ability to inspect the entire thoracic cavity and to perform visually directed biopsies with a minimally invasive technique (Table 24-2). Postoperative pain is reported to be less with thoracoscopy than with a limited thoracotomy [4]. Early studies on cost analysis reveal that the total cost of thoracoscopy and open thoracotomy are not significantly different. However, thoracoscopy patients had a shorter hospital stay (4.4 days versus 6.5) [5].

Patients ideally suited for diagnostic thoracoscopy include those elective cases with undiagnosed pleural effusions, diffuse lung disease, solitary pulmonary nodules, and mediastinal masses in whom conventional methods have failed to make a diagnosis (Table 24-3). Caution should be expressed in applying thoracoscopic techniques to critically ill and ventilator-dependent patients. The possibility of longer anesthesia times and single lung ventilation may be deleterious in this clinical setting. A limited, open thoracotomy may be a more prudent choice.

Anatomy

The chest wall is covered by the pectoralis muscles anteriorly and by the latissimus dorsi and serratus anterior muscles posteriorly. Twelve pairs of ribs are present; the first seven communicate directly with the sternum while ribs 8 to 10 communicate indirectly. Ribs 11 and 12 do not com-

Table 24-1. Limitations of thoracoscopy

Single lung ventilation
Loss of tactile sensation
Loss of three-dimensional vision
Vascular control
Anatomic locations
Deep parenchymal lesions
Hilar lesions
Parenchymal lesions adjacent to the superior mediastinum and paravertebral area

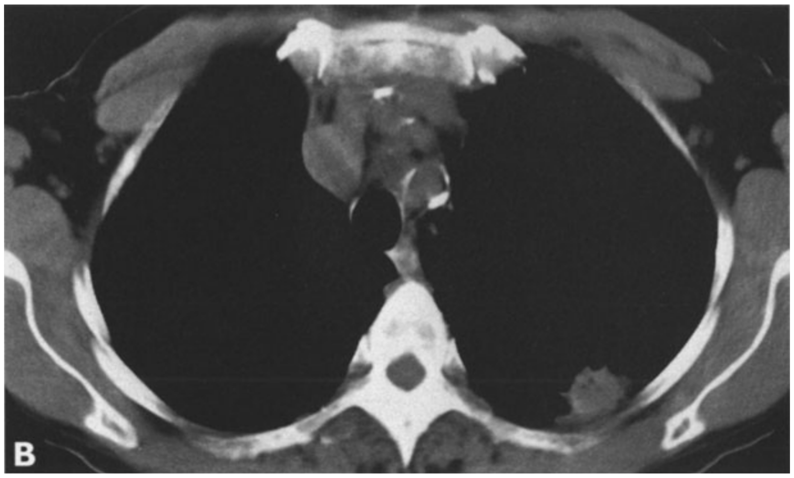


FIGURE 24-1.
PA chest radiograph (*panel A*) and computed tomography scan (*panel B*) are shown from a patient with a solitary pulmonary nodule suitable for a thoracoscopic approach. Multiple attempts at percutaneous transthoracic needle biopsy were nondiagnostic. The lesion was successfully resected using a thoracoscopic technique.

municate anteriorly and are free-floating. The intercostal space contains the intercostal muscle fibers, and the intercostal nerve, artery, and vein that course along the inferior aspect of the rib. The parietal pleura covers the rib cage, the mediastinum, and the diaphragmatic surface. The visceral pleura is tightly adherent to the lung surface.

The right lung is divided by two fissures. The major fissure divides the upper and middle lobes from the lower lobe, while the minor fissure separates the upper and middle lobes. The left lung has a single fissure that divides the upper and lower lobes. Accessory fissures may exist, most commonly separating the superior segment from the remainder of the lower lobe or the lingular segment from the remainder of the left upper lobe. The relationship of the lobes and fissures to external rib anatomy is depicted in Figure 24-2. The lobes of the lung are divided into bronchopulmonary segments that have their own segmental bronchus and pulmonary arterial supply.

The trachea bifurcates at the carina into the right and left mainstem bronchus (Figure 24-3). The right main bronchus arises almost directly in line with the trachea and is shorter than the left main bronchus. The right main bronchus bifurcates into the right upper lobe bronchus and the bronchus intermedius that gives off two branches, the superior segment to the right lower lobe and the right middle lobe bronchus before continuing as the basal stem. The basal stem subsequently divides into the remainder of the segmental bronchi to the right lower lobe. The left main bronchus divides into the left upper lobe and left lower lobe bronchi. The left upper lobe bronchus bifurcates into the superior and inferior (lingular) divisions prior to dividing into the segmental bronchi. The left lower lobe continues and gives rise to the segmental bronchi of the left lower lobe.

The mediastinum extends superiorly and inferiorly from the thoracic inlet to the diaphragm and is bordered laterally by the mediastinal or parietal pleura (Figure 24-4). This region is arbitrarily divided into the anterior, middle, and posterior mediastinum. The anterior mediastinum contains the thymus and lymphatic, adipose, and areolar tissue. The trachea, major bronchi, heart, and great vessels are located in the middle mediastinum. The posterior mediastinum contains the esophagus, descending thoracic aorta, and the sympathetic and peripheral nerves.

Indications for Diagnostic Thoracoscopy

Pleural Disease

Pleural effusions that remain undiagnosed after thoracentesis and pleural needle biopsy as well as complex loculated pleural effusions are indications for thoracoscopic exploration. Thoracoscopy provides excellent visualization of the entire pleural surface and allows for directed biopsy of suspicious areas. This technique can also release adhesions, complete drainage of pleural effusions, and provide access for therapeutic pleurodesis.

Parenchymal Disease

Undiagnosed diffuse lung disease and solitary pulmonary nodules represent the main indications for diagnostic thora-

Table 24-2. Advantages of thoracoscopy

Minimally invasive
Direct visualization of multiple biopsy areas
Decreased postoperative pain
Shorter hospital stay

Table 24-3. Indications for diagnostic thoracoscopy

Pleural disease
Undiagnosed pleural effusions
Complex pleural effusions
Parenchymal disease
Diffuse lung disease
Isolated pulmonary infiltrates
Solitary pulmonary nodules
Mediastinal disease
Lymphadenopathy
Cysts (including bronchogenic, enteric, and pericardial)
Neurogenic tumors
Unknown mediastinal masses

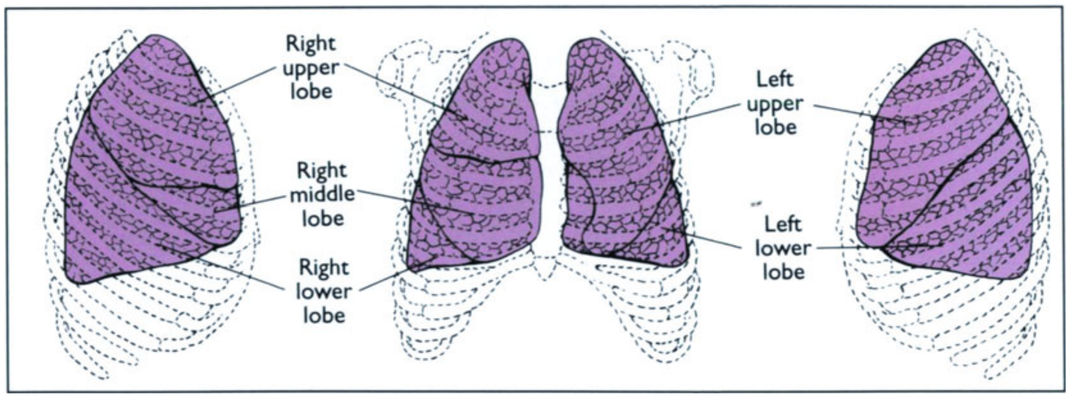


FIGURE 24-2.
The relationship of the lobes and fissures of the lung to external rib anatomy.

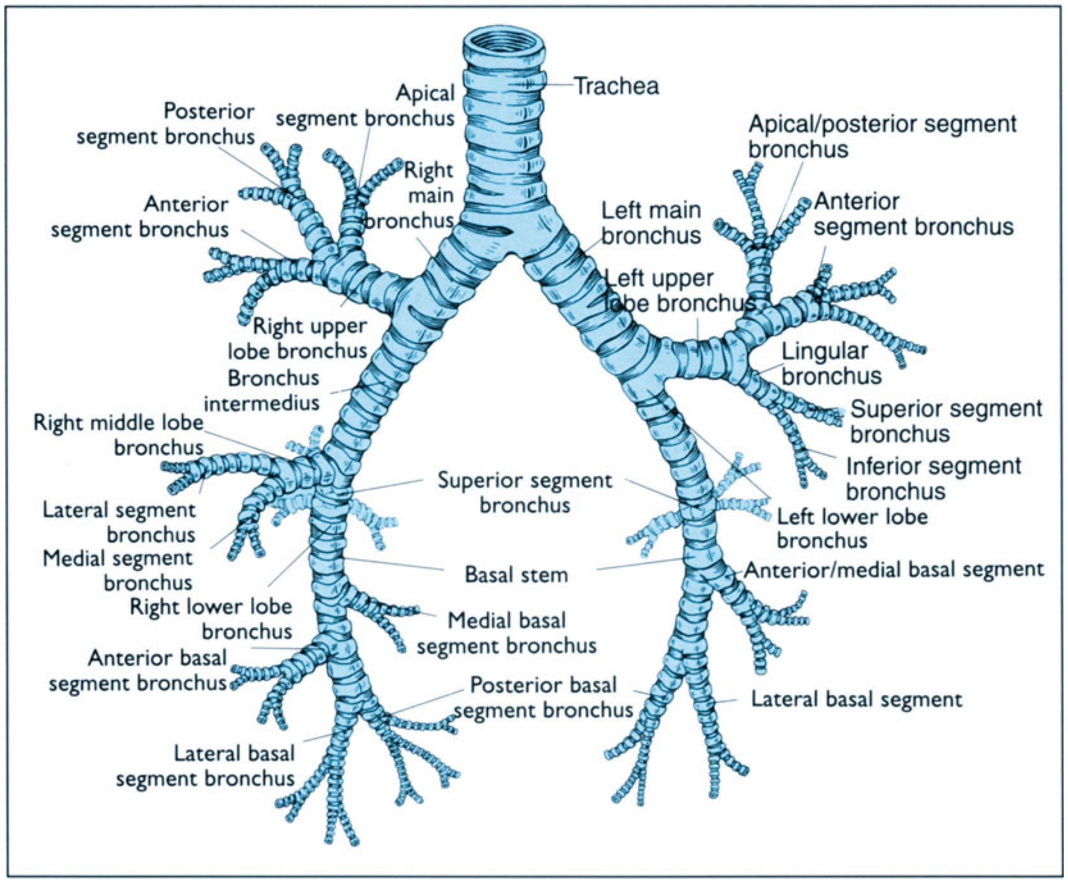


FIGURE 24-3.
The tracheobronchial tree.

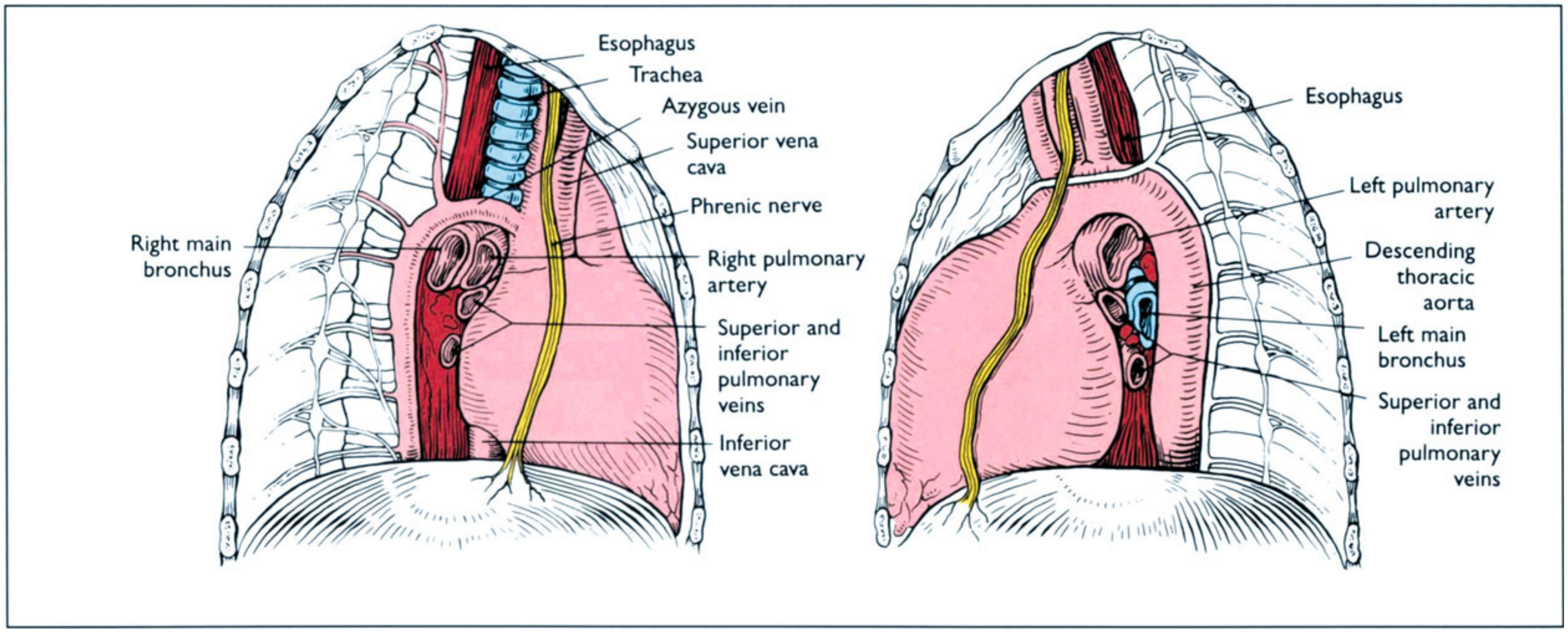


FIGURE 24-4.
The right and left mediastinum.

coscopy and lung biopsy. Diffuse lung disease including interstitial lung disease, diffuse fibrosis, pulmonary infiltrates, and miliary nodules are all amenable to diagnosis by thoracoscopy. Conventional diagnostic methods, including bronchoscopy with bronchoalveolar lavage and transbronchial biopsy, frequently obtain a diagnosis. Thoracoscopic lung biopsy is indicated when these conventional methods fail and when a specific diagnosis would result in a change in therapy. Thoracoscopy provides excellent visualization of the entire surface of the lung and allows for multiple directed biopsies.

The solitary pulmonary nodule remains a significant clinical challenge for physicians (Table 24-4). Overall, 40% of resected nodules are reported as malignant [6]. An accurate, minimally invasive method for diagnosis is essential in their management. Multiple clinical variables are associated with an increased risk of malignancy and these include increased patient age, smoking history, increased nodule size, increased rate of growth, and lack of specific calcification. Small (< 1 cm) calcified nodules, unchanged in size on serial radiographs, may be considered benign, however, few nodules fall into this category. Fiberoptic bronchoscopy and transthoracic needle biopsy are two minimally invasive procedures that can obtain tissue for diagnosis. Bronchoscopy is limited by the peripheral location in the majority of these nodules. Transthoracic needle biopsy can retrieve tissue from peripheral locations and can be diagnostic in up to 95% of malignant nodules. However, a specific benign diagnosis is obtained infrequently, and 5% to 18% of nodules reported with no evidence of malignancy are later proven to be malignant [7,8]. These limitations frequently mandate surgical resection in patients with solitary pulmonary nodules.

Thoracoscopic lung biopsy provides adequate tissue for a definitive diagnosis. In addition, a formal thoracotomy can be avoided in patients with a benign diagnosis. Open thoracotomy and definitive resection can also be performed when indicated in patients with a malignant diagnosis.

The Mediastinum

The anterior, middle, and posterior mediastinum are accessible to thoracoscopic exploration. Undiagnosed mediastinal masses can be identified and directly evaluated for malignant potential (Table 24-5). Lymphadenopathy from lymphoma or metastatic carcinoma can be biopsied. Simple cysts and small, well circumscribed solid tumors can be completely excised.

Table 24-4. Differential diagnosis of solitary pulmonary nodules

Benign	Malignant	Metastatic
Hamartoma	Bronchogenic carcinoma	Colon cancer
Granuloma	Squamous cell carcinoma	Renal cell carcinoma
Tuberculosis	Adenocarcinoma	Breast cancer
Fungal	Small cell carcinoma	Malignant melanoma
Fibrosis/scar	Large cell carcinoma	
Pneumonia	Bronchoalveolar cell carcinoma	
Vascular tumors		

Table 24-5. Mediastinal masses by location

Anterior	Middle	Posterior
Thymoma	Pericardial cyst	Neurogenic tumor
Lymphoma	Bronchogenic cyst	Enteric cyst
Teratoma	Lymphoma	
Thyroid adenoma		

Surgical Technique

Diagnostic Thoracoscopy and Lung Biopsy

Figures 24-5 through 25-15 depict the surgical technique for diagnostic thoracoscopy and lung biopsy.

Set-up

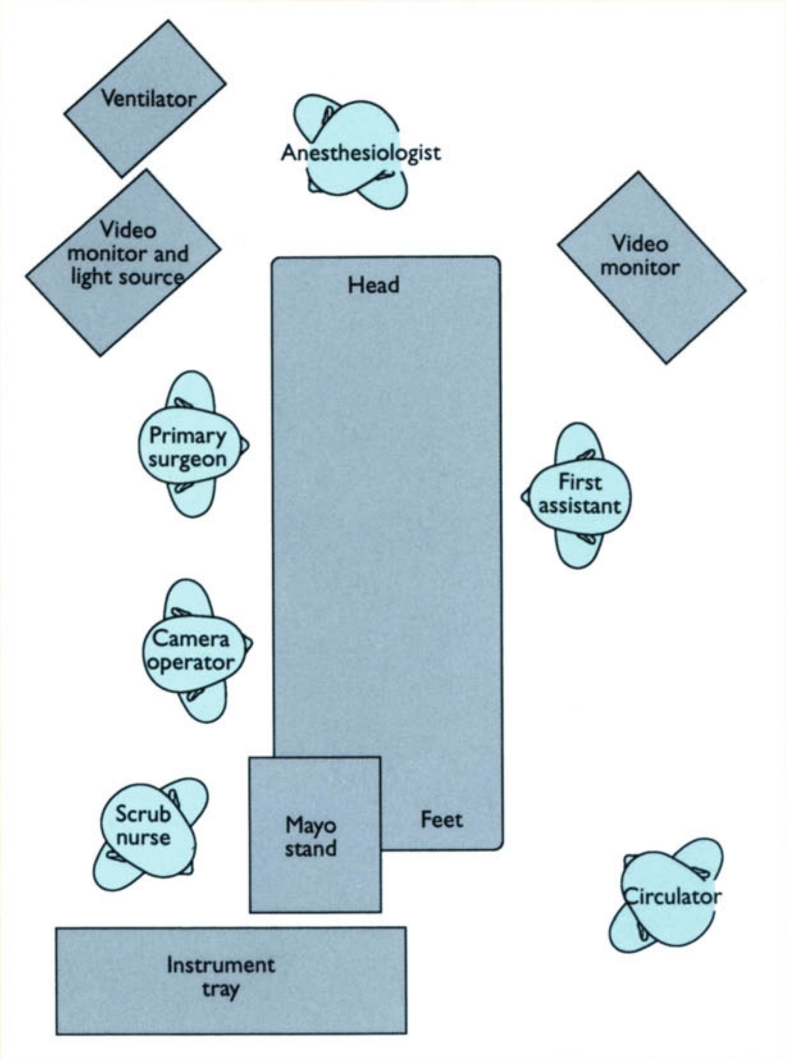


FIGURE 24-5.
The operative set-up for diagnostic thoracoscopy and lung biopsy is depicted here. The optimal placement of the video monitors depends upon the location of the biopsy region. In general, the thoracoscope, the biopsy region, and the video monitor should be in a straight line. This alignment facilitates dissection and manipulation and prevents "mirror image" action on the video monitor.

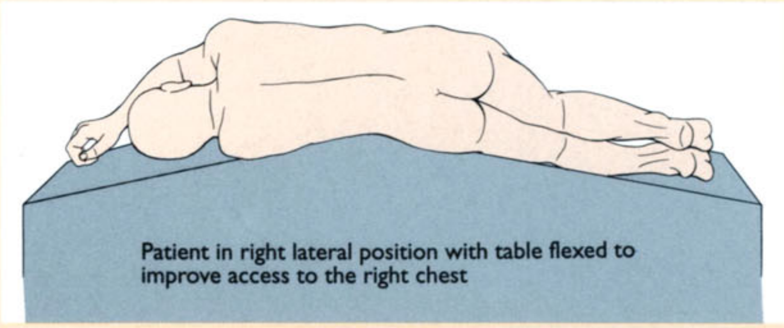


FIGURE 24-6.
The patient is intubated with a dual lumen endotracheal tube to allow selective one lung ventilation. A Foley catheter and a nasogastric tube are placed. The patient is placed in the right lateral position and the table is flexed so the shoulders and hips fall away from the operative field. The chest is prepped and draped so that a formal thoracotomy may be performed if needed. The right lung is isolated from ventilation.

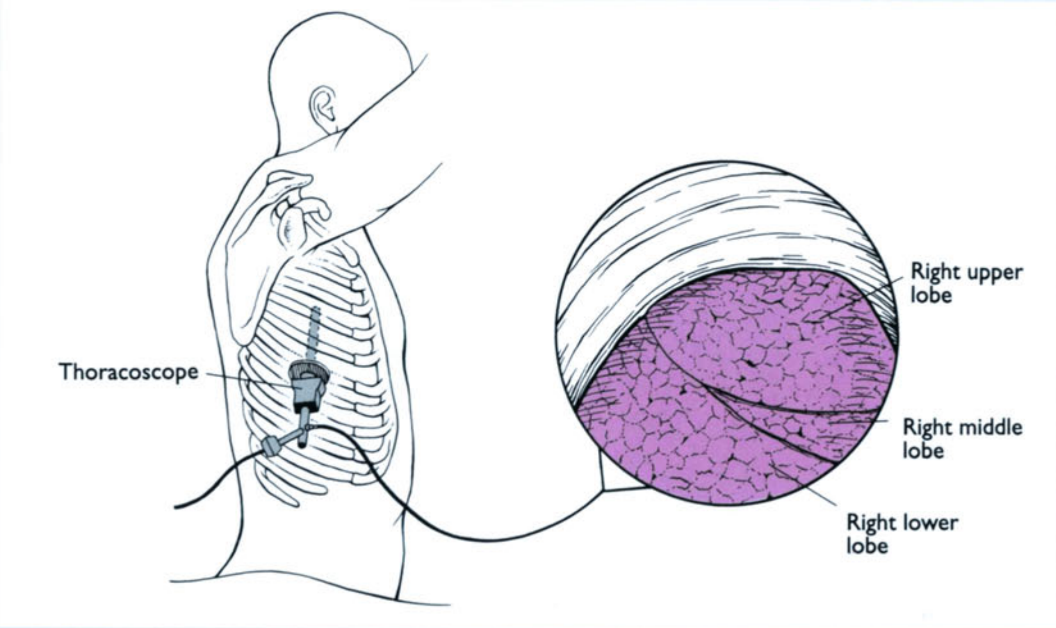


FIGURE 24-7.
Access to the thoracic cavity is performed with blunt dissection just above the rib. A finger is gently inserted into the chest to ensure that the lung is free. A 10-mm port is introduced into the 6th or 7th interspace in the midaxillary line. It is advisable to insert this port at some distance from the expected area of biopsy. This allows for better visual perspective and instrument manipulation. Insufflation with carbon dioxide is optional. A brief period of insufflation may aid in lung collapse. The thoracic cavity is explored and a suitable area for biopsy identified.

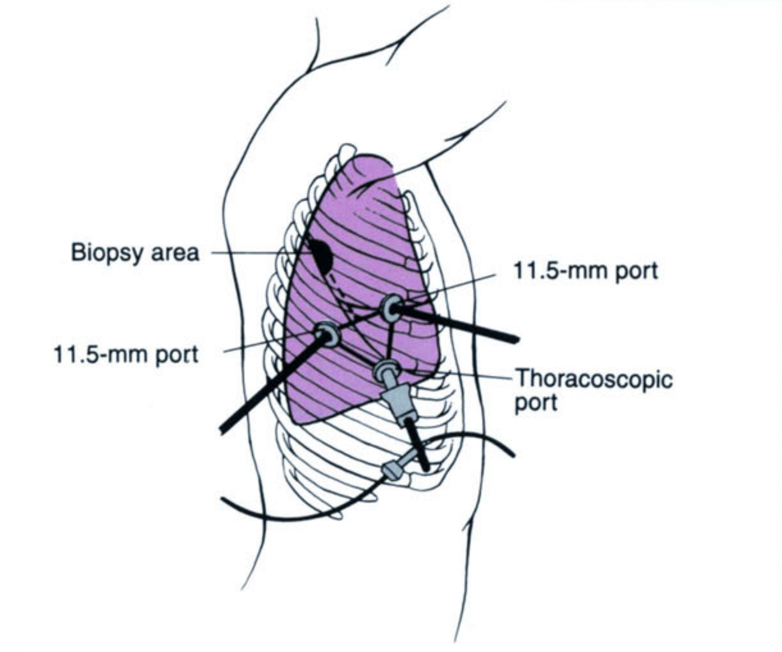


FIGURE 24-8.
Two 11.5-mm ports are then inserted under direct vision. The use of two 11.5-mm ports allows for the stapler to be introduced through either port and may reduce the number of staple loads needed. These ports are usually inserted an interspace or two higher and to the left and right of the thoracoscope; however, the exact location will depend upon the anatomic location of the biopsy region. In general, the two access ports and the thoracoscope port should form a triangle. The base of the triangle should be perpendicular to the region of biopsy. This concept of "triangulation" can be applied to virtually all thoracoscopic procedures.

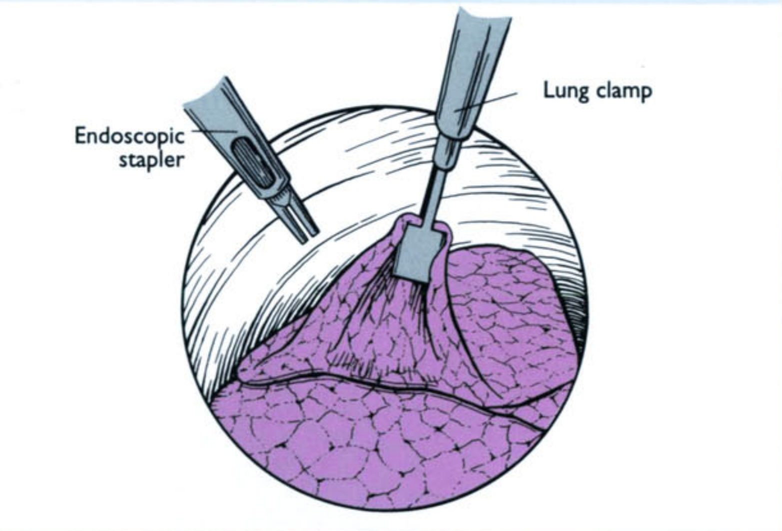


FIGURE 24-9.
An endoscopic lung clamp is introduced and a segment of the right upper lobe is grasped for biopsy.

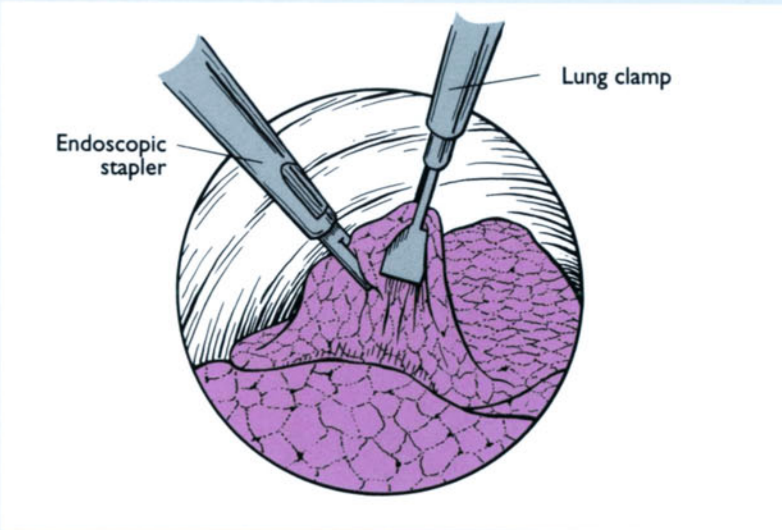


FIGURE 24-10.
The endoscopic stapler is opened and clamped on the lung. All sides of the stapler are inspected to ensure correct positioning.

Procedure

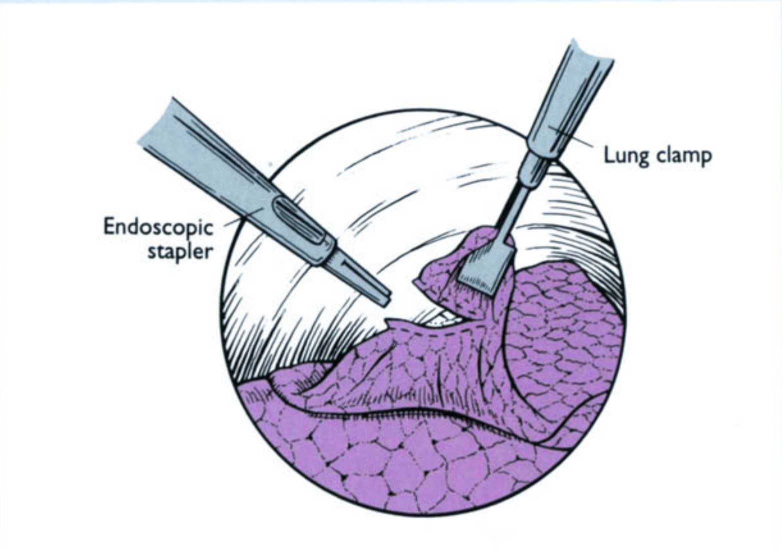


FIGURE 24-11.
The endoscopic stapler is fired, unclamped, and withdrawn.

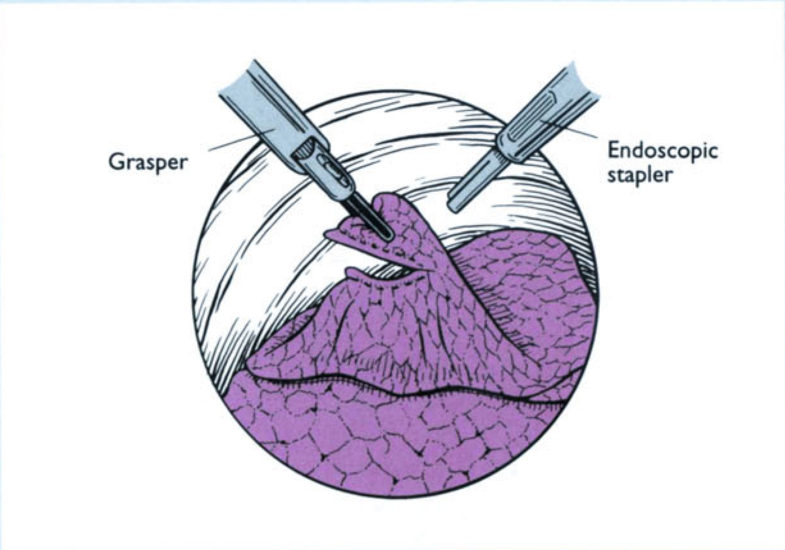


FIGURE 24-12.
When more than one staple load is necessary, a grasper is inserted and the biopsy specimen is taken from the lung clamp. The lung clamp is withdrawn and the endoscopic stapler introduced through the right port.

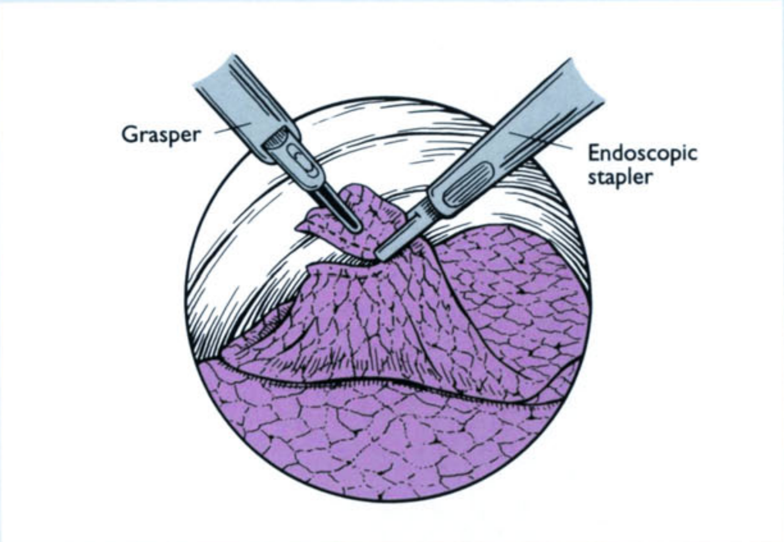


FIGURE 24-13.
The endoscopic stapler is positioned on the lung, clamped, and fired. This "two-sided" technique will virtually always perform a biopsy with two staple loads and is technically simple.

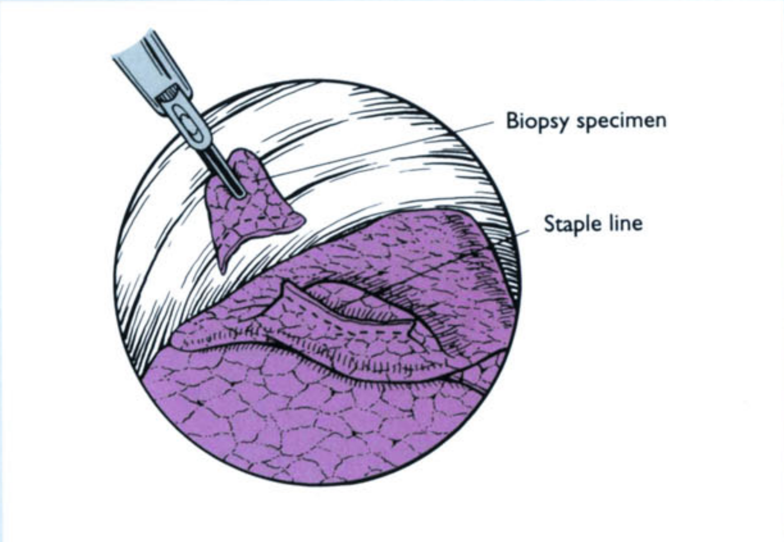


FIGURE 24-14.
The biopsy specimen is withdrawn. The staple line and port sites are inspected for hemostasis.

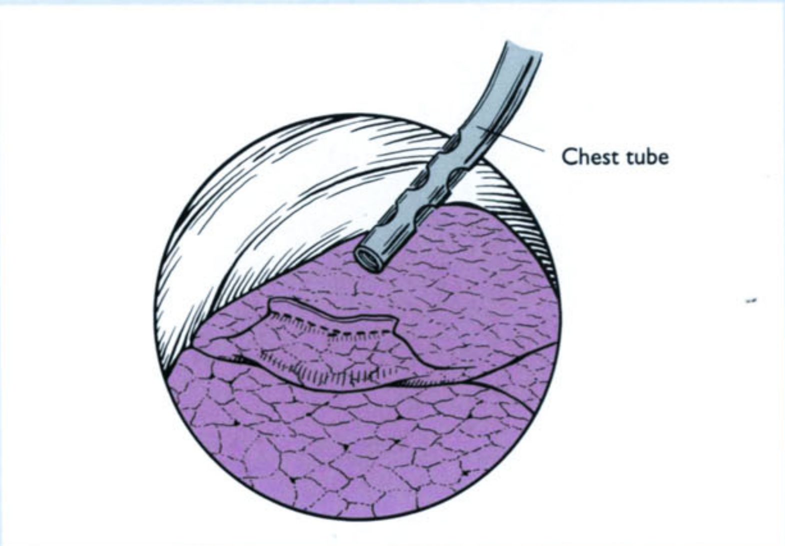


FIGURE 24-15.
A 28-French chest tube is inserted under direct vision. The thoracoscope is withdrawn and the lung inflated.

Thoracoscopic Mediastinal Lymph Node Biopsy

Figures 24-16 through 24-21 depict the surgical technique for thoracoscopic mediastinal lymph node biopsy.

Procedure

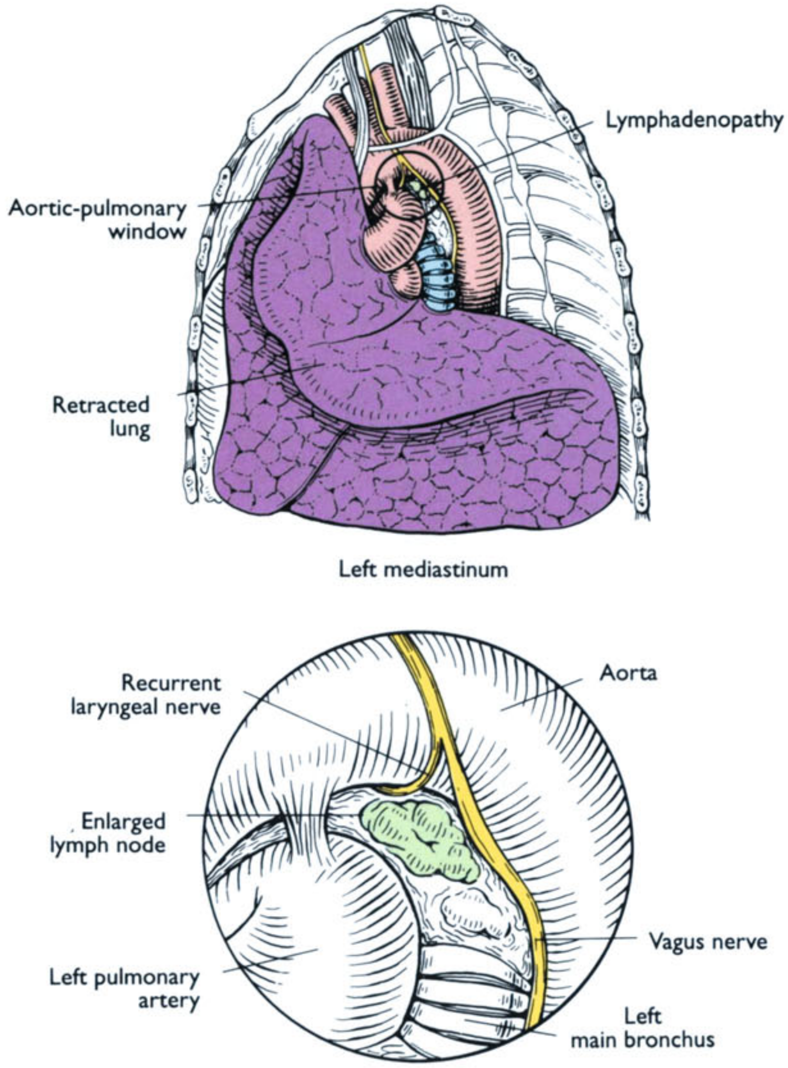


FIGURE 24-16.

Operating room set-up, patient positioning, and port placement are similar to that of diagnostic thoracoscopy and lung biopsy. An additional port is placed for a lung (fan) retractor. The lung is retracted exposing the left mediastinum. Lymphadenopathy is present in the aortic-pulmonary window. The positions of the phrenic and recurrent laryngeal nerves are noted.

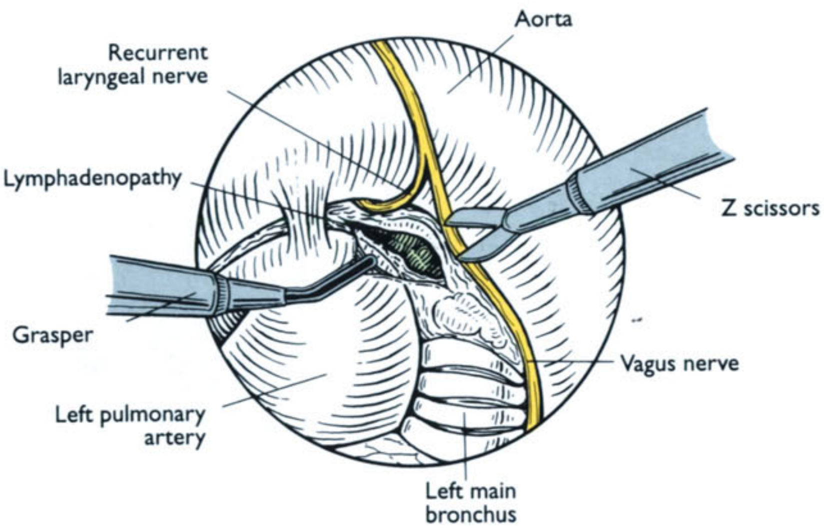


FIGURE 24-17.

The mediastinal pleura is incised over the lymphadenopathy.

Results

Pleural Disease

Thoracoscopy is highly effective for the diagnosis of pleural effusions [9]. Boutin and coworkers [10] reported a series of 1000 patients with pleural effusions, 215 of which were undiagnosed after thoracentesis. Ninety-six percent were subsequently diagnosed by thoracoscopy. The majority of these effusions (70%) were malignant. Lyses of pleural adhesions, complete drainage, and pleurodesis can also be performed. Using thoracoscopic drainage and pleurodesis, Daniel and coworkers [11] were able to obtain a 90% success rate in patients with pleural effusions.

Parenchymal Disease

Thoracoscopic lung biopsy for diffuse and isolated pulmonary disease has a high diagnostic accuracy. Initial reports cite a diagnostic accuracy of 100% in patients with diffuse lung disease using the endoscopic stapler [12,13]. These results compare favorably with the reported 92% diagnostic accuracy for open lung biopsy [14]. Mack and coworkers [15] recently reported on thoracoscopy for solitary pulmonary nodules. Two hundred forty-two patients underwent diagnostic thoracoscopy and a diagnosis was obtained in 100% of the patients with no operative mortality. A malignant diagnosis was obtained in 52%.

Mediastinal Disease

The role of thoracoscopy in the mediastinum is evolving. This method is highly effective when biopsies can be obtained as in the case of mediastinal lymphadenopathy. It has also been advocated for the accurate staging of lung cancer. Safe and effective excision of mediastinal cysts and neurogenic tumors as well as thymectomy have been described [16–19]. Early reports are encouraging but more results are needed before its role in the mediastinum can be completely defined.

In summary, diagnostic thoracoscopy is an exciting new modality that appears to have an expanding role in general thoracic surgery. Many thoracic diagnostic procedures can be performed with a high diagnostic yield and minimal patient discomfort. Limitations in equipment and tactile sensation still exist; therefore, careful preoperative planning is necessary to ensure adequate exposure for safe diagnostic procedures.

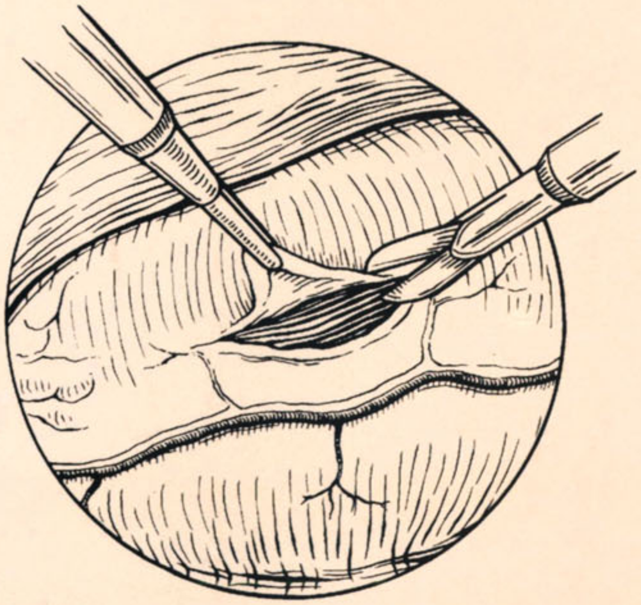
References

1. Jacobaeus HC: Ueber die Moglichkeit die Zystoskopie bei untersuchung seroser hohlungen anzuwenden. *Munchen Med Wochenschr* 1910, 57:2090–2092.
2. Day JC, Chapman PT, O'Brien EJ: Closed intrapleural pneumonolysis: an analysis of 1,000 consecutive operations. *J Thorac Surg* 1948, 17:537–554.
3. Landreneau RJ, Mack MJ, Keenan RJ, *et al.*: Strategic planning for video-assisted thoracic surgery. *Ann Thorac Surg* 1993, 56:615–619.
4. Landreneau RJ, Hazelrigg SR, Mack MJ, *et al.*: Postoperative pain related morbidity: video-assisted thoracic surgery versus thoracotomy. *Ann Thorac Surg* 1993, 56:1285–1289.
5. Hazelrigg SR, Nanchuck SK, Landreneau RJ, *et al.*: Cost analysis for thoracoscopy: thoracoscopic wedge resection. *Ann Thorac Surg* 1993, 56:633–635.
6. Lillington GA: Management of solitary pulmonary nodules. *Dis Mon* 1991, 37:271–318.
7. Penketh AL, Robinson AA, Barker V, Flower CDR: Use of percutaneous needle biopsy in the investigation of solitary pulmonary nodules. *Thorax* 1987, 42:967–971.
8. Westcott JL: Percutaneous transthoracic needle biopsy. *Radiology* 1988, 169:593–601.
9. Rusch VW, Mountain C: Thoracoscopy under regional anesthesia for the diagnosis and management of pleural disease. *Am J Surg* 1987, 154:274–278.
10. Boutin C, Astroul P, Seitz B: The role of thoracoscopy in the evaluation and management of pleural effusions. *Lung* 1990, 168:1113–1121.
11. Daniel TM, Tribble CG, Rodgers BM: Thoracoscopy and talc poudrage for pneumothoraces and effusions. *Ann Thorac Surg* 1990, 50:186–189.
12. Miller D, Allen M, Trastek V, *et al.*: Video thoracoscopic wedge excision for diffuse interstitial lung disease. *Chest* 1992, 102(suppl):1695.
13. Lewis RJ, Caccavoule RJ, Sisler GE, Mackenzie SW: One hundred consecutive patients undergoing video-assisted thoracic operations. *Ann Thorac Surg* 1992, 54:421–426.
14. Gaensler EA, Carrington CB: Open biopsy for chronic diffuse infiltrative lung disease. *Ann Thorac Surg* 1980:30:411–426.
15. Mack MJ, Hazelrigg SR, Landreneau RJ, Acuff TE: Thoracoscopy for the diagnosis of the indeterminate solitary pulmonary nodule. *Ann Thorac Surg* 1993, 56:825–832.
16. Sugarbaker DJ: Thoracoscopy in the management of anterior mediastinal masses. *Ann Thorac Surg* 1993, 56:653–656.
17. Lewis RJ, Caccaoule RJ, Sisler GE: Imaged thoracoscopic surgery: a new thoracic technique for resection of mediastinal cysts. *Ann Thorac Surg* 1992, 53:318–320.
18. Naunheim KS: Video thoracoscopy for masses of the posterior mediastinum. *Ann Thorac Surg* 1993, 56:657–658.
19. Hazelrigg SR, Landreneau RJ, Mack MJ, Acuff TE: Thoracoscopic resection of mediastinal cysts. *Ann Thorac Surg* 1993, 56:659–660.

CHAPTER 25

Thoracoscopic Pericardiectomy

Scott H. Johnson
James M. Douglas, Jr



Hippocrates (460 BC) accurately described the pericardium and Galen (AD 150) named it and suggested its physiologic role. The first successful pericardiotomy for drainage of an effusion was performed by Romero in 1819 [1]. Schuh and Karanaeff [2] subsequently described pericardiocentesis in 1840. Kussmaul [3] in 1873 described the classic signs of pericardial tamponade: neck vein distension and pulsus paradoxus.

Multiple surgical options are available when approaching the pericardium. Traditional methods include a left thoracotomy, a median sternotomy, and a subxiphoid approach. The development of video-assisted endosurgical equipment has led to the successful application of thoracoscopy to pericardial resection in effusive disease.

Anatomy

The parietal pericardium is composed of dense collagen and elastin fibers with an inner serous layer composed of a single layer of mesothelial cells. The parietal pericardium is a sac-like structure that surrounds the heart and fuses to the adventitia of the proximal great vessels (Figure 25-1). The visceral pericardium covers the surface of the heart and consists of a thin layer of fibrous tissue covered by mesothelium. The parietal and visceral pericardium are continuous at the sites of attachment to the proximal great vessels. Ligaments fix the pericardium anteriorly to the sternum, posteriorly to the spine, and inferiorly to the diaphragm. The phrenic nerve and pericardiacophrenic artery course along the lateral aspect of both sides of the pericardium. Normally, the pericardium contains up to 50 mL of serous fluid.

The pericardium reduces friction between the heart and surrounding tissues and fixes the heart within the mediastinum. Experimental evidence reveals that the pericardium performs important physiologic functions that include equalization of hydrostatic forces, limitation of cardiac distension, and diastolic hemodynamic coupling [4].

Pathophysiology

Pericardial effusions may develop after acute pericarditis and trauma. The most common types of pericardial effusions include neoplastic, idiopathic, uremic, infectious, and traumatic. A complete list is presented in Table 25-1. Acute inflammation in the pericardium results in increased vascular permeability and fibrin deposition. Fibrous adhesions and exudation are typical. Complications of fibrosis (constriction) and effusions (tamponade) may develop.

Pericardial tamponade develops if the accumulation of fluid causes a rise in intrapericardial pressure (normal = -5 to +5 cm H_2O). This rise in pressure depends on the volume of effusion and the rate at which it accumulates. Chronically, large volumes (1500 mL) may collect without

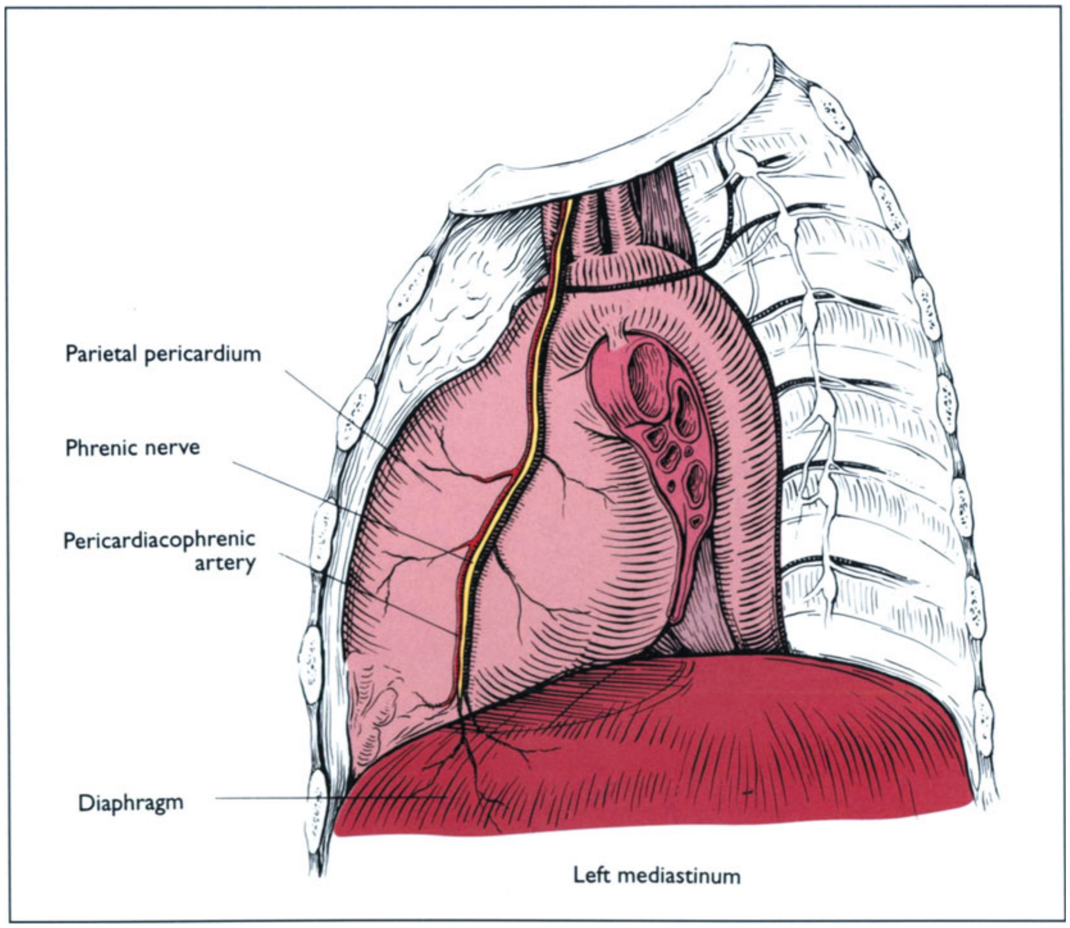


FIGURE 25-1.
Anatomy of the pericardium. The pericardium phrenic nerve and pericardiacophrenic artery are shown within the mediastinum.

Table 25-1. Pericardial effusions

Neoplastic
Lung
Breast
Lymphoma
Idiopathic
Infectious
Pyogenic
Tuberculous
Fungal
Systemic disease
Collagen vascular disease
Uremia
Thyroid disease
Trauma
Penetrating and blunt injury
Cardiac catheterization
Postcardiac procedure
Postpericardiotomy syndrome
Radiation
Drugs and hypersensitivity

hemodynamic compromise. However, the acute accumulation of as little as 150 to 250 mL of pericardial fluid may cause acute pericardial tamponade (Figure 25-2). Elevated intrapericardial pressures decrease ventricular filling, decrease stroke volume, and thereby reduce cardiac output. The reduced stroke volume is compensated by increased heart rate and sympathetic tone. When these compensatory mechanisms fail, systemic perfusion decreases and cardiogenic shock follows.

Presentation and Differential Diagnosis

Acute pericarditis is characterized by chest pain, a pericardial friction rub, and electrocardiogram changes. Chest pain is variable in location and may be exacerbated by supine position and deep inspiration. The pericardial friction rub classically contains three components that correspond with atrial systole, ventricular systole, and ventricular filling during diastole. The ECG changes are described in four stages. Stage 1 consists of ST segment elevation in all leads except AVR and V1. Stage 2 is characterized by normalization of ST segments and T-wave flattening. Later, in Stage 3, the T waves become inverted. In Stage 4, the T waves normalize. Acute pericarditis is usually self-limiting. However, hemodynamic complications may develop in the form of cardiac tamponade from a pericardial effusion, constriction from fibrosis, or both.

The onset of cardiac tamponade may be sudden or insidious. The signs of tamponade include distended neck veins, distant heart sounds, and hypotension (Table 25-2). This triad of symptoms is known as Beck's triad [5]. Tamponade is also characterized by a pulsus paradoxus that is an inspiratory fall in arterial systolic blood pressure greater than 10 mm Hg. Cyanosis, tachycardia, and tachypnea may also be present. In general, signs of cardiogenic shock predominate. The ECG may show electrical alternans, a phasic alteration in the amplitude of the R wave. The chest radiograph may show an enlarged cardiac silhouette. Invasive monitoring reveals rising central venous pressure with decreased cardiac output and mean arterial pressure.

Echocardiography is the most sensitive test for the diagnosis of a pericardial effusion. In addition, it may also reveal findings of early cardiac tamponade. Increased respiratory variation in valvular flow, diastolic right ventricular collapse, and loss of normal inspiratory inferior vena cava collapse are sensitive indicators of cardiac tamponade.

The differential diagnosis of cardiac tamponade includes other major disorders of the chest that cause shock and hypotension (Table 25-3). These include tension pneumothorax, hemothorax, acute myocardial infarction, congestive heart failure, pulmonary embolism, superior vena cava syndrome, and constrictive pericardial disease.

Surgical Indications

Surgical drainage of a pericardial effusion is indicated when medical management fails to control the effusion and a specific diagnosis is required to direct therapy. Early physical signs of tamponade may be present or may be demonstrated by echocardiography. The objectives of surgical therapy are to drain the effusion, prevent recurrence, and provide a specific diagnosis.

Surgical options include a left thoracotomy, a subxiphoid approach, and thoracoscopy. A subxiphoid pericardial win-

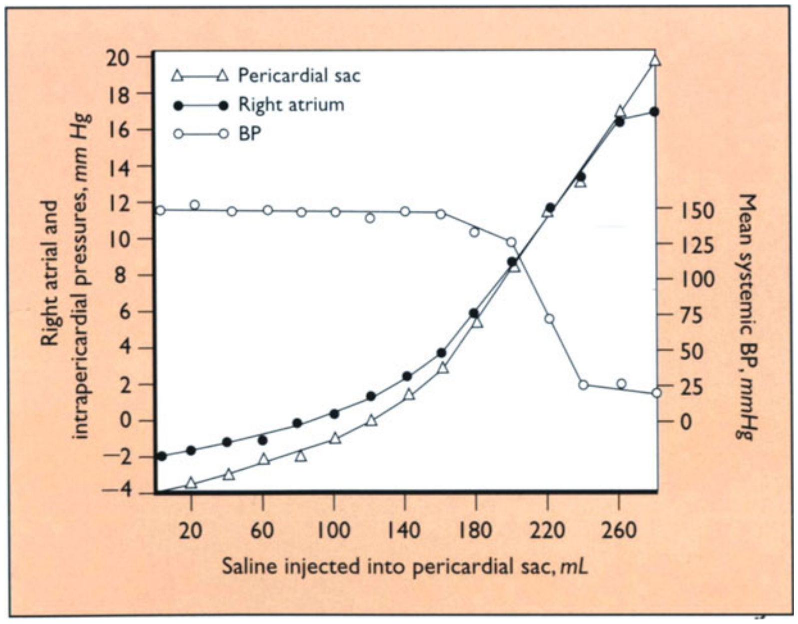


FIGURE 25-2.
Experimental cardiac tamponade produced by injection of saline into the pericardium. As the volume of pericardial fluid increases, mean arterial pressure falls and right atrial and pericardial pressures rise. (*From* Fowler [11]; with permission.)

Table 25-2. Signs of cardiac tamponade

Hypotension
Distended neck veins
Distant heart sounds
Pulsus paradoxus
Tachycardia
Tachypnea

Table 25-3. Differential diagnosis of cardiac tamponade

Tension pneumothorax/hemothorax
Hypovolemic shock
Myocardial infarction
Congestive heart failure
Pulmonary embolism
Superior vena cava syndrome
Constrictive pericarditis

dow can be performed under local anesthesia and is usually well tolerated. However, the extent of pericardial resection is limited and reported recurrence rates are as high as 10% to 18% [6–8]. Therefore, a subxiphoid window is usually reserved for patients who are high-risk surgical candidates or who have a poor overall prognosis. A left thoracotomy allows for a more complete pericardial resection and a decreased incidence of recurrent effusions [6]. However, the added morbidity of general anesthesia and a more invasive procedure are present.

A thoracoscopic approach has the advantage of providing access for an extended pericardial resection while avoiding a formal thoracotomy. Postoperative pain would be expected to be less than with a thoracotomy [9]. Disadvantages include the need for general anesthesia and single lung ventilation. If tamponade physiology is present, pericardiocentesis should be performed prior to the induction of general anesthesia.

Surgical Technique

Figures 25-3 through 25-8 depict the surgical technique for thoracoscopic pericardiectomy.

Set-up

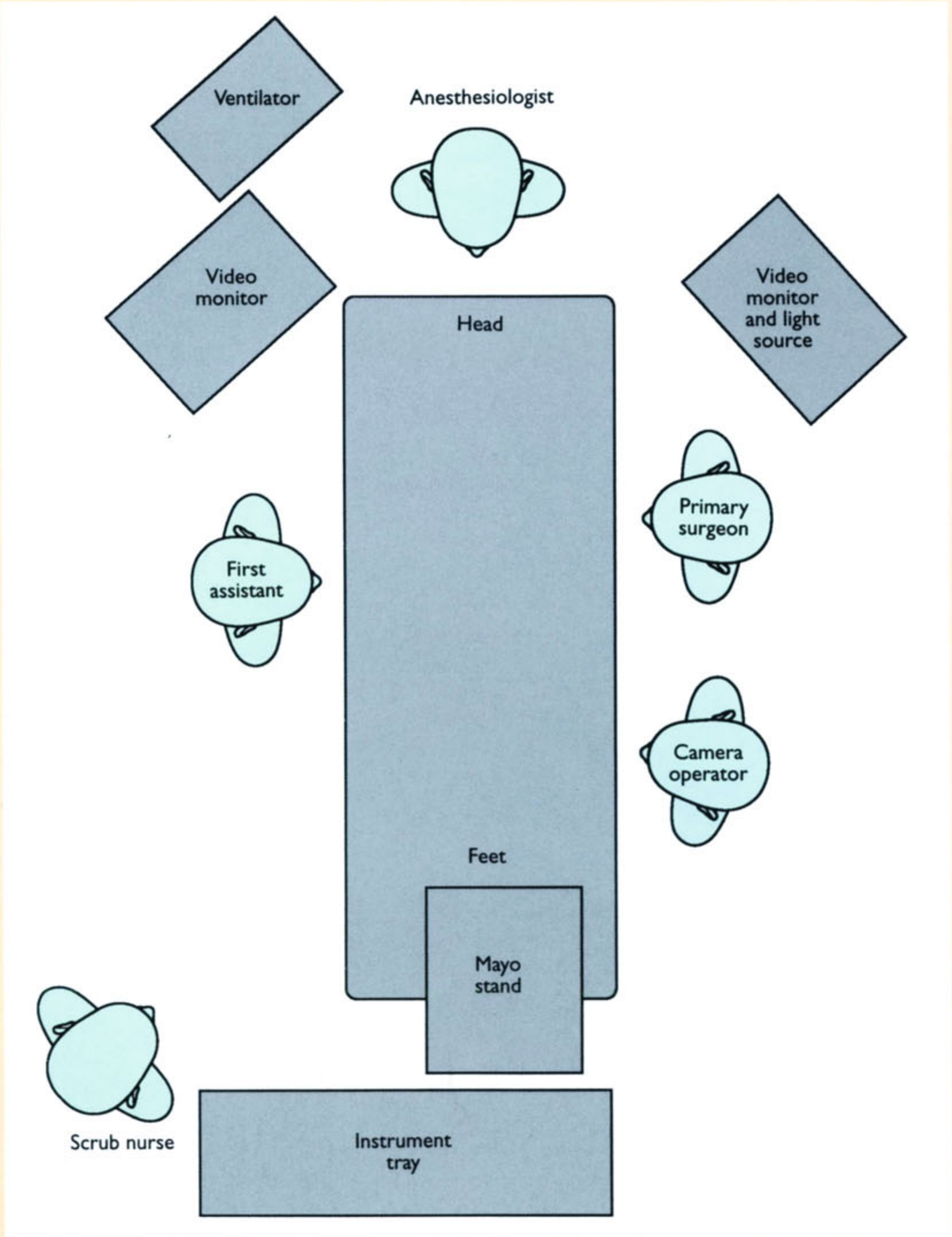


FIGURE 25-3. The operative set-up for thoracoscopic pericardial window.

Procedure

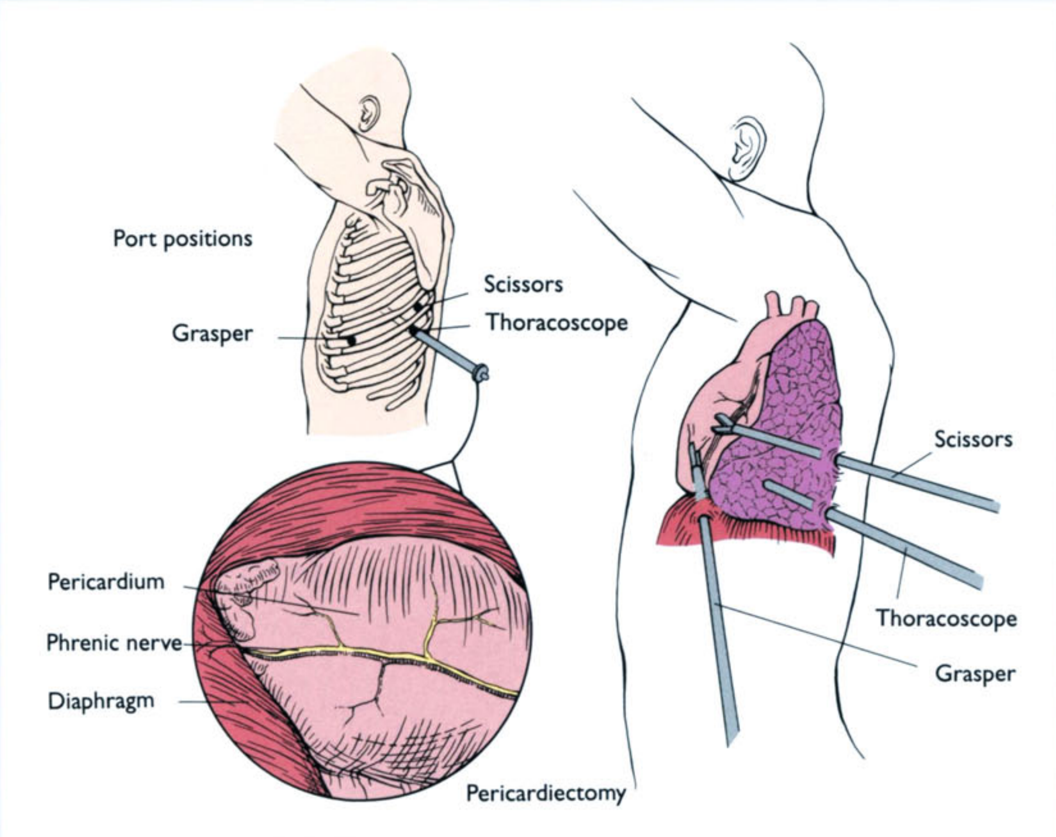


FIGURE 25-4.

The patient is intubated with a dual lumen endotracheal tube for single lung ventilation. A Foley catheter and nasogastric tube are inserted. If significant tamponade is present, pericardiocentesis should be performed prior to the induction of anesthesia. The patient is placed in the left lateral position and single lung ventilation is established. Access to the thoracic cavity is gained by blunt dissection over the 8th rib (7th interspace) in the midscapular line posteriorly. A 10-mm port is inserted and the thoracoscope introduced. The chest cavity is explored. Two 5-mm ports are inserted under direct vision an interspace higher (6th) in the midscapular line and in the anterior axillary line. A grasper and scissors are introduced.

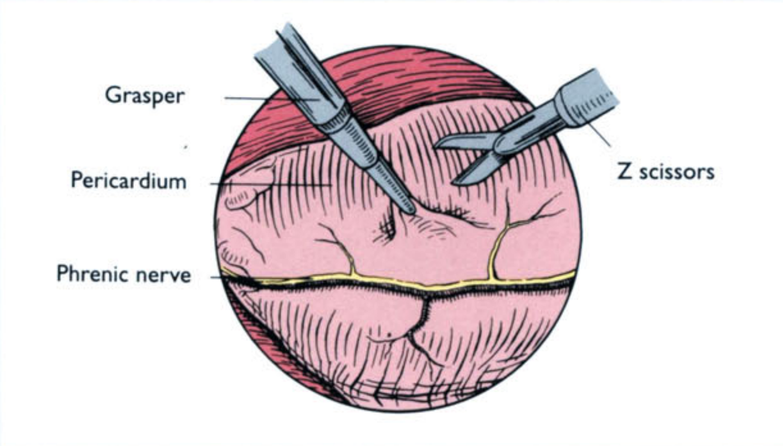


FIGURE 25-5.

The pericardium and phrenic nerve are identified. The pericardium anterior to the phrenic nerve is grasped and incised. Care is taken to avoid injury to underlying cardiac structures.

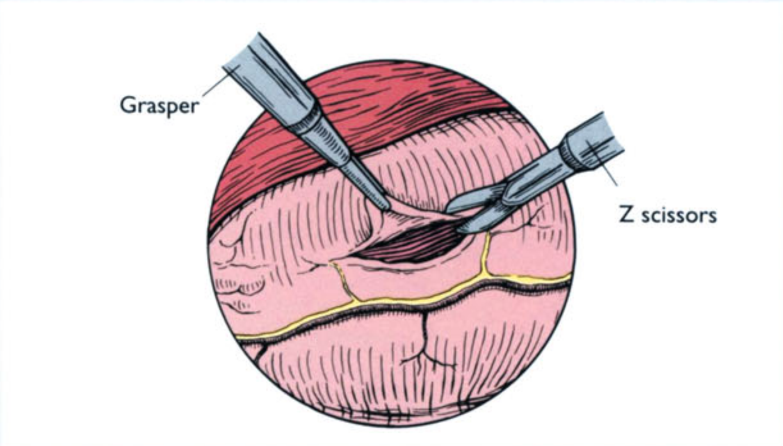


FIGURE 25-6.

The anterior pericardium is widely excised. If posterior loculated fluid collections exist, a posterior resection of pericardium may also be performed.

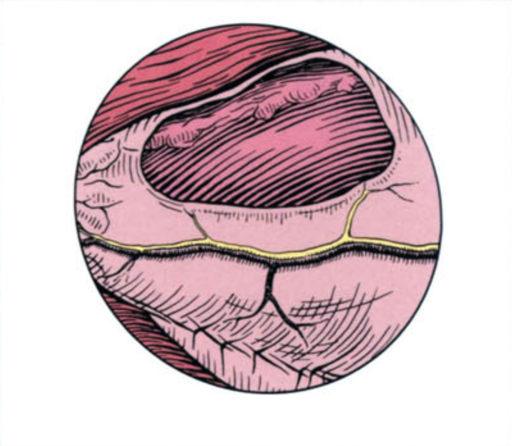


FIGURE 25-7.

The pericardium is removed. The area of resection is inspected for adequate hemostasis.

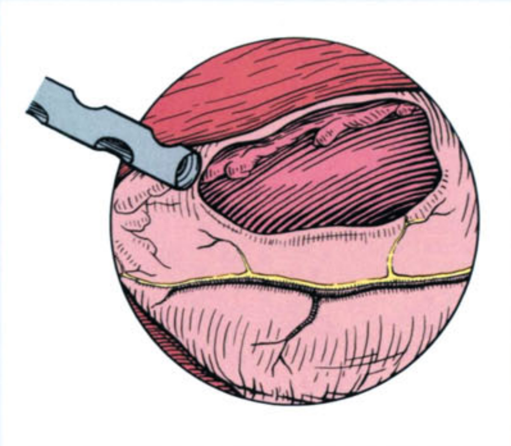


FIGURE 25-8.

A 28- or 32-French chest tube is placed and angled toward the pericardium. Port sites are inspected for hemostasis and the thoracoscope is withdrawn.

Results

Early results of thoracoscopic pericardial resection have been encouraging. Hazlerigg and coworkers [10] reported on thoracoscopic pericardiectomy in 35 patients. Malignant effusions accounted for just over half (52%) of their patients. There was no operative mortality and hospital stay averaged 4.6 days. There were no recurrent effusions at 9 months of follow-up. The authors emphasize the low likelihood of benefit from this technique in patients with malignant effusions and a poor prognosis. A reported advantage is the ability to address any pleural or parenchymal process simultaneously.

Thoracoscopic pericardial window is a new alternative to thoracotomy and the subxiphoid approach. This technique produces a wide pericardial resection and avoids the morbidity associated with open thoracotomy. Initial reports are encouraging and reveal a low incidence of recurrent pericardial effusions on short-term follow-up.

References

1. Romero, cited by Baizeau: Memoire sur le fonction du pericarde au point de vue chirurgical. *Gas Med Chirc* 1868:565.
2. Karanaeff: Paracentese des brustkastens und des pericardiums. *Med Ztg* 1840, 9:251.
3. Kussmaul A: Uber schwielige mediastion: perikarditis und den paradoxen puls. *Berlin Klin Wochenschr* 1873, 10:433–461.
4. Spodick DH: The normal and diseased pericardium: current concepts of pericardial physiology, diagnosis and treatment. *J Am Coll Cardiol* 1983, 1:240.
5. Beck CS: Two cardiac compressor triads. *JAMA* 1935, 104:714.
6. Piehler JM, Pluth JR, Schaff HV, *et al.*: Surgical management of effusive pericardial disease: influence of extent of pericardial resection on clinical course. *J Thorac Cardiovasc Surg* 1985, 90:506.
7. Naunheim KS, Kesler KA, Fiore AC, *et al.*: Pericardial drainage: subxiphoid vs. transthoracic approach. *Eur J Cardiothorac Surg* 1991, 5:99–104.
8. Sugimoto JT, Little AG, Ferguson MK, *et al.*: Pericardial window; mechanisms of efficacy. *Ann Thorac Surg* 1990, 50:442–445.
9. Landreneau RJ, Hazlerigg SR, Mack MR, *et al.*: Postoperative pain related morbidity; video-assisted thoracic surgery versus thoracotomy. *Ann Thorac Surg* 1993, 56:1285–1289.
10. Hazlerigg SR, Mack MJ, Landreneau RJ, *et al.*: Thoracoscopic pericardiectomy for effusive pericardial disease. *Ann Thorac Surg* 1993, 56:792–795.
11. Fowler NO: Physiology of cardiac tamponade and pulsus paradoxus. *Med Conc Cardiovasc Dis* 1978, 47:109.

CHAPTER 26

Thoracoscopic Pulmonary Resection

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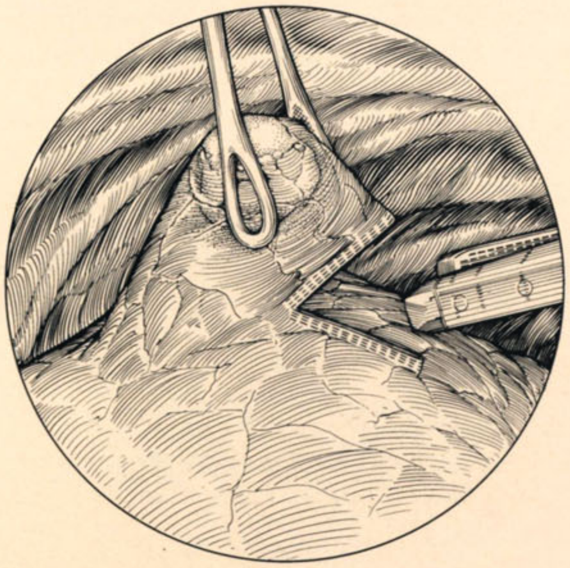


Thoracoscopy was first performed by Jacobaeus in 1910 [1] to divide pleural adhesions. However, because of limited instrumentation and poor visualization, this technique received little enthusiasm over the subsequent 80 years [2]. With the introduction of solid-state video technology in the past 5 years, thoracoscopy (now referred to as video-assisted thoracic surgery [VATS] has become an essential technique in the diagnosis and management of numerous categories of general thoracic surgery [3]. This chapter describes VATS for pulmonary wedge resection.

Management of a Solitary Pulmonary Nodule

The differential diagnosis of a solitary pulmonary nodule, usually found incidentally on plain chest radiography, is listed in Table 26-1. The significant majority of these nodules are benign, with only 5% ultimately proving to contain a malignancy. However, when resection is indicated due to size or rapid growth, approximately 40% of *resected* nodules are malignant. Therefore, the decision to perform a biopsy or resect a pulmonary nodule is of critical importance.

In any patient with a newly detected pulmonary nodule, a thorough history should emphasize tobacco use as well as exposure to chemicals, asbestos, or coal mining. Symptoms such as shortness of breath, chest pain, cough, hemoptysis, or weight loss may be elicited. Physical examination obligates careful palpation for cervical, clavicular, and axillary adenopathy and thorough auscultation of all lung fields. The probability of malignancy is low in patients under 30 years of age and is significantly greater in patients over 50 years of age.

Table 26-1. Pulmonary nodule differential diagnoses

Arteriovenous malformation
Hamartoma
Hematoma
Infectious
Fungal (eg, *Histoplasma, Coccidioides, Aspergillus*)
Pneumonia
Pulmonary abscess
Tuberculosis
Neoplasia
Benign
Adenoma
Mesothelioma
Papilloma
Malignant
Adenocarcinoma
Carcinoid
Large cell carcinoma
Mesothelioma
Secondary malignancy (metastatic from nonlung primary)
Small cell carcinoma
Squamous cell carcinoma
Pulmonary infarction

Old radiographs must be sought aggressively. If available, comparison of the current chest radiograph with previous ones may provide immediate diagnostic and prognostic information. Lesions larger than 3 cm in diameter, regardless of other features or time course, are usually malignant. With nodules smaller than 3 cm in diameter, radiographic characteristics such as smooth contour, diffuse calcification, or popcorn calcification are suggestive of benign tumors. Tumor doubling time, defined by the period in which tumor volume (not diameter) has increased twofold, provides the most reliable means of distinguishing between malignant and benign lesions. Malignant nodules double in volume over a period of weeks to months. By contrast, benign nodules may double over several years or remain unchanged in size. A solitary pulmonary nodule smaller than 3 cm that is radiographically unchanged over 2 years of documented observation may be considered a benign lesion and no further diagnostic work-up is required. Chest radiography should be performed annually as follow-up for these patients.

If these clinical and radiographic indicators are vague or suggestive of malignancy, further diagnostic measures are required immediately. This evaluation should begin with computed tomography (CT) of the chest, liver, and adrenal glands. With distant metastasis, extensive mediastinal adenopathy, involvement of the trachea, or tumor in the contralateral bronchus or lymph nodes, the cancer is considered inoperable and the prognosis is usually grave. Additional criteria for lung cancer inoperability are listed in Table 26-2.

In the absence of definitive clinical and radiologic findings consistent with a benign lesion, histologic diagnosis of an indeterminant pulmonary nodule is essential. Fiberoptic bronchoscopy is often performed as the next step in the diagnostic work-up. However, although bronchoscopy is necessary to identify endobronchial lesions, bronchoscopic biopsy is an unreliable technique for obtaining histologic diagnosis. Transthoracic needle aspiration (TTNA) is performed under fluoroscopic guidance with risks that include pneumothorax, bleeding, air leak, and infection. With malignancy, TTNA has a reported sensitivity ranging from 64% to 97%, whereas a benign diagnosis is only 14% specific.

A negative biopsy result obtained via TTNA does not rule out malignancy. Therefore, direct biopsy via thoracotomy or VATS is required in either case when TTNA is "negative" or positive for malignancy. TTNA is therefore reserved for

Table 26-2. Criteria for lung cancer inoperability

Horner's syndrome (except superior sulcus tumors)
Contralateral disease
Distant metastasis
Involvement of the trachea
Tumor in contralateral main bronchus
Contralateral lymph node metastasis
Superior vena caval obstruction
Bloody pleural effusion
Malignant cells in a pleural effusion

only those circumstances in which disease is considered inoperable (*see* Table 26-2) and tissue diagnosis is desired for palliative radiotherapy or chemotherapy. Positron emission tomography (PET) with ^{18}F-fluorodeoxyglucose may provide a new approach to differentiate benign from malignant focal pulmonary nodules. In a recent study of 51 patients, diagnostic specificity of benign lesions with PET was 100%, whereas sensitivity was 89% [4]. Further studies with this technology are necessary to establish the utility of this technique in the routine clinical setting.

In the absence of inoperable disease, open lung biopsy should be performed on all pulmonary nodules suspicious for malignancy. Preoperative work-up (Table 26-3) should consist of bronchoscopy to identify endobronchial extension of tumor or extrinsic bronchial compression that may influence pulmonary function. CT of the chest and upper abdomen with intravenous contrast and lung field windows should then be performed. CT scanning will precisely define the dimensions and location of the pulmonary mass and identify hilar or mediastinal adenopathy as well as contralateral disease. This study should also be extended to the liver and adrenal glands to rule out distant metastases. If any neurologic abnormalities are detected by history or physical examination, head CT should also be performed. After completing these studies, pulmonary function testing is necessary to determine the available pulmonary reserve after a potential wedge resection, lobectomy, or possibly pneumonectomy. Patients are excluded from pneumonectomy if the FEV_1 (forced expiratory volume in 1 second) is predicted to be less than 1.0 L after resecting the pulmonary nodule. However, thoracoscopic lung resection can be safely performed on patients with FEV_1 less than 1.

All patients requiring pulmonary resection should be considered for VATS. As listed in Table 26-4, VATS wedge resection offers several advantages over conventional thoracotomy. These include enhanced visualization, decreased postoperative pain, and minimal cosmetic impairment as well as the potential for decreased hospital length of stay and earlier return to work. The most significant disadvantage of VATS compared with pulmonary resection remains loss of direct tactile feedback for the surgeon.

Inclusion criteria for VATS wedge resection is listed in Table 26-5. In general, VATS wedge resection can be performed in most patients with noncalcified nodules measuring less than 3 cm in diameter. VATS resection of lesions located in the outer one third of the lung is easily accomplished with little risk of injury to segmental vessels or bronchi. Preoperative CT-guided needle or coil placement or methylene blue injection may facilitate localization and resection of intraparenchymal nodules, which otherwise may be difficult to identify visually on the pleural surface of the lung [5–8].

Anatomy

The anatomy of the lung is defined by the branching of each bronchus (Table 26-6 and Figure 26-1). Each lobe is

Table 26-3. Preoperative work-up of pulmonary nodule

Bronchoscopy
Computed tomography scan
Pulmonary function testing
Mediastinoscopy

Table 26-4. Advantages of video-assisted thoracic surgery for pulmonary resection

Enhanced visualization of entire thorax
Decreased postoperative pain
Decreased wound complications
Decreased incidence of post-thoracotomy pain syndrome
Hastened recovery of pulmonary mechanics
Minimal cosmetic impairment
Decreased hospital length of stay and earlier return to work

Table 26-5. Inclusion criteria for video-assisted thoracic surgery wedge resection

Noncalcified, <3 cm in diameter
Location in outer third of lung parenchyma
Absence of endobronchial extension

Table 26-6. Pulmonary lobar and segmental anatomy

Left lung			Right lung	
Lobes	**Divisions**	**Segments**	**Lobes**	**Segments**
Upper	Upper	Apical-posterior	Upper	Apical
		Anterior		Posterior
	Lingular	Superior	Middle	Anterior
		Inferior		Lateral
				Medial
Lower		Superior	Lower	Superior
		Anterior-medial basal		Medial basal
		Lateral basal		Anterior basal
		Posterior basal		Lateral basal
				Posterior basal

supplied by divisions of the main bronchus. Each segment is supplied by divisions of the lobar branches. The pulmonary artery divides to the left of the ascending aorta. The right branch courses behind the ascending aorta whereas the left branch runs through the concavity of the aortic arch. In their respective hila, each pulmonary artery gives off a large first branch or anterior trunk, supplying one or more of the segments of the upper lobe. Further branching occurs parallel to bronchial divisions. The pulmonary veins arise from pulmonary capillary plexi at the alveoli. Venules run in the interlobular spaces and form the trunks of the pulmonary veins. Two main trunks are derived from each lung, one superiorly and one inferiorly, and enter the posterior aspect of the left atrium. Bronchial arteries perfuse the lung parenchyma and are derived directly from the aorta or aortic intercostal vessels. They may number from one to three and accompany the bronchioles to the lung lobules. Below the root of the lung, the pulmonary ligaments are created by the two layers of pleura that form a distinct band that attaches from the inferior aspect of the pericardium to the inferior portion of the mediastinal surface of the pleura.

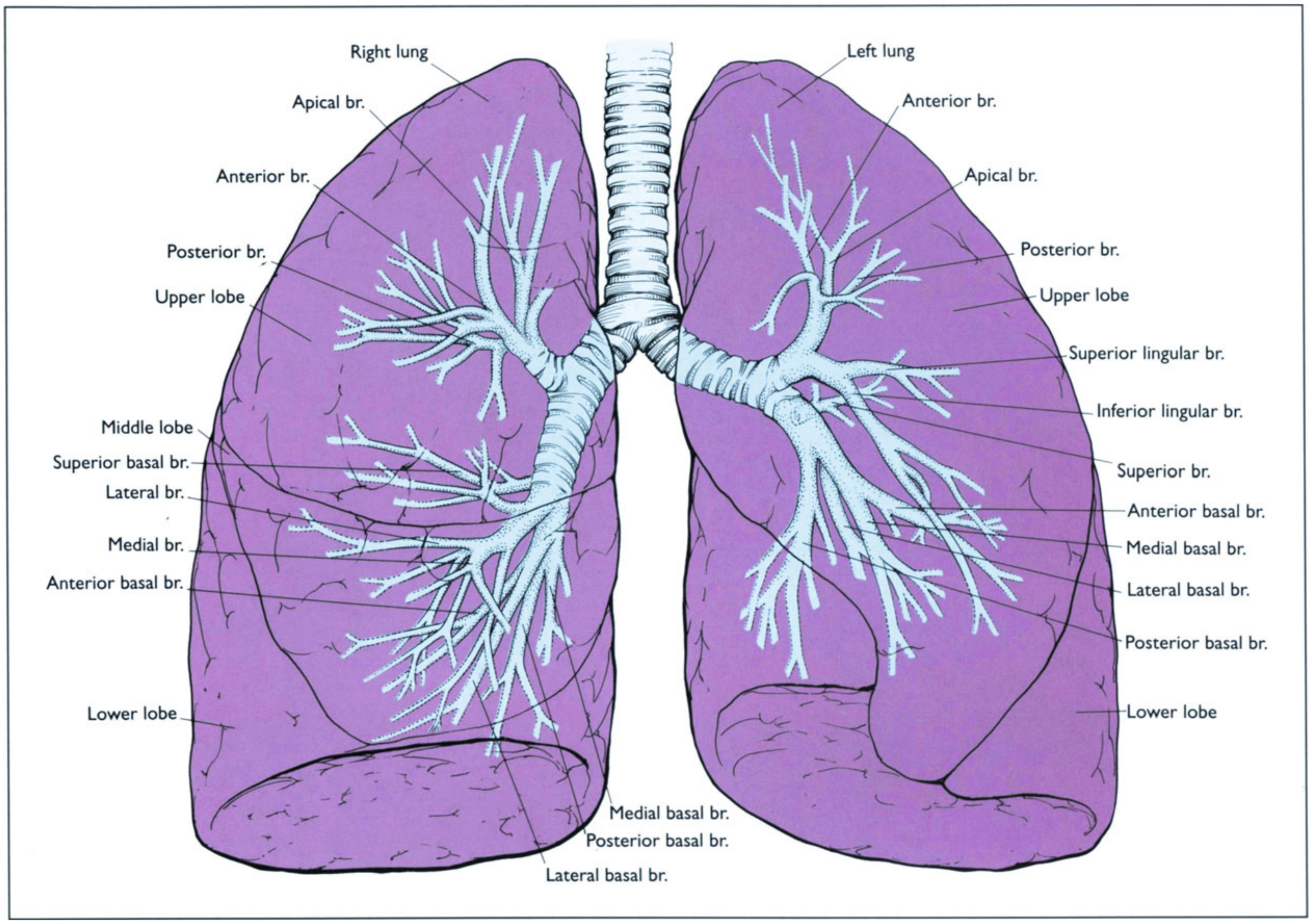


FIGURE 26-1.

Pulmonary anatomy. The topical surface of the lungs as well as the bronchial tree are illustrated. The right lung is composed of three lobes. The oblique (major) fissure separates the lower lobe from the upper and middle lobes whereas the horizontal (minor) fissure separates the upper from the middle lobe. The left lung is composed of two lobes separated by the oblique (major) fissure. A thorough knowledge of the topical features of the lung as they relate to the underlying anatomic structures is essential to successful use of video-assisted thoracic surgery for pulmonary resections.

Surgical Technique

Figures 26-2 through 26-12 depict the surgical technique for VATS. Wedge resection of a left upper lobe nodule is used as the demonstration example.

Set-up

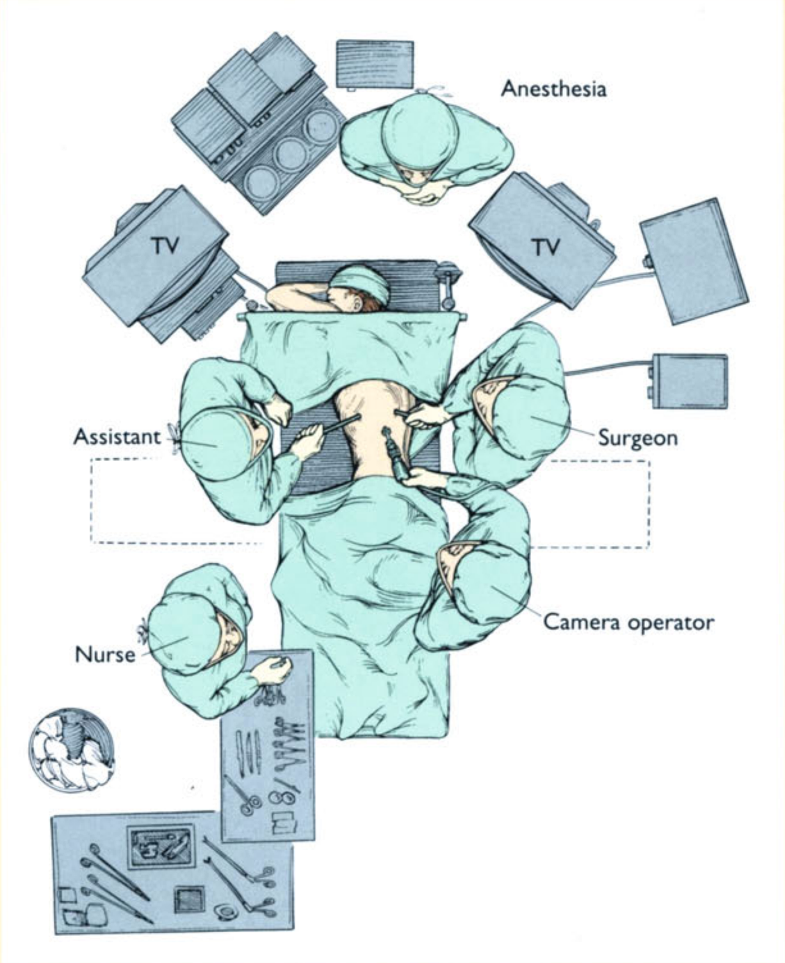


FIGURE 26-2.

Operating room equipment and set-up for video-assisted thoracic surgery (VATS). Specialized equipment useful for VATS includes thoracic trocars or ports, optical systems (angled scope), fan retractor, thoracoscopic lung clamp, endoscopic staplers, and the endoscopic ultrasound probe. Thoracoscopic ports are useful for smooth movement of the video camera during VATS but are not essential. Often, standard thoracotomy instruments can be used through small open incisions. After positioning the patient in the lateral decubitus position and properly placing a double-lumen endotracheal tube, the appropriate lung should be excluded from mechanical ventilation while the surgeons are scrubbing. This will allow adequate time for total lung deflation and absorption atelectasis. Insufflation is rarely necessary for VATS. If lung decompression is inadequate, insufflation may be introduced to the set-up. In these cases, insufflation pressure should be limited to no more than 10 mm Hg and patients should be carefully monitored for signs of impaired venous return and decreased cardiac output. In the operating room set-up, the position of the surgeon and assistants are the same as with an open thoracotomy. Video displays are positioned in a direct line between the operators and the surgical target. For upper thoracic lesions, video displays are usually positioned on opposite sides at the head of the table and at the foot of the table for lower thoracic lesions. VATS provides visualization of thoracic anatomy through a smaller, magnified, field of vision. Thus orientation of the operative field as seen on the video display is essential. The two fields of vision recommended for VATS are obtained with the videoscope inserted through the posterior port or the inferior port. As viewed from the posterior port, the thoracic anatomy can be seen in the same orientation as that of the operating surgeon during an open thoracotomy. With left-chest thoracoscopy viewed on a standard video display, anterior structures appear at the top; posterior structures at the bottom; inferior structures to the left; and superior structures to the right. To achieve better visualization of the apical structures of the chest, the videoscope can be inserted through a port positioned inferiorly at the midaxillary line. In this orientation, apical structures will appear at the top of the screen; inferior structures at the bottom; anterior structures to the left; and posterior structures to the right.

Set-up

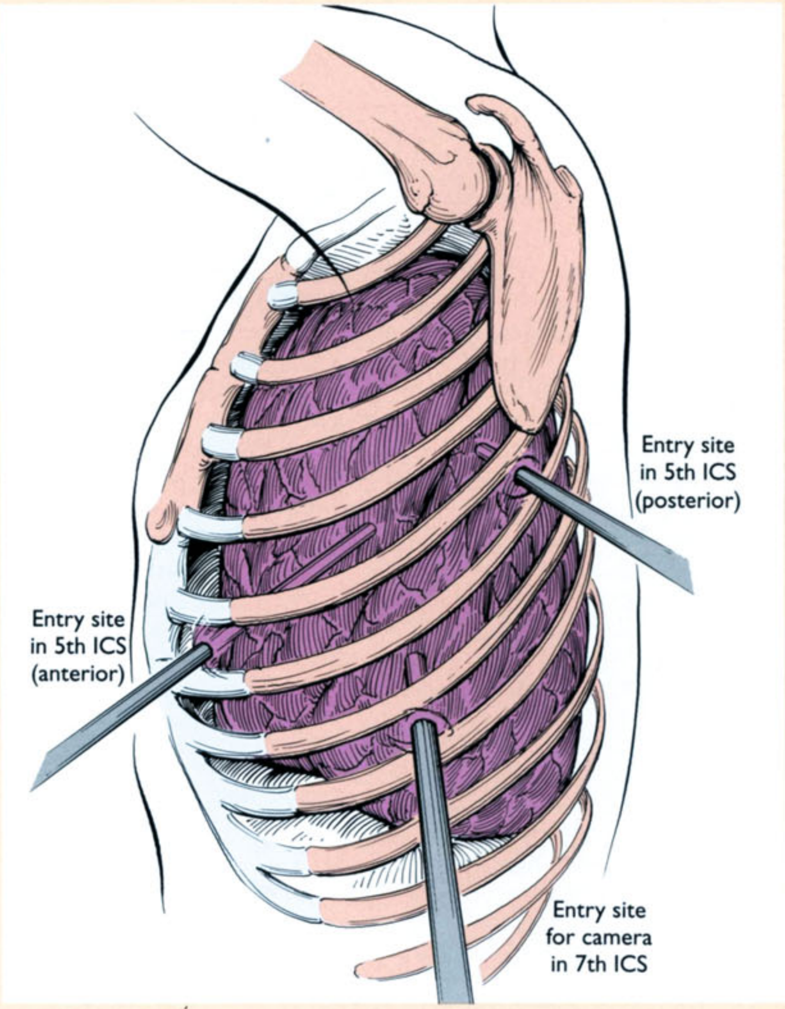


FIGURE 26-3.

Port placement is of critical importance to successful video-assisted thoracic surgery (VATS) resection and is dictated by the location of the lesion to be resected. Ports should be positioned to create a "baseball diamond," in which the video camera is home plate relative to the pulmonary pathology, which is located at second base. Working ports for retraction, grasping, and stapling are inserted at first and third bases. Wide port placement provides more room for effective retraction and adequate room to maneuver instruments. The initial port is inserted using an open technique. The skin incision is made to accommodate the video camera and port (usually 10 mm) and the intercostal muscles are separated under direct vision using a tonsil clamp down to the parietal pleura. The pleura is penetrated sharply and a finger is then inserted to confirm a circumferential space for insertion of the trocar and video camera. ICS—intercostal space.

Procedure

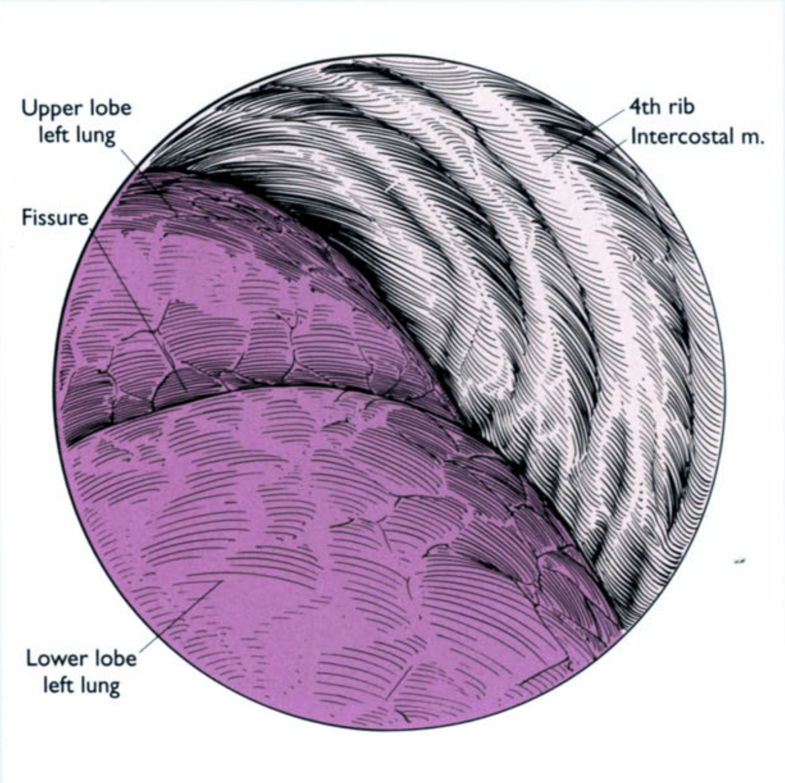


FIGURE 26-4.

Initial thoracoscopic exploration. Once the first trocar has been successfully introduced, the thoracic cavity is explored using the video camera. Lung surfaces should be examined carefully for trocar injury as well as dimpling or retraction of the visceral pleura, which may indicate the exact location of pulmonary disease. Additional time should be directed at examination of the mediastinum for nodal pathology. Additional ports are inserted transthoracically under direct vision with the video camera. Successful creation of the baseball diamond is facilitated by external palpation of the chest wall in relation to the pathology to be removed.

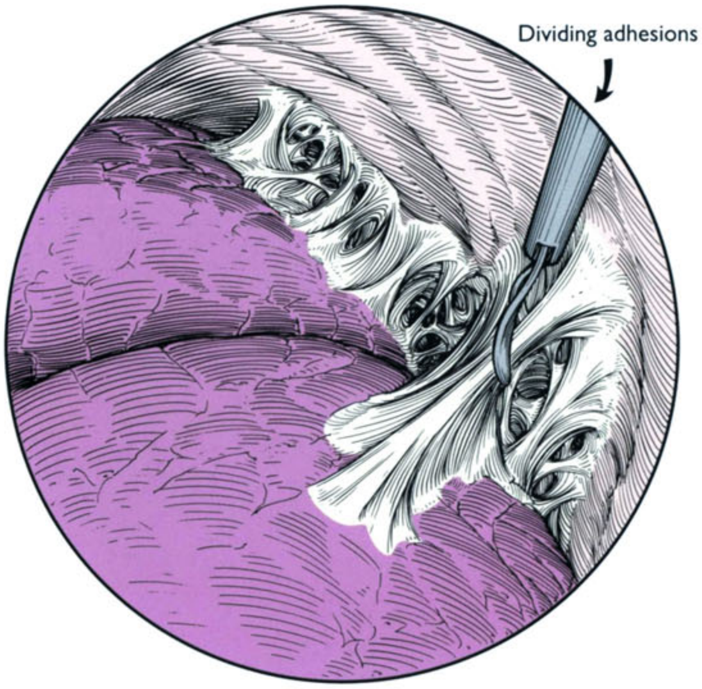


FIGURE 26-5.

Takedown of pleural adhesions. Pleural adhesions are occasionally encountered upon insertion of the initial trocar and video camera. In this circumstance, endoscopic scissors may be inserted immediately next to the video camera in order to create enough free pleural space for placement of additional ports. These adhesions are usually taken down sharply with scissors connected to the electrocautery while cutting. Care must be taken to avoid tearing lung parenchyma or creating excessive bleeding.

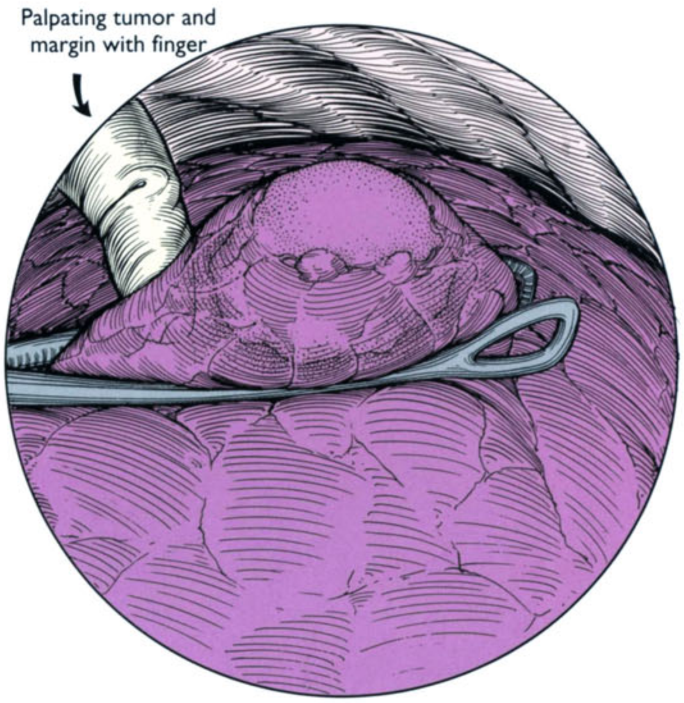


FIGURE 26-6.

Finger palpation of pulmonary mass. Localization of pulmonary nodules using video-assisted thoracic surgery (VATS) requires extensive preoperative planning. As described earlier, computed tomography (CT) scanning is essential to identify the position of the nodules in question. Peripheral one-third nodules that are 1 cm or larger in diameter are easily located thoracoscopically using the video camera only. Nodules that are less than 1 cm in diameter or are located deep in the visceral pleura usually require additional techniques for intraoperative localization and subsequent resection. Palpation of a nodule may be accomplished by using a blunt instrument to observe visual changes in the contour of the lung surface as the instrument is used to gently compress areas of lung tissue. Direct finger palpation of lung tissue may also be done by grasping lung tissue with a ring forceps, Babcock, or lung clamp and moving it to the chest wall where an index finger can be inserted through a trocar site. Lung tissue may also be digitally palpated between two fingers inserted through adjacent trocar sites. Preoperative CT-guided techniques such as methylene blue injection, needle placement, and coil placement should provide immediate and accurate localization of the pathology to be resected. Although ultrasonography is not possible when the lung is inflated with air, the collapsed lung allows more precise sonographic imaging. Lung collapse and ultrasonography may be further enhanced by placement of fluid in the thoracic cavity to submerge the lung.

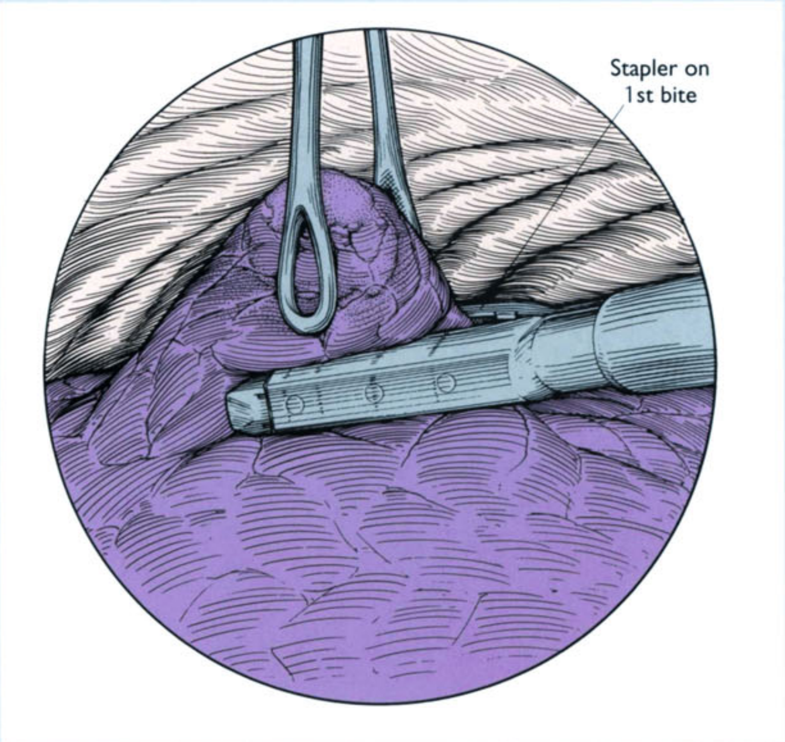


FIGURE 26-7.
Grasping of nodule with Babcock clamp and initial placement of the stapler. After localization of the pulmonary nodule, an endoscopic stapler is used to resect the specimen. In most cases, the diseased area can be grasped with an instrument such as ring forceps, a Babcock clamp, or a lung clamp to create a leading edge for insertion of the stapler. If a nodule is located on a flat surface not amenable to insertion into the narrow jaws of the endoscopic stapler, laser techniques may be used to create a leading edge of lung tissue for stapling.

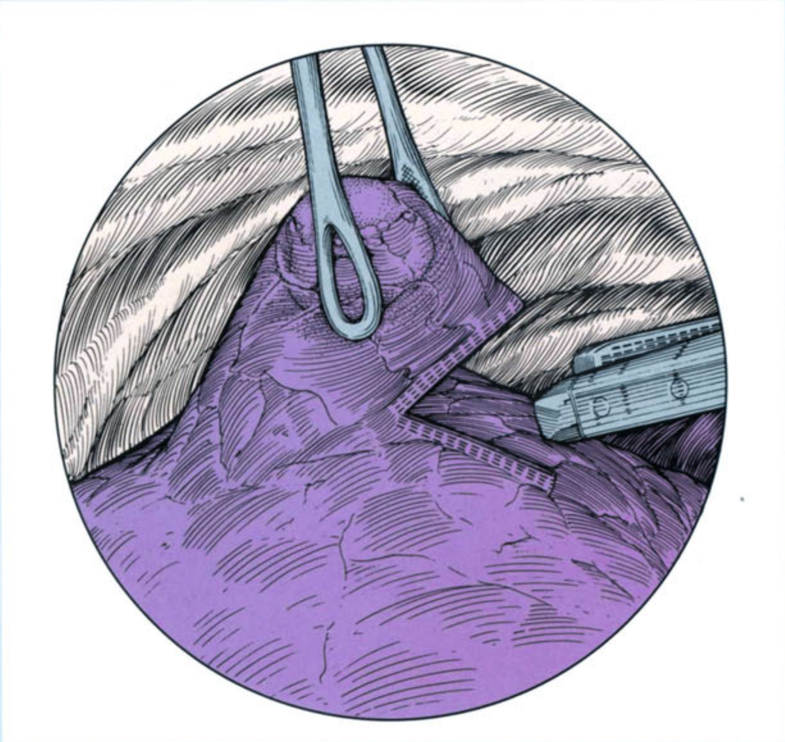


FIGURE 26-8.
Wedge resection staple line. After firing the staple load and opening the jaws of the instrument, the staple line should be inspected for proper staple closure, bleeding, and air leak.

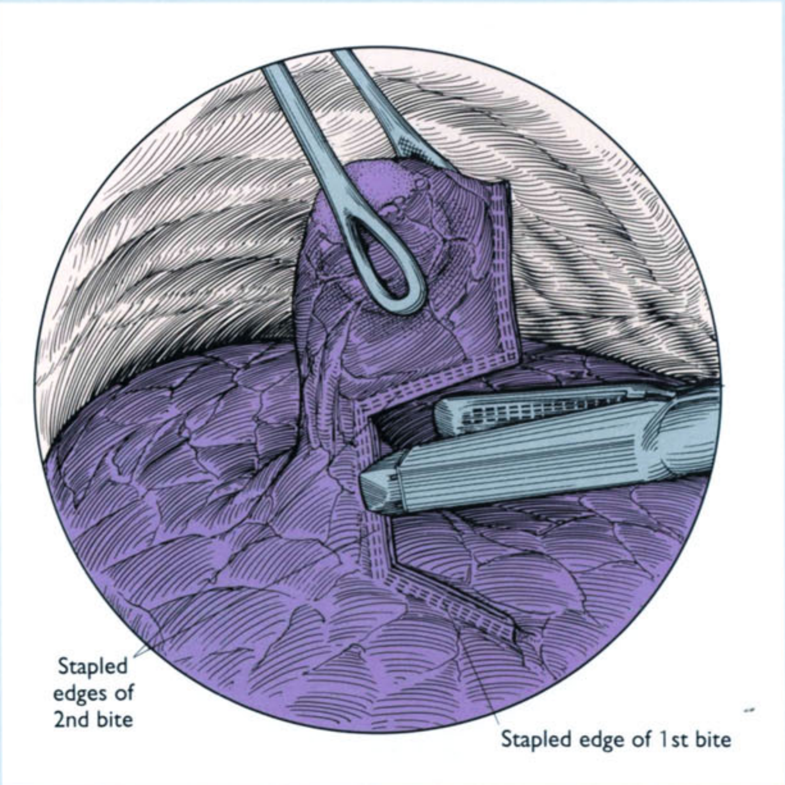


FIGURE 26-9.
Final staple load. Several staple loads are often required to resect a single specimen. With each firing, the specimen should be repositioned to facilitate smooth entry of the lung tissue into the jaws of the stapler.

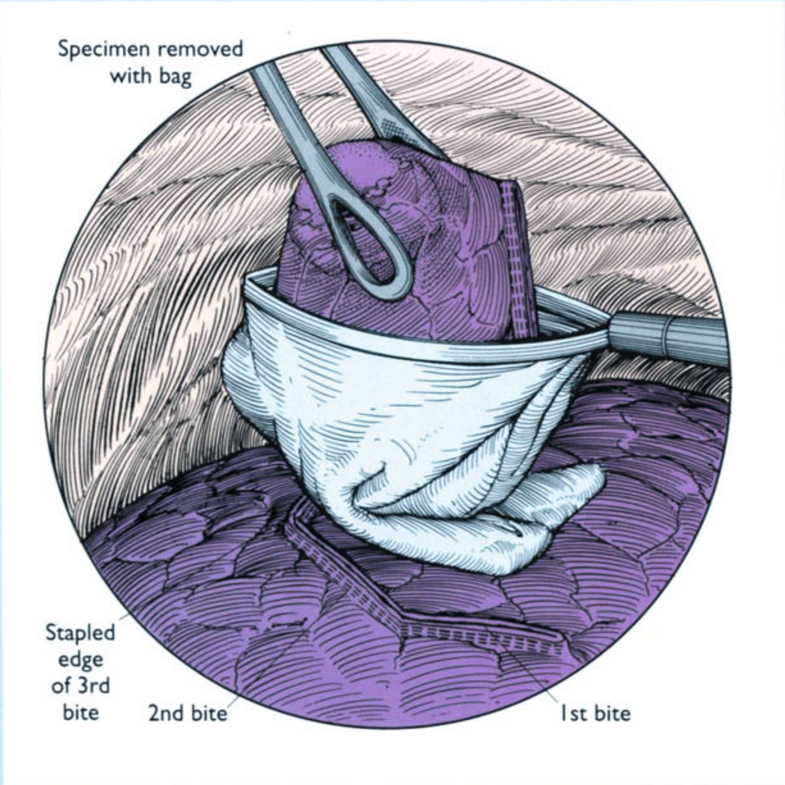


FIGURE 26-10.
Placement of specimen into protective sleeve. To minimize the potential for local contamination of the trocar sites to a possible cancer, the specimen should be placed in a protective sleeve using an endoscopic bag or a simple glove prior to removal from the chest.

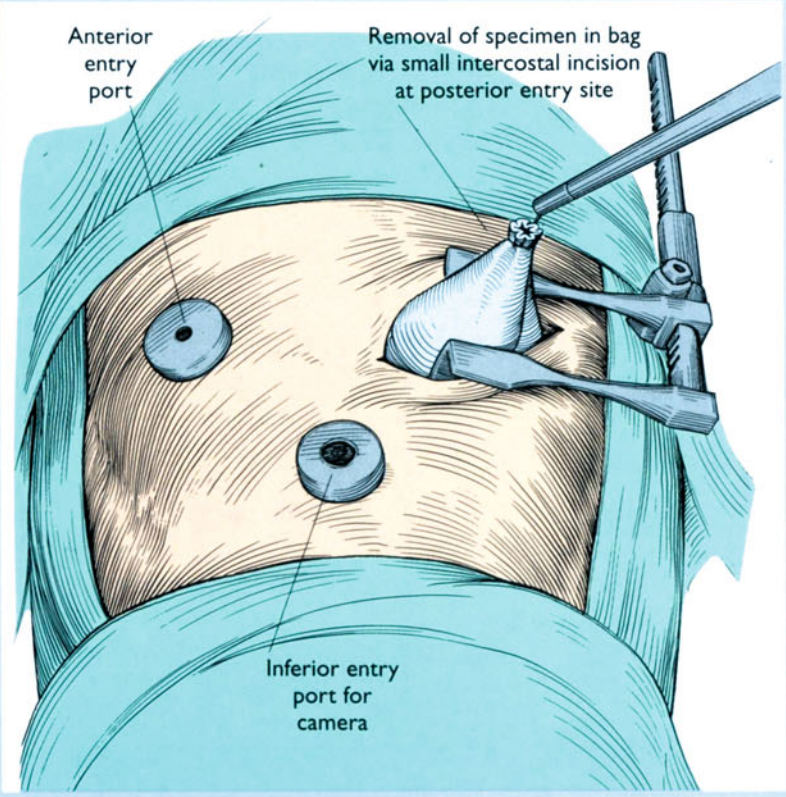


FIGURE 26-11.

Utility thoracotomy and removal of specimen. A small utility thoracotomy slightly smaller than the length of the resected specimen may be required to facilitate its removal from the chest. The posterior port is recommended as the appropriate site if necessary.

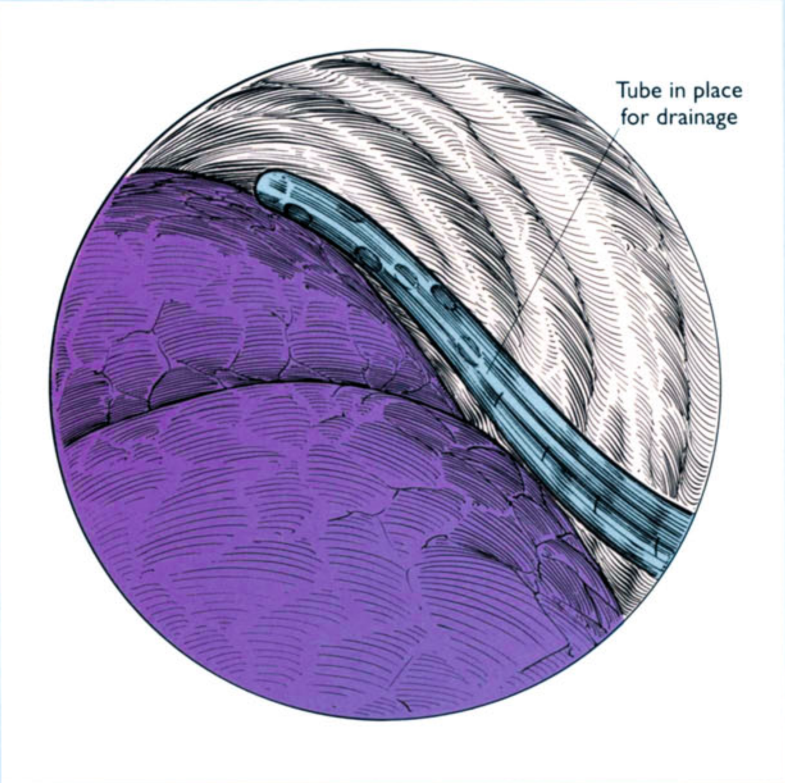


FIGURE 26-12.

Chest tube placement. After removal of the specimen, the chest should then be thoroughly reexamined with the video camera. The chest cavity should be partially filled with saline solution and the lungs inflated to examine the staple lines for air leaks or bleeding. A chest tube is then inserted through the most inferior port and directed to the apex under direct vision and connected to 20 cm H_2O suction after closing the trocar sites.

Results

Among 791 VATS resections reported in the recent literature, successful localization and resection of pulmonary nodules was accomplished in 93.9% of cases (Table 26-7). Common reasons for conversion to open thoracotomy are listed in Table 26-8.

Kaiser and Bavaria [11] described the associated complications of 266 thoracoscopic procedures with no deaths. The overall incidence of complications was 10%, with the most prevalent complication being prolonged air leak (3.7%). There were five superficial wound infections (1.9%) and five patients who bled significantly enough to require either transfusion or reoperation, or both. In 11 patients (4.1%), the proposed thoracoscopic procedure could not be completed as planned, and a thoracotomy was required. Additional complications that have been reported with VATS are listed in Table 26-9.

Table 26-7. Results of thoracoscopic pulmonary resection

Study	Year	Patients, *n*	Conversion, *n*(%)	Comments
Landreneau *et al.* [9]	1992	85	0 (0)	10% overall complication rate including 3.5% prolonged air leak
Allen *et al.* [10]	1993	118	35 (30)	Decreased analgesia and LOS; cost equal to open surgery
Kaiser and Bavaria [11]	1993	266	11 (4.1)	10% overall complication rate including 3.7% prolonged air leak
Mack *et al.* [7]	1993	300	2 (0.01)	200 consecutive successful VATS localization and resection
Santambrogio *et al.* [12]	1995	22	1 (5)	Randomized, prospective comparison of VATS vs open thoracotomy
DeCamp *et al.* [13]	1995	425	5 (1.42)	14% complication rate; 4.7% prolonged air leak
Total		1216	53 (4.4)	

LOS—hospital length of stay; VATS—video-assisted thoracic surgery.

Table 26-8. Indications for conversion to open thoracotomy

Excessive adhesions (pleural space obliterated)
Uncontrolled bleeding
Trocar damage to intercostal bundle
Equipment malfunction
Inability to localize nodule
Hypoxemia or hypercapnia

Table 26-9. Complications of thoracoscopic pulmonary resection

Pneumothorax	Inadequate margins of resection
Persistent air leak	Lung injury
Hemorrhage	Intercostal neurovascular bundle injury
Air embolism	Equipment malfunction
Diaphragmatic perforation	Infection

References

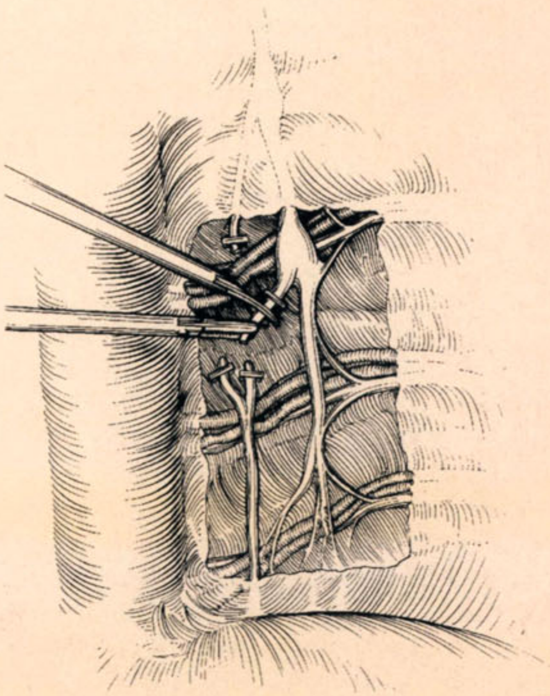
1. Jacobaeus HC: Ueber die Möglichkeit die Zystoskopie bei untersuchung seröser höhlungen anzuwenden. *München Med Wochenschr* 1910, 57:2090–2092.
2. Bloomberg AE: Thoracoscopy in perspective. *Surg Gynecol Obstet* 1978, 147:433–443.
3. The 1st International Symposium on Thoracoscopic Surgery: Proceedings. San Antonio, Texas, January 22-23, 1993. *Ann Thorac Surg* 1993, 56:603–806.
4. Patz EFJ, Lowe VJ, Hoffman JM, Paine SS, Burrowes P, Coleman RE, Goodman PC: Focal pulmonary abnormalities: evaluation with F-18 fluorodeoxyglucose PET scanning. *Radiology* 1993, 188:487–490.
5. Asamura H, Kondo H, Naruke T, Tsuchiya R, Wakao F, Kaneko M, Suemasu K: Computed tomography-guided coil injection and thoracoscopic pulmonary resection under roentgenographic fluoroscopy. *Ann Thorac Surg* 1994, 58:1542–1545.
6. Lenglinger FX, Schwarz CD, Artmann W: Localization of pulmonary nodules before thoracoscopic surgery: value of percutaneous staining with methylene blue. *AJR Am J Roentgenol* 1994, 163:297–300.
7. Mack MJ, Shennib H, Landreneau RJ, Hazelrigg SR: Techniques for localization of pulmonary nodules for thoracoscopic resection. *J Thorac Cardiovasc Surg* 1993, 106:550–553.
8. Shah RM, Spirn PW, Salazar AM, Steiner RM, Cohn HE, Solit RW, Wechsler RJ, Erdman S: Localization of peripheral pulmonary nodules for thoracoscopic excision: value of CT-guided wire placement. *AJR Am J Roentgenol* 1993, 161:279–283.
9. Landreneau RJ, Hazelrigg SR, Ferson PF, Johnson JA, Nawarawong W, Boley TM, Curtis JJ, Bowers CM, Herlan DB, Dowling RD: Thoracoscopic resection of 85 pulmonary lesions. *Ann Thorac Surg* 1992, 54:415–419.
10. Allen MS, Deschamps C, Lee RE, Trastek VF, Daly RC, Pairolero PC: Video-assisted thoracoscopic stapled wedge excision for indeterminate pulmonary nodules. *J Thorac Cardiovasc Surg* 1993, 106:1048–1052.
11. Kaiser LR, Bavaria JE: Complications of thoracoscopy. *Ann Thorac Surg* 1993, 56:796–798.
12. Santambrogio L, Nosotti M, Bellaviti N, Mezzetti M: Videothoracoscopy versus thoracotomy for the diagnosis of the indeterminate solitary pulmonary nodule. *Ann Thorac Surg* 1995, 59:868–870.
13. DeCamp MM, Jaklitsch MT, Mentzer SJ, Harpole DH, Sugarbaker DJ: The safety and versatility of video-thoraroscopy: a prospective analysis of 895 cases. *J Am Coll Surg* 1995, 181:113–120.

CHAPTER

27

Thoracoscopic Splanchnicectomy

Kevin P. Landolfo
Henry L. Laws
William C. Meyers



The management of pain in patients with chronic abdominal disease remains a difficult clinical challenge, and the pain caused by pancreatic dysfunction, both benign and malignant, is often severe and intractable. Historically, the concept of visceral sensation remained controversial until 1911 when Hearst [1] demonstrated that pain could be induced by balloon distention of the intestinal tract. With the subsequent acceptance of this concept, efforts were directed at defining the nature and location of pain perception in various intra-abdominal viscera [2].

This increased understanding of visceral pain sensation led to the observation that patients undergoing sympathectomy for treatment of essential hypertension had attenuated or ablated visceral pain sensation [3]. The anatomic explanation for this finding was a common pathway for the visceral afferents and the thoracic sympathetics. A clinical application was presented in 1945 when Mallet-Guy and coworkers [4] reported a small series of patients with chronic pancreatitis treated by unilateral (left) splanchnicectomy. His operative approach was a modification of that initially described by Peet [5] in which a lumbar incision was made with subsequent removal of a portion of the twelfth rib. An extrapleural dissection allowed exposure of the lower thoracic ganglia and intervening trunk. The great splanchnic nerve and celiac ganglion as well as postganglionic branches were resected. Further experience and long-term follow-up by Mallet-Guy has continued to demonstrate that this procedure is both safe and relatively effective [6,7].

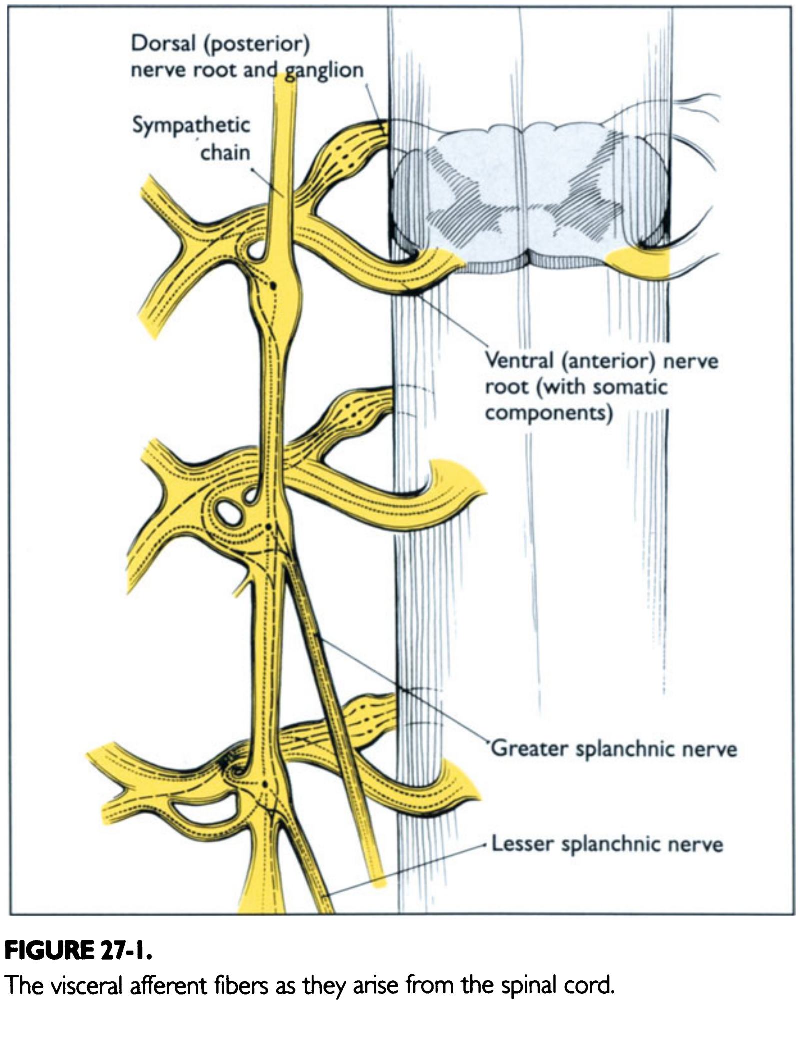


FIGURE 27-1.
The visceral afferent fibers as they arise from the spinal cord.

Rienhoff and Baker [8] was the first American investigator to report the use of splanchnic section for the control of pancreatic pain and he utilized a transthoracic exposure. A variety of reports have appeared in the literature that describe both unilateral and bilateral thoracic as well as abdominal incisions to allow division of the visceral afferents in patients with chronic abdominal pain [9–12].

A novel approach to splanchnic denervation was devised by one of the authors (Henry L. Laws, MD, in conjunction with H. Harlan Stone, MD) in which a thoracoscopic technique is used to facilitate unilateral transthoracic exposure and division of the visceral afferents. The procedure was first performed at Duke University Medical Center in December of 1991. Although no long-term studies are yet available, application of thoracoscopic splanchnicectomy for pain management in patients with pancreatic disease offers a relatively simple and effective method for the complete division of visceral afferent pathways.

Anatomy

Traditionally, neuroanatomists have described the autonomic nervous system as an efferent system that supplies the heart, the glands, and the smooth muscle with efferent innervation. At the same time, afferent sensory fibers from the viscera are carried by the sympathetic nerves and white rami. Pain impulses arising within the abdominal cavity may reach the central nervous system by one or a combination of channels: 1) the sympathetic nerves (main pathway); 2) the somatic nerves innervating the body wall and diaphragm; and 3) the parasympathetic nerves (minor importance). However, these visceral afferent nerve fibers that transmit pain should not be thought of as part of the autonomic nervous system. Visceral innervation is mediated by mixed nerves with distinct sympathetic or parasympathetic efferent motor and visceral afferent sensory components [13]. The viscerosensory nerve fibers, both myelinated and nonmyelinated, run in the autonomic trunks and pass through the ganglia without synapses to reach their cells in the posterior root ganglia (Fig. 27-1).

Three nerves, present bilaterally, constitute the entire viscerosensory supply of the abdominal organs (Figs. 27-2, 27-3). The first is the greater splanchnic nerve, which is made up of rami leaving the fifth through the ninth ganglia of the paravertebral chain. The nerve descends on the lower thoracic vertebrae to penetrate the crus of the diaphragm and ends in the celiac ganglia around the origin of the celiac axis from the aorta. The celiac or solar plexus is the central distributing center for both the splanchnic nerves and the vagi. The plexus constitutes a network of nerve fibers around the aorta at the origin of the celiac axis, the superior mesenteric, and the renal arteries. The lesser splanchnic nerve originates from the tenth and eleventh thoracic ganglia and travels posterior to the greater nerve in the thoracic cavity. After piercing the crus of the diaphragm it enters both the celiac and adrenocortical ganglion. The third nerve, denoted the least splanchnic nerve, arises from the twelfth thoracic paravertebral ganglia (may not be visualized thoracoscopically), lies posterior to the lesser splanchnic nerve, and ends in the renal ganglion. These fibers, with or without the sympathetic chain, may be divided bilaterally with little morbidity, and division of these nerves effectively interrupts viscerosensory afferents from the intra-abdominal organs.

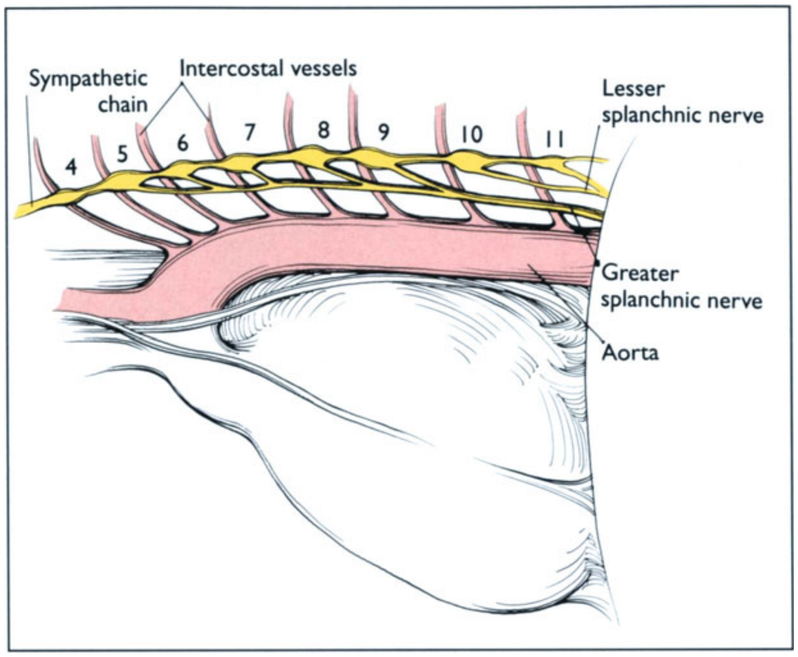


FIGURE 27-2.
Anatomic configuration of the visceral afferent fibers as seen in the left hemithorax.

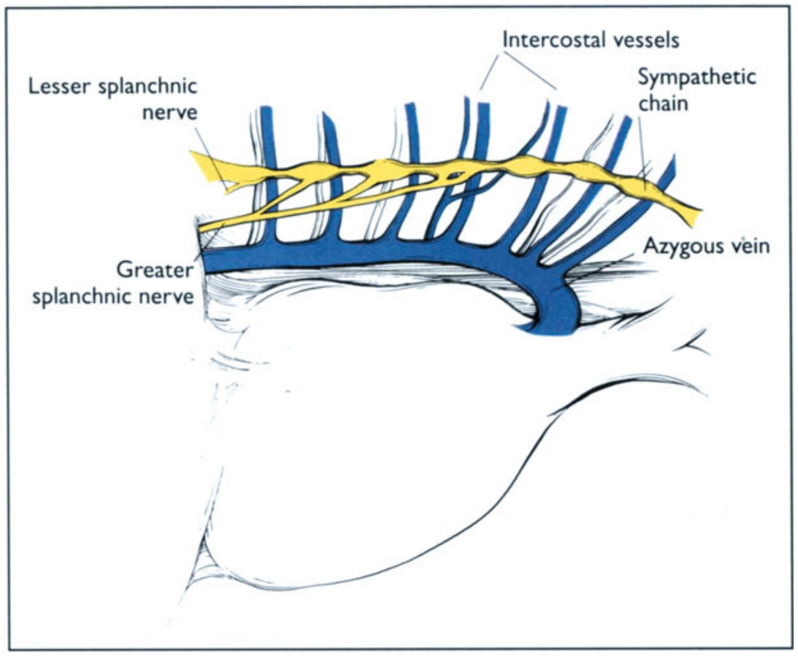


FIGURE 27-3.
The anatomic configuration of the visceral afferents as seen in the right hemithorax.

Surgical Technique

Figures 27-4 through 27-8 depict the surgical technique for thoracoscopic splanchnicectomy.

Set-up

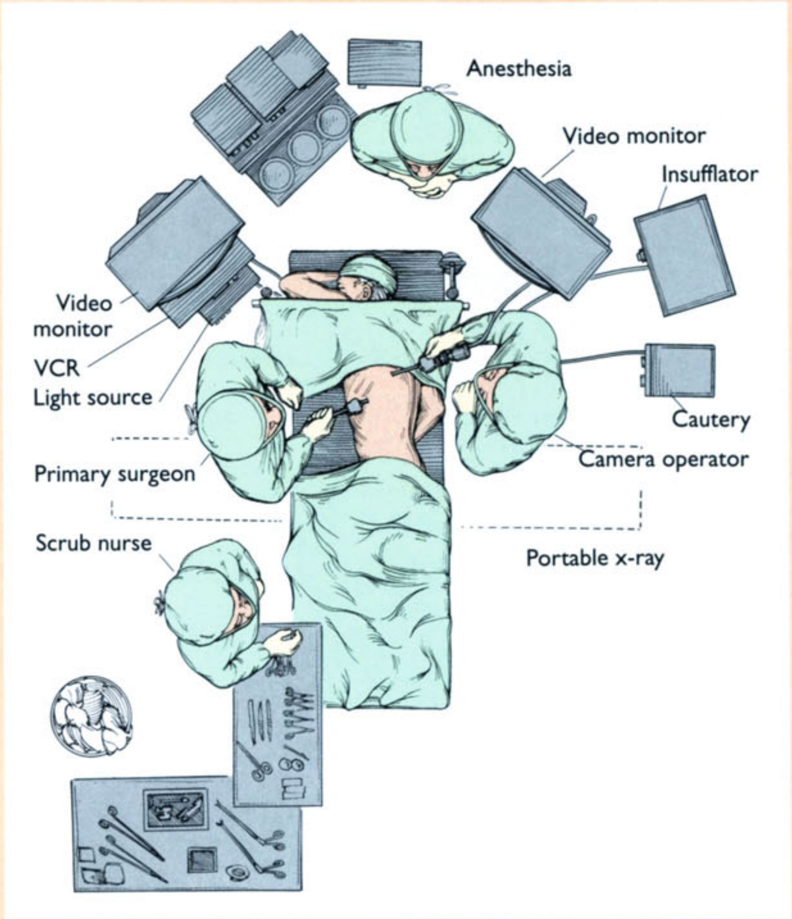


FIGURE 27-4.

Operative set-up for left thoracoscopic splanchnicectomy. Preoperative antibiotics are administered in routine fashion. A double-lumen endotracheal tube allows for single lung ventilation on the nonoperative side. The patient is placed in the right lateral decubitus position on the operating table (for a left splanchnic section) with appropriate cushioning at contact points, the axilla, and between the legs. The position of the surgeon and first assistant are shown.

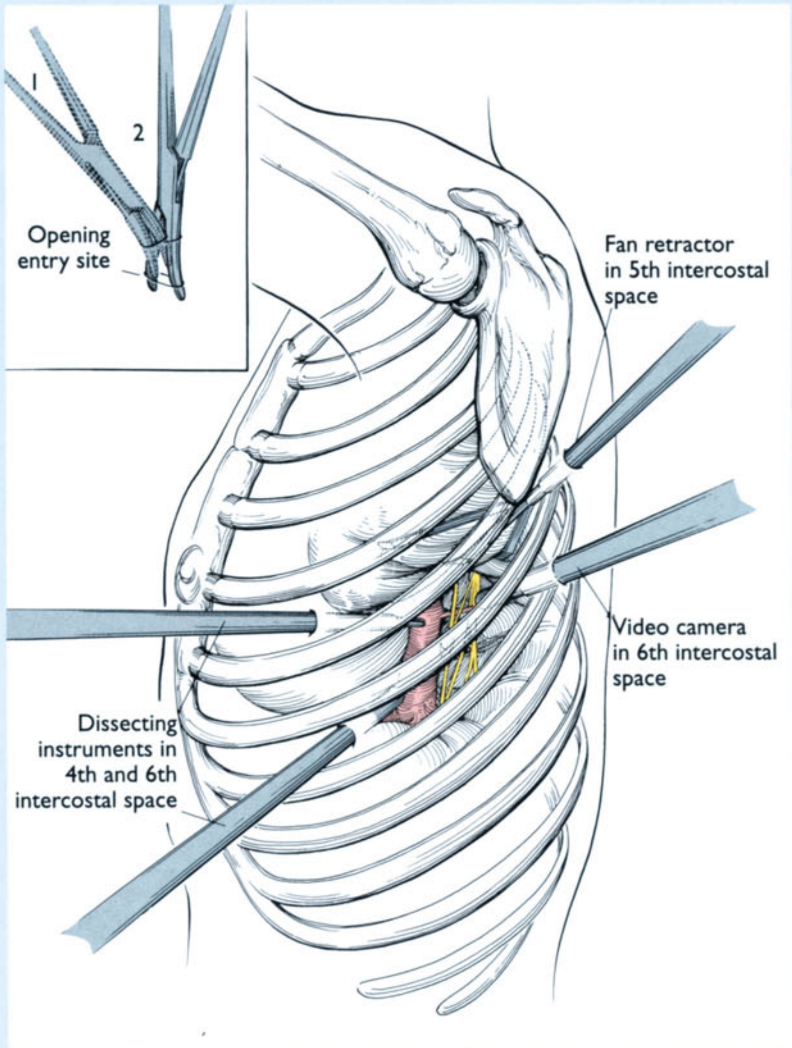


FIGURE 27-5.

The left lung is deflated prior to instrumentation. The first trocar (10 mm) is placed using blunt dissection through the chest wall in the manner shown to avoid injury to underlying thoracic structures (*inset*). This trocar will serve as the camera port and should be positioned two interspaces below the tip of the scapula. The remaining three trocars are placed under direct vision following insertion of the camera and inspection of the hemithorax for incidental findings. The operating trocars (5 mm and 10 mm) are placed in the 4th and 6th intercostal spaces and located in the anterior and mid-axillary lines, respectively. The larger trocar site is necessary to allow passage of a clip applier to facilitate nerve division. The last trocar (10 mm) is placed slightly posterior to the tip of the scapula through which a fan retractor is placed to retract the left lower lobe of the lung. The surgeon then passes a grasper and scissors through the operating ports.

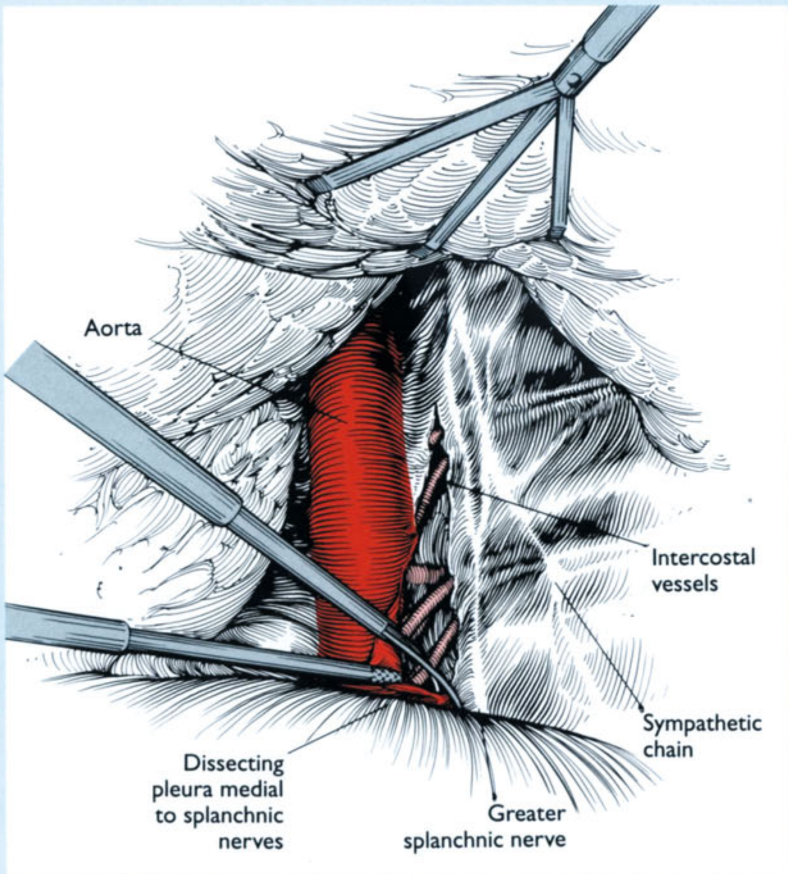


FIGURE 27-6.

The lung is retracted superiorly for exposure and the sympathetic chain (seen overlying and just anterior to the vertebral column), the greater, lesser, and least (may not always be seen) splanchnic nerves are visualized posterior to the aorta and beneath the parietal pleura. A vertical incision of the parietal pleura is made between the aorta and the sympathetic chain and blunt dissection is used to clearly define the visceral branches. A window in the parietal pleura is created by incising the pleura as shown, with care to avoid the intercostal vessels during the dissection. Once dissection is complete, surgical clips should be applied to each branch sequentially. As the nerve fibers become less distinct at the level of the diaphragm, the objective should be to clear all branches between the sympathetic chain and aorta. The sympathetic chain itself may also be divided.

Results

Pain control for patients suffering from both benign and malignant pancreatic disease is an important component of therapy. Analgesics, the mainstay of therapy, become less effective, and addiction to opiates may become a significant problem. Excluding patients with mechanical ductal abnormalities or resectable tumors that are amenable to direct surgical correction, alternatives to chronic analgesic use remain limited.

Chemical splanchnicectomy, using percutaneous celiac ganglion blockade for pain control, is one option. However, this approach is effective in only half the patients and has a relatively short duration of action [14–17].

Surgical denervation of the pancreas by division of visceral afferents may also be performed as an alternative. Previous results described in the literature used either a left or bilateral approach to splanchnicectomy coupled with a celiac ganglionectomy or thoracic sympathectomy with or without division of the vagi [18–22]. The patients demonstrated good to excellent pain relief in 49% to 59% of cases. The effectiveness was somewhat higher with bilateral incisions, although a higher morbidity was observed. The necessity of division of the vagi is uncertain in view of the increased risk of delayed gastric emptying. In a recent report of patients with chronic pancreatitis, unilateral left open thoracotomy offered excellent exposure of the visceral afferents and significant pain control was obtained in two thirds of patients [23].

The use of thoracoscopic technique offers an alternative to formal thoracotomy while achieving similar exposure. Patients having either chronic pancreatitis or pancreatic malignancy as the cause of the abdominal pain should be considered for thoracoscopic splanchnicectomy. Initially, division of the left greater and lesser splanchnic nerves, and where identified the least splanchnic nerve, should be performed. Immediate amelioration of pain may be seen, especially in patients with malignancy, although the long-term effectiveness of this procedure awaits follow-up studies. There have been no operative deaths or significant morbidity in patients undergoing this procedure. Patients with good initial palliation with subsequent recurrence should be considered for division of the right-sided visceral afferents.

In conclusion, thoracoscopic splanchnicectomy offers an alternative to open thoracotomy or lumbar incisions for the division of visceral afferents to the pancreas and other abdominal viscera. Early experience with this procedure demonstrates it to be an effective and safe approach to the surgical management of chronic abdominal pain of either a benign or malignant nature.

References

1. Hearst AF: On the sensibility of the alimentary canal in health and disease. *Lancet* 1911, i:1051.
2. Ray BS, Neill CL: Abdominal visceral sensation in man. *Ann Surg* 1947, 126:709–722.
3. Bingham JR, Ingelfinger FJ, Smithwick RH: The effects of sympathectomy on abdominal pain in man. *Gastroenterology* 1950, 15:18–31.
4. Mallet-Guy PA, Jeanjean R, Sevvettaz P: Distant results in the treatment of chronic pancreatitis by unilateral splanchnicectomy. *Lyon Chir* 1945, 40:293–314.
5. Peet MM: Splanchnic section for hypertension: a preliminary report. *Univ Hosp Bull* 1935, 1:17–18.
6. White TT, Lawinski M, Poland D, Stacher G: Treatment of pancreatitis by left splanchnicectomy and celiac ganglionectomy. *Am J Surg* 1966, 112:195–199.
7. Mallet-Guy PA: Late and very late results of resections of the nervous system in the treatment of chronic relapsing pancreatitis. *Am J Surg* 1983, 145:234–238.
8. Rienhoff WF, Baker BM: Pancreolithiasis and chronic pancreatitis: preliminary report of a case of apparently successful treatment by transthoracic sympathectomy and vagotomy. *JAMA* 1947, 134:20–21.
9. Smithwick RH: Discussion of paper of A.O. Whipple. *Ann Surg* 1946, 124:1006.
10. De Takats G, Walter LE: The treatment of pancreatic pain by splanchnic nerve section. *Surg Gynecol Obstet* 1947, 95:742–746.
11. McDonough FE, Heffernon EW: Chronic relapsing pancreatitis. *Surg Clin North Am* 1948, 28:733–740.
12. Connolly JE, Richards VR: Bilateral splanchnicectomy and lumbodorsal sympathectomy for chronic relapsing pancreatitis. *Ann Surg* 1950, 131:58–63.
13. White JC, Sweet WH, eds.: *Pain: Its Mechanism and Neurosurgical Control.* Springfield, Il: Charles C. Thomas Publisher; 1955.
14. Copping J, Willix R, Kraft R: Palliative chemical splanchnicectomy. *Arch Surg* 1969, 98:418–420.
15. Gorbitz C, Leavens ME: Alcohol block of the celiac plexus for control of upper abdominal pain caused by cancer and pancreatitis. *J Neurosurg* 1971, 34:575–579.
16. Haaga JR, Kori SH, Eastwood DW, Borkowski GP: Improved technique for CT-guided celiac ganglia block. *Am J Radiol* 1984, 42:1202–1204.
17. Hegedus V: Relief of pancreatic pain by radiography-guided block. *Am J Radiol* 1979, 133:1101–1103.
18. Rack FJ, Elkins CW: Experiences with vagotomy and sympathectomy in the treatment of chronic pancreatitis. *Arch Surg* 1950, 61:937–943.
19. Heisy WG, Dohn DF: Splanchnicectomy for the treatment of intractable abdominal pain. *Cleve Clin Quart* 1967, 34:9–25.
20. Hurwitz A, Gurwitz J: Relief of pain in chronic relapsing pancreatitis by unilateral sympathectomy. *Arch Surg* 1950, 61:372–378.
21. Sadar ES, Cooperman AM: Bilateral thoracic sympathectomy-splanchnicectomy in the treatment of intractable pain due to pancreatic carcinoma. *Cleve Clin Quart* 1974, 41:185–188.
22. White TT, Lawinski M, Stacher G, *et al.*: Treatment of pancreatitis by left splanchnicectomy and celiac ganglionectomy. *Am J Surg* 1966, 112:195–198.
23. Stone HH, Chauvin EJ: Pancreatic denervation for pain relief in chronic alcohol associated pancreatitis. *Br J Surg* 1990, 77:303–305.

CHAPTER 28

Heller Myotomy for Esophageal Achalasia

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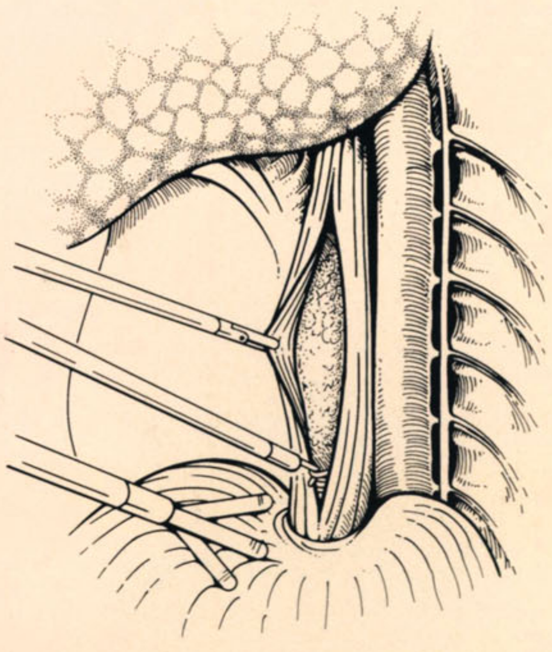
Sean J. Mulvihill



Achalasia is the best characterized motility disorder affecting the esophagus. The clinical symptoms were first described by Sir Thomas Willis of Oxford, England, in 1674, and the term *achalasia* (failure to relax) was coined by Sir Cooper Perry in 1913. Achalasia is a rare disorder with an annual incidence of 0.6 to two cases per 100,000 population per year. This disorder causes failure of the principle function of the esophagus, the transport of food from the pharynx to the stomach, because of two basic defects: lack of relaxation of a normotensive or hypertensive lower esophageal sphincter and absence of peristalsis in the esophageal body.

In 1913, Heller [1] first described extramucosal esophagomyotomy for the treatment of achalasia, and with some modifications of the original technique, surgery was for many years the principal therapy. Our institution [2] and many other centers obtained excellent results with minimal morbidity and mortality [3–6]. A thoracotomy or a laparotomy was required, which resulted in a 7- to 10-day hospital stay, and residual discomfort and inability to work for 4 to 6 weeks. Pneumatic balloon dilatation was introduced for the treatment of achalasia in 1971 [7]. It rapidly became the most popular treatment for achalasia because of the short hospital stay required and minimal patient discomfort and disability [8]. Complications of balloon dilatation, such as esophageal perforation [9] and gastroesophageal reflux [3,9] were perhaps underappreciated. Through the 1980s, surgery was reserved for patients with complications of dilatation [9], refractory dysphagia, or megaesophagus [10].

Since January 1991, we have altered our approach and we now perform a Heller myotomy using minimally invasive techniques [11] preferentially over balloon dilatation. We initially adapted the thoracoscopic approach developed by Dr. Alfred Cuschieri [12] and modified the operation as we gained experience. This chapter describes our strategy for diagnosis of achalasia and the technical aspects of the Heller myotomy as performed at the University of California, San Francisco.

Anatomy

The esophagus is a muscular tube about 25 cm in length. It extends from the pharynx at the level of sixth cervical vertebra to the stomach at the level of the eleventh thoracic vertebra. The esophagus is a midline structure in the neck, and may be surgically approached from either the left or right side. In the upper left chest, the esophagus is obscured by the aortic arch, but as it descends in the posterior mediastinum it lies anterior to the aorta. In its lower portion above the diaphragm, it is located in a triangle bounded by the pericardium anteriorly, the aorta posteriorly, and the diaphragm inferiorly (Figure 28-1). The esophagus passes from the chest into the abdominal cavity through the esophageal hiatus, usually made by fibers of the right crus of the diaphragm.

The esophageal wall, which does not have a serosal layer, consists of an outer longitudinal muscle layer and an inner circular muscle layer. The muscular wall of the esophagus is made up of striated muscle in the upper 5% and of smooth muscle in the lower half. The intervening segment is a mixture of striated and smooth muscle. The mucosa is normally lined by stratified squamous epithelium.

Physiology

The body of the esophagus is limited by two high pressure zones, the pharyngoesophageal or upper esophageal sphincter (UES), and the gastroesophageal or lower esophageal sphincter (LES). These sphincters exist in a state of tonic contraction to prevent abnormal movement of air or food into the esophagus. The LES relaxes as a reflex initiated by propulsive peristalsis of a food bolus. LES relaxation is primarily mediated by nonadrenergic, noncholinergic neurons of the enteric nervous system. Vasoactive intestinal peptide (VIP) and nitric oxide (NO) are the most important neurotransmitters [13]. The transport function of the esophagus is accomplished by the regulated contraction of the musculature of the esophageal body (peristalsis), which progresses in an aboral direction. Figure 28-2 illustrates the coordinated activity of the UES, the body of the esophagus, and the LES. This coordination is essential for normal deglutition.

Pathophysiology of Achalasia

Achalasia is a neuromuscular disorder of unknown origin. Absence or degeneration of the ganglion cells of the myenteric plexus of Auerbach is a constant finding [14], which could explain the lack of peristalsis of the esophageal body. In addition, there is a marked decrease in VIP-containing

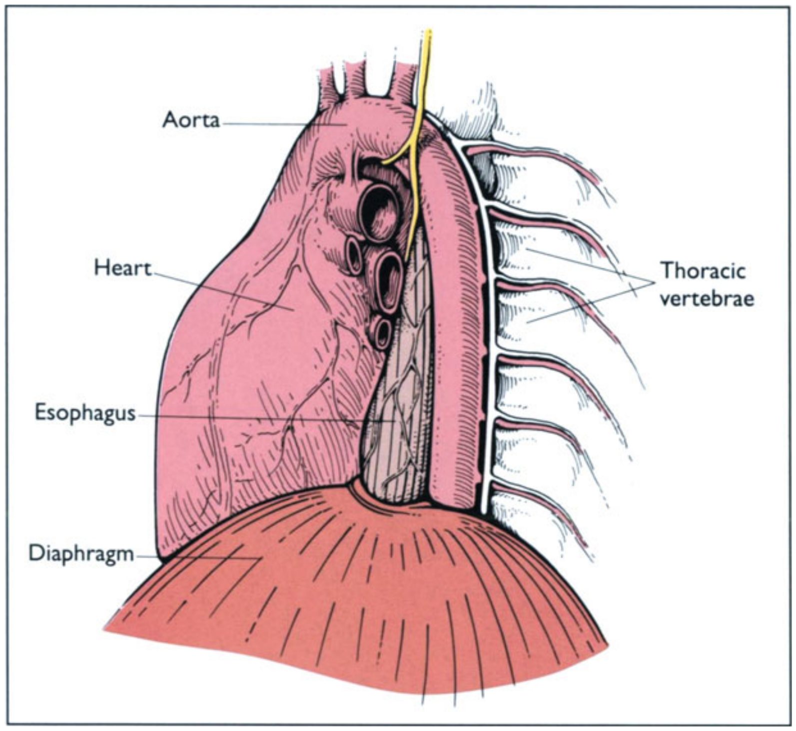


FIGURE 28-1.

Anatomy of the esophagus. When viewed from the left, the distal esophagus is found in a triangle bounded by the heart anteriorly, the aorta posteriorly, and the diaphragm inferiorly.

nerve fibers at the level of the LES [15], which is probably responsible for the failure of the LES to relax in response to swallowing [13]. The underlying cause of these defects in enteric neurons is unknown.

Clinical Findings

Symptoms

Achalasia is more common in men than women. Most patients are between 30 and 60 years of age, but symptoms can develop at any age. Progressive dysphagia for solids and liquids is the dominant symptom. Regurgitation, aspiration with cough, wheezing, pneumonia, and weight loss may also be present.

Imaging Studies

A barium esophagogram shows a characteristic "bird's beak" smooth narrowing of the distal esophagus with various degrees of esophageal dilatation (Figure 28-3). In long-standing achalasia, the esophagus may become extremely dilated and sigmoid in shape. In these advanced cases, total esophagectomy rather than dilatation or myotomy should be considered [10]. Fluoroscopic examination shows weak and incoordinated or absent peristaltic waves in the body of the esophagus. Radionucleide esophageal transit is severely delayed [16].

Endoscopy

Esophagogastroduodenoscopy should always be performed to rule out the presence of an infiltrating carcinoma of the distal esophagus or the gastric fundus that may have the same radiologic and manometric appearance of achalasia [17]. At endoscopy, patients with achalasia are found to have a smooth narrowing of the esophagus at the LES with no mucosal abnormalities. As pressure is exerted on the endoscope, the LES "gives way" in a characteristic fashion, allowing examination of the stomach.

Manometry

Esophageal manometry is the gold standard for the diagnosis of achalasia [18]. The three classic manometric findings are 1) decreased or absent peristalsis in the esophageal body; 2) elevated resting LES pressure; and 3) incomplete or absent relaxation of the LES in response to swallowing (Figure 28-4).

These tests help in differentiating primary achalasia from scleroderma, and from benign and malignant strictures of the distal esophagus. These latter conditions may mimic achalasia and should be considered as diagnostic possibilities.

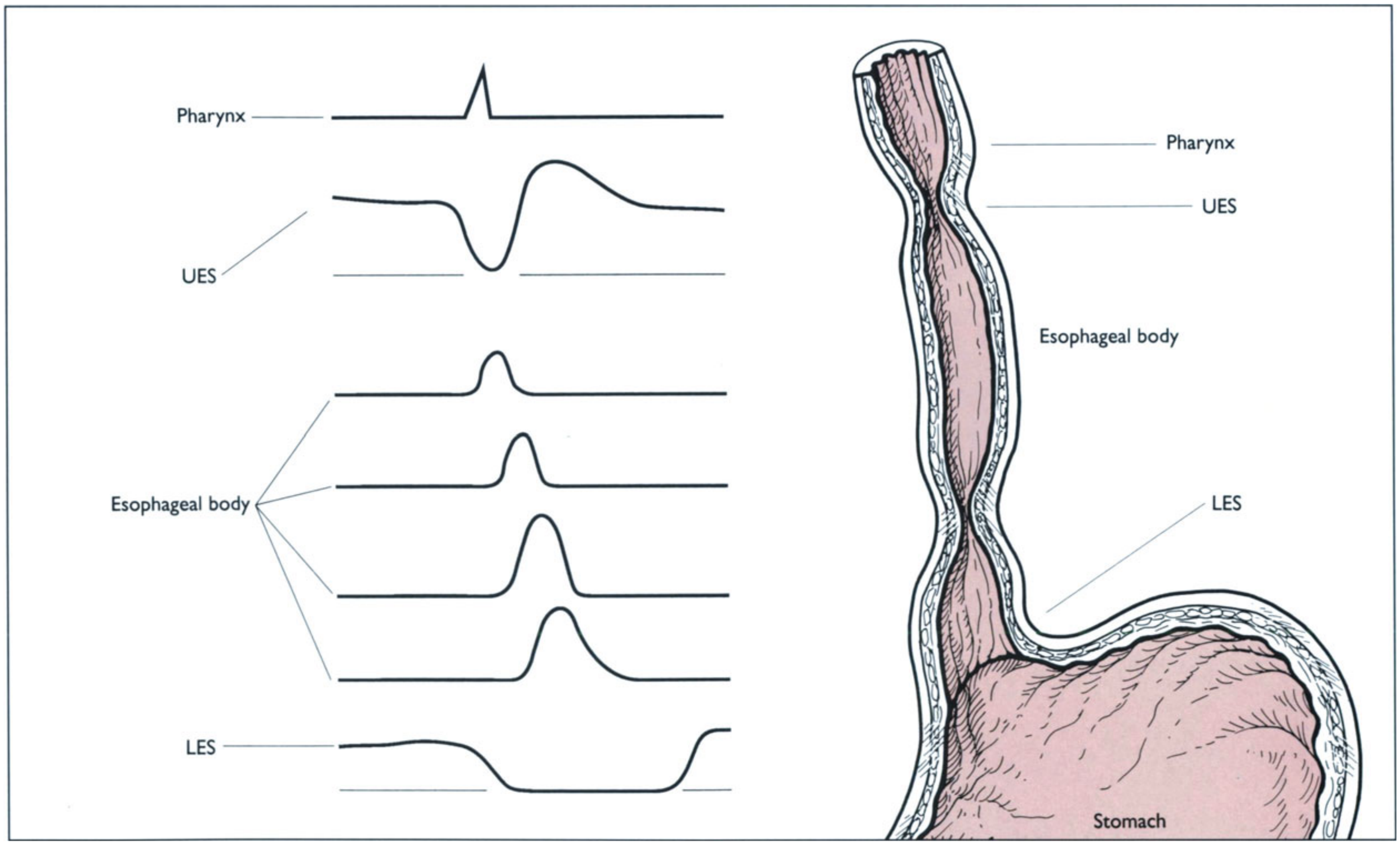


FIGURE 28-2.

Manometric evaluation of peristalsis. With deglutition, relaxation of the upper esophageal sphincter (UES) is followed by segmental contractions of the body of the esophagus that are propagated distally. The lower esophageal sphincter (LES) normally relaxes to allow passage of the food bolus into the stomach.

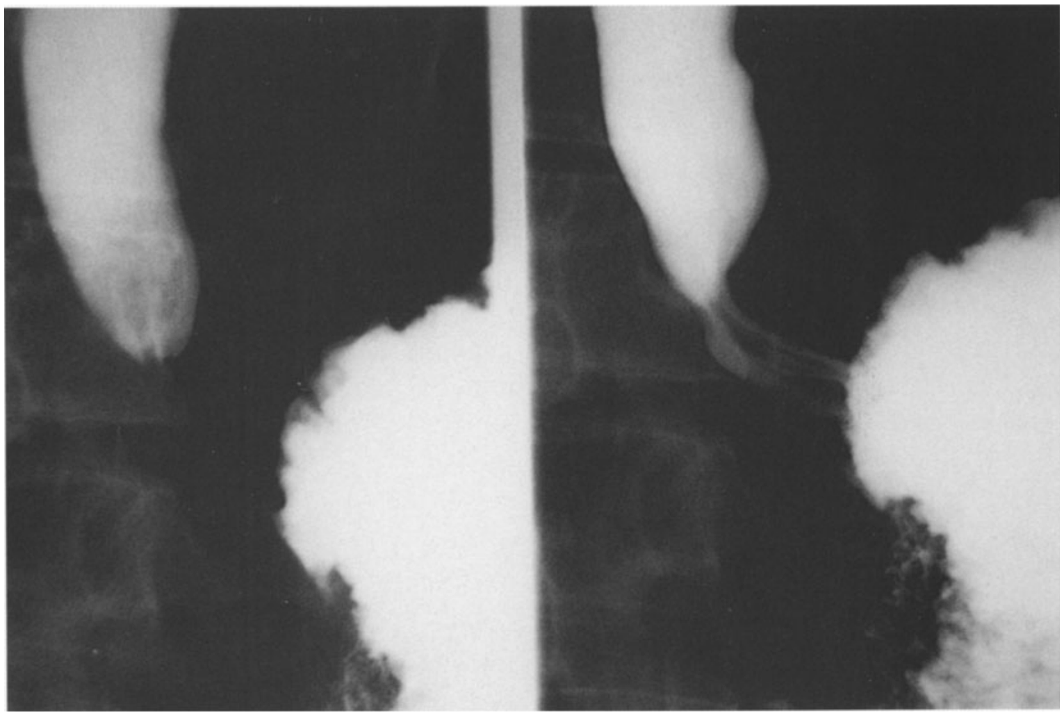


FIGURE 28-3.
Barium esophagogram in a patient with achalasia demonstrating the typical bird's beak deformity.

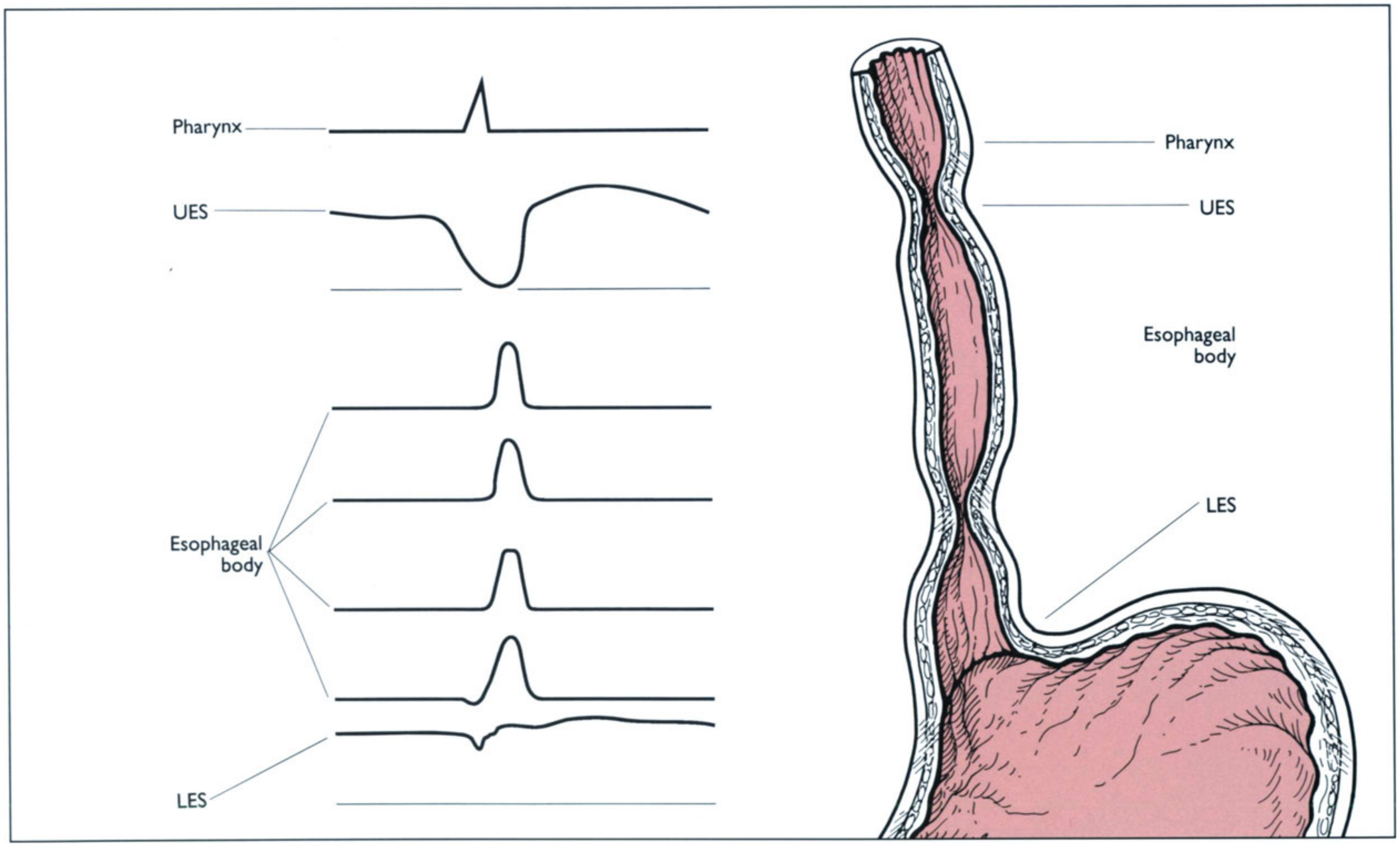


FIGURE 28-4.
Manometric evaluation of the esophagus in a patient with achalasia. Pertinent findings include absence of propulsive peristalsis in the body of the esophagus (note simultaneous contractions), elevated resting lower esophageal sphincter (LES) pressure, and absence of LES relaxation.

Surgical Technique

Figures 28-5 through 28-12 depict the surgical technique for thoracoscopic Heller myotomy.

Set-up

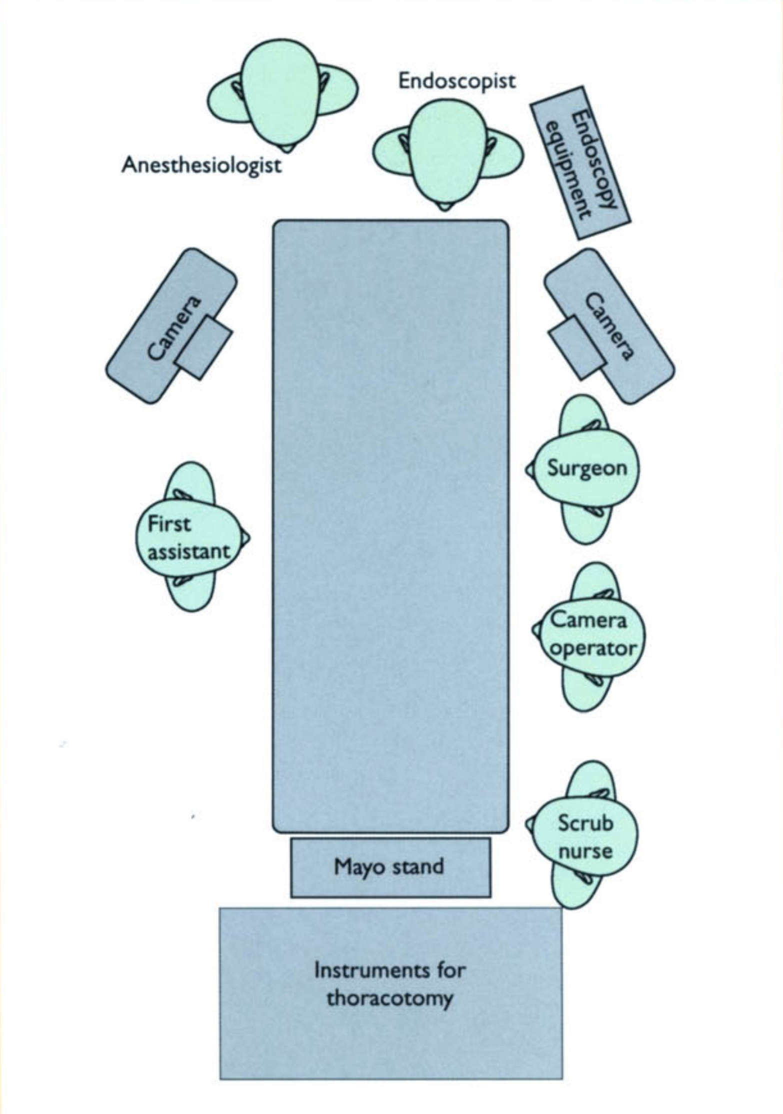


FIGURE 28-5.
Operating room set-up for thoracoscopic Heller myotomy. The patient is positioned in the right lateral decubitus position on a beanbag and with a rolled towel supporting the chest in the right axilla. The surgeon stands facing the patient's back with the camera operator. If necessary, the surgeon may operate with one hand and manipulate the camera with the opposite hand. The assistant stands facing the patient. Preoperative broad-spectrum antibiotics (such as cefazolin) are given intravenously in case the esophageal mucosa is injured during the procedure. Instruments for thoracotomy must be readily available in case severe bleeding is encountered.

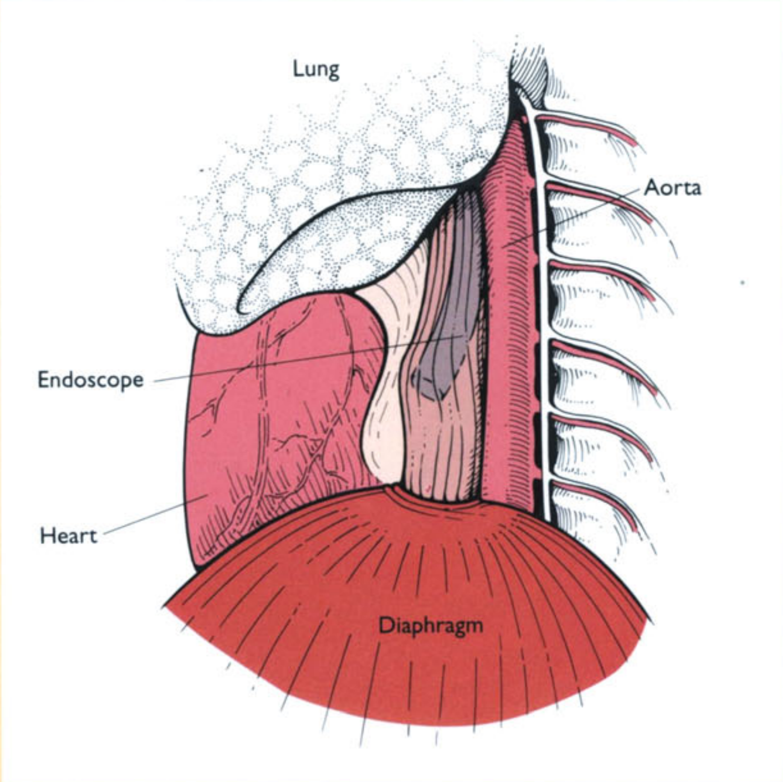


FIGURE 28-6.
Intraoperative endoscopy. After induction of general anesthesia, a double lumen endotracheal tube is placed to allow collapse of the left lung. A fiberoptic endoscope is inserted into the esophagus. Intraoperative endoscopy facilitates the operation both by allowing internal retraction of the esophagus and by providing internal illumination to aid identification of the esophageal layers. In addition, endoscopy establishes the length of the narrowing, allows immediate evaluation of the adequacy of the myotomy, and helps to confirm the integrity of the mucosa at the conclusion of the procedure.

Set-up

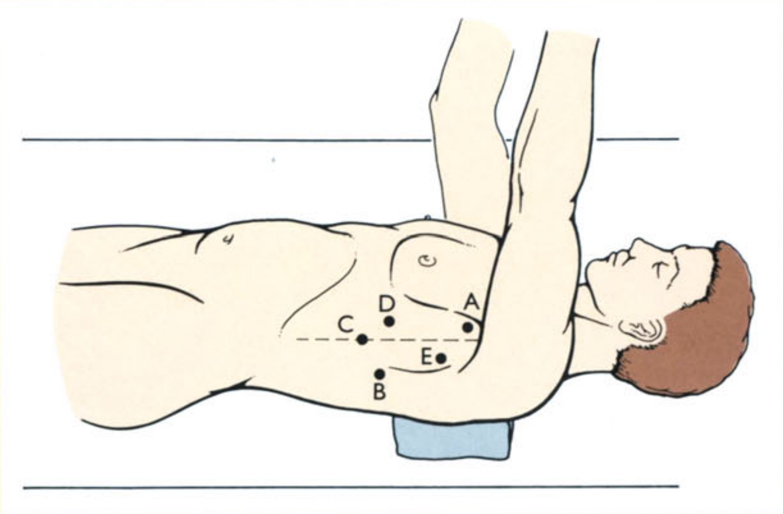


FIGURE 28-7.

Placement of the trocars. The patient is shown in the right lateral decubitus position with a view from above. Four trocars are inserted into the left chest cavity as follows: 1) *A* is a 10.5-mm trocar inserted in the third intercostal space just anterior to the axillary line. This port accommodates an endoscopic fan retractor used to retract the lung. 2) *B* is inserted in the sixth intercostal space, about 2 inches behind the posterior axillary line. This port is used for the camera. 3) *C* is inserted in the sixth intercostal space at the level of the mid-axillary line. This port is used by the operator. 4) *D* is inserted in the fifth intercostal space at the level of the anterior axillary line, and is used by the assistant to push the diaphragm downward or to lift the anterior edge of the muscular layer of the esophagus during the dissection. If necessary, a fifth trocar may be used to aid in exposure and dissection. This trocar (*E*) is inserted in the fourth intercostal space at the level of the posterior axillary line and is also used by the operator.

Procedure

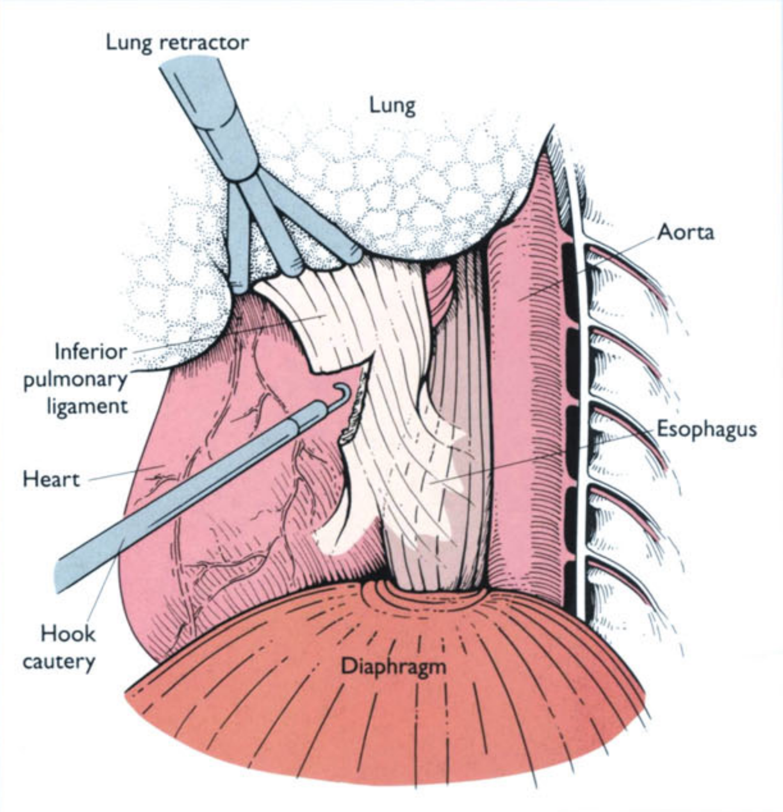


FIGURE 28-8.

Insertion of the lung retractor, incision of the inferior pulmonary ligament, and incision of mediastinal pleura overlying the esophagus. After deflation of the left lung by the anesthesiologist, the three-prong lung retractor is inserted through the upper port. The lung is retracted upward. This maneuver puts tension on the inferior pulmonary ligament, which is then divided with bipolar scissors or with a hook cautery. The esophagus, which lies in the groove between aorta and pericardium, is then identified by the transillumination given by the endoscope. The mediastinal pleura overlying the esophagus is incised.

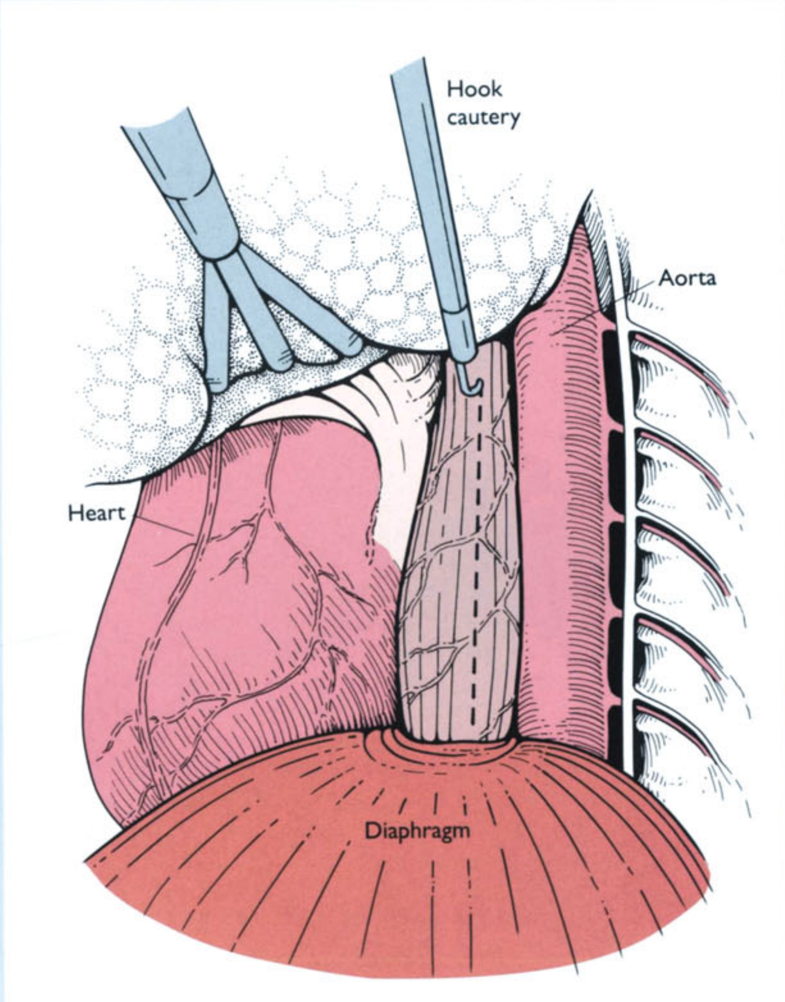


FIGURE 28-9.

Marking the line of the myotomy on the esophagus. The endoscopist subsequently tilts the tip of the endoscope at 90°, pushing the esophagus towards the left chest, clearly into the surgeon's view. The line of myotomy, as straight as possible, is then drawn with the hook cautery on the left side of the esophagus, avoiding injury to the left vagus nerve, the pericardium, and the aorta. The intent of this maneuver is to clearly delineate the line and extent of the myotomy before tissues are stained with blood.

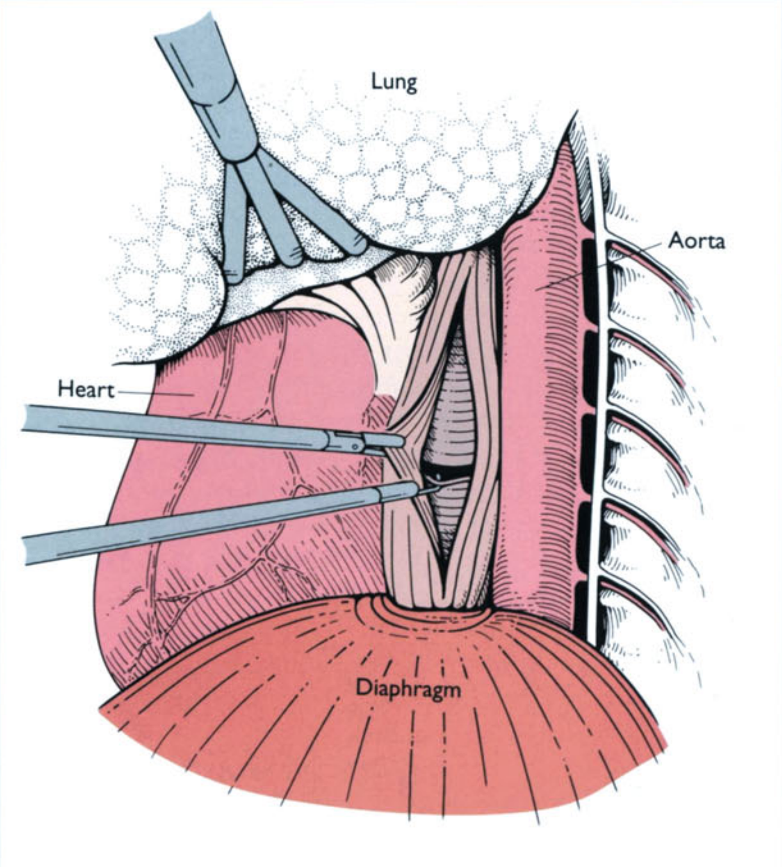


FIGURE 28-10.
Starting the myotomy. The longitudinal muscle fibers are divided in a point midway between the inferior pulmonary vein and the diaphragm. The goal is to deepen the incision and to expose the mucosa as early as possible in the course of the procedure. The circular muscle fibers are then pulled away from the mucosa and divided using a 90° hook cautery. This is a critical part of the operation because of the risk of injuring the mucosa. Once the mucosa is exposed and the correct submucosal plane identified, the remaining myotomy is relatively easy. The myotomy is extended upward and downward using the hook cautery or bipolar scissors. Use of the latter probably decreases the risk of mucosal injury because the current travels only between the two jaws. With monopolar cautery, the operator must be aware of the potential field effect of the current.

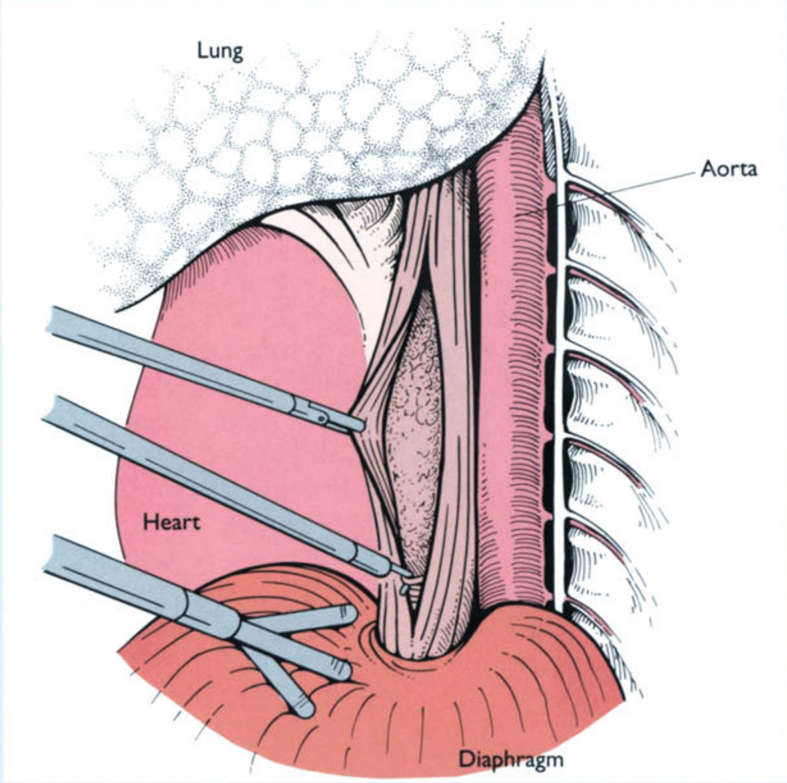


FIGURE 28-11.
Extending the myotomy to the cardioesophageal junction. The second critical part of the operation is the extension of the myotomy to the cardioesophageal junction. At this level, the mucosa is at risk for injury, as the muscular layer becomes thinner. The myotomy should be carried down just to the gastric side of the cardioesophageal junction to relieve the area of obstruction. If it is carried too far, gastroesophageal reflux will develop, but if not extended enough, only partial relief of the dysphagia will be obtained. The help of the endoscopist in confirming complete division of the lower esophageal sphincter fibers is useful. In order to expose completely the cardioesophageal junction, the diaphragm must be pushed caudad by the first assistant using a grasper or another retractor, while the esophagus is pulled cephalad. In addition, the stomach must be deflated by suctioning the air with the endoscope. The gastric musculature is easily identified because of the different orientation of the muscle fibers and because the vascular supply becomes more abundant. The myotomy is usually carried down onto the stomach for approximately 0.5 cm.

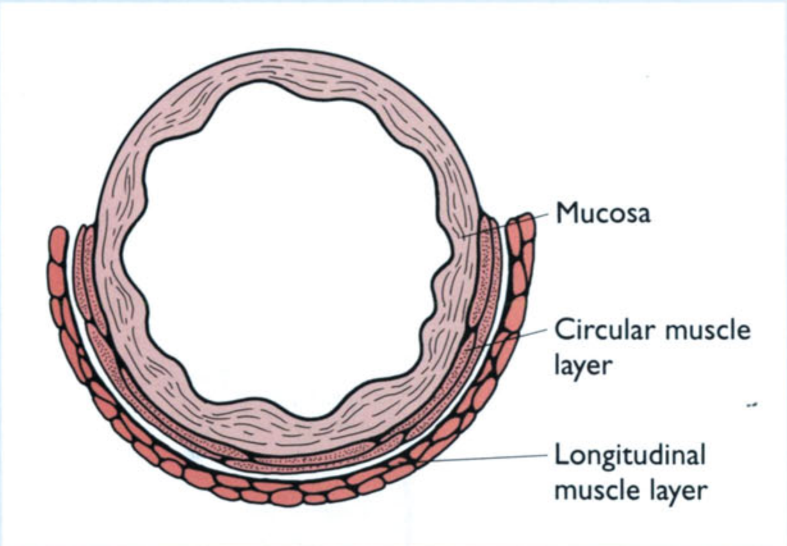


FIGURE 28-12.
End result of the myotomy. After the myotomy is completed, the next step is to pull the edges of the muscularis away from the mucosa for 40% to 50% of the circumference of the esophagus. This avoids narrowing of the lower esophageal sphincter region during healing of the myotomy. This figure shows the cross-sectional anatomy of the esophagus after completion of the esophagomyotomy. The operation is completed by inserting a 28-French right angle chest tube through one of the lower trocar sites. This maneuver is done under direct vision of the telescope, avoiding direct contact of the tube with the esophageal mucosa or the aorta.

Procedure

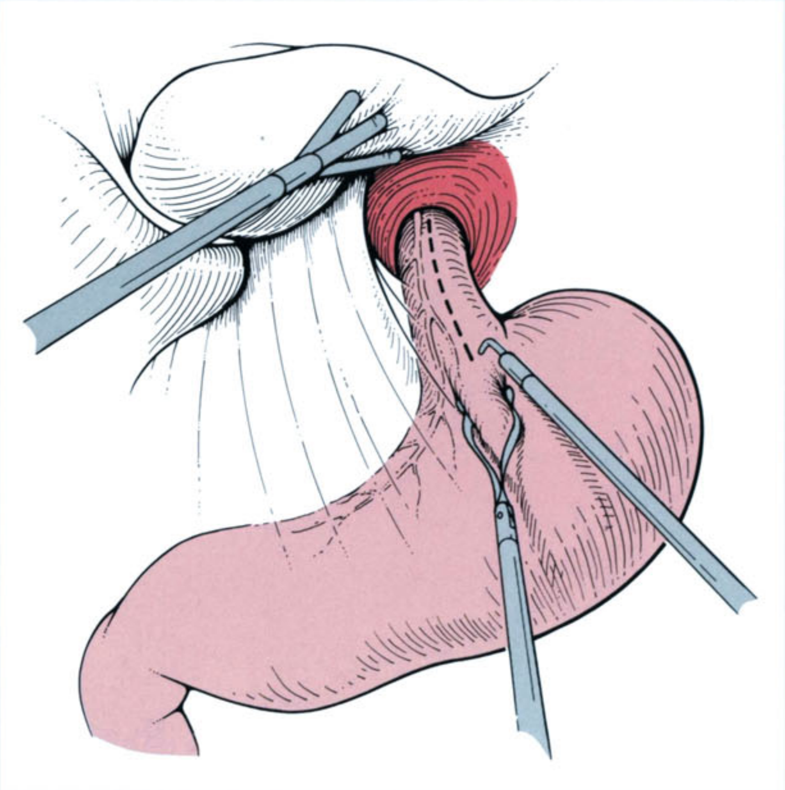


FIGURE 28-14.

Starting the myotomy. The left lobe of the liver is retracted anteriorly and toward the right side of the patient using a fan retractor. This maneuver exposes the esophageal hiatus. A 30° or 45° telescope allows an improved view of the anterior wall of the esophagus. The phrenoesophageal membrane overlying the esophagus is divided with cautery. The left anterior vagus is identified and preserved. The stomach is pulled downward using a Babcock clamp. The myotomy is started in the middle third of the exposed esophagus, lateral to the anterior vagus nerve. As in the thoracic approach, the myotomy is begun with the hook cautery until the submucosal plane is reached.

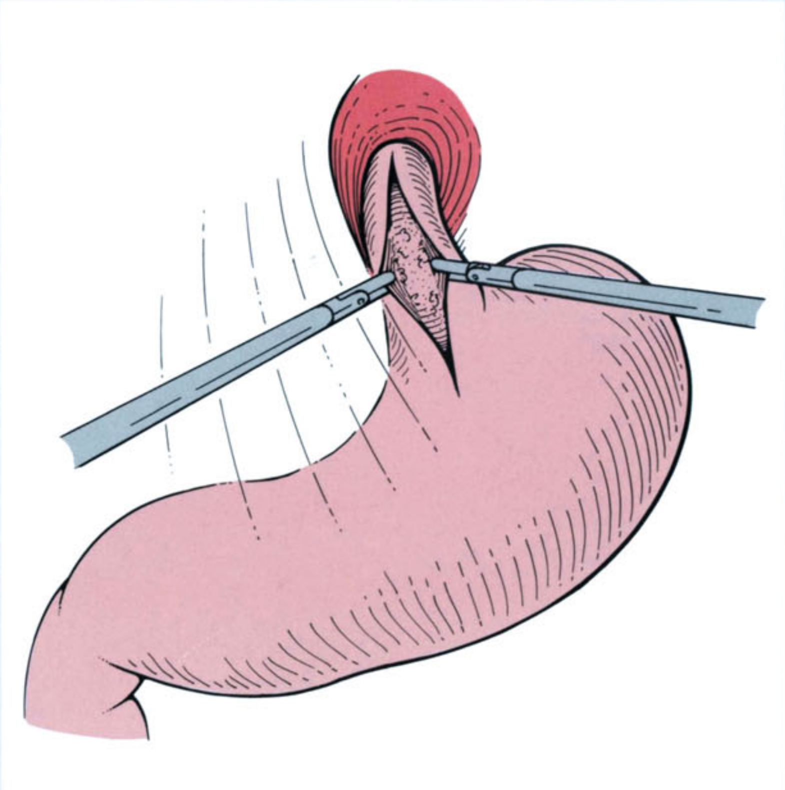


FIGURE 28-15.

Completed myotomy. The myotomy is then extended upward using the bipolar scissors, and downward onto the stomach for about 0.5 cm using the hook cautery. After completion of the myotomy, the edges of the muscularis are separated from the underlying mucosa.

References

1. Heller E: Extramukose Karioplastic beim chronishen Kardiospasmus mit Dilatation des Oesophagus. *Mitt Grenzgeb Med Chir* 1914, 27:141–149.
2. Grimes OF, Stephens HB, Margulis AR: Achalasia of the esophagus. *Am J Surg* 1970, 120:198–202.
3. Okike N, Spencer Payne W, Neufeld DM, *et al.*: Esophagomyotomy versus forceful dilatation for achalasia of the esophagus: results in 899 patients. *Ann Thorac Surg* 1979, 28:119–125.
4. Ferguson MK: Achalasia: current evaluation and therapy. *Ann Thorac Surg* 1991, 52:336–342.
5. Little AG, Soriano A, Ferguson MA, *et al.*: Surgical treatment of achalasia: results with esophagomyotomy and Belsey repair. *Ann Thorac Surg* 1988, 45:489–494.
6. Ellis FH Jr, Gibbs PS, Crozier RE: Esophagomyotomy for achalasia of the esophagus. *Ann Surg* 1980, 192:157–163.
7. Vantrappen G, Hellemans J, Deloof W, *et al.*: Treatment of achalasia with pneumatic dilatation. *Gut* 1971, 12:268–275.
8. Vantrappen G, Hellemans J: Treatment of achalasia and related motor disorders. *Gastroenterology* 1980, 79:144–154.
9. Sauer L, Pellegrini CA, Way LW: The treatment of achalasia: a current perspective. *Arch Surg* 1989, 124:929–932.
10. Orringer MB, Stirling MC: Esophageal resection for achalasia: indications and results. *Ann Thorac Surg* 1989, 47:340–345.
11. Pellegrini CA, Wetter LA, Patti MG, *et al.*: Thoracoscopic esophagomyotomy: initial experience with a new approach for the treatment of achalasia. *Ann Surg* 1992, 216:291–299.
12. Shimi S, Nathanson LK, Cuschieri A: Laparoscopic cardiomyotomy for achalasia. *J R Coll Surg Edinb* 1991, 36:152–154.
13. Guelrud M, Rossiter A, Souney PF, *et al.*: The effect of vasoactive intestinal polypeptide on the lower esophageal sphincter in achalasia. *Gastroenterology* 1992, 103:377–382.
14. Csendes A, Smok G, Braghetto I, *et al.*: Gastroesophageal sphincter pressure and histological changes in patients with achalasia of the esophagus. *Dig Dis Sci* 1985, 30:941–944.
15. Aggestrup S, Uddman R, Sundler F, *et al.*: Lack of vasoactive intestinal peptide nerves in esophageal achalasia. *Gastroenterology* 1983, 84:924–927.
16. Holloway RH, Krosin G, Lange RC, *et al.*: Radionuclide esophageal emptying of a solid meal to quantitate results of therapy in achalasia. *Gastroenterology* 1983, 84:771–776.
17. Kahrilas PJ, Kishik SM, Helm JF, *et al.*: Comparison of pseudoachalasia and achalasia. *Am J Med* 1987, 82:439–446.
18. Katz PO: Achalasia. In *Esophageal Motility Testing.* Edited by Castell DO, Richter JE, Dalton CB. New York: Elsevier; 1987:107–117.
19. Pellegrini CA, Leichter R, Patti MG, *et al.*: Thoracoscopic esophageal myotomy in the treatment of achalasia. *Ann Thorac Surg* 1993, 56:680–682.

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