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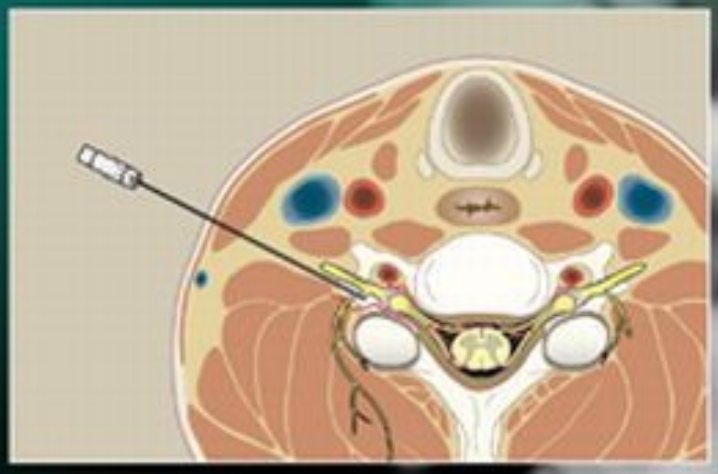
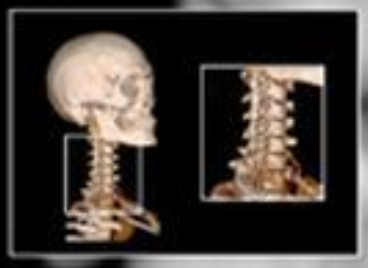
Atlas of Image-Guided Intervention

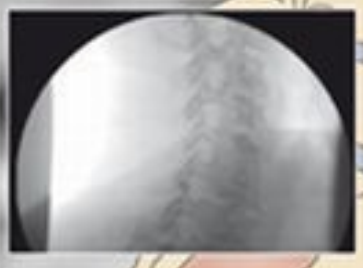
in Regional Anesthesia and Pain Medicine

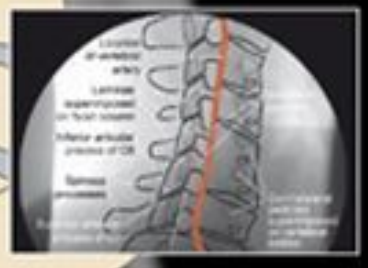
SECOND EDITION

James P. Rathmell









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Atlas of Image-Guided Intervention in Regional Anesthesia and Pain Medicine

Second Edition

Atlas of Image-Guided Intervention in Regional Anesthesia and Pain Medicine

Second Edition

James P. Rathmell, MD
Professor of Anaesthesia, Harvard Medical School
Chief, Division of Pain Medicine
Department of Anesthesia, Critical Care and Pain Medicine
Massachusetts General Hospital
Boston, Massachusetts

Illustrations by

Gary J. Nelson
Medical Illustrator
University of Vermont College of Medicine (Retired)

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To those who have encouraged
my enthusiasm,
those who believed
something might come of it

James K. Rathmell, Jr.
Harry M. Schey
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Simon Gelman
Howard M. Schapiro
David L. Brown
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Warren M. Zapol
Edward Lowenstein

Barbara A. Rathmell

Preface to the Second Edition

It is now almost 20 years since I finished training in anesthesiology and pain medicine. Radiographic guidance is now a routine part of performing many interventions used in pain treatment. The first edition of *The Atlas of Image-Guided Intervention in Regional Anesthesia and Pain Medicine* has been well-received among physicians-in-training and experienced clinicians alike. The original concept of presenting simple, high-quality anatomic drawings alongside the most common radiographic views has proven to be intuitive and to rapidly facilitate learners' understanding of the relevant radiographic anatomy. I have had the pleasure of watching dozens of physicians use the first edition right at the bedside to rapidly review their understanding of the radiographic anatomy before performing a procedure. Two major drivers have led me to create the second edition: The first edition lacked a detailed description of the quality of scientific evidence available about each technique, and new imaging techniques have improved our ability to conduct many of these interventions more safely and effectively.

Pain medicine as a discipline has struggled with the creation of scientific evidence regarding the usefulness of many of the techniques we employ. In this, the new era of evidence-based medicine, it is crucial that we all understand the level of evidence that exists for the treatments we employ. In this edition, I have added a chart to each chapter with an evidence-based recommendation regarding the use of each technique, along with a brief description of the available evidence and a summary of recent expert practice guidelines. I have made concerted efforts to follow internationally accepted guidelines for rating the quality of the scientific evidence and in grading the strength of the recommendations (Appendix). We are still a long way from the large-scale trials that are needed in this field, but I am strongly encouraged by the appearance of much high-quality evidence in the short interval since the first edition appeared in 2006.

Newer imaging modalities have emerged in the past several years and developed to the point where they are now very useful in training and in making daily management decisions, foremost among them are computed tomography and ultrasound. Three-dimensional reconstruction of high-quality computed tomography data (3D-CT) is an extraordinary tool in visualizing the relevant anatomy as trainees learn new techniques. For each technique, I have included a 3D-CT image rotated to the same orientation that is shown in the adjacent fluoroscopic images. My own trainees here at Mass General and trainees at many venues around the world where I have taught workshops have universally found the addition of 3D-CT images to be a significant aid in assimilating the relevant anatomy. CT has long been used in diagnostic evaluation of patients, including those with intra-abdominal malignancies such as pancreatic cancer. In the first edition, I included a detailed description of the use of CT for performing celiac plexus block, an approach that I still feel offers superior anatomic information and improves safety of the technique. However, in the past few years, computerized workstations have become widely available beyond the radiology department and this now allows us to use the diagnostic imaging studies in the process of planning a precise approach to performing interventions. In our clinic in Boston, we can pull up any diagnostic study for review and make detailed measurements, which we can then immediately apply in the fluoroscopy suite. I have added a description of the use of diagnostic CT in planning celiac plexus block under fluoroscopy to this edition. Finally, the use of ultrasound has become commonplace in the practice of regional anesthesia for providing surgical anesthesia. Practitioners have found that the use of ultrasound guidance improves the success rate for many peripheral nerve blocks and its use has been adopted rapidly into daily clinical practice around the world. The use of ultrasound in the pain clinic has been slower to evolve, largely because we already have superior anatomic information available from fluoroscopy. Nonetheless, there are several areas where ultrasound may simplify specific techniques as well as enhancing their safety. In this edition, I have described the ultrasound anatomy relevant to stellate ganglion block and intercostal nerve block side by side with the fluoroscopic technique. These are two techniques where ultrasound appears to offer significant advantages; others will undoubtedly emerge in the years ahead.

As in the first edition, the choice of techniques included is arbitrary and based on my own perceptions about which among them are performed most commonly. It is my ongoing hope that this atlas will help to educate and guide practitioners toward a more uniform approach to performing pain treatment techniques in the safest possible manner. With more consistent methodology, we can continue the work of assembling scientific trials to determine which among these techniques are most useful in aiding our patients suffering with pain.

James P. Rathmell, MD
Boston, Massachusetts
July 2011

Preface to the First Edition

During the course of my own training in pain medicine, now well over a decade ago, radiographic guidance was used infrequently—it was reserved for major procedures such as neurolytic celiac plexus block. In the years since my training, I have experienced two forces at work. First, pain practitioners are now being called on to serve as diagnosticians. Patients and referring practitioners expect pain physicians to have familiarity with imaging modalities and their usefulness in diagnosing pain conditions. At the same time, pain practitioners have come to realize the usefulness of radiographic guidance in achieving precise anatomic placement of needles and catheters. Although the evidence supporting the need for routine radiographic guidance is still evolving, the intuitive appeal of this more precise approach has caught firm hold—to the point where the majority of practitioners now perform at least a portion of their injections using fluoroscopic guidance. In some cases, such as with patients with intractable pain associated with metastatic cancer, radiographic guidance has proven invaluable in the planning and implementation of therapy directed toward pain relief. There are numerous excellent atlases for practitioners of regional anesthesia. However, there remains no single, comprehensive and well-illustrated atlas for the pain practitioner that both describes the injection techniques and illustrates the relevant radiographic anatomy. *Atlas of Image-Guided Intervention in Regional Anesthesia and Pain Medicine* is an atlas designed to fill this void.

In 1999, I attended the annual meeting of the American Society of Regional Anesthesia and Pain Medicine (ASRA) in Philadelphia to present a paper on a study I had conducted with a radiologist colleague and a medical student. We examined the distribution of injectate in a series of patients who received epidural steroid injections for radicular pain associated with a new herniated disc. To our surprise, the injectate often spread to the side opposite the disc herniation. In retrospect, this is not at all surprising; if a disc herniation is present on one side, this might well obstruct the flow of fluid through the relatively confined epidural space. The fluid would follow the path of least resistance, spreading preferentially to the contralateral, unaffected side and exiting the contralateral intervertebral foramina. This study and others that emerged at about the same time challenged the conventional wisdom that suspending the steroid in a modest volume was sufficient to consistently produce spread of the injectate to the affected levels, regardless of where the solution was placed within the epidural space. Perhaps the blind loss-of-resistance technique is not the best way to deliver steroid to the site of inflammation.

Using radiographic guidance, we are able to visualize bony structures directly and in real time. We can see the needle within the radiographic field and use simple geometry to guide the needle directly from the skin's surface to its destination. During that same ASRA meeting in 1999, I was introduced to Dr. David Brown, an anesthesiologist and author of several texts on regional anesthesia. He was then editor in chief of *Regional Anesthesia and Pain Medicine (RAPM)*, and he was in search of a young and enthusiastic Associate Editor to head a new section in *RAPM* on imaging. Although Dr. Brown's well-known text, *An Atlas of Regional Anesthesia*, has sold innumerable copies without anything more than a brief mention of radiographic guidance, he clearly recognized that imaging modalities of all sorts—plain radiography, computed tomography (CT), magnetic resonance imaging, and ultrasound—held untapped potential for advancing the accurate conduct of neural blockade. After a brief discussion, I took the post as Associate Editor, and I have now solicited, written, and reviewed many articles for the Imaging Section in *RAPM*. These articles have helped establish the clear-cut benefit of imaging in the conduct of regional anesthetic techniques in pain medicine, and images from many of the articles are included in this atlas.

The atlas is designed to serve as a practical guide to practitioners who perform (or want to learn how to perform) a wide range of different treatments for acute, chronic, and cancer-related pain with the assistance of radiographic guidance. It is meant to be a useful resource for a range of practitioners. Those already familiar with regional anesthesia but wanting to learn more about the use of radiographic guidance will find the techniques they know illustrated with images encountered when the same techniques are carried out using radiographic guidance. Practitioners already well versed in the use of radiographic imaging will find clinically relevant details, including an overview of each technique, a detailed and illustrated review of the relevant anatomy, technical aspects of each treatment, and a description of the complications associated with these pain treatment modalities.

The atlas begins with an overview of basic techniques for using image guidance to guide needle placement, radiation safety, clinical use of radiographic contrast agents, and the pharmacology of the most common agents used for these injection treatments. The bulk of the atlas is devoted to descriptions of individual techniques. For each technique, concise summaries of common clinical applications, technical details, adverse events, and clinical outcomes are included. Each technique is illustrated using a simple line

drawing and the plain x-ray images encountered when the technique is carried out using radiographic guidance. The radiographs are displayed without labels side by side with a detailed overlay on the same image that illustrates the relevant anatomic structures. When published reports suggest that CT might be particularly useful in performing a specific technique (e.g., neurolytic celiac plexus block), details of the CT-guided technique and accompanying CT images are included.

The field of pain medicine suffers from a lack of well-controlled studies to guide our choice of the most effective therapies. Indeed, many of the techniques described in the atlas lack clear evidence to support their efficacy. Even so, the techniques described are in widespread clinical use. I have made every effort to provide a clear summary of the current evidence available supporting the use of each technique, but all too often these data are scant. Precisely because of this lack of outcome data, I have chosen to omit several emerging technologies, including epidural lysis of adhesions and epiduroscopy. The choice of techniques included, although arbitrary, was based on my own perception of those that are performed most commonly. It is my hope that the atlas will help educate and guide practitioners toward a more uniform approach to performing these techniques. With more consistent methodology, we can begin the much-needed work of assembling randomized controlled trials to determine which among these techniques are most useful in aiding those with intractable pain.

James P. Rathmell, MD
Burlington, Vermont
March 2005

Acknowledgments

This project would not have been possible without the help of many people. First among those who have made this atlas more than a compendium of x-ray images is Gary Nelson, retired medical illustrator at the University of Vermont. I have worked with Gary for many years and was delighted that he was willing to emerge from retirement to complete the illustrations for this second edition, now in color. Gary couples a detailed understanding of anatomy with an absolute attention to detail. When he did not understand a given technique, Gary would venture to my office or to the operating room to see the technique being performed. We would often spend long evening hours by telephone perfecting the details. The results speak for themselves, making this atlas uniquely suited as a practical reference for reviewing the anatomy of each technique as you are about to perform the block.

The images are almost solely from my own practice, including many produced in the course of daily patient care by my partners in practice. In Vermont: Michael Borrello, Jerry Tarver, Rayden Cody, and Anne Marie Munoz; in Boston: Shihab Ahmed, Gary Brenner, Lucy Chen, Christopher Gilligan, Padma Gulur, Jianren Mao, Gary Polykoff, and Brian Wainger. All my colleagues have helped in choosing the best images and critiquing the manuscript. Smith Manion worked for a year after his pain fellowship as a research fellow in our division and, as Esther Benedetti did for the first edition, he spent many hours reviewing and sorting through thousands of images to find those best illustrating each technique for this edition. Josh Hirsch, Bill Palmer, and Stuart Pomerantz, my colleagues in radiology, were invaluable in providing their expertise and open access, including the use of the computed tomography workstation; they have served as valuable clinical and research collaborators throughout my time in Boston. Adrian Desjardins with Philips Medical Systems, now a research scientist at University College London, offered technical expertise and helped ensure that my discussion and illustration of radiation exposure during C-arm use was sound.

Those in my academic office, most notably Linda Castellano, have made sure that I was organized and reasonably on time. She has helped whenever asked to revise manuscripts, request permissions, or field calls from the many others helping with the project.

The atlas began in 2001, after a discussion with Craig Percy, then an Acquisitions Editor with Lippincott Williams & Wilkins during the annual meeting of the American Society of Anesthesiologists. Brian Brown moved into that same role during the latter stages of finalizing the first edition, and I am now proud to call Brian "my editor." Brian has helped me with many projects, large and small, and he has remained a patient friend at all times. Other key people at Lippincott Williams & Wilkins who brought the project to a close include Nicole Dernoski, Developmental Editor, who ferried the final submission toward production, and Keith Donnellan, who moved into Nicole's role as the second edition was nearing completion.

The encouragement to tackle an entire book on my own came from two people. As Editor in chief of *Regional Anesthesia and Pain Medicine*, David Brown helped me learn how to assemble an article and make it teach something of value to practitioners. This atlas is, quite purposefully, styled after Dr. Brown's *Atlas of Regional Anesthesia*: concise, well illustrated, and meant for everyday use in real clinical practice. I have been involved in many projects with Dr. Brown in more recent years, and he serves as a trusted sounding board. Despite an impossibly busy schedule, he always seems to answer the phone whenever I call for advice. My friend and Chair of the Department of Anesthesia at the University of Vermont, Howard Schapiro, has encouraged me through just about every project I have done and is the one who keeps me out of trouble. Dr. Schapiro reminds me that contracts and costs are a reality, and he generously supplied me with time for an unconventional sabbatical, the first in many years in our department, to work on the first edition of this text.

Finally, but foremost, I thank my family—my wife, Bobbi, and my children, Lauren, James, and Cara. They have simply stared in amazement as I sat day after day, week after week, month after month in my home office—reading, writing, and working with images. They have come to understand that this is something of a passion for me, and they have provided all the encouragement I needed to complete another project of this size.

Contents

SECTION I

BASIC TECHNIQUES, RADIATION SAFETY, AND PHARMACOLOGY

CHAPTER 1

Basic Techniques for Image-guided Injection

OUTLINE

Patient Positioning and C-arm Alignment

Throughout this book, suggestions for optimal positioning of the patient and alignment of the C-arm are illustrated for each type of block (Fig. 1-1). The patient's position is chosen with three factors in mind: safety, access for the block, and patient comfort, in this order of priority. Safety is first and requires a clear understanding of the anatomy, thus the description of each block begins with a discussion of the relevant regional anatomy. Avoiding critical structures is best accomplished at the outset in planning the approach for neural blockade. A good example is found in the celiac plexus block. Although the rib margins and the vertebral column are easily visualized under fluoroscopy, the position of the abdominal aorta, diaphragm and pleural reflections, and adjacent liver, kidney, and spleen must be inferred to perform this block safely and successfully. As you review the regional anatomy for each block, it will be apparent that the same target can be approached from many different angles. In most cases, only a single technique is illustrated. The illustrated techniques have been chosen with an eye toward minimizing the risks of the procedure. Although some approaches are actually simpler to perform (e.g., cervical medial branch blocks from a lateral approach), they are best reserved for experienced practitioners because of the inherent dangers in getting confused by the complex radiographic anatomy of the cervical spine. Finally, when all else is equal, position can be chosen to promote patient comfort. Indeed, most patients are more comfortable in the supine position than in the prone position, particularly for cervical injections. Once you understand the anatomy of the target for any given block and the critical structures between the skin's surface and the needle's final destination, you may choose to vary both patient position and alignment of the C-arm to suit your own preferences.

Alignment of the C-arm is illustrated for each block, and the approximate angle of the C-arm is also described within the text. The accepted convention is to describe the position and angle of the C-arm according to the direction the x-rays travel from the x-ray source, through the patient, to the image intensifier. To minimize radiation exposure, the x-ray source is typically kept under the x-ray table (see Fig. 2-6). Thus, when the patient is placed prone without angulation of the C-arm, an *anterior-posterior* radiograph is obtained, and when he or she is placed supine, a *posterior-anterior* radiograph results. Lateral movement of the C-arm from the sagittal plane is termed *oblique* angulation. When the x-ray path is angled away from the axial plane toward the head, this is termed *cranial* angulation and when toward the foot is termed *caudal* angulation.

The Coaxial Technique

Image guidance can improve the accuracy and comfort of many injections while minimizing the time required to perform them when a coaxial technique for needle placement is used. The term "coaxial" emphasizes that the advancing needle and the x-ray path share a common axis. In this way, the needle tip is advanced from the skin's surface to the final target at a depth with only small changes in the needle's direction. The needle tip and the target are seen at all times. Compare this with the more traditional means of using surface landmarks to determine the initial site of needle entry through the skin, followed by advancing the needle until it contacts a bony surface. Subsequent adjustments require that the needle is withdrawn its entire length before redirection. In the past, radiographic guidance was used infrequently and then only to confirm the needle's final position.

To illustrate the coaxial technique, an intra-articular lumbar facet injection is shown in Figure 1-1. The patient is positioned prone. The lumbar facet joint to be injected is brought into clear view by moving the

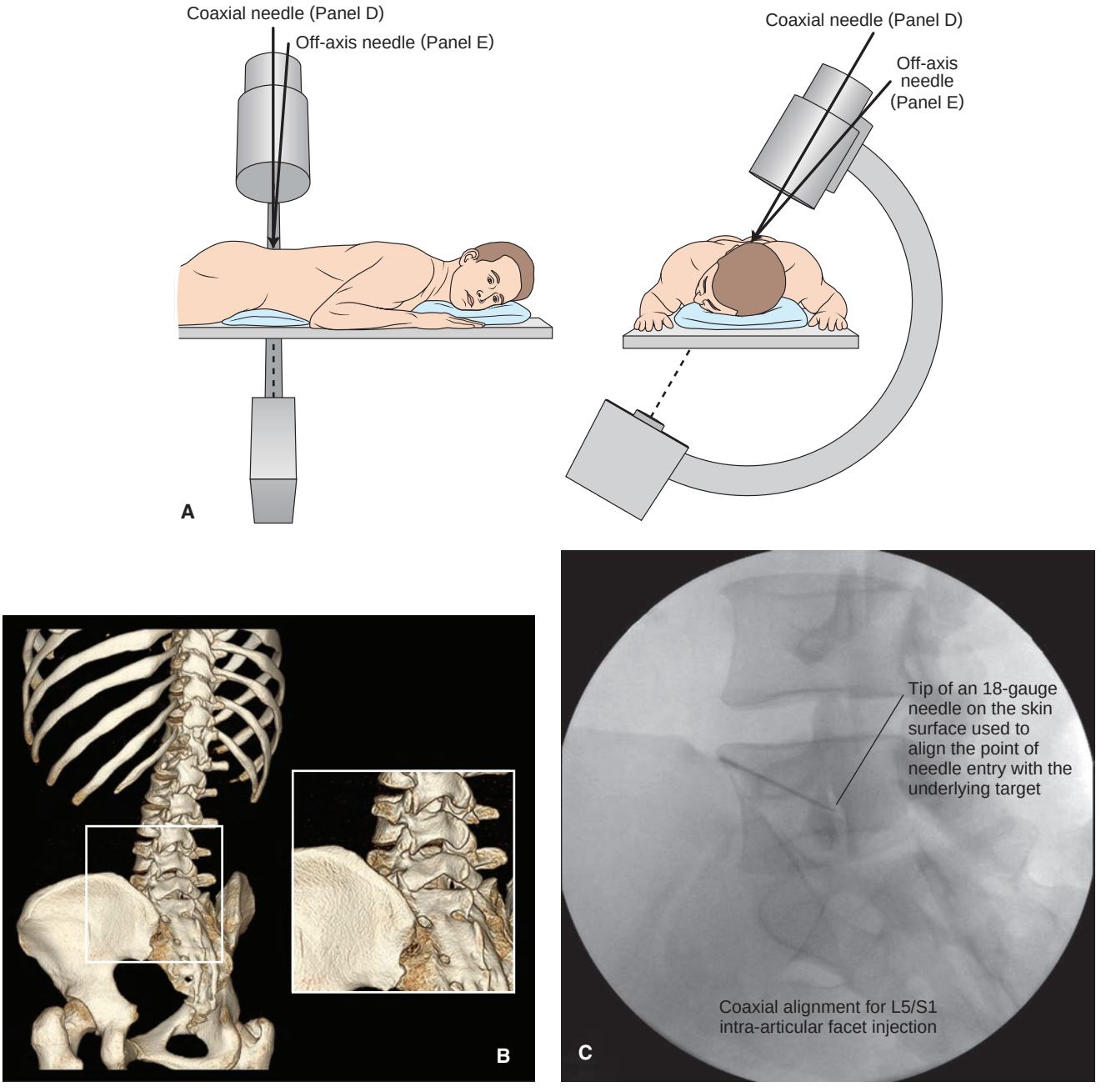

Figure 1-1.

The coaxial technique for needle placement. **A:** Patient position and axis of the C-arm are shown for coaxial intra-articular left lumbar facet injection. The axis of the needle shown in **panel D** (coaxial) and **panel E** (off-axis) is shown. **B:** Three-dimensional CT reconstruction of the lumbar spine rotated to correct orientation for L5/S1 intra-articular facet injection; **inset** shows the same region and orientation shown in the radiographs in **panels C through F**. **C:** The L5/S1 facet joint is shown with the articular surfaces in good alignment. An 18-gauge needle has been placed on the skin surface overlying the target to determine the point to anesthetize the skin. **(*Cont.*)**

C-arm to align the x-ray path with the axis of the joint (see Fig. 1-1A). Using computed tomography (CT) and three-dimensional reconstruction, an image rotated to the same axis illustrates the bony anatomy (see Fig. 1-1B). Once the facet joint is seen clearly, a radiopaque marker is placed on the skin's surface until it overlies the target joint (see Fig. 1-1C). In this way, the area of skin directly overlying the target along the x-ray axis is identified. The skin and subcutaneous tissues are then anesthetized directly under the tip of the surface marker using a small amount of local anesthetic. The needle is inserted a short distance until it is seated in the subcutaneous tissues overlying the target. The angle of the needle is adjusted until it is roughly parallel to the x-ray axis. This initial adjustment is performed without

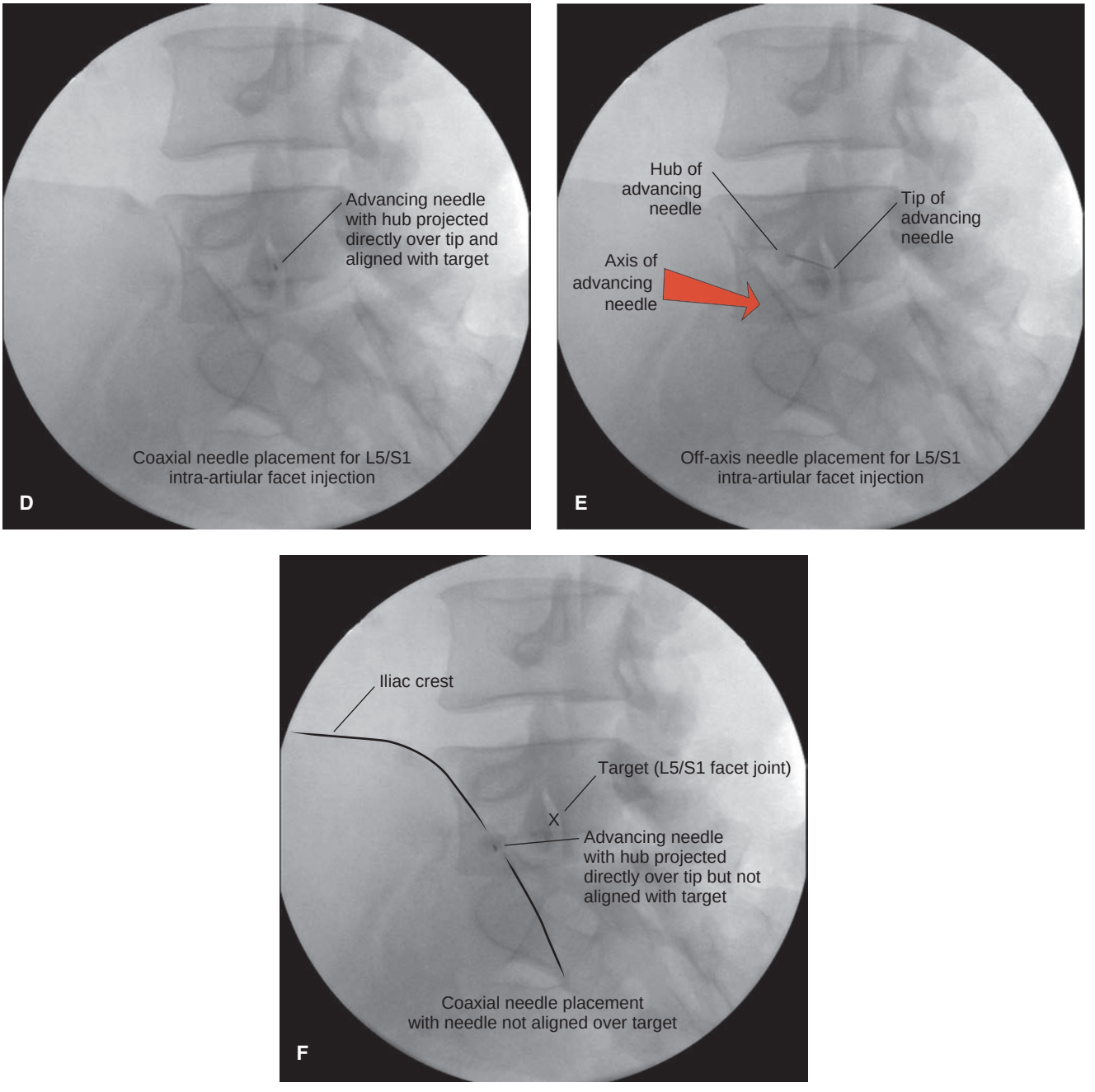

Figure 1-1. ***(Continued)***
D: A coaxial needle shown in good position over the L5/S1 facet joint. The hub of the needle lies directly over the tip of the needle. **E:** The needle is approaching the L5/S1 facet joint off axis from the x-ray beam, from lateral to medial. **F:** The needle is entering in good coaxial alignment but does not overly the target (*X*) of the L5/S1 facet joint.

taking any radiographs—a glance at the axis of the C-arm image intensifier in comparison to the axis of the needle is all that is needed to bring them into rough alignment during initial needle placement. The needle should remain quite superficial until it is well aligned with the x-ray beam (see Fig. 1-1D). The needle is perfectly aligned with the x-ray beam when the hub of the needle is superimposed on the tip and appears as a radiolucent circle. Only after it is well aligned should the needle be advanced any deeper. Some examples of common difficulties with initial needle placement are shown: Figure 1-1E illustrates poor needle alignment, and Figure 1-1F shows the needle in good coaxial alignment, but not overlying the target. As long as the needle is directed toward the final target, needle advancement continues until the target is reached. If the needle is coaxial but does not lie over the final target, the needle should be removed and replaced over the target. When a needle is advanced using a coaxial technique, small changes in needle direction can

Figure 1-2.
Quincke needle. The 22-gauge, 3.5-inch Quincke spinal needle is the most common needle used by many practitioners for image-guided injection (22-gauge with *black hub*, 25-gauge with light *blue hub*; tip of 22-gauge needle is shown at various angles of rotation). The Quincke needle has a sharp bevel that advances easily through tissue planes. Most manufacturers produce a needle with a central stylette that has a small notch in the hub. The notch lies on the same side as the needle's bevel face and can be used to determine the direction of the bevel as the needle is advanced.

be accomplished easily; large deviations inevitably lead to multiple needle passes to steer the needle to its final destination.

Needles

The most common needle used for image-guided injection is the 22-gauge, 3.5-inch (~10 cm) Quincke spinal needle (Fig. 1-2). This length is suitable for all but the deepest injections. The Quincke point is sharp and advances easily through most tissues. The 22-gauge diameter is a reasonable compromise between needle diameter and stiffness. Although smaller diameter needles produce slightly less pain during placement, they lack stiffness and tend to bend easily.

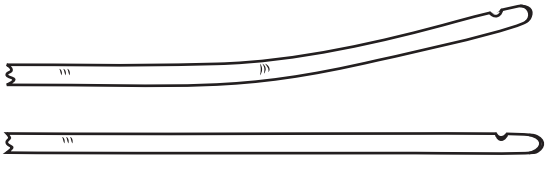

Figure 1-3.
Blunt nerve block needle. Some manufacturers produce blunt-tip needles with the idea that the rounded needle tip will be less likely to penetrate nerves or vascular structures. Blunt needles are supplied either straight or with a curved tip to facilitate redirection of the needle as it is advanced.

Figure 1-4.
Tuohy epidural needle. The Tuohy needle is among the most common needles for interlaminar epidural injection using a loss-of-resistance technique. The needle's orifice is aligned nearly perpendicular to the shaft to direct a catheter threaded through the needle along the plane of the epidural space.

Several manufacturers now produce blunt-tip or rounded-tip needles (Fig. 1-3), with the idea that the blunt tip is less likely to penetrate nerves or arteries during placement. Most needles are also available with curved tips placed by the manufacturer (see Fig. 1-3) that allow the needle to be "steered" as it is advanced. Alternately, a curve can easily be placed at the tip of most straight needles by the operator at the time of use.

The most common needle used for performing epidural injection using the loss-of-resistance technique via an interlaminar route is the Tuohy needle (Fig. 1-4). Tuohy needles are manufactured with the distal orifice of the needle oriented nearly perpendicular to the axis of the needle's shaft. The needle was designed to direct a catheter advanced through the needle along the axis of the epidural space, parallel to the dura mater. The Tuohy needle remains useful for single-shot epidural techniques, catheter placement, and epidural spinal cord electrode placement. Tuohy needles are available in a range of sizes, the most common being 18- and 20-gauge diameter and 8 cm in length.

The most common radiofrequency cannulae used for treating spine-related pain are slight variations of a typical Quincke-style needle (Fig 1-5). The original cannula was designed by Drs. Menno Sluijter and Mark Mehta and is often referred to as the SMK (Sluijter-Mehta Kannula) cannula or needle. A typical 22-gauge beveled needle is covered with a nonconductive, insulating coating on the external surface of the needle shaft extending from the hub to the tip of the needle. The last several millimeters of the needle shaft is left exposed and acts as the active

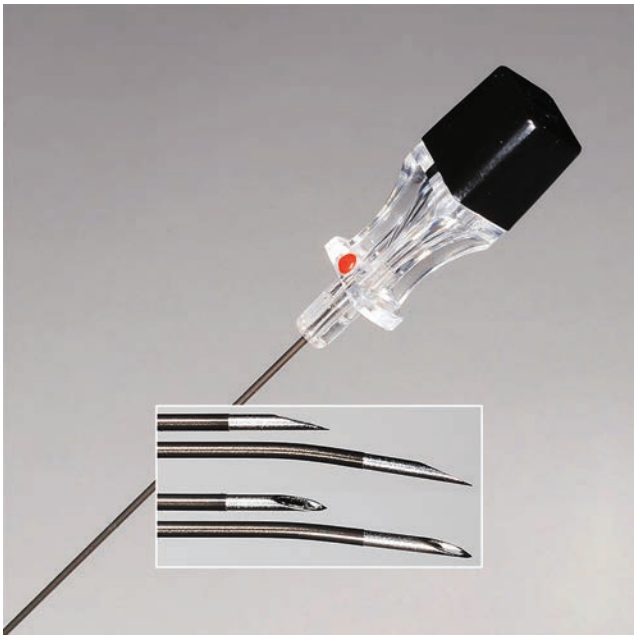

Figure 1-5.
Quincke style radiofrequency cannulae. The most common radiofrequency cannulae used are 22-gauge cannulae in 5- and 10-cm lengths with 5-mm active tips; radiofrequency cannulae are available in both straight and curved styles from many different manufacturers. This style radiofrequency cannula has been termed the SMK (Sluijter-Mehta Kannula) needle or cannula for the original inventors, Drs. Menno Sluijter and Mark Mehta.

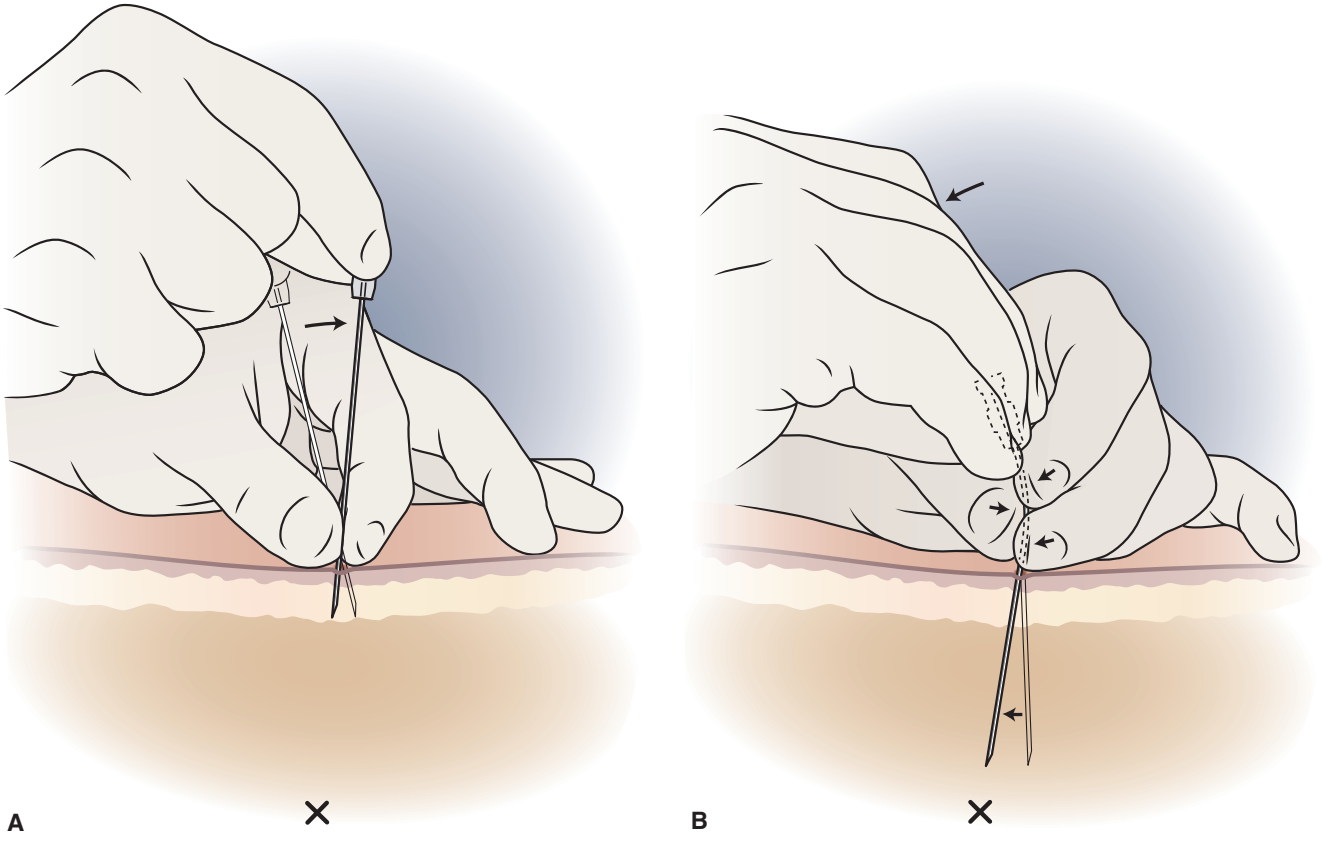

Figure 1-6.
Changing the direction of an advancing needle. **A:** Changing the needle direction when the needle tip remains superficial is accomplished by simply changing the axis of the straight needle. The tip will move opposite to the direction of the hub and can be aligned with the desired target (*X*) before advancing the needle any further. **B:** Only small changes in needle position can be accomplished once the tip is within deeper tissues. The direction of the needle tip that is within deeper tissues can be changed by grasping the needle shaft at the point where it enters the skin with one hand and at the needle hub with the other hand. By anchoring the shaft at the midpoint and moving the shaft in a direction opposite the direction the hub is moved, an arc is created along the shaft of the needle that can be directed toward the target (*X*).

treatment surface. The most common size of active tip in use is 5 mm, but available sizes include 2, 4, 5, and 10 mm in lengths of 5, 10, and 15 cm.

Changing the Direction of an Advancing Needle

With use of a precise coaxial technique, only small changes in needle direction are needed to steer the needle to the final destination. The most precise needle placement with the fewest and smallest changes in direction is best accomplished with the use of a precise coaxial technique and a simple beveled needle *without* any additional bend placed near the tip.

To illustrate the techniques used to position a needle, a straight 22-gauge, 3.5-inch spinal needle is shown in Figure 1-6. Most manufacturers have placed a notch in the hub of the needle with a lock-and-key design. The notch serves to lock the stylette of the needle in position, and it also indicates the direction that the needle's bevel is facing. Beveled needles will naturally veer slightly away from the face of the bevel as they advance through tissue (Fig. 1-7); thus, the bevel should be turned to face away from the direction the operator wants the needle tip to move as it is advanced. However, the magnitude of deviation of a straight, bevel-tip needle is quite small, typically causing the needle tip to veer only a few millimeters as it advances. More drastic changes in needle direction are best accomplished by simply realigning the needle while it is in the superficial tissues (see Fig. 1-6A). Once the needle is seated within the tissues at a depth beyond the first few centimeters, dramatic changes in needle direction are difficult to accomplish and most often require that the needle be retracted to a more superficial level and redirected. One simple means of "steering" a needle that has been seated more deeply is to grasp the needle at the point where it enters the skin with one hand and at the needle's hub with the other hand. By anchoring the needle's shaft at the midpoint and moving the midshaft in a direction opposite the direction the hub is moved, an arc is created along the shaft of the needle (see Fig. 1-6B), and the needle can be effectively steered in any direction desired. Avoid bending the needle so aggressively that it does not return to a straight line when the needle is released. Overly aggressive bending seldom results in more effective steering and ultimately results in a distorted, misshapen needle that is difficult or impossible to direct any further. Extreme and repeated bending of the needle can also lead to fracture of the needle along the shaft.

Some practitioners advocate creating a small bend several millimeters proximal to the tip of the needle. Indeed, many manufacturers market needles with "curved" or "angled" tips for just this purpose. This small curve causes the needle to predictably deviate in the direction of the needle's tip and can be used to facilitate steering the needle toward the target (see Fig. 1-7). The size and shape of the curved needle tip differ from manufacturer to manufacturer, and only repeated use will familiarize the operator with the characteristics of each needle. A straight needle and precise coaxial technique are best in the majority of circumstances. However, when the actual target can not be aligned with the skin's surface using a coaxial technique, a curved needle can be quite helpful in steering the needle during advancement. This situation is often encountered during discography at the L5/S1 level. The plane of the intervertebral disc is angled in a cephalad-to-caudal direction and lies well below the pelvic brim. The sacral ala and iliac crest often lie directly in the path between the skin's surface and the posterolateral margin of the annulus fibrosis. A curved needle can be guided around the sacral ala and toward the disc behind this obstacle (see further description of lumbar discography in Chapter 9).

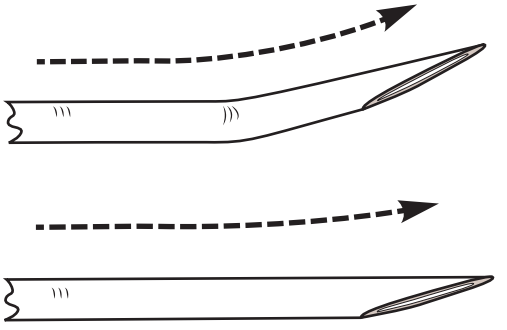

Figure 1-7.
Needle deviation during advancement. A straight, beveled-tip Quincke needle will veer slightly away from the bevel as it is advanced. A curved-tip needle will veer more dramatically toward the direction of the curved needle tip.

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CHAPTER 2

Radiation Safety

OUTLINE

I. Overview
II. Basic Radiation Physics
III. Minimizing Patient Radiation Exposure
IV. Minimizing Practitioner Exposure
V. Optimizing Image Quality

Overview

Pain practitioners have come to rely on fluoroscopy, and to a lesser but growing extent on computed tomography (CT), to facilitate image-guided pain treatment techniques. Fluoroscopy and CT employ ionizing radiation to produce the x-rays needed for imaging. Understanding the physics and biology underlying the biologic effects of ionizing radiation will help pain practitioners to minimize radiation exposure to their patients, other involved personnel, and themselves during image-guided injection. The basic elements of the fluoroscopy unit are illustrated in Figure 2-1. X-rays emanate from an x-ray tube, typically positioned beneath the table and the patient to minimize radiation exposure. The x-rays pass through the table and the patient to strike the input phosphor of the image intensifier, where they are converted to visible light and in turn detected by an output phosphor that transfers the signal to a digital camera for visual display on a monitor or transfer to film. The size and shape of the x-ray beam can be adjusted after exiting the x-ray tube and before entering the patient, from side to side by an adjustable linear collimator or in a circular, concentric fashion by an iris collimator. The C-arm allows variation in the axis of the x-ray beam in numerous planes relative to the patient.

In recent years, the use of CT has become more commonplace, particularly among radiologists. With the advent of fluoroscopy units that can rotate around the patient and acquire images at numerous angles and then reconstruct the images in multiple planes, the distinction between CT-fluoroscopy and traditional CT has become blurred. These CT-fluoroscopy units yield data that can be reformatted in multiple planes and produce final images rivaling the quality of conventional CT. However, acquiring images in multiple planes with either CT-fluoroscopy or conventional CT requires significantly greater radiation exposure than conventional fluoroscopy. In most instances, the superior anatomic information provided does not warrant the routine use of these advanced imaging modalities (see further discussion of radiation dose later in this chapter). Patients undergoing high-risk procedures where small variations in anatomy can alter the risk/benefit ratio of a given technique may benefit from CT-fluoroscopy or conventional CT guidance. The use of CT guidance is discussed in detail later in this text when celiac plexus block is covered (see Chapter 11).

Basic Radiation Physics

Radiation is energy radiated or transmitted as rays, waves, or in the form of particles. X-rays are one portion of the spectrum of electromagnetic radiation. As x-rays pass through matter, they impart enough energy to dislodge electrons (ionizing radiation), yielding free radicals that can lead to harmful biologic effects. In radiography, it is the x-rays that penetrate the body without effect that emerge to strike an image intensifier where they are converted to visible light and can be displayed on a monitor or transferred to film, producing an image based on x-ray penetrability of various tissues.

Several factors and definitions are central to any basic understanding of radiation safety. The biologic effects of ionizing radiation are proportional to the time of exposure, whereas radiation exposure is inversely proportional to the *square* of the distance from the radiation source. Radiation exposure is expressed as roentgen or coulomb per kilogram, whereas the energy absorbed from radiation is expressed as radiation absorbed dose (rad) or as gray (Gy). Because different types of radiation can have different biologic effects, units of exposure are converted from rad to radiation equivalent in man (rem) or sievert (Sv). The units used to express radiation exposure are listed in Table 2-1. For x-rays, 1 roentgen (R) ≈ 1 rad ≈ 1 rem.

The electrical input to the tube that generates the x-rays can be varied to produce x-rays that differ in number and energy. Increased current applied to the x-ray tube

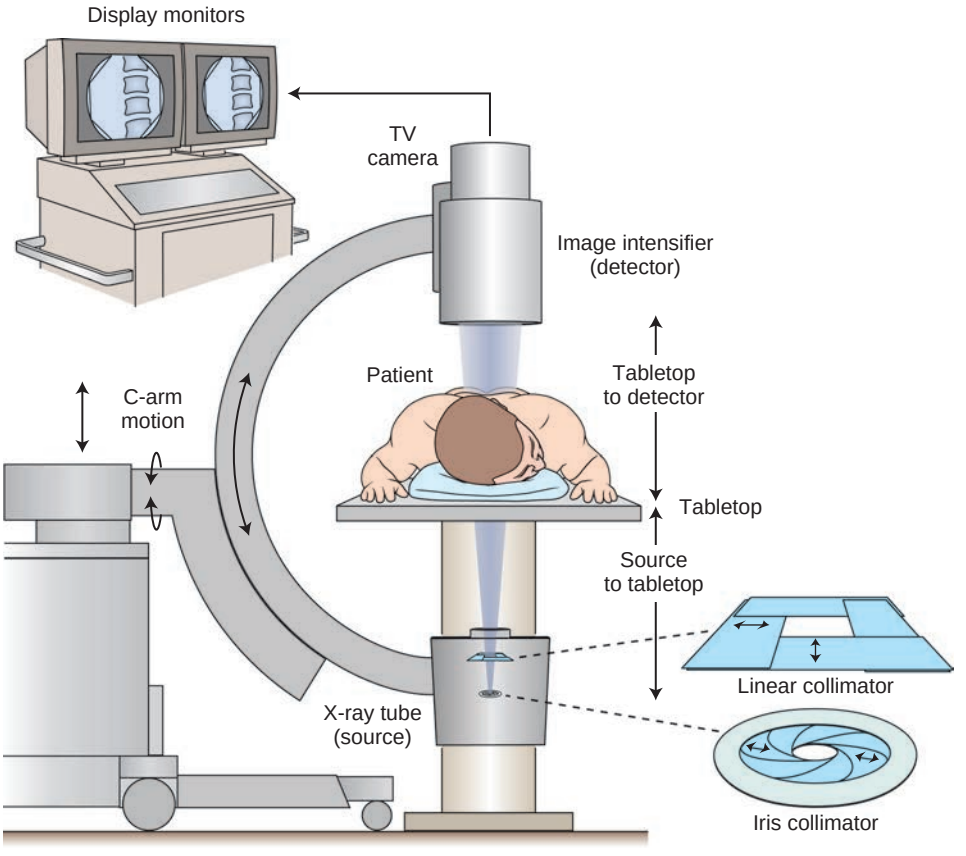

Figure 2-1.
Diagram of the components of a typical fluoroscopy unit.

(expressed as milliamps or mA) produces more x-rays, and the more x-rays that strike the image intensifier, the darker the image. Lengthening the exposure time will also increase the number of x-rays reaching the image intensifier, thus variations in current and exposure time are expressed as milliamps (mA) × seconds. Increased voltage (expressed as kilovoltage peak or kVp) applied to the x-ray tube results in x-ray emission at higher energy levels (i.e., with greater ability to penetrate). In general, high kVp (75 to 125 kVp) and low mA (50 to 1,200 mA) are employed for fluoroscopy with short exposure times. This combination optimizes image quality while minimizing radiation exposure. High-kVp/low-mA combinations expose the patient to significantly less radiation than low-kVp/high-mA combinations. Modern fluoroscopy units typically employ automatic brightness control (ABC), which automatically adjusts kVp and mA to yield optimal brightness and contrast.

The x-rays generated during fluoroscopy are a form of ionizing radiation and have the potential to produce significant biologic effects. Small doses of ionizing radiation can produce molecular changes that take years to manifest in the form of cancerous transformation. Exposure to low doses of ionizing radiation is likely inconsequential because normal cellular mechanisms repair the damage. The International Committee on Radiation Safety Protection (ICRP) has produced estimates of the maximum permissible dose (MPD) of annual radiation to various organs (Table 2-2). Exposure below these levels is unlikely to lead to any significant effects, but the ICRP recommends that workers should not receive more than 10% of the MPD.

Use of fluoroscopy for interventional procedures grew rapidly during the late 1980s, leading to increased concerns about radiation exposure. In 1994, the U.S. Food and Drug Administration (FDA) issued a public health advisory about

Table 2–1
Units Used to Express Radiation Exposure and Dose

Term	Traditional Units	SI Units	Conversion
Exposure	Roentgen (R)	Coulomb/kg (C/kg)	1 R = 2.5 × 10^{-4} C/kg
Radiation absorbed dose	rad	Gray (Gy)	100 rad = 1 Gy
Radiation equivalent in man	rem	Sievert (Sv)	100 rem = 1 Sv

Table 2–2
Annual Maximum Permissible Radiation Doses

Area/Organ	Annual Maximum Permissible Dose
Thyroid	0.5 mSv (50 rem)
Extremities	0.5 mSv (50 rem)
Lens of the eye	0.15 mSv (15 rem)
Gonads	0.5 mSv (50 rem)
Whole body	0.05 mSv (5 rem)
Pregnant women	0.005 mSv to fetus (0.5 rem)

Data from the National Council on Radiation Protection and Measurements (NCRP). Report No. 116. *Limitation of exposure to ionizing radiation*. Bethesda, MD: NCRP Publications; 1993.

serious radiation-related skin injuries resulting from some fluoroscopic procedures. Today's equipment and techniques have reduced the risks of radiation exposure dramatically. Radiation exposure during a typical epidural steroid injection carried out with fluoroscopy and assuming the practitioner is at least 1 m from the x-ray tube has been reported to be as low as 0.03 mR. In contrast, the typical entrance skin exposure during fluoroscopy ranges from 1 to 10 R per minute. A typical single chest radiograph leads to a skin entrance exposure of 15 mR. Thus, 1 minute of continuous fluoroscopy at 2 R per minute is equivalent to the exposure during 130 chest radiographs. Minimum target organ radiation doses that lead to pathologic effects are shown in Table 2-3. Radiation dermatitis still occurs in fluoroscopists with unknown long-term consequences. Estimates of the relative radiation dose to the patient during use of fluoroscopy in comparison to other common diagnostic radiologic procedures are shown in Table 2-4.

Minimizing Patient Radiation Exposure

Minimize Dose and Time

Practitioners using ionizing radiation should adhere to the ALARA principle ("As Low As Reasonably Achievable"), combining optimal technique and shielding to minimize patient and personnel exposure. Because no dose of ionizing radiation is without biologic effects and can be considered absolutely safe, radiographs should be used only when necessary, and the dose and exposure time should be limited. Dose is a factor of both the number of x-rays (proportional to mA × seconds of exposure) and the energy of the x-rays (proportional to kVp). Modern fluoroscopy units employ ABC, which automatically controls mA and kVp settings to optimize brightness and contrast while minimizing dose. However, if you choose to use fluoroscopy in the manual mode (e.g., to increase penetration in an obese patient), the kVp should be increased while minimizing mA. For an equivalent increase in exposure, the mA must be doubled, whereas the kVp must be raised only 15%. When using ABC mode, the only element under practitioner control is the exposure time, and this should be held to the minimum required to complete the procedure. Short pulses of exposure rather than continuous exposure should be employed whenever feasible. Continuous fluoroscopy in the form of movies (cineradiography) and digital subtraction exposes patients to markedly higher doses than brief spot images (Table 2-4). Many modern units include an option termed *pulsed* mode for use in place of a continuous technique. This mode substitutes brief, periodic spot images separated by an interval without exposure (e.g., a new image is displayed one to two times per second). Use of this mode in place of continuous fluoroscopy can reduce overall exposure dramatically and is suitable for procedures in the pain clinic where continuous fluoroscopy is needed (e.g., while threading an epidural catheter or spinal cord stimulation lead; see Figure 2-2).

Table 2–3
Minimum Target Organ Radiation Doses to Produce Organ Pathologic Effects

Organ	Dose (rad)	Dose (Gy)	Results
Eye lens	200	2	Cataract formation
Skin	500	5	Erythema
	700	7	Permanent alopecia
Whole body	200–700	2–7	Hematopoietic failure (4–6 wk)
	700–5,000	7–50	Gastrointestinal failure (3–4 d)
	5,000–10,000	50–100	Cerebral edema (1–2 d)

Table 2–4

Comparative Radiation Doses for Common Diagnostic X-ray and Fluoroscopic Procedures

X-ray—chest	0.1 mSv (10 mrem)
X-ray—mammography	0.42 mSv (42 mrem)
X-ray—skull	0.1 mSv (10 mrem)
X-ray—cervical spine	0.2 mSv (20 mrem)
X-ray—lumbar spine	6 mSv (600 mrem)
X-ray—upper GI	6 mSv (600 mrem)
X-ray—abdomen (kidney/bladder)	7 mSv (700 mrem)
X-ray—barium enema	8 mSv (800 mrem)
X-ray—pelvis	0.6 mSv (60 mrem)
X-ray—hip	0.7 mSv (70 mrem)
X-ray—dental bitewing/image	0.005 mSv (0.5 mrem)
X-ray—Extremity (hand/foot)	0.005 mSv (0.5 mrem)
Fluoroscopy,[a] intermittent, e.g., for lumbar transforaminal or facet injection	0.007–0.03 mSv (0.7–3 mrem)
Fluoroscopy,[a] high dose	(three- to sixfold the radiation exposure of standard dose)
Fluoroscopy,[a] continuous, pulsed mode	0.2–1 mSv/min of exposure (20–100 mrem/min of exposure)
Fluoroscopy,[a] continuous	2–10 mSv/min of exposure (200–1,000 mrem/min of exposure)
Fluoroscopy,[a] continuous, high dose	10–20 mSv/min of exposure (1,000–2,000 mrem/min of exposure)
Fluoroscopy,[a] continuous, digital subtraction	20–40 mSv/min of exposure (2,000–4,000 mrem/min of exposure)
CT—head	2 mSv (200 mrem)
CT—chest	7 mSv (700 mrem)
CT—abdomen/pelvis	10 mSv (1,000 mrem)
CT—extremity	0.1 mSv (10 mrem)
CT—angiography (heart)	20 mSv (2,000 mrem)
CT—angiography (head)	5 mSv (500 mrem)
CT—spine	10 mSv (1,000 mrem)
CT—whole body	10 mSv (1,000 mrem)
CT—cardiac	20 mSv (2,000 mrem)

Data adapted from American Nuclear Society. Radiation dose chart. Available at *http://www.new.ans.org/pi/resources/dosechart/* (accessed January 9, 2011).
[a]Fluoroscopy exposure values are approximate and vary widely based on the region of the body examined and the body habitus of each patient. The values presented are extrapolated from data provided by Philips Medical Systems for the Pulsera 9-inch mobile C-arm and the following references: Wagner AL. Selective lumbar nerve root blocks with CT fluoroscopic guidance: technique, results, procedure time, and radiation dose. *AJNR Am J Neuroradiol.* 2004;25:1592–1594; and Mahesh M. The AAPM/RSNA physics tutorial for residents. Fluoroscopy: patient radiation exposure issues. *Radiographics.* 2001;21:1033–1045.

Optimize the Position of the X-ray Tube

Radiation exposure to the patient is best minimized by ensuring optimal distance between the patient and the x-ray tube (Fig. 2-3). When the x-ray tube is positioned close to the patient, a small area of skin will be exposed to radiation, but due to the close proximity of the x-rays, the dose that this smaller area will be exposed to is much higher. When the tube is positioned further from the patient, a larger area is exposed to a smaller dose of radiation. The x-ray tube should be positioned as far from the patient as possible, without including unnecessary structures in the field of view.

Employ Shielding Whenever Possible

The use of lead shielding can prevent exposure of regions adjacent to the area that is to be imaged from being exposed to any ionizing radiation. Small lead shields can be placed on the table underneath the patient, directly in front of the x-ray beam *before* it penetrates the patient to protect the gonads or the fetus, in the rare instance where fluoroscopy is necessary in a pregnant patient. Although lead shields should be readily available in the fluoroscopy suite, they are seldom practical for use during image-guided injection of the lumbosacral spine because the shield would lie directly in the path of the structures to be imaged.

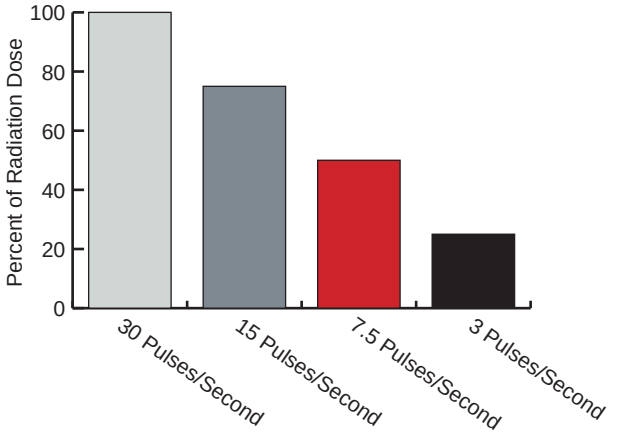

Figure 2-2.
Effect of pulsed fluoroscopy on radiation dose (patient entrance skin dose). For example, by switching from continuous fluoroscopy (typically 30 pulses per second) to 15 pulses per second, dose savings of nearly 22% are achieved. (Adapted from Mahesh M. The AAPM/RSNA physics tutorial for residents. Fluoroscopy: patient radiation exposure issues. *Radiographics*. 2001;21:1033–1045, with permission.)

Employ Collimation

Fluoroscopy units have built-in mechanisms that allow the emitted x-ray beam to be reduced in size and changed in shape (or *collimated*) so the area of the patient exposed is minimized. All units have both linear and circular collimation. Linear collimation employs shutters that can be moved in from either side of the exposure field and is helpful in imaging long, thin structures such as the spine (Fig. 2-4). Circular or "iris" collimation can be helpful when a small, circular area is to be imaged (Fig. 2-5). Collimation is also helpful in optimizing image quality because the ABC mode attempts to optimize the image quality by taking into account the exposure needed across the entire field of exposure; it is often difficult to visualize radiodense and radiolucent areas in the same image. Useful employment of collimation can exclude areas of greatly varying radiodensity to improve image quality by reducing the range of densities included in the field. Two good examples are imaging of the thoracic spine, where the large density differences between the spine and the adjacent air-filled lungs can make it difficult to see the bony elements of the spine with any resolution. Linear collimation

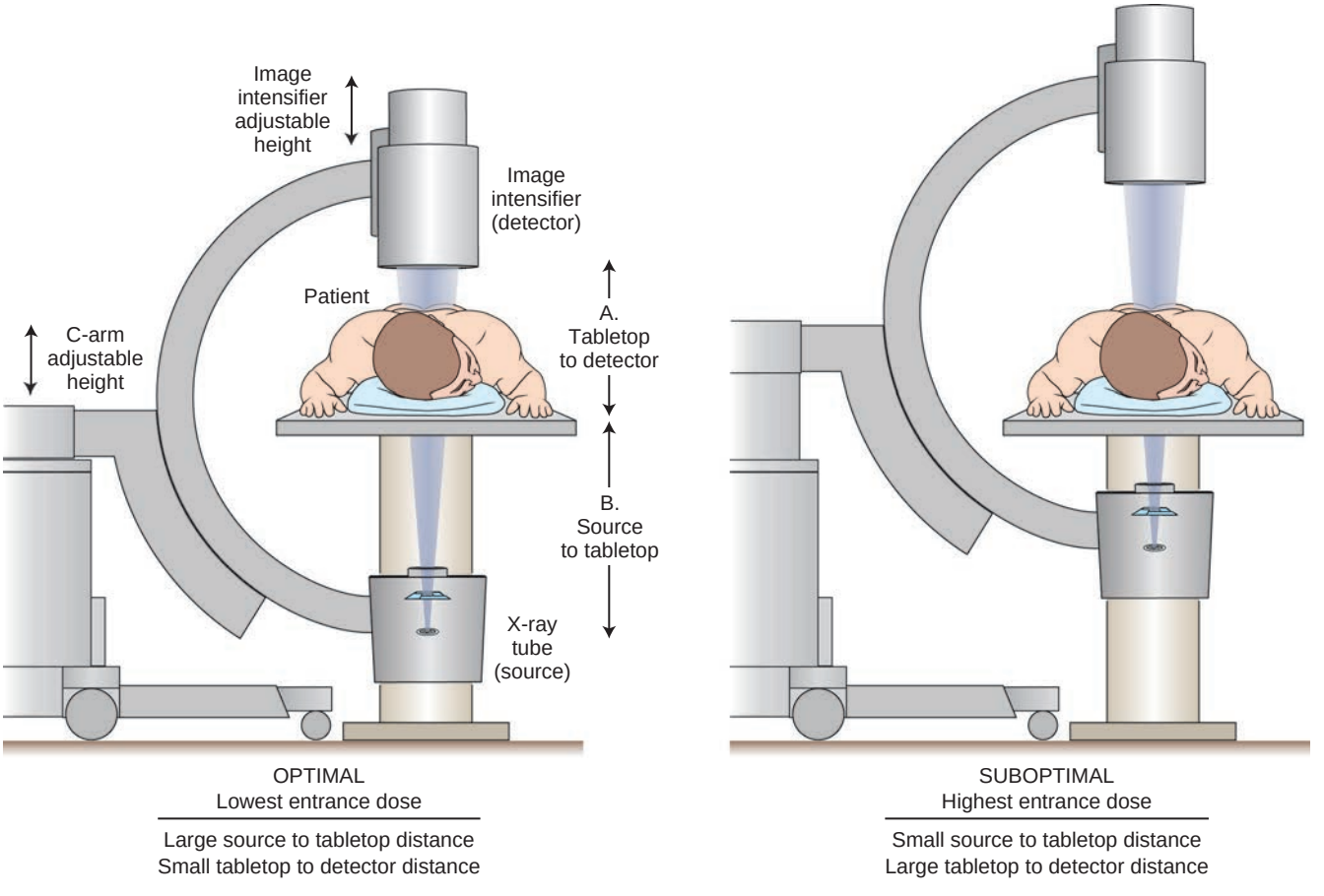

Figure 2-3.
Optimal spacing between the x-ray source and the patient to minimize radiation exposure.

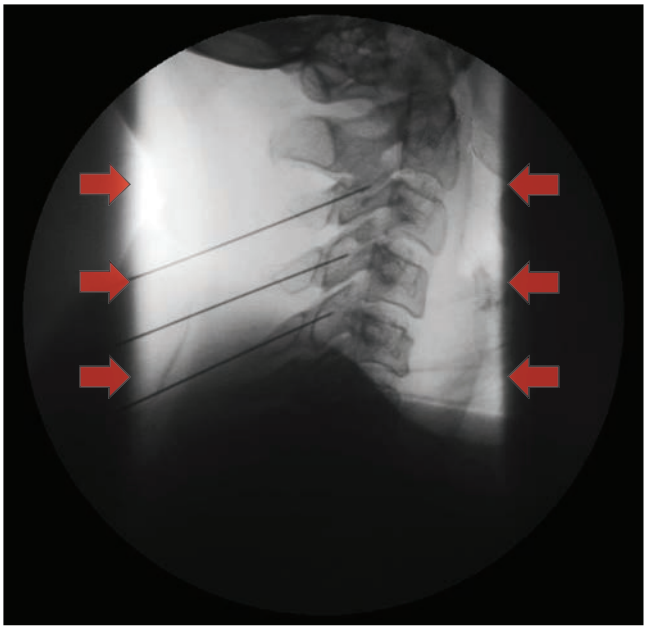

Figure 2-4.
Use of adjustable (linear) collimator to decrease radiation exposure to the patient, while improving image resolution by decreasing the range of tissue density included in the image field.

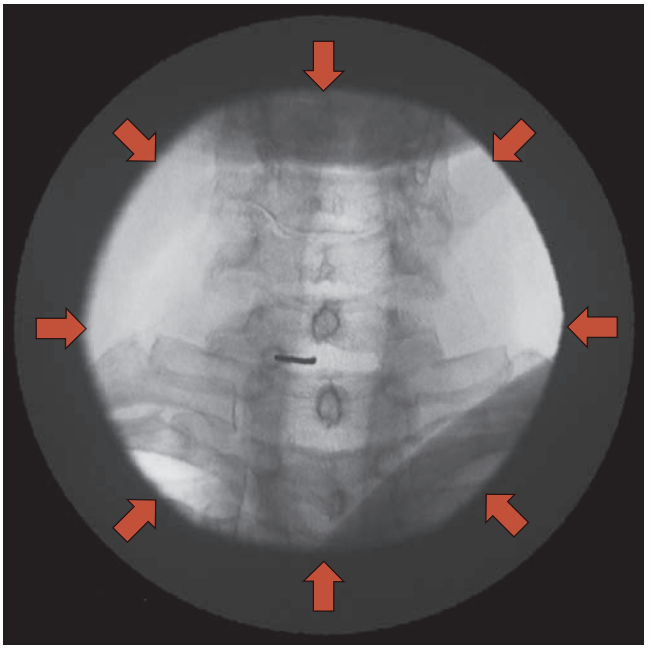

Figure 2-5.
Use of adjustable (iris) collimator to limit the field to the area of interest reduces radiation exposure to the patient and improves image resolution by decreasing the range of tissue density included in the image field.

to limit the field to the spine itself will dramatically improve the image quality. Likewise, imaging in the cervical spine is fraught with the same difficulties when the air on either side of the neck is included in the x-ray field (see Fig. 2-4). Either linear collimation or circular collimation (see Fig. 2-5) can be used to limit the field to the area of interest, improving image quality and reducing radiation exposure. Modern fluoro units may also allow for *magnification* of the image by electronically magnifying the area of interest. Magnification allows better visualization of a smaller area but leads to increased radiation exposure as the system increases output to compensate for losses in gain. To minimize the dose to the patient, the largest field of view, in conjunction with the tightest collimation, should be employed.

Minimizing Practitioner Exposure

Employ Proper Shielding

Only the personnel needed to conduct the procedure should be in the fluoroscopy suite. All personnel should be shielded with lead aprons *before* use of fluoroscopy begins. The practitioner using the fluoroscopy unit should alert everyone in the room that he or she is about to begin and ensure that personnel are shielded. Routine use of thyroid shields can minimize the long-term risk of thyroid cancer. Although protective lead gloves can reduce the exposure of the hands to radiation, they can produce a false sense of security. When leaded gloves are employed and the practitioner's hands are in the field of exposure, units with ABC will increase their output to compensate for the radiodense leaded gloves, and negate their protective effects. Techniques that eliminate the practitioner's hands from direct exposure within the x-ray field should be used at all times. Protective eyeglasses are available that dramatically reduce eye exposure during fluoroscopy; leaded eyewear is recommended for practitioners who accumulate monthly readings on collar badges above 400 mrem (4 Sv). Levels of exposure in this range are typically encountered only in areas where continuous cineangiography is conducted frequently (e.g., the cardiac catheterization laboratory).

Practitioner Position

The practitioner must understand the geometry of the radiation path as it passes from the x-ray tube to the image intensifier and adopt positions that minimize his or her exposure during fluoroscopy (Fig. 2-6). The dose drops proportionally to the square of the distance from the x-ray source. Thus, standing as far from the x-ray tube as practical is the first means to minimize exposure. Using an intravenous extension tube and taking a step back from the table during periods where contrast is injected under continuous or live fluoroscopy will reduce exposure. When the x-ray tube is rotated to obtain a lateral image, the practitioner should step completely away from the table beneath the x-ray tube and out of the path of the x-ray beam or move to the side of the table of the image intensifier. Inverting the C-arm so the x-ray tube is above the table and the image intensifier is below the table is a means used by some practitioners

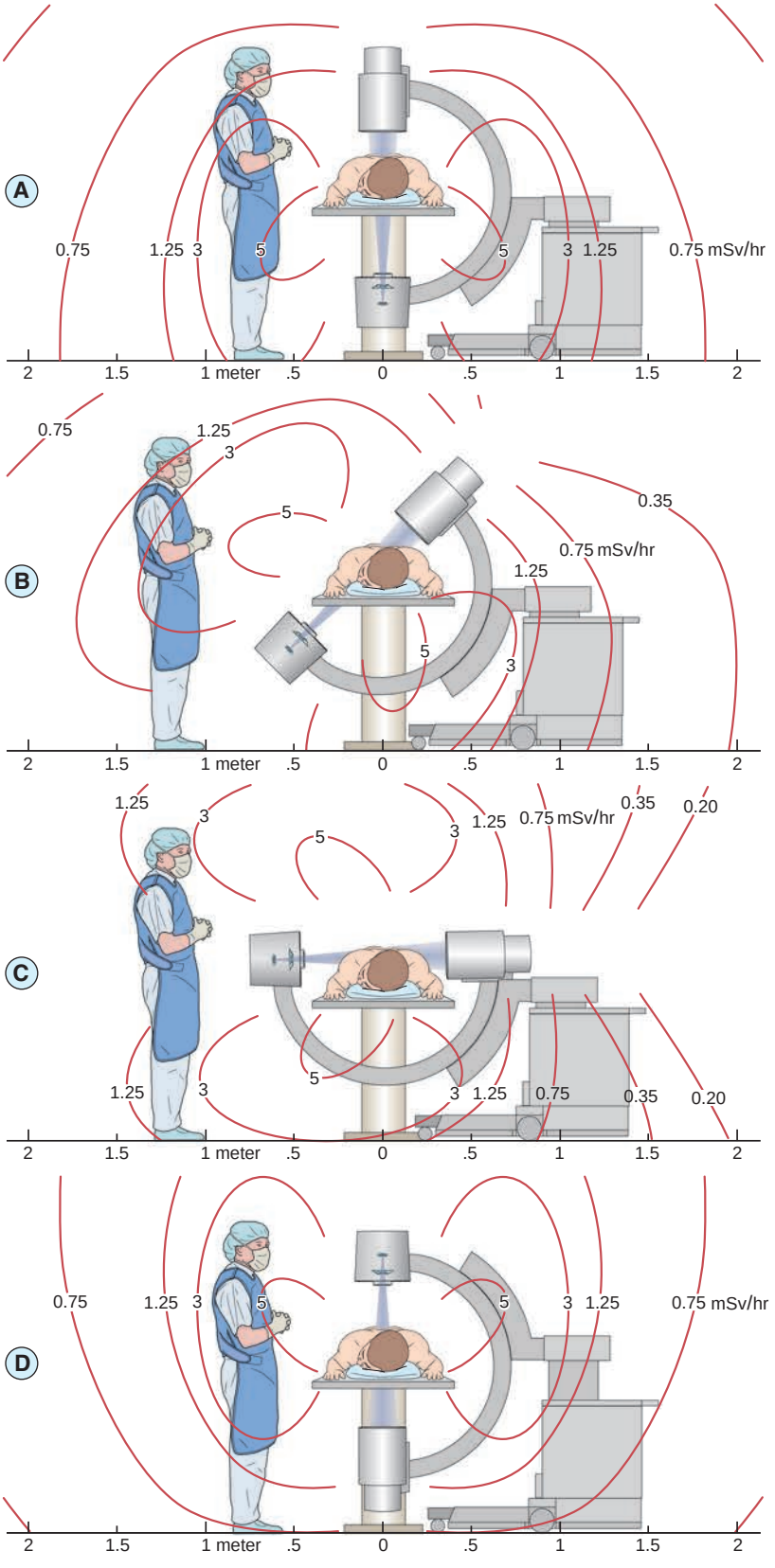

Figure 2-6.
Radiation exposure dosage during fluoroscopy. **A:** During routine use in the anterior-posterior plane, the x-ray tube (source) should be positioned below the patient and the detector above the patient to minimize radiation exposure to both the patient and the practitioner. **B:** The oblique projection results in markedly increased exposure to the practitioner. **C:** During use in the lateral projection, the practitioner should step completely behind the x-ray tube (source) to minimize radiation exposure. When it is necessary to work close to the patient during lateral fluoroscopy, the practitioner should step away from the x-ray tube and move to the side of the table opposite the x-ray tube to minimize exposure. **D:** Radiation exposure to both the patient and the practitioner is dramatically increased when the x-ray tube (source) is inverted above the patient. Some practitioners invert the C-arm to allow for more extreme lateral angle (e.g., rotation beyond 35 to 45 degrees oblique to the side opposite the C-arm is not possible without inverting the C-arm on some units). Radiation exposure can be reduced by rotating the patient on the table and keeping the x-ray source below the table. (Adapted with the assistance of Philips Medical Systems USA, Seattle, WA, based on radiation exposure data for the Pulsera 9-inch mobile C-arm.)

to increase the C-arm's range of lateral movement beyond the typical 45 to 55 degrees allowed by the unit. This practice dramatically increases exposure to both the patient and the practitioner by bringing them in close proximity to the x-ray source.

Optimizing Image Quality

Modern fluoroscopy units use ABC, which automatically adjusts mA and kVp to optimize image brightness and contrast while minimizing radiation exposure. These controls can be adjusted separately. Increased kVp produces x-rays of higher energy that penetrate without attenuation, thus the resulting image is brighter with less contrast between different tissues, thereby reducing image detail. The clarity of small structures, or image detail, can be improved by lowering kVP, reducing the distance between the patient and the image intensifier, and by using collimation to limit the field of exposure to only those structures of interest. Fluoroscopic images also have less sharpness at the periphery of the image due to a fall off in brightness and spatial resolution, a phenomenon called *vignetting*. Placing the structure of interest in the center of the image will yield maximum image detail. Finally, *pincushion distortion* occurs toward the periphery of the image because the x-rays emanate from a spherical surface and are detected on a flat surface. This results in an effect much like a fisheye camera lens with a splaying outward of objects toward the periphery of the image. This can lead to particular difficulties when attempting to advance a needle using a coaxial technique if the needle is toward the periphery of the image. Within the past several years, several manufacturers have developed electronic flat plate detectors to replace conventional image intensifiers. Flat plate detectors employ a grid-like electronic detector that eliminates both vignetting and pincushion distortion, providing optimum image quality from the center to the very peripheral portions of each image. Flat plate digital detectors are rapidly replacing traditional image intensifiers. Digital flat plate detectors are capable of dramatically reducing radiation exposure while improving image quality and eliminating the distortion of the image at the periphery of the detector that occurs with traditional image intensifiers.

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CHAPTER 3

Radiographic Contrast Agents

OUTLINE

Overview

Iodine is the only element that has proven satisfactory as an intravascular radiographic contrast medium (RCM). Iodine produces the radiopacity while the other portions of the molecule act as the carriers for the iodine, improving solubility and reducing the toxicity of the final compound. Organic carriers of iodine are likely to remain in widespread use for the foreseeable future. During image-guided injection, injection of RCM can prove invaluable in determining the final location and distribution of the injectate (Figs. 3-1 to 3-3). Use of RCM can improve the safety of many techniques by allowing for detection of intravascular (Figs. 3-4 and 3-5), subdural (see Fig. 3-2), or intrathecal (see Fig. 3-3) needle location *before* a local anesthetic or steroid is placed.

Pharmacology

Currently, there are four chemical varieties of iodinated RCM in widespread use: ionic monomers, nonionic monomers, ionic dimers, and nonionic dimers. On intravascular injection, all four are redistributed rapidly via capillary permeability to the extravascular space, they do not enter the interior of blood or tissue cells, and they are rapidly excreted, more than 90% eliminated via glomerular filtration within 12 hours of administration. None of the four varieties have marked pharmacologic actions. All RCM agents come in a range of concentrations that vary in their radiopacity and viscosity. Because iodine is the element that is responsible for the radiopacity, the iodine concentration in milligrams per milliliter represents the radiopacity. The nonionic monomers are now used almost exclusively in pain medicine; the nonionic dimers offer increased radiopacity at low osmolar concentrations, but are not in widespread clinical use and offer questionable clinical advantages.

There are several important chemical properties that determine the characteristics of RCM in clinical use. *Osmolality* depends on the number of particles of solute in solution and is highest for the ionic contrast agents. Adverse reactions, particularly discomfort on injection, have been reduced dramatically with the advent of low-osmolar RCM. Contrast media with osmolality below 500 mOsm per kg of water are virtually painless. *Radiopacity* depends on the iodine concentration of the solution and, therefore, on the number of iodine atoms per molecule and the concentration of the iodine-carrying molecule in solution. Digital subtraction electronically enhances the image, reducing the amount of contrast medium needed by a factor of twofold to threefold. With use of digital subtraction, RCM with as little as 150 to 200 mg per mL of iodine can be used even for intra-arterial use. Ionic molecules dissociate into cation and anion in solution. Nonionicity, or a molecule that does not dissociate in solution, is essential for myelography or use along the neuraxis, where inadvertent placement within the CSF is possible during injection. The chemical properties of common RCM used in clinical practice are compared in Table 3-1.

The most frequently used ionic monomers are diatrizoate (Urografin), iothalamate (Conray), and metrizoate (Isopaque). All ionic monomers are the salts of meglumine or sodium as the cation and a radiopaque tri-iodinated fully substituted benzene ring as the anion. The ionic monomers are still used for intravenous pyelography and similar applications; however, they have been completely replaced by the low-osmolar, nonionic RCM for many applications, including intrathecal administration. The most common nonionic monomers in clinical use include iodixanol (Visipaque), iohexol (Omnipaque), iopamidol (Isoview), and ioversol (Optiray); only iohexol and iopamidol are labeled for intrathecal use. The nonionic monomers appeared in the 1970s, and now represent the most common RCM in clinical use. They are more stable in solution and less toxic than the ionic monomers.

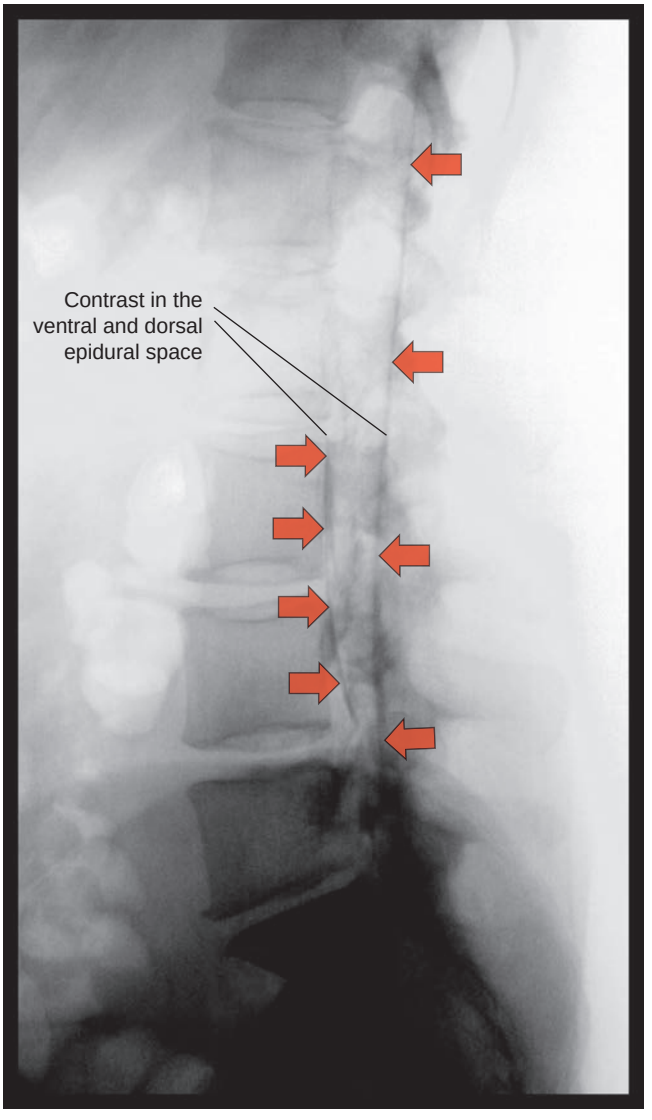

Figure 3-1.
Epidural contrast injection. This typical lateral lumbar epidurogram demonstrates the "double-line" or "railroad track" appearance of radiographic contrast in the anterior and posterior epidural space (*arrows*). (Reprinted from Rathmell JP, Torian D, Song T. Lumbar epidurography. *Reg Anesth Pain Med*. 2000;25:541, with permission.)

Adverse Reactions to Radiographic Contrast Media

Modern contrast agents have reduced, but not eliminated, the risk of adverse reactions. To minimize the risk, RCM should be used in the smallest concentrations and in the smallest total dose that will allow adequate visualization. Adverse reactions associated with RCM can be divided into idiosyncratic anaphylactoid reactions, nonidiosyncratic reactions, and combined reactions. The risk of adverse reactions is significantly greater with use of high-osmolar, ionic agents when compared with low-osmolar, nonionic agents. This discussion is limited to the risks associated with low-osmolar, nonionic agents because they are used almost exclusively in pain medicine applications.

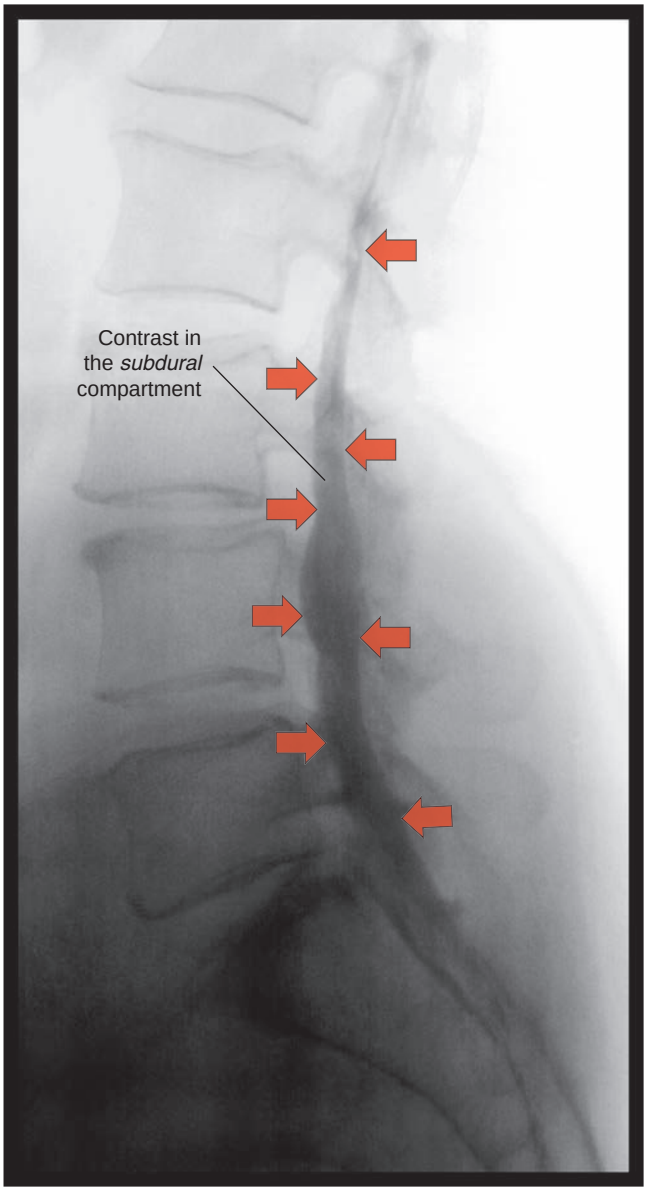

Figure 3-2.
Subdural contrast injection. Injection of contrast in the subdural (epiarachnoid) space is recognized by the regular posterior border and irregular anterior border of loculated contrast collection on this lateral radiograph of the lumbar spine. The contrast is contained posteriorly by the dural membrane, but extends only partially anteriorly, as it is contained by the thin arachnoid membrane. Compare with Figure 3-3, subarachnoid administration, where the contrast extends all the way from the posterior to the anterior limits of the thecal space. Although the contrast does not extend to the anterior portion of the thecal sac, it is not limited to the epidural space. (Reprinted from Ajar A, Rathmell JP, Mukerji S. The subdural compartment. *Reg Anesth Pain Med*. 2002;27:73, with permission.)

Idiosyncratic Anaphylactoid Reactions

Idiosyncratic reactions are the most feared and most serious complications associated with RCM. At present, we cannot predict or prevent this type of reaction reliably, and they occur without warning. These reactions usually begin within 5 minutes of injection, and may be mild and self-limited or

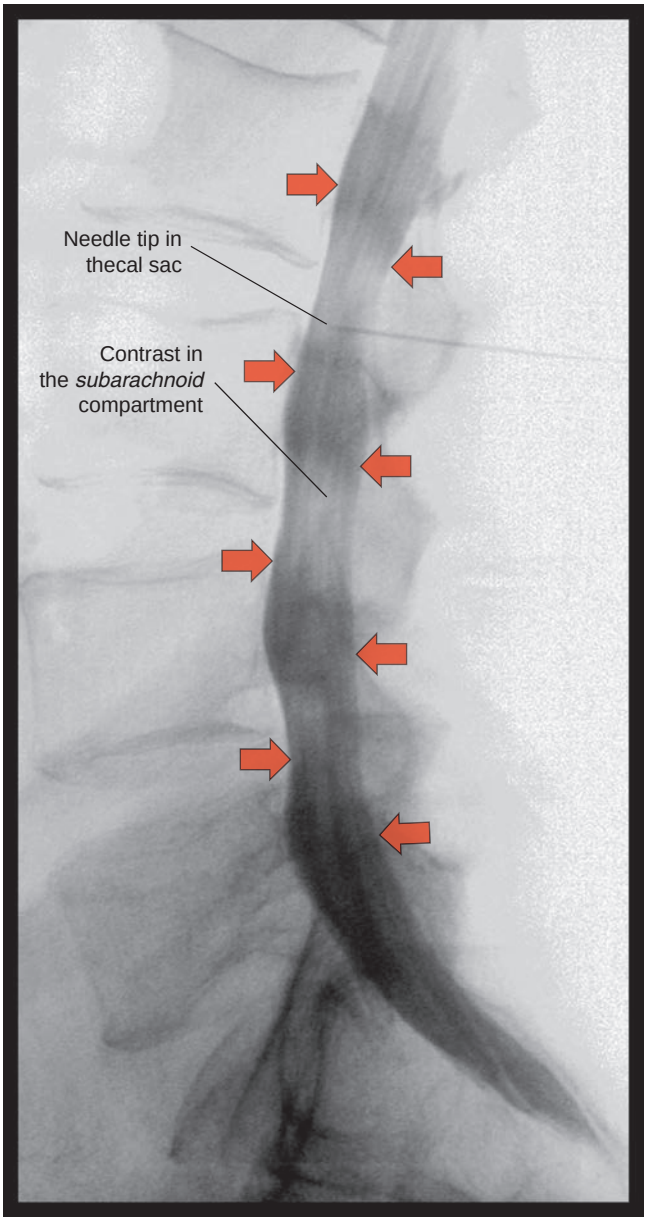

Figure 3-3.
Subarachnoid (intrathecal) contrast injection. This typical myelogram demonstrates contrast within the thecal sac (*arrows*) on this lateral radiograph of the lumbar spine. The spinal cord and exiting nerve roots are visible as hypodense regions within the contrast collection. (Reprinted from Rathmell JP, Torian D, Song T. Lumbar epidurography. *Reg Anesth Pain Med*. 2000;25:543, with permission.)

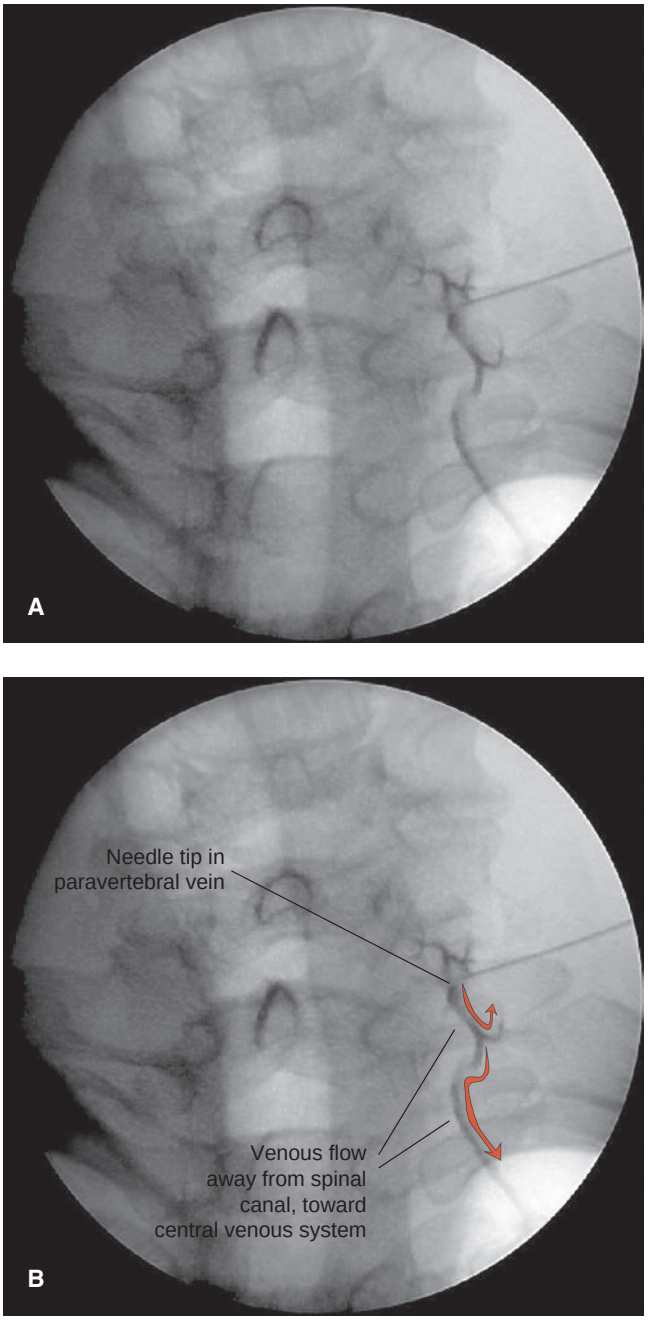

Figure 3-4.
Intravenous contrast injection. **A:** Intravenous contrast injection is typically not seen on still images because the contrast material is rapidly diluted in the bloodstream. During real-time or live fluoroscopy, intravenous contrast injection appears as in this anterior-posterior radiograph of the cervical spine taken during cervical transforaminal injection. The contrast can be seen flowing away from the spinal canal and toward the central venous circulation with the venous blood. **B:** Labeled image showing direction of contrast flow.

proceed rapidly to life-threatening cardiovascular collapse and death. The risk of anaphylactoid reaction is increased in patients with previous reaction to RCM (sixfold), in asthmatics (eightfold), in allergic and atopic patients (fourfold), and in those with advanced heart disease (threefold) (Table 3-2).

Nonidiosyncratic Anaphylactoid Reactions

Nonidiosyncratic reactions can be divided into chemotoxic reactions (chemical reactions to the iodine-carrying molecule) and osmotoxic reactions (those caused by high osmolality of the contrast medium). These nonidiosyncratic reactions are dose dependent; therefore, this type of reaction should be exceedingly rare in patients receiving the small volumes of RCM required to facilitate needle localization during image-guided pain treatment.

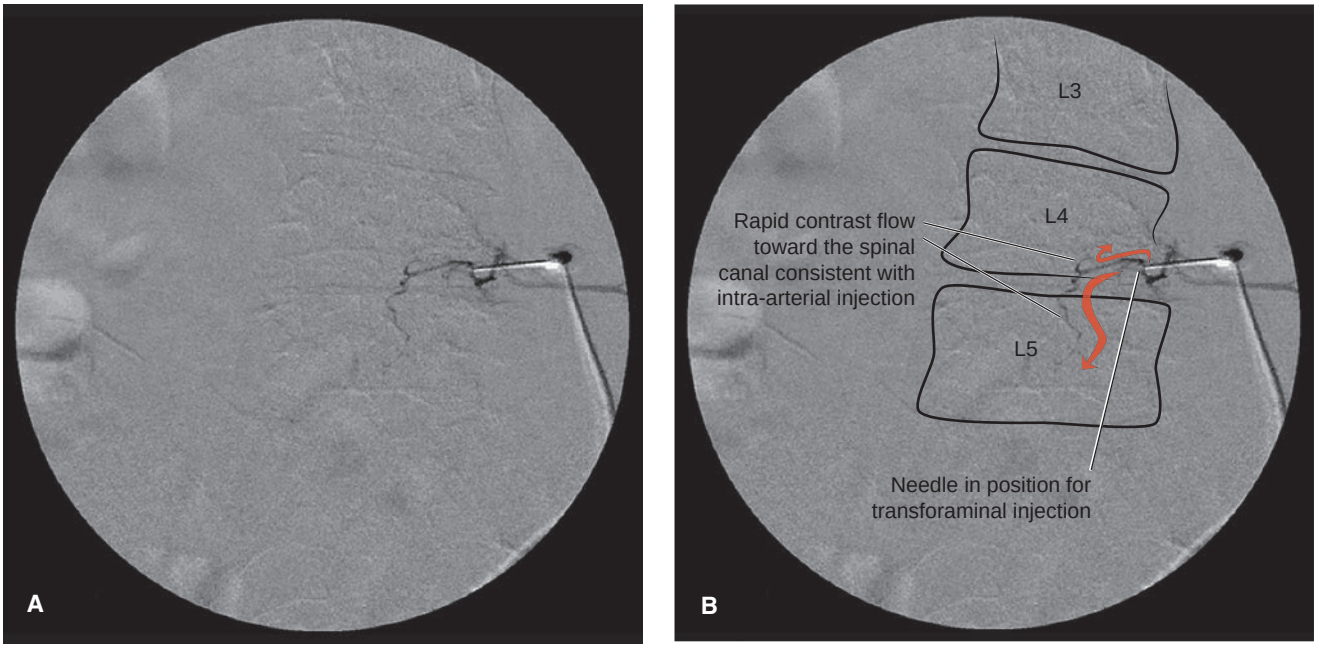

Figure 3-5.
Intra-arterial contrast injection (digital subtraction). **A:** Intra-arterial contrast injection is typically not seen on still images because the contrast material is rapidly diluted in the bloodstream. During real-time or live fluoroscopy, intra-arterial contrast injection appears as in this anterior-posterior digital subtraction radiograph of the lumbar spine taken during lumbar transforaminal injection. The contrast can be seen flowing toward the end organ (in this image, toward the lumbar spinal cord) with the arterial blood. Use of digital subtraction cineradiography allows for detection of intravascular injection with small doses of radiographic contrast material. **B:** Labeled image showing direction of contrast flow.

Chemotoxic reactions are rare and may result in direct organ toxicity and include cardiac (direct and prolonged decrease in cardiac contractility), neurologic (seizures), and renal toxicity (oliguria, impaired creatinine clearance, and reduced glomerular filtration rate that may progress to acute renal failure).

Osmotoxic reactions were much more common with the high-osmolar contrast media, where the osmolality of the RCM can reach several times that of physiologic osmolality of 300 mOsm per kg H_2O (see Table 3-1). Osmotoxic reactions have been dramatically reduced with the advent of low-osmolar, nonionic agents such as iohexol and should be exceedingly rare after administration of the small volumes used in pain medicine applications. Hyperosmolar reactions include erythrocyte damage (hemolysis), endothelial

Table 3–1
Comparison of Common Radiographic Contrast Agents Used in Clinical Practice[a]

Chemical Composition	Trade Name	Iodine (mg/mL)	Osmolality (mOsm/kg H_2O)	Viscosity (cps @ 37°C)	RCM Agent Type
Sodium/meglumine diatrizoate 30%	Urografin 150	146	710	1.4	Ionic, high-osmolar
Sodium/meglumine diatrizoate 67%	Urografin 325	325	1,650	3.3	Ionic, high-osmolar
Iohexol 180 mg/mL	Omnipaque 180	180	360	2.0	Nonionic, low-osmolar
Iohexol 300 mg/mL	Omnipaque 300	300	640	6.1	Nonionic, low-osmolar
Iopamidol 41%	Isovue 200	200	413	2.0	Nonionic, low-osmolar
Iopamidol 61%	Isovue 300	300	616	4.0	Nonionic, low-osmolar

RCM, radiographic contrast media.
[a]The ionic, high-osmolar agent diatrizoate and the nonionic, low-osmolar agents iohexol and iopamidol. Iohexol and iopamidol are commonly used in image-guided pain treatment. These agents provide a nonionic, low-osmolar RCM that balances a low risk of adverse reaction, safety for intrathecal use, and sufficient radiopacity for identifying intravascular and intrathecal placement.

Table 3–2
Incidence of Severe Adverse Drug Reactions

Clinical History	Severe ADR (%)[a]
No history of allergy or previous ADR to RCM	0.03
Renal disease	0.04
Diabetes mellitus	0.05
Heart disease	0.10
History of allergy	0.10
Atopy	0.11
History of previous ADR to RCM	0.18
Asthma	0.23

ADR, adverse drug reaction; RCM, radiographic contrast media.
[a]ADR following intravenous injection of low-osmolar, nonionic RCM.
Katayama H, Yamaguchi K, Kozuka T, et al. Adverse reactions to ionic and non-ionic contrast media. A report from the Japanese Committee on the Safety of Contrast Media. *Radiology*. 1990;175:621–628.

damage (capillary leak and edema), vasodilation (flushing, warmth, hypotension, cardiovascular collapse), hypervolemia, and direct cardiac depression (reduced cardiac contractility). The relative incidence of various adverse reactions to RCM is listed in Table 3-3.

Recognition and Treatment of Reactions to Radiographic Contrast Media

Reactions can be generally grouped as mild, moderate, or severe. The incidence of these reactions following the small volumes of RCM used in pain medicine has not been reported, but the incidence following intravenous administration of larger volumes of contrast is given here. Mild reactions occur in 5% to 15% of those receiving intravenous contrast, and include flushing anxiety, nausea, arm pain, pruritus, vomiting, headache, and mild urticaria. These are generally mild and self-limiting, and require no specific treatment. Occasionally, an oral antihistamine (diphenhydramine 25 mg) can be useful in managing pruritus and anxiety. More serious reactions occur in 0.5% to 2% of those receiving intravenous contrast and include more pronounced severity of mild symptoms, as well as moderate degrees of hypotension and bronchospasm. Suggested treatments for moderate reactions are given in Table 3-4.

Severe reactions are life threatening, occur in <0.04% of those receiving intravenous RCM, and include convulsions, unconsciousness, laryngeal edema, severe bronchospasm, pulmonary edema, severe cardiac arrhythmias, and cardiovascular collapse. Treatment of these life-threatening reactions is urgent, necessitating the immediate availability of full resuscitation equipment and trained personnel, along with a practiced routine for responding to these rare events. The airway must be secured, and oxygen, mechanical ventilation, external cardiac massage, and electrical cardiac defibrillation must be administered as required. Epinephrine is the drug of choice for the treatment of anaphylaxis; the usual adult starting dose is 0.01 mg per kg (maximum of 0.5 mg) subcutaneously, intravenously, or intramuscularly. Death may ensue following this type of severe adverse reaction; the incidence is not known with accuracy, but likely lies between 1 per 14,000 and 1 per 170,000 intravenous administrations of RCM.

Table 3–3
Type and Relative Incidence of Adverse Drug Reactions

Patient Characteristics in Trial	
Total number of patients	163,363
Total ADRs	3.13%
Total severe ADRs	0.04%
Death	(1)
Symptoms	**% of ADR[a]**
Nausea	1.04
Heat	0.92
Vomiting	0.45
Urticaria	0.47
Flushing	0.16
Venous pain	0.05
Coughing	0.15
Dyspnea	0.04

ADR, adverse drug reaction.
[a]ADR following intravenous injection of low-osmolar, nonionic radiographic contrast media.
Adapted from Katayama H, Yamaguchi K, Kozuka T, et al. Adverse reactions to ionic and non-ionic contrast media. A report from the Japanese Committee on the Safety of Contrast Media. *Radiology*. 1990;175:621–628, with permission.

Prevention of Reactions to Radiographic Contrast Media

Recognition of the factors that predispose patients to adverse reactions when receiving RCM is the first step in prevention (see Table 3-2). The risk of reaction is increased in those with previous reaction to RCM (sixfold), in asthmatics (eightfold), in allergic and atopic patients (fourfold), and in patients with advanced heart disease (threefold). If there is any chance that the injectate will end up in the subarachnoid space, then a low-osmolar, nonionic contrast agent must be used. Infrequent deaths have been reported following the inadvertent intrathecal administration of ionic RCM. Most pain medicine practitioners have adopted the universal use of a low-osmolar, nonionic RCM in a moderate concentration (e.g., iohexol 180 mg per mL or iopamidol 41%) for all applications.

There is no known premedication regimen that can reliably eliminate the risk of severe reactions to RCM. The most common strategies suggested combine pretreatment with corticosteroids (e.g., oral prednisone 50-mg doses 12 and 2 hours before RCM administration) and antihistamines (e.g., oral diphenhydramine 50-mg doses 1 to 2 hours

Table 3–4

Suggested Treatment for Reactions to Radiographic Contrast Media of Moderate Severity

Adverse Reaction	Suggested Treatment
Urticaria	Diphenhydramine 25–50 mg PO, IM, or IV
Anxiety	Diazepam 5–10 mg PO or midazolam 1–2 mg IV
Bronchospasm	Mild: Inhaled albuterol
	Severe:
	Hydrocortisone 100 mg IV
	Epinephrine 0.05–0.1 mg SQ, IM, IV
Anaphylaxis	Epinephrine 0.01 mg/kg SQ, IM, IV (maximum adult dose 0.5 mg)

before RCM administration). Some authors recommend addition of H_2-antagonists (e.g., oral ranitidine). This approach has proven to reduce the incidence of subsequent adverse reactions in those with a history of previous reaction to high-osmolar contrast agents; however, it is less clear whether prophylactic treatment is needed prior to use of low-osmolar, nonionic contrast agents such as iohexol. Patients believed to be at greater than usual risk are listed in Table 3-5. It has been our practice to avoid radiographic contrast altogether in those at elevated risk for adverse reaction. Most procedures in pain medicine can be carried out safely without use of radiographic contrast. In some instances (e.g., epidural placement), the location can be established using loss of resistance alone, and final needle position can be verified using anterior-posterior and lateral radiography without contrast. However, some injections should not be attempted without radiographic contrast injection (e.g., transforaminal injection); in this case, injection of contrast under live or real-time fluoroscopy (with or without digital subtraction) is the only means to detect intra-arterial needle location (see Fig. 3-5) and to prevent catastrophic injection of particulate steroid directly into critical vessels supplying the spinal cord. Performing interlaminar epidural steroid injection without contrast may well be a safe and effective alternative to transforaminal injection in the patient with greater than usual risk for adverse reaction to RCM.

Use of Gadolinium as an Alternative to Iodinated Radiographic Contrast Media

Gadolinium chelates, for example, gadopentate dimeglumine (Magnevist), are commonly used intravenous contrast agents used to enhance vascular structures during diagnostic magnetic resonance imaging. Gadolinium chelates also have an intrinsic ability to attenuate x-rays and have been used successfully in place of iodinated contrast media for angiography and spinal injections used in image-guided pain treatment. They have also been used as an alternative to iodinated contrast agents in patients with known contrast allergy. The radiopacity of gadolinium is less than that of iodinated contrast agents, resulting in a less conspicuous appearance on fluoroscopic images (Fig. 3-6A,B). Nonetheless, 1 to 3 mL

Table 3–5

Patients Considered at Greater than Usual Risk of Severe Adverse Reactions to Radiographic Contrast Media

Those with a history of previous adverse reactions to RCM (excluding mild flushing and nausea)
Asthmatics
Allergic and atopic patients
Cardiac patients with congestive heart failure, unstable arrhythmia, or recent myocardial infarction
Patients with diabetic nephropathy or renal failure of any etiology
Feeble, elderly patients
Those with severe, general debility or dehydration
Extremely anxious patients
Patients with specific hematologic or metabolic disorders (e.g., sickle cell anemia, polycythemia, multiple myeloma, pheochromocytoma)

RCM, radiographic contrast media.
Adapted from Grainger RG. Intravascular radiologic iodinated contrast media. In: Grainger RG, Allison DJ, Adam A, et al., eds. *Grainger & Allison's Diagnostic Radiology*. 4th ed. New York: Churchill Livingstone; 2001, with permission.

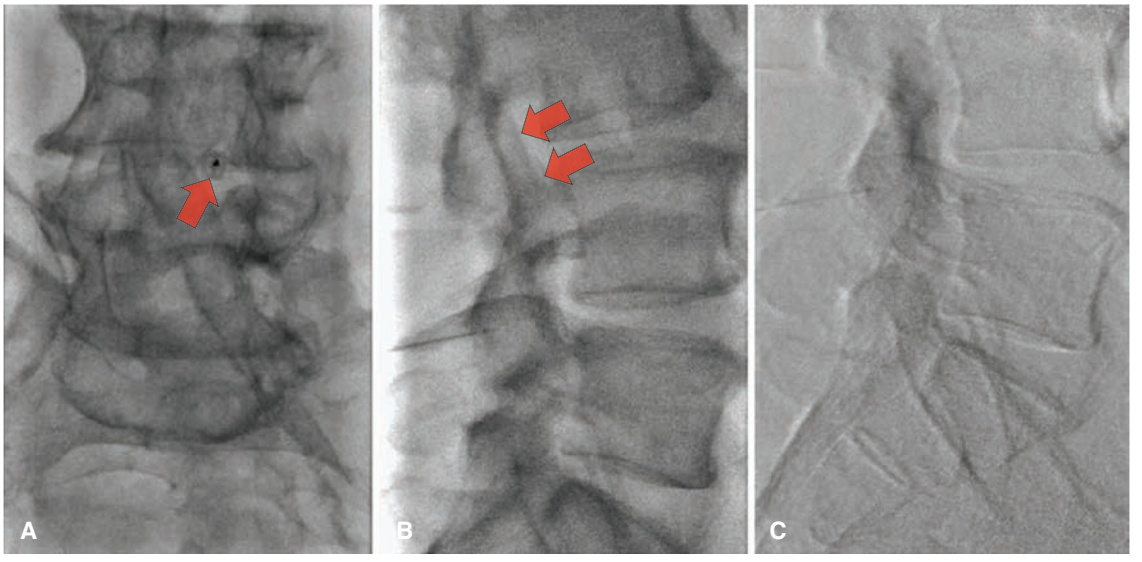

Figure 3-6.
Utility of digital subtraction fluoroscopy for visualization of the gadolinium-based contrast epidurogram. A nonselective epidural steroid injection performed in a 62-year-old male at L4 to L5 employing an interlaminar approach. **A:** Right anterior oblique projection of the lumbar spine shows a needle (*arrow*) inserted into the interlaminar space at L4 to L5. **B:** Conventional fluoroscopy permits visualization of an epidurogram in the lateral projection (*arrows*). **C:** Digital subtraction fluoroscopy in the lateral projection more clearly demonstrates the distribution of the gadolinium chelate in the epidural space. (Adapted from Shetty SK, Nelson EN, Lawrimore TM, et al. Use of gadolinium chelate to confirm epidural needle placement in patients with an iodinated contrast reaction. *Skeletal Radiol.* 2007;36:301–307, with permission.)

of undiluted gadopentate dimeglumine (Magnevist) has been used successfully and reliably for identification of the epidural space; the visualization can be further enhanced through use of digital subtraction in combination with gadolinium (Fig. 3-6C). Limited experience with intrathecal administration of gadolinium chelates suggests that it is safe when administered directly within the CSF. Use of gadolinium-based contrast agents has been linked to the subsequent development of nephrogenic systemic fibrosis in patients with renal disease. The risk depends on the degree of renal dysfunction, dose of contrast agent, and severity of concomitant illness and varies from negligible in healthy patients up to 2% to 5% in select high-risk patients. Given the small dose of gadolinium used in most pain treatment applications, the risk of renal toxicity should be negligible, making gadolinium a viable and readily available alternative in those at risk of reaction to iodinated agents.

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CHAPTER 4

Pharmacology of Agents Used During Image-guided Injection

OUTLINE

Overview

The most common agents used during image-guided injection in the pain clinic are local anesthetics and adrenocortical steroids (glucocorticoids). Most injection techniques used in pain medicine are aimed at depositing a potent steroidal anti-inflammatory drug adjacent to a region where there is presumed to be inflammation causing pain. Local anesthetics are a core part of the armamentarium for anesthetizing the needle track during placement and producing neural blockade. In certain circumstances (e.g., neurolytic celiac plexus block for pain associated with intra-abdominal malignancy), neurolytic solutions are used to effect long-lasting or "permanent" neural blockade. In this section, we discuss the pharmacology of these drugs.

Pharmacology of Local Anesthetics

Mechanism of Action

Local anesthetics completely abolish neuronal signal transmission by binding reversibly within sodium channels on neuronal membranes. They produce dense sensory blockade in the region injected when infiltrated into the skin and subcutaneous tissues, or within the territory of the specific nerve when injected around a major peripheral nerve. When local anesthetics are injected along the neuraxis, they produce segmental anesthesia in a dermatomal distribution when placed in the epidural space, and profound sensory and motor block of the trunk and lower extremities when placed within the thecal sac. When large doses of local anesthetic are placed within the lumbar thecal sac or any local anesthetic is placed intrathecally at higher thoracic or cervical spinal levels, total spinal anesthesia can occur, heralded by sudden loss of consciousness, bradycardia, and hypotension.

Local Anesthetic Structure and Function

Local anesthetics have three basic building blocks: a lipophilic aromatic end (benzene ring), a hydrophilic tertiary amine end, and an intermediate chain connecting the two ends. The chemical connection between the intermediate chain and the aromatic end allows us to classify local anesthetics as either "esters" or "amides." Figure 4-1 illustrates these basic chemical building blocks. Amino amides are chemically more stable and have less potential for allergic reactions than the esters. The properties of amide and ester local anesthetics are compared in Table 4-1. The two most common agents used for image-guided injection are the amide local anesthetics, lidocaine and bupivacaine. Ropivacaine is another amino amide local anesthetic with a potency and duration similar to that of bupivacaine; preclinical data suggest that ropivacaine has significantly less cardiotoxicity when compared to racemic bupivacaine, but this has not translated into any measurable clinical difference in the safety of these two agents. The onset and duration of the common local anesthetics are illustrated in Figure 4-2.

Local Anesthetic Dose versus Site of Injection

The doses and expected distribution of neural blockade of local anesthetics are second nature to the anesthesiologist. Those with less experience using local anesthetics must gain some familiarity with their dosing and potential toxicities before attempting to use these drugs during image-guided injection. The typical doses of lidocaine and bupivacaine used to produce local anesthesia, peripheral nerve block, and epidural or spinal anesthesia are compared in Table 4-2.

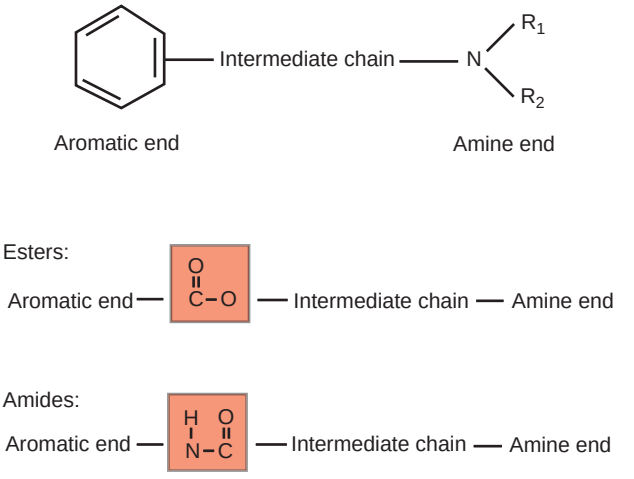

Figure 4-1.
Structure of the local anesthetic molecule. (Adapted from Viscomi CM. Pharmacology of local anesthetics. In: Rathmell JP, Neal JM, Viscomi CV, eds. *Requisites in Anesthesiology: Regional Anesthesia*. Philadelphia, PA: Elsevier Health Sciences; 2004:14, with permission.)

Table 4–1
Properties of Amide and Ester Local Anesthetic Agents

	Esters	Amides
Metabolism	Plasma cholinesterase	Hepatic
Serum half-life	Shorter	Longer
Allergic potential	Low	Very low
Specific drugs	Procaine, chloroprocaine, cocaine, tetracaine	Lidocaine, mepivacaine, bupivacaine, ropivacaine, etidocaine, prilocaine

Local Anesthetic Allergy

Local anesthetics have low allergic potential. The majority of "allergic reactions" reported by patients are misinterpretations of the cause of symptoms following local anesthetic injection. A frequent scenario reported by patients as "an allergy to local anesthetic" arises from use of local anesthetics in dental practice. On close questioning, the symptoms are usually attributable to intravascular injection of local anesthetic containing epinephrine as a vasoconstrictor (e.g., racing of the heart, palpitations, even a feeling of doom). Rarely are actual allergic manifestations (e.g., urticaria, bronchospasm, anaphylaxis) part of the history.

Local Anesthetic Toxicity

Local anesthetics are associated with life-threatening toxicities. As serum levels of local anesthetic rise, symptoms of excitation of the central nervous system appear, first in the form of tinnitus and dizziness followed by generalized seizures (Fig. 4-3). At higher serum levels, local anesthetics produce cardiac arrhythmias and cardiovascular collapse. Recommended maximal doses of local anesthetics are shown in Table 4-3.

It is important to know that even small doses of local anesthetic can have profound effects when injected in specific locations. Intrathecal injection of 150 mg of lidocaine or 20 mg of bupivacaine can lead to total spinal anesthesia, and the need for ventilatory support until the anesthetic level recedes. Likewise, direct intra-arterial injection of just a few milligrams of local anesthetic into the vertebral artery can cause immediate generalized seizures because the local anesthetic travels directly to the brain in high concentration. Any practitioner performing injection techniques with local anesthetics must be familiar with these toxicities and their management and work in a facility equipped to handle such adverse events.

Treatment of Local Anesthetic Systemic Toxicity

The American Society of Regional Anesthesia and Pain Medicine published a Practice Advisory on the treatment of local anesthetic systemic toxicity in 2010 (Table 4-4). This group of experts emphasizes the need to seek additional help and institute basic life support measures immediately upon any suspicion of local anesthetic systemic toxicity. Once the ventilation with 100% oxygen has been established, immediate cessation of seizure activity with a small dose of benzodiazepine should follow. Cardiac toxicity can rapidly lead to cardiac arrest, and cardiopulmonary resuscitation (CPR) must be initiated immediately; prolonged use of CPR is both necessary and warranted, given the time needed for metabolism and elimination of these agents. In recent years, remarkable reductions

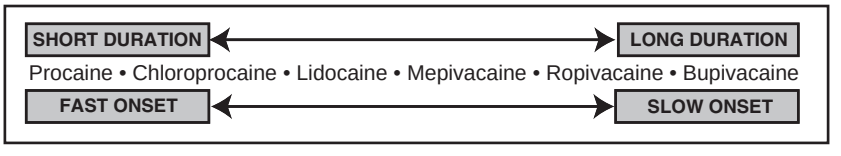

Figure 4-2.
Onset and duration of local anesthetics. (Adapted from Viscomi CM. Pharmacology of local anesthetics. In: Rathmell JP, Neal JM, Viscomi CV, eds. *Requisites in Anesthesiology: Regional Anesthesia*. Philadelphia, PA: Elsevier Health Sciences; 2004:17, with permission.)

Table 4–2

Typical Local Anesthetic Doses Used to Produce Neural Blockade[a]

	Typical Drug Dose	
Type of Block	**Lidocaine**	**Bupivacaine**
Local anesthesia (e.g., a 2–3 cm diameter area of skin)	10–40 mg (1–2 mL of 1%–2% solution)	2.5–10 mg (1–2 mL of 0.25%–0.50% solution)
Peripheral nerve block (e.g., lumbar selective nerve root block)	20–40 mg (1–2 mL of 2% solution)	5–10 mg (1–2 mL of 0.5% solution)
Epidural anesthesia (e.g., dense anesthesia for surgery on the lower extremity)	300–600 mg (20–30 mL of 1.5%–2% solution)	100–150 mg (20–30 mL of 0.5% solution)
Spinal anesthesia (e.g., dense anesthesia for surgery on the lower extremity)	50–100 mg (1–2 mL of 5% solution)	10–15 mg (1–2 mL of 0.825% solution)

[a]The drug doses shown are meant to illustrate the dramatic differences in drug dose required, depending on where the local anesthetic is placed. Even small doses of local anesthetic placed within the thecal sac (spinal anesthesia) can produce profound sensory and motor block that extends to the upper torso and, at higher doses, to the head and neck (total spinal anesthesia).

in systemic toxicity have been demonstrated in experimental animals that have been given infusions of lipid emulsion following cardiac arrest induced by systemic administration of local anesthetics, a practice termed "lipid rescue". Based on the improvement in survival demonstrated in animal studies and the lack of major adverse effects associated with intravenous administration of lipid emulsion, the use of lipid rescue has been rapidly moved to use in emergent treatment of local anesthetic toxicity (Table 4-4). Finally, a number of case reports detail successful resuscitation and full recovery when cardiopulmonary bypass is instituted soon after cardiac arrest caused by local anesthetic systemic toxicity.

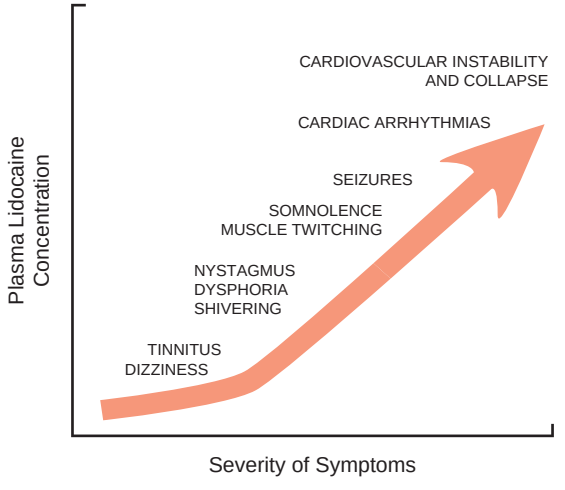

Figure 4-3.
Patient symptoms with progressive rise in plasma lidocaine levels. This symptom progression—from dizziness and tinnitus to generalized seizures followed by cardiovascular collapse at the highest plasma concentrations—occurs reliably with lidocaine. However, cardiovascular instability and collapse may present without the appearance of other signs or symptoms following intravascular injection of the more potent amide local anesthetic bupivacaine. (Adapted from Viscomi CM. Pharmacology of local anesthetics. In: Rathmell JP, Neal JM, Viscomi CV, eds. *Requisites in Anesthesiology: Regional Anesthesia*. Philadelphia, PA: Elsevier Health Sciences; 2004:22, with permission.)

Pharmacology of Steroid Preparations

The pharmacology of the corticosteroids is complex, and this group of drugs affects almost all body systems. In pharmacologic doses (e.g., exceeding the rate of endogenous steroid production of ~20 mg per day of hydrocortisone or the equivalent), glucocorticoids decrease inflammation by stabilizing leukocyte lysosomal membranes; preventing release of destructive acid hydrolases from leukocytes; inhibiting macrophage accumulation in inflamed areas; reducing leukocyte adhesion to capillary endothelium; reducing capillary wall permeability and edema formation; decreasing complement components; antagonizing histamine activity and release of kinins from substrates; and reducing fibroblast proliferation, collagen deposition, and subsequent scar tissue formation. Several long-acting steroid preparations are available for parenteral use in formulations approved for intramuscular administration. These parenteral formulations are widely used in image-guided injections for perineural and epidural administration, but *none of the available formulations has been approved by any regulatory agency in the United States or internationally for these applications*.

Table 4–3

Recommended Maximum Local Anesthetic Doses[a]

Anesthetic	Maximum Recommended Dose (mg/kg)
Lidocaine	4–5
Mepivacaine	5–6
Bupivacaine, ropivacaine, L-bupivacaine	2.5–3

[a]Large doses of local anesthetic are used infrequently during image-guided injections in pain medicine; however, doses nearing toxicity are used during certain blocks (e.g., celiac plexus block).

Table 4–4

Treatment for Patients Experiencing Signs or Symptoms of Local Anesthetic Systemic Toxicity[a]

Get Help

Initial focus

- Airway management: ventilate with 100% oxygen
- Seizure suppression: benzodiazepines are preferred
- Basic and Advanced Cardiac Life Support (BLS/ACLS) may require prolonged effort

Infuse 20% lipid emulsion (values in parenthesis are for a 70-kg patient)

- Bolus 1.5 mL/kg (lean body mass) intravenously over 1 min (100 mL)
- Continuous infusion at 0.25 mL/kg/min (18 mL/min; adjust by roller clamp)
- Repeat bolus once or twice for persistent cardiovascular collapse
- Double the infusion rate to 0.5 mL/kg/min if blood pressure remains low
- Continue infusion for at least 10 mins after attaining circulatory stability
- Recommended upper limit: ~10 mL/kg lipid emulsion over the first 30 min

Avoid vasopressin, calcium channel blockers, β-blockers, or local anesthetic

Alert the nearest facility having cardiopulmonary bypass capability

Avoid propofol in patients having signs of cardiovascular instability

[a]Reproduced with permission from Neal JM, Bernards CM, Butterworth JF IV, et al. ASRA practice advisory on local anesthetic systemic toxicity. *Reg Anesth Pain Med* 2010;35:152–161.

There are several available steroid preparations with prolonged duration of action. They are commercially available in solutions that are designed to be equipotent (i.e., a single milliliter of each commercially available solution should produce similar glucocorticoid effects). The equipotent doses for commonly used steroids are shown in Table 4-5.

Equivalent doses are approximations and may not apply to routes of administration other than the oral route. The duration of anti-inflammatory activity of glucocorticoids is approximately equal to the duration of suppression of the hypothalamic-pituitary-adrenal (HPA) axis. The duration of suppression of the HPA axis following intramuscular injection of steroid preparations commonly used for epidural injection is shown in Table 4-6.

Table 4–5

Approximate Equivalent Glucocorticoid Oral Dosages Established by Laboratory Assays

Drug	Equivalent Dose (mg)
Cortisone	25
Hydrocortisone	20
Prednisolone	5
Prednisone	5
Methylprednisolone	4
Triamcinolone	4
Dexamethasone	0.75
Betamethasone	0.6

From ASHP Staff. *AHFS Drug Information Handbook 2004*. Bethesda, MD: American Society of Health-System Pharmacists; 2004:2897, with permission.

All of the available long-acting glucocorticoid formulations contain a number of preservatives and excipients (benzyl alcohol, benzalkonium chloride, and edetate sodium are common in these solutions). The safety of subarachnoid administration of the steroids themselves, as well as their preservatives and excipients, has been questioned. The manufacturer of Depo-Medrol states that this preparation of methylprednisolone acetate should not be administered intrathecally due to association with "severe medical events" when administered by this route (arachnoiditis has been reported). Other adverse events associated with glucocorticoid administration are shown in Table 4-7. The vast majority of these adverse reactions are associated with long-term glucocorticoid administration. The most common adverse reactions after single-dose or short-course epidural administration of glucocorticoids include asymptomatic peripheral edema and increased insulin requirements in diabetic patients. All steroid preparations in use have some degree of mineralocorticoid effect, and the resultant fluid retention can lead to exacerbation of congestive heart failure (CHF) in those with chronic CHF. Finally, anaphylactoid reactions following glucocorticoid administration are rare but have been well described.

Much attention has been given to the use of particulate steroid preparations during transforaminal injection. Some practitioners have touted the use of betamethasone or triamcinolone over methylprednisolone acetate, because the size of the particles is larger in the latter preparation. In the event that steroid is administered into a critical reinforcing artery supplying the spinal cord or brain, the smaller particles might be

Table 4–6

Duration of Suppression of the Hypothalamic-pituitary-adrenal Axis Following Intramuscular Administration of Several Commercially Available Steroid Preparations

Drug	Brand Name (How Supplied)	IM Dose (mg)	Duration of HPA Axis Suppression
Particulate Steroid Preparations			
Betamethasone sodium phosphate/ betamethasone acetate suspension	Celestone Soluspan (betamethasone 6 mg/mL, betamethasone sodium phosphate 3 mg/mL, and betamethasone acetate 3 mg/mL)	9	1 wk
Methylprednisolone acetate	Depo-Medrol (20, 40, or 80 mg/mL)	40–80	4–8 d
Triamcinolone acetonide	Kenalog (10 and 40 mg/mL)	40–80	2–4 wk
Triamcinolone diacetate	Aristocort Intralesional (25 mg/mL)	50	1 wk
	Aristocort Forte (40 mg/mL)	40	2–4 wk
Nonparticulate Steroid Preparations			
Dexamethasone sodium phosphate	Decadron (4 and 10 mg/mL)	4	3–4 wk

less likely to cause spinal cord infarction or stroke (Fig. 4-4). All available parenteral suspensions contain a wide and overlapping range of particle sizes; practitioners should not rely on the choice of steroid to eliminate the risk of direct intra-arterial injection. The nonparticulate, soluble synthetic glucocorticoid dexamethasone sodium phosphate has been used in substitution for particulate steroid preparations in a number of recent small studies. It is clear from experimental animal studies that when particulate steroids are injected into the vertebral artery, massive stroke occurs, and animals do not regain consciousness. In these same studies, injection of dexamethasone into the vertebral artery results in no discernable sequelae. Small clinical studies in humans suggest that the duration of pain relief following cervical

Table 4–7

Adverse Reactions Associated with Parenteral Glucocorticoid Administration

Body System	Adverse Reaction
Cardiovascular	Thromboembolism Thrombophlebitis Aggravation of hypertension
Dermatologic	Hyperpigmentation or hypopigmentation Subcutaneous fat atrophy Petechiae and ecchymoses
Central nervous system	Steroid psychoses Headache
Endocrine	Amenorrhea/menstrual abnormalities Hyperglycemia Increased insulin requirements in diabetics
Electrolyte disturbance	Sodium and fluid retention Hypokalemia Exacerbation of chronic CHF Peripheral edema
Gastrointestinal	Peptic ulcer with perforation and hemorrhage
Musculoskeletal	Steroid myopathy Osteoporosis Aseptic necrosis of femoral and humeral heads Spontaneous fractures
Miscellaneous	Anaphylactoid/hypersensitivity reactions

Data from *Drug Facts and Comparisons*. St. Louis, MO: Wolters Kluwer Health; 2005.

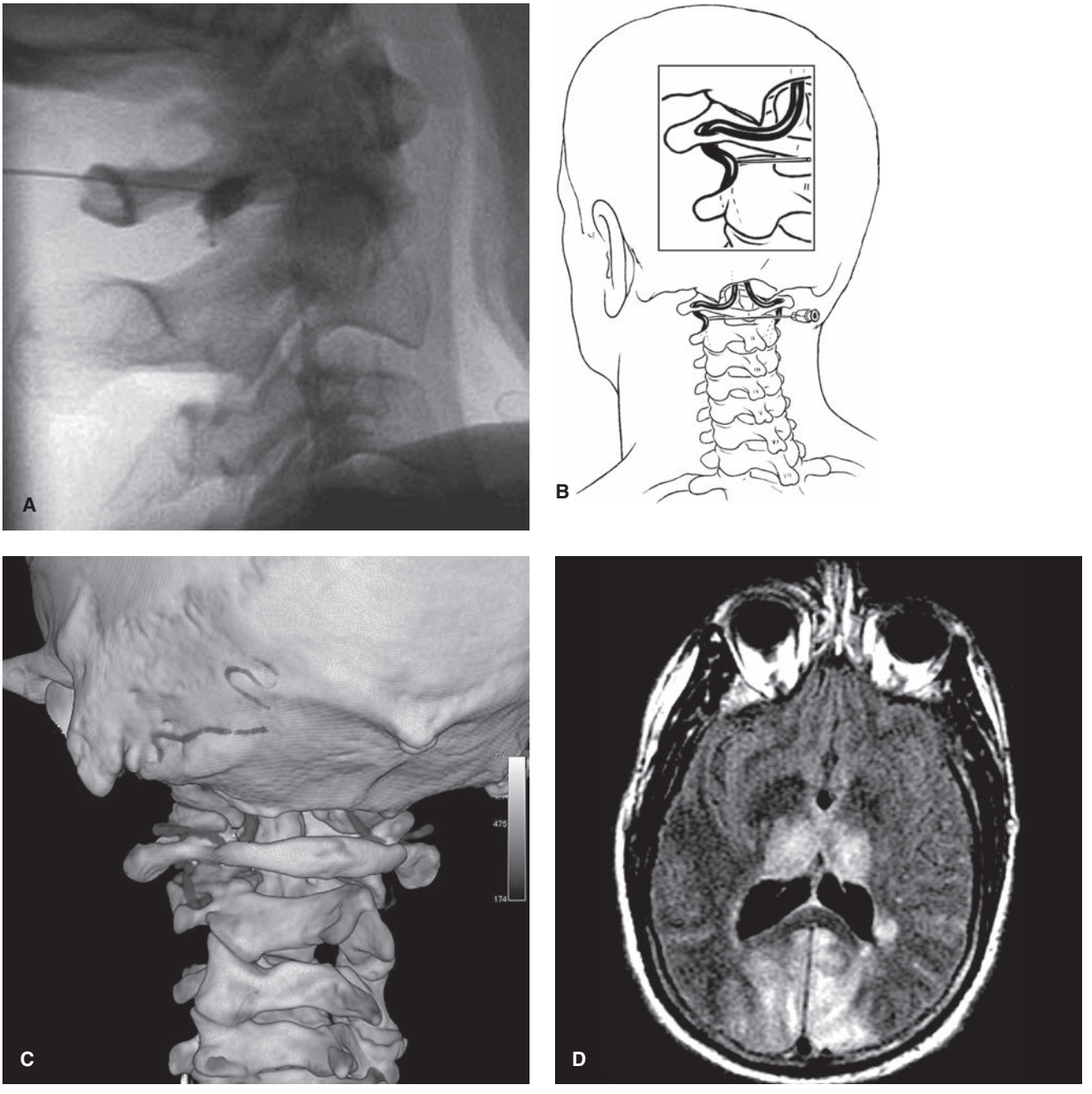

Figure 4-4.

Massive posterior circulation stroke resulting from inadvertent injection of particulate steroid into the left vertebral artery during C1/C2 intra-articular facet injection. This patient became comatose immediately after the intra-articular cervical facet steroid injection. **A:** Lateral x-ray shows needle posterior to the C1/C2 joint, with radiographic contrast over the posterior portion of the joint. **B:** Schematic illustration, with **inset** highlighting the anatomic area of interest, demonstrates proximity of superior cervical portion of the vertebral artery to the injection site. **C:** Reformatted computed tomography angiography of the left vertebral artery (posterior view), performed 5 hours after the cervical injection, does not reveal evidence of arterial dissection, vasospasm, or occlusion. **D:** Axial T2 fluid attenuated inversion recovery sequence MRI reveals signal hyperintensity within the posterior circulation territory. ***(Cont.)***

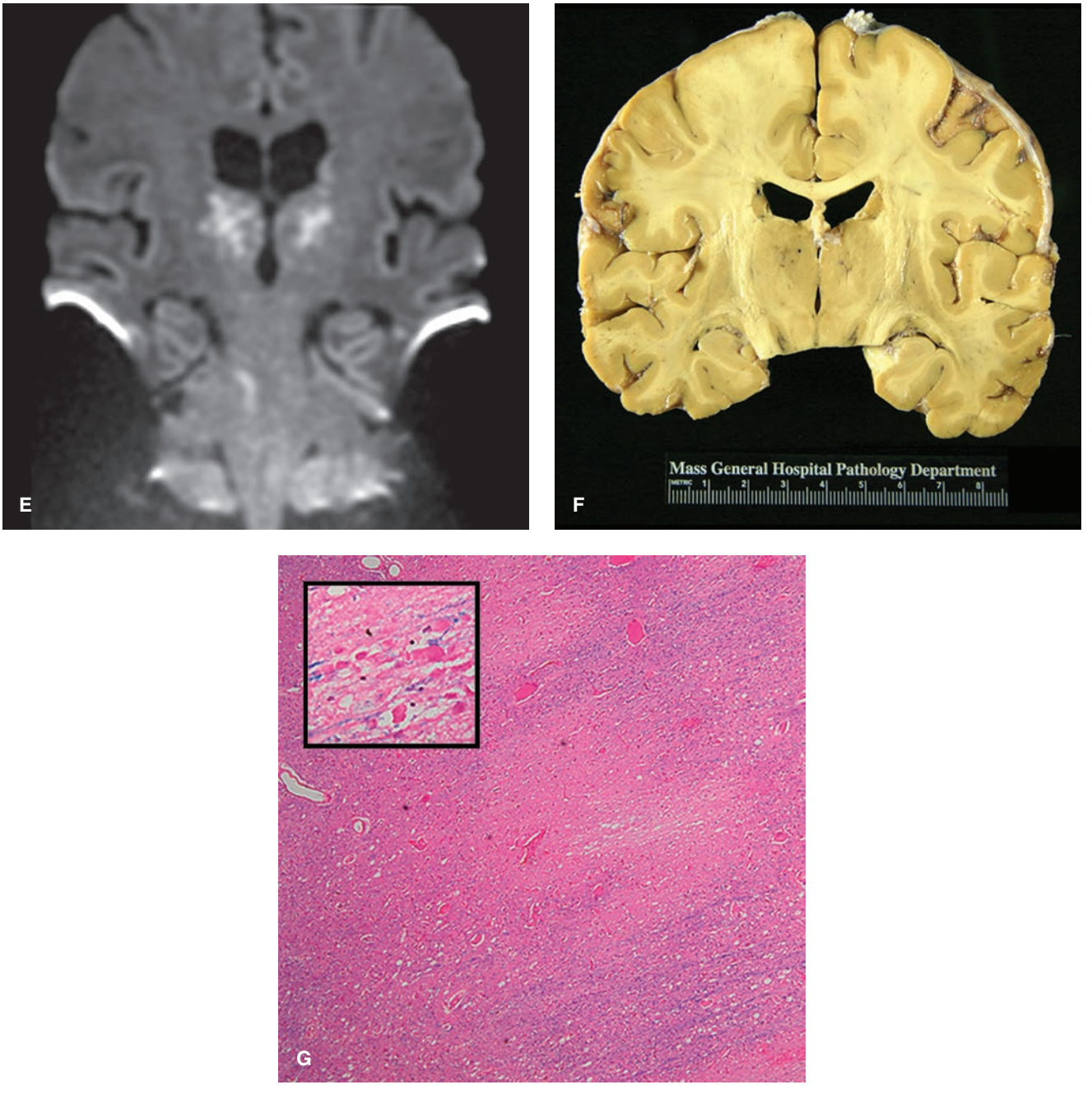

Figure 4-4. ***(Continued)***

E: Coronal diffusion-weighted imaging sequence through the thalami demonstrates bithalamic diffusion restriction, as well as right pontine. **F:** Fixed brain demonstrates gross evidence of bithalamic necrosis and microhemorrhages. **G:** Luxol fast blue with hematoxylin and eosin staining of thalamic section demonstrates small irregular discrete areas of acute infarction. **G, Inset:** Axonal spheroids are present in the surrounding thalamus adjacent to the lesions, consistent with ischemic injury. The combination of small, distinct regions of infarction with axonal spheroids confirms that the ischemic lesions occurred due to occlusion of distal vascular beds, consistent with the hypothesis of microembolization. (Adapted from Edlow BL, Wainger BJ, Frosch MP, et al. Posterior circulation stroke after C1-C2 intraarticular facet steroid injection: evidence for diffuse microvascular injury. *Anesthesiology*. 2010;112:1532–1535, with permission.)

transforaminal injection of steroid to treat cervical radicular pain is shorter than when a depot formulation of methylprednisolone acetate is employed. However, further studies are needed to ensure the safety and effectiveness of nonparticulate steroids.

Pharmacology of Neurolytic Solutions

The idea that chemical destruction of neural pathways can produce long-lasting pain relief has been around for many years. However, neurolytic blockade has met with limited success in treating most chronic pain conditions. Likely, the anatomic and functional changes that occur within the dorsal horn of the spinal cord and at higher centers within the brain lead to ongoing perception of pain even after destruction of the peripheral nerves that originally carried the nociceptive signals. Nonetheless, there are a number of neurolytic blocks that have proven beneficial and are still routinely performed. Foremost among efficacious neurolytic blocks is neurolytic celiac plexus block for the treatment of pain associated with intra-abdominal malignancy. Here, we briefly discuss the pharmacology of the two most common neurolytic agents: phenol and absolute alcohol.

Phenol

Phenol is the combination of carbolic acid, phenic acid, phenylic acid, phenyl hydroxide, hydroxybenzene, and oxybenzene. There is no commercially available phenol preparation, but a solution can be prepared by a compounding pharmacist from anhydrous phenol crystals available from chemical supply houses. The limit of solubility of phenol in water is ~6.67%. Phenol is highly soluble in glycerin and in radiographic contrast solutions. We have tested the stability of 12% phenol in iohexol 180 mg per mL and found that no precipitation or release of free iodine occurs over 30 days at room temperature. We prefer mixing phenol in radiographic contrast so that the pattern of spread of the neurolytic solution can be monitored radiographically throughout the injection. Solutions of aqueous phenol, phenol in glycerin, and phenol in iohexol are all markedly viscous and can be difficult to inject through small-bore needles. Care should be taken to use interlocking extension tubing and syringes to avoid sudden disconnections and splattering of personnel with the neurolytic solution.

Phenol has local anesthetic properties at lower concentrations and is neurolytic at higher concentrations. Concentrations below 5% cause protein denaturation, whereas higher concentrations produce protein coagulation and segmental demyelination. Poorly myelinated and unmyelinated nociceptive fibers are destroyed at concentrations of 5% to 6%, whereas higher concentrations cause axonal damage, spinal cord infarction, arachnoiditis, and meningitis. In contrast to alcohol, there is little or no pain on injection of phenol. The degree of neural blockade following injection of phenol is maximal in the first hours after injection and tends to subside somewhat thereafter. Large systemic doses of phenol (>8.5 g) cause effects similar to those seen with local anesthetic overdose: generalized seizures and cardiovascular collapse. Clinical doses up to 1,000 mg are unlikely to cause serious toxicity.

Ethyl Alcohol

Absolute (>98% concentration) ethyl alcohol is available commercially in 1- or 5-mL vials specifically for therapeutic neurolysis. Unlike phenol, alcohol injects readily through small-bore needles. Phenol causes intense pain when injected perineurally and must be preceded with local anesthetic or mixed directly with local anesthetic for injection to be tolerable to the patient.

Alcohol in concentrations above 33% results in extraction of cholesterol, phospholipids, and cerebrosides from neural tissue and precipitation of lipoproteins and mucoproteins. Alcohol produces nonselective destruction of neural tissue. The degree of neural blockade increases over the first several days following neurolysis with alcohol. Intravascular injection of 30 mL of 100% ethanol will result in a blood ethanol level well above the legal limit for intoxication but below danger of severe alcohol toxicity. Alcohol is intensely inflammatory and has been associated with persistent or worsened pain and neuritis, particularly following peripheral neurolysis. This is believed to be caused by partial nerve injury during neurolysis.

Image-guided Intervention in the Patient Receiving Antithrombotic Therapy

The long-term use of antiplatelet therapy as well as oral and parenteral anticoagulants is now commonplace among ambulatory patients and places this group at significant risk for bleeding complications associated with needle placement during image-guided intervention. It is essential that a standard approach to screening patients for ongoing antithrombotic therapy is adopted to assure that all patients are identified *before* needle placement. Localized hematoma formation with compression of adjacent vascular or neural structures has been reported frequently following needle placement in patients receiving these therapies. However, the most feared complication is the formation of an epidural hematoma with subsequent spinal cord compression that has been associated with the conduct of neuraxial techniques in patients receiving many different antithrombotic agents. The American Society of Regional Anesthesia and Pain Medicine (ASRA) has published and periodically updated comprehensive guidelines for performing regional anesthesia in patients receiving various agents. The guidelines include suggested intervals following discontinuation of each agent before injection can be carried out safely. A multidisciplinary group of experts at our own institution has made minor adaptations to the ASRA guidelines and publishes an update each year for use in our institution (Table 4-8). Decision making around stopping antithrombotic therapy of any

TABLE 4–8

Suggested Guidelines for Anticoagulation and Neuraxial Anesthesia/Analgesia

Massachusetts General Hospital, Medication Education and Safety Approval Committee (MESAC), Anticoagulation Working Group Boston, Massachusetts, October 2009

Drug (Generic)	Common Trade Names	Time Interval for Placement of Catheter after Last Dose	Time Interval for Removal of Catheter after Post-op Dose	Time Interval to Restart Med after Catheter is removed
Abciximab	REOPRO	48 h	48 h	12 h
		Time to recovery of normal platelet aggregation after ABCIXIMAB/REOPRO is 24–48 h		
Argatroban		At least 6 h after administration of last dose; check PTT or ACT	Check PTT or ACT	2 h
Cilostazol (alone)	PLETAL (T 1/2 =12 h)	Placement and removal of catheter is okay		
Cilostazol (with Aspirin)	PLETAL	48 h	48 h	1 h
Clopidogrel	PLAVIX (75 mg)	7 d	<24 h or >7 d	Uncertain; suggest 24 h
Clopidogrel	PLAVIX (300–600 mg)	7 d	>7 d	24 h
Desirudin	DESIRUDIN	Uncertain; check ACT	Uncertain; check ACT	Uncertain; suggest 24 h
Eptifibatide	INTEGRILIN	8 h	8 h	4 h
Fondaparinux (see *Note*)(prophylaxis dose)	ARIXTRA (2.5 mg)	4 d	4 d	Uncertain; suggest 12 h
Fondaparinux (see *Note*)(treatment dose)	ARIXTRA (5, 7.5, or 10 mg)	7 d	4 d	Uncertain; suggest 24 h
Note: FONDAPARINUX should *not* be given if regional anesthesia is anticipated or has been used. If, however, FONDAPARINUX is given, the above guidelines are suggested.				
Unfractionated heparin (UFH) (prophylactic sc dosing)	HEPARIN	No significant risk at dose of 5,000 U bid, unknown risk at higher doses; check PTT		
Unfractionated heparin (UFH) (therapeutic iv dosing)	HEPARIN	2–4 h, PTT < 35	2–4 h, PTT < 35	1 h
Low molecular weight heparin (LMWH) (prophylactic dose) dalteparin and enoxaparin	FRAGMIN and LOVENOX (< 60 mg QD)	12 h	12 h	2 h
Low molecular weight heparin (LMWH) (therapeutic dose), dalteparin, enoxaparin, and tinzaparin	FRAGMIN, LOVENOX, and INNOHEP	24 h	Catheter *should* be removed prior to first dose. If not, wait >24 h	2 h
Note: LMWH: prophylactic dosing may be started 6–8 h postoperatively. Therapeutic dosing should be started at least 24 h postoperatively. Epidural catheters should be removed prior to initiation of therapy.				
NSAID, Aspirin	CELEBREX, MOTRIN, NAPROSYN, etc.	No significant risk		
Tirofiban	AGGRASTAT	8 h	8 h	4 h
Warfarin	COUMADIN	3–5 d, INR < 1.5	Check INR if treatment >24 h, INR < 1.5	Same day

kind is complex, particularly in the modern era of percutaneous coronary stent placement. The pain practitioner should closely consider the risks and benefits of stopping antithrombotic therapy for even brief intervals in consultation with the practitioner overseeing the management of the antithrombotic therapy, before any decision to discontinue these agents is made.

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SECTION II

SPINAL INJECTION TECHNIQUES

CHAPTER 5

Interlaminar Epidural Injection

OUTLINE

Overview

Epidural injection of local anesthetics has long been used to produce surgical anesthesia for operative procedures on the trunk, abdomen, and lower extremities. Continuous infusion of local anesthetic and opioid combinations through indwelling epidural catheters are now frequently used to provide analgesia for several days after major surgery. The most common use of epidural injection in the pain clinic is to place steroids into the epidural space, where they spread to bathe the spinal nerves to either side of midline. The rationale for injecting steroids is that they suppress inflammation involving the nerve and adjacent soft tissues. This inflammation is thought to be the cause for acute radicular pain. A needle can be advanced directly into the epidural space between adjacent vertebral laminae using a posterior approach to the spinal canal near midline. This is the most common approach to the epidural space and has been termed the "interlaminar approach." Identification of the epidural space requires familiarity with the loss-of-resistance (LOR) technique, which is described in detail later in this section. Using this technique, the epidural space is identified by the sudden decrease or LOR to injection that occurs as a needle passes from the interspinous ligament between adjacent spinous processes through the ligamentum flavum and into the epidural space. Although anesthesiologists have used epidural anesthesia and analgesia for many years, more recently, pain practitioners have been moving toward use of the transforaminal route for placing steroids near an inflamed nerve root. The rationale for using the transforaminal route of injection, rather than the interlaminar route, is that the injectate is delivered directly to the target nerve in the area of inflammation. This ensures that the medication reaches the target area in maximum concentration at the site of the suspected pathology. There have been few studies directly comparing the interlaminar and transforaminal routes for epidural injection of steroids, thus it is unclear if the safety or efficacy of either of the two techniques is superior.

Anatomy

Bony Anatomy of the Vertebrae and Spinal Column

The structure of the vertebrae is distinct in the cervical, thoracic, and lumbar regions (Fig. 5-1). A typical vertebra consists of a spinous process that joins at its most anterior extent with the laminae, which extend anterolaterally to each side of midline. The epidural space lies anterior to the laminae and is bordered laterally by the pedicles and anteriorly by the vertebral body. Access to the epidural space is through the space between adjacent laminae (the "interlaminar" space). The superior and inferior articular processes of the facet joints lie posterolaterally at the junction between the laminae and the pedicles and provide the posterolateral articulating surfaces between adjacent vertebrae. The sacral hiatus is the area where the fifth sacral vertebra (S5) lacks a spinous process and laminae posteriorly (Fig. 5-2). The two sacral cornua lie on either side of the sacral hiatus and cephalad to the coccyx.

Individual vertebral components can affect epidural block technique. The spinous processes vary in their degree of angulation at the various vertebral levels (Fig. 5-3). In the cervical and lumbar regions, the spinous process attaches to the lamina nearly horizontally, thus facilitating a midline perpendicular approach to the neuraxis. Conversely, the midthoracic spinous processes (T5 to T9) are steeply angled in a cephalad to caudad direction to such an extent that the paramedian approach gives more direct access to

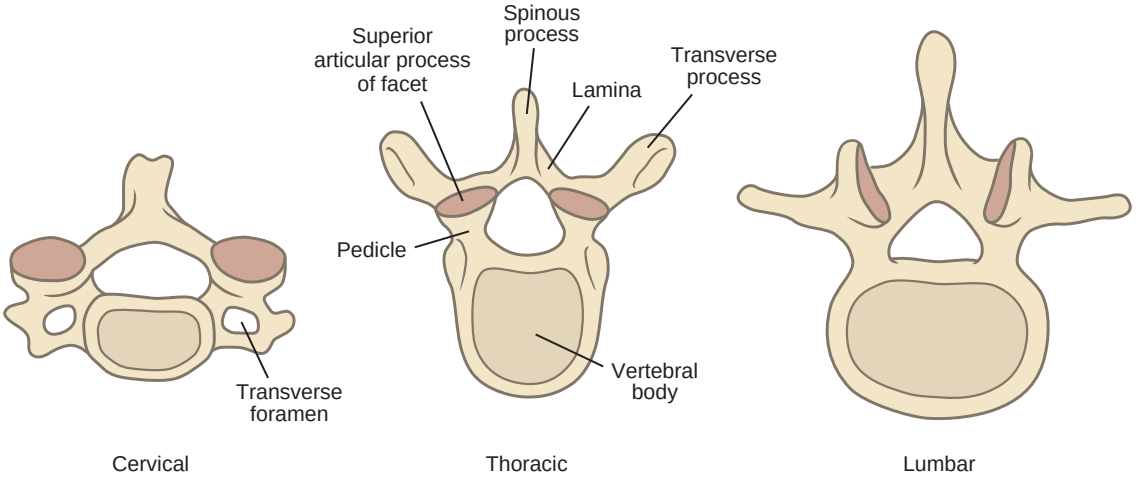


Figure 5-1.
Anatomy of the cervical, thoracic, and lumbar vertebrae.

the epidural space and is easier to carry out than the midline approach. High (T1 to T4) and low (T10 to T12) thoracic spinous processes are intermediate in their orientation and are thus amenable to either a steeply angled midline or a paramedian approach. The laminae become more vertically oriented as one progresses caudally; therefore, "walking off" the lamina is associated with progressively deeper needle placement from superior to inferior in the thoracic region. This also accounts for the shallower depth on entering the epidural space in the lumbar region.

Surface landmarks can assist in identifying the approximate vertebral interspace (Table 5-1). In most humans, the C7 spinous process (the vertebrae prominens) is the most noticeable midline structure at the posterior neck base. A line drawn between the inferior angles of the scapulae lies approximately at the level of the T7 spinous process, while a line drawn between the iliac crests crosses the tip of the L4 spinous process or the L4/L5 interspace. The spinal cord

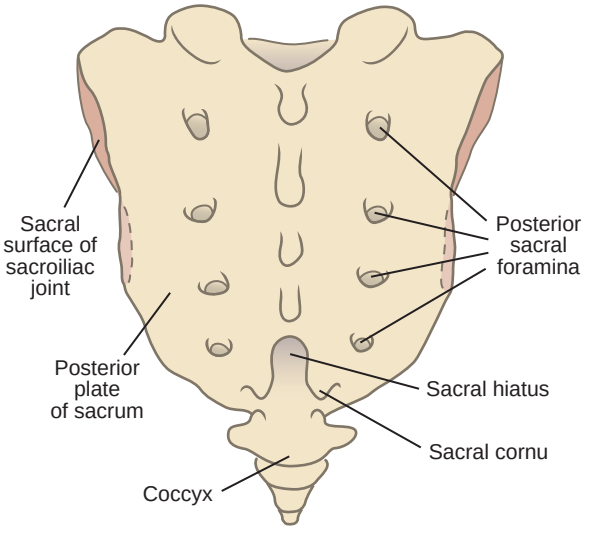


Figure 5-2.
Anatomy of the posterior sacrum and coccyx.

generally terminates at about the L2 level (Fig. 5-4), and the dural sac ends at S2 (the level of the posterior-superior iliac spines). The tip of an equilateral triangle drawn between the posterior-superior iliac spines and directed caudally overlies the sacral cornua and sacral hiatus.

Anatomy of the Epidural Space

Just as the bony structure of the vertebrae varies from the cervical to the sacral levels, so does the anatomy of the epidural space. The epidural space extends from the foramen magnum to the sacrococcygeal ligament. It is filled with epidural fat, a robust venous plexus, and loose areolar tissue. The dimensions of the epidural space are less in the thoracic and cervical space as compared with the lumbar region. The ligamentum flavum is a structure of variable thickness and completeness that defines the posterolateral soft-tissue boundaries of the epidural space. Because the leather-like consistency of the ligamentum flavum resists active expulsion of fluid from a syringe, loss of this resistance is valuable in signaling entry into the epidural space as a needle is advanced. The ligament's structure is steep and tent-like, with the peak of the tent's roof in the midline and most posterior and the substance of the ligamentum flavum extending in an anterolateral direction to both sides of midline forming the eaves of the tent's roof. The lateral aspect of the ligamentum flavum may be as much as 1 cm more anterior than at the midline, thus entry into the epidural space will occur at a significantly deeper level when the needle strays laterally from midline.

In the cervical and thoracic epidural spaces, the ligamentum flavum often does not fuse in the midline, which can become problematic when using the LOR technique. When the dense ligamentum flavum is absent in the midline, it is possible to enter the epidural space without ever sensing significant resistance to injection. The ligamentum flavum is thickest at the lumbar and thoracic levels and thinnest at the cervical level. Its thickness also diminishes at the cephalad aspect of each interlaminar space and as the ligamentum flavum tapers off laterally. The epidural space itself progressively narrows in

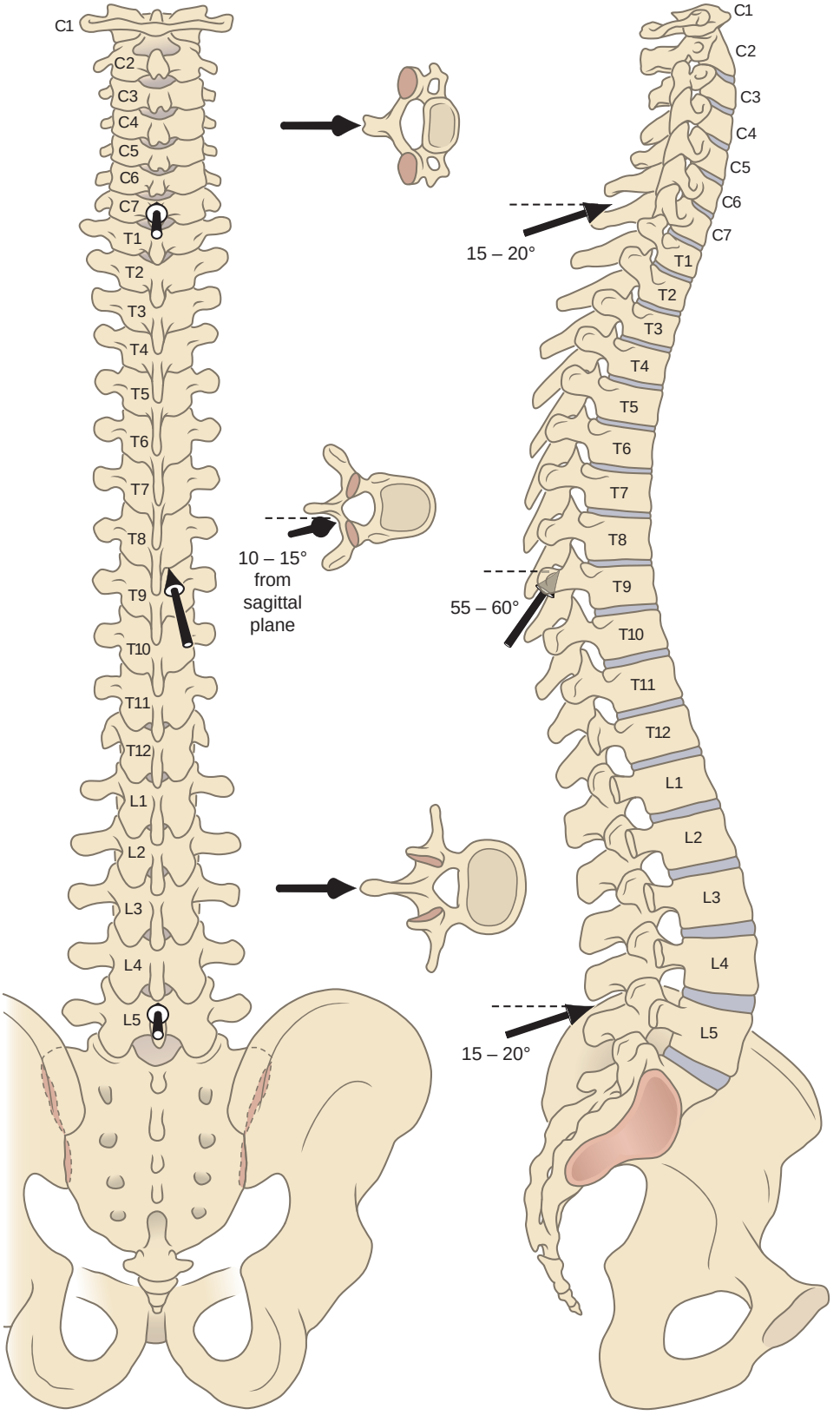


Figure 5-3.
Anatomy of the vertebral column. In most humans, the most prominent spinous process at the base of the neck is the spinous processes of C7 (the vertebrae prominens). Note that the angle of the spinous processes changes dramatically from cervical to lumbar levels, with the steepest cephalad to caudad angle in the midthoracic region. The approximate plane of needle entry for interlaminar epidural injection is shown for cervical, thoracic, and lumbar levels.

Table 5–1

Correlation between Surface Landmarks and Vertebral Levels

Surface Landmark	Approximate Vertebral Level
Most prominent spinous process at base of neck (vertebra prominens)	C7 spinous process
Inferior angle of scapula	T7 spinous process
Superior margin of iliac crest	L4 spinous process or L4/L5 interspace
Posterior-superior iliac spine	S2, termination of the dural sac
Inferior tip of equilateral triangle between posterior-superior iliac spines	Sacral hiatus

anterior-posterior (AP) dimension from the lumbar level (5 to 6 mm) to the thoracic level (3 to 5 mm) and is narrowest between the C3 and C6 vertebral levels (2 mm). Because the spinal cord typically terminates at the L2 vertebral level, unintentional needle puncture of the dura below this level encounters the free-floating filum terminale and individual nerves of the cauda equina, rather than the spinal cord (Fig. 5-4). The posterior epidural space is narrow at cervical and thoracic levels, thus when the epidural space is entered, the needle tip lies in close proximity to the spinal cord.

Above C7 to T1 and at intermittent areas along the posterior spinal canal, the epidural space is best described as a potential space that is easily dilated by injection of anesthetic solutions. Distribution of solutions within the epidural space is not uniform, especially as distance from the injection site increases. Rather, solutions spread along various routes as determined by small, low-resistance channels that exist between the epidural fat and veins. Nevertheless, solutions flow preferentially along the dural sheaths of the spinal nerves because the only significant barrier to epidural flow appears to be the posterior longitudinal ligament. Thus fluid injected within the epidural space will tend to exit the spinal canal through the adjacent intervertebral foramina. In patients who have undergone previous spinal surgery, scarring of the posterior epidural space is common, and the flow of injected solutions is less predictable. Cases have been reported where

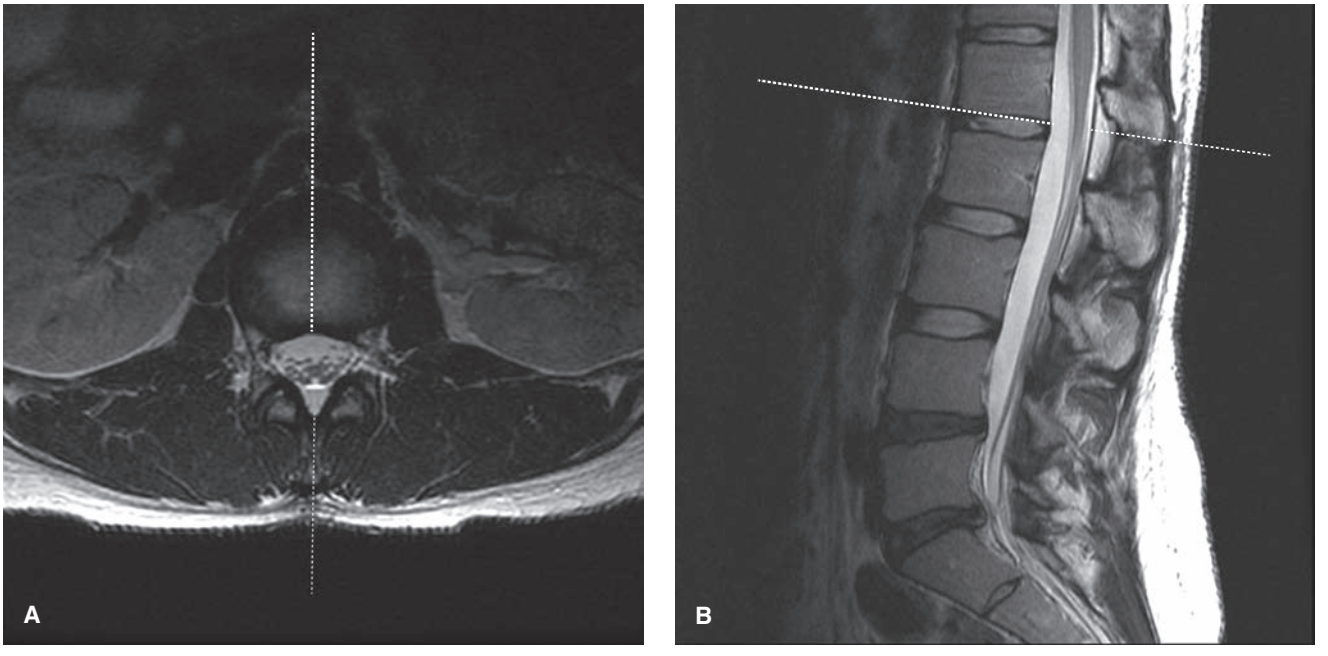


Figure 5-4.

Appearance of the conus medullaris and cauda equina on magnetic resonance imaging (MRI). T2-weighted MRI of the lumbosacral spine (without contrast) in a patient with a small central disc protrusion at L4/5 and a prominent central disc protrusion at L5/S1. **A:** Axial image at the level of termination of the conus medullaris (inferior endplate of the L1 vertebral body), demonstrating the inferior most extent of the conus and the nerves of the cauda equina (*dashed line* illustrates the position of the corresponding sagittal image in **(B)**). **B:** Axial image at the level of termination of the conus medullaris, demonstrating the inferior most extent of the conus and the nerves of the cauda equina (*dashed line* illustrates the position of the corresponding axial image in **(A)**).

fluid injected into the epidural space forms an area of loculation that can tent the dura anteriorly and lead to compression of the neural elements, thus it is essential to avoid injecting fluid into the epidural space under high pressure.

Loss-of-resistance Technique

Anesthesiologists learn to identify the epidural space "blindly" without the help of fluoroscopic guidance. This is accomplished using the LOR technique. Even when radiographic guidance is available, the LOR technique is still needed to identify the epidural space. Image guidance can help direct the needle toward the midline, between laminae, but neither AP nor lateral images can identify the precise location of the epidural space. The LOR technique is identical in the cervical, thoracic, and lumbar regions. After the skin and subcutaneous tissue have been anesthetized with a small volume of local anesthetic, an epidural needle is seated in the interspinous ligament, advancing 2 to 3 cm from the skin's surface (the most common type of needle is the 18- or 20-gauge Tuohy needle; see Fig. 1-4). A syringe containing air or saline is then attached to the needle. Many practitioners prefer a 10-mL syringe containing 1 to 3 mL of preservative-free, isotonic saline and a small (~0.5 mL) bubble of air (Fig. 5-5A). The needle shaft is then grasped by the thumb and index finger of the nondominant hand and advanced 1 to 2 mm at a time, while the first three fingers of the dominant hand are used to place gentle, steady or intermittent pressure on the plunger of the syringe to test for resistance to injection as the needle is advanced toward the epidural space. The small bubble in the syringe is more compressible than the saline and serves to visually reinforce the degree of resistance felt with each push on the syringe's plunger. As the needle tip traverses the ligamentum flavum and enters the dorsal epidural space, there is a discreet LOR to injection, and the saline exits the syringe to the epidural space. Also, because there is very low resistance to injection, the air bubble is no longer compressed (Fig. 5-5B).

Patient Selection

The most common indication for epidural injection in the pain clinic is to place corticosteroid adjacent to an inflamed nerve root that is causing radicular symptoms. Nerve root inflammation may stem from an acutely herniated intervertebral disc causing nerve root irritation or other causes of nerve root impingement such as isolated foraminal stenosis due to spondylitic spurring of the bony margins of the foramen. Epidural steroid injection is also used to treat symptoms of neurogenic claudication associated with spinal stenosis (stenosis of the central spinal canal). There are no scientific guidelines or any body of scientific literature to help choose between the interlaminar route and the transforaminal route for epidural injection of steroids, and each has unique complications. The spread of injectate during interlaminar injection, particularly when volumes of 5 mL or more are used, will often extend to both sides of midline and bathe the spinal nerves at the interspace of injection and at several adjacent interspaces. Thus, in those patients who present with bilateral radicular symptoms due to a midline disc herniation or neurogenic claudication in both legs due to central canal stenosis, it seems logical (if yet unproven) that interlaminar injection would be more likely to get the steroid solution to the target sites of nerve irritation.

Level of Evidence

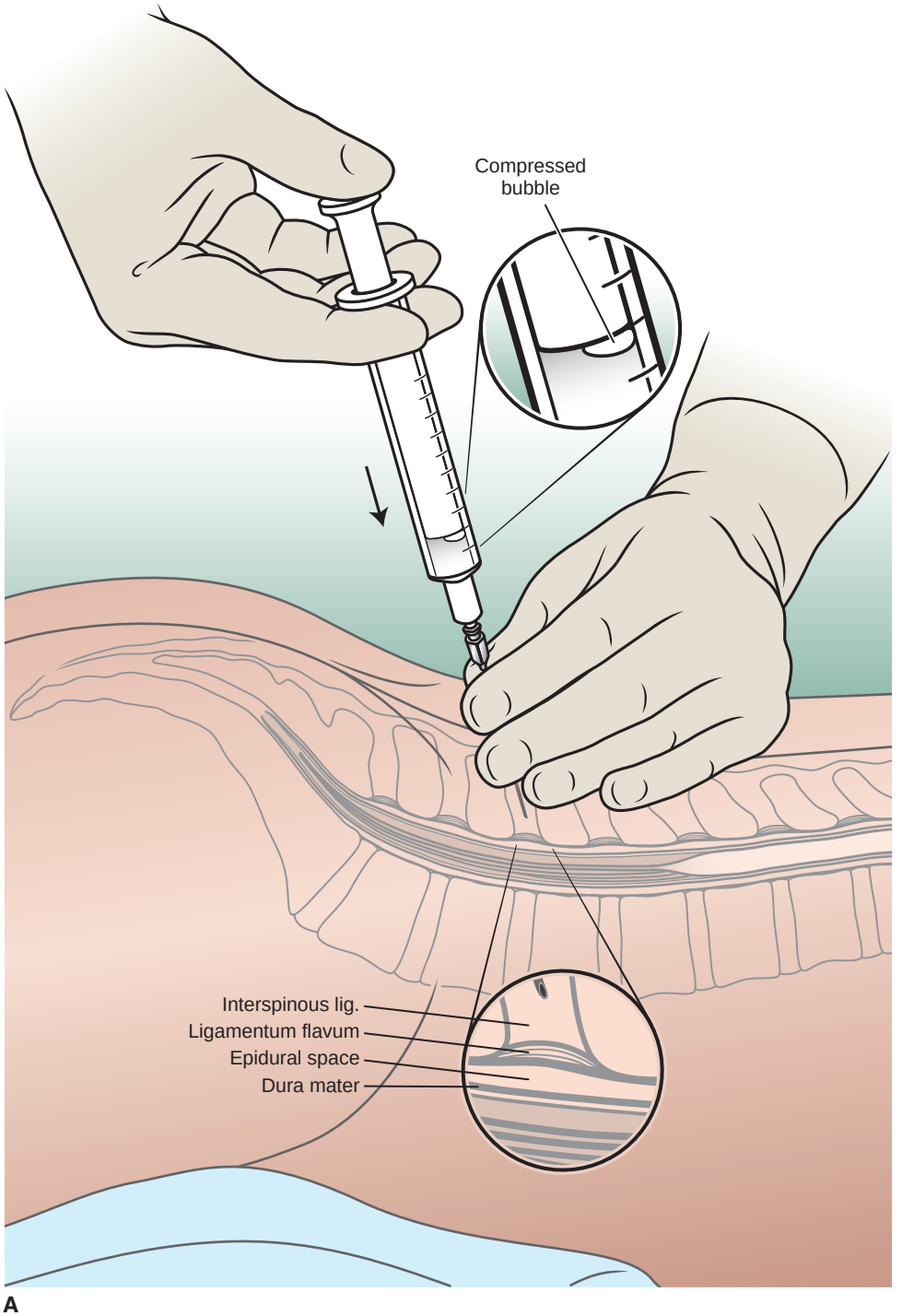
Quality of Evidence and Grading of Recommendation

Grade of Recommendation/ Description	Benefit vs Risk and Burdens	Methodological Quality of Supporting Evidence	Implications
RECOMMENDATION: *Interlaminar epidural steroid injections may be used as part of a multimodal treatment regimen to provide pain relief in selected patients with radicular pain or radiculopathy.*			
1B/strong recommendation, moderate quality evidence	Benefits clearly outweigh risks and burden	*For short-term relief of radicular pain (up to 6 weeks):* I: RCTs with important limitations (inconsistent results, methodological flaws	Strong recommendation, can apply to most patients in most circumstances without reservation

There has been an exponential rise in the use of epidural injection of steroids during the past decade in the United States, while the prevalence of acute pain associated with various spinal disorders has changed little. Several organizations have closely examined the scientific literature and made evidence-based guidelines regarding the use of this treatment. The available randomized controlled trials examining the efficacy of epidural injection of steroids are limited to use in the treatment of radicular pain associated with acute lumbar intervertebral disc herniations. The American Academy of Neurology Technology Assessment Committee published an analysis in 2007, concluding, "(a) epidural steroid injections may result in some improvement in radicular lumbosacral pain when assessed between 2 and 6 weeks following the injection, compared to control treatments. The average magnitude of effect is small and generalizability of the observation is limited by the small number of studies, highly selected patient populations, few techniques and doses, and variable comparison treatments; (b) in general, epidural steroid injection for radicular lumbosacral pain does not impact average impairment of function, need for surgery, or provide long-term pain relief beyond 3 months. Their routine use for these indications is not recommended; (c) there is insufficient evidence to make

any recommendation for the use of epidural steroid injections to treat radicular cervical pain."

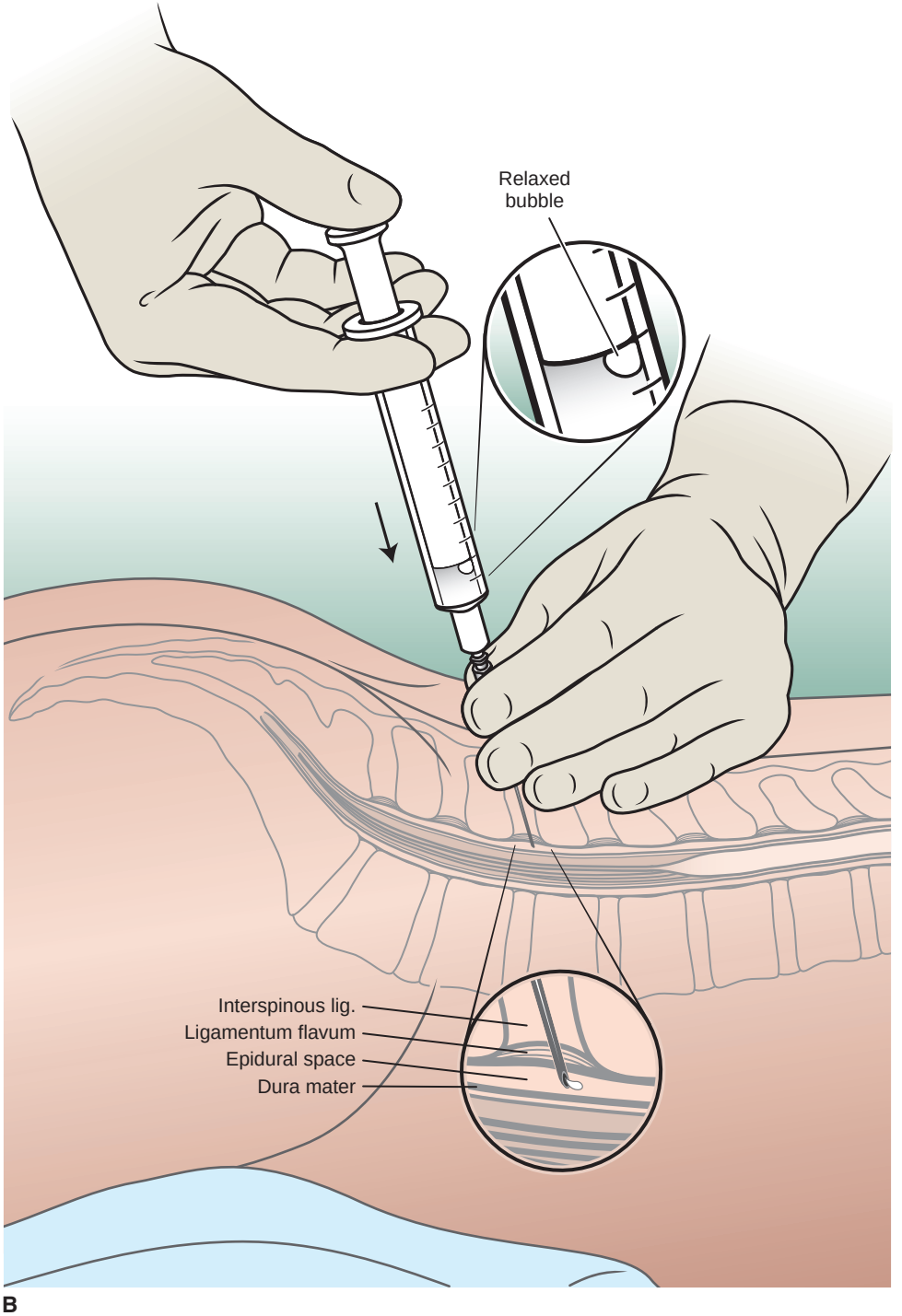
The American Pain Society Low Back Pain Guideline Panel published a report in 2009, concluding, "In patients with persistent radiculopathy due to herniated lumbar disc, it is recommended that clinicians discuss risks and benefits of epidural steroid injection as an option (weak recommendation, moderate-quality evidence). It is recommended that shared decision making regarding epidural steroid injection include a specific discussion about inconsistent evidence showing moderate short-term benefits, and lack of long-term benefits. There is insufficient evidence to adequately



A

Figure 5-5.

The LOR technique for identification of the epidural space using an interlaminar approach. **A:** The needle is seated in the interspinous ligament, and a syringe containing 1 to 3 mL of preservative-free saline and a small (~0.5 mL) air bubble is attached to the needle. The shaft of the needle is grasped firmly with the nondominant hand and intermittent or continuous light pressure is applied to the syringe plunger with the dominant hand. ***(Cont.)***



B

Figure 5-5. *(Continued)*

B: As the needle passes through the ligamentum flavum and into the epidural space, there is a sudden decrease or "loss" of resistance to injection. The air bubble in the syringe expands, and the saline in the syringe flows into the epidural space. Note the close proximity of the posterior surface of the dural sac; advancing the needle just a few additional millimeters will result in dural puncture and intrathecal location of the needle tip.

evaluate benefits and harms of epidural steroid injection for spinal stenosis."

Most recently, the American Society of Anesthesiologists Task Force on Chronic Pain Management published A 2010 Practice Guideline, offering the following recommendations: "Epidural steroid injections with or without local anesthetics may be used as part of a multimodal treatment regimen to provide pain relief in selected patients with radicular pain or radiculopathy. Shared decision making regarding epidural steroid injections should include a specific

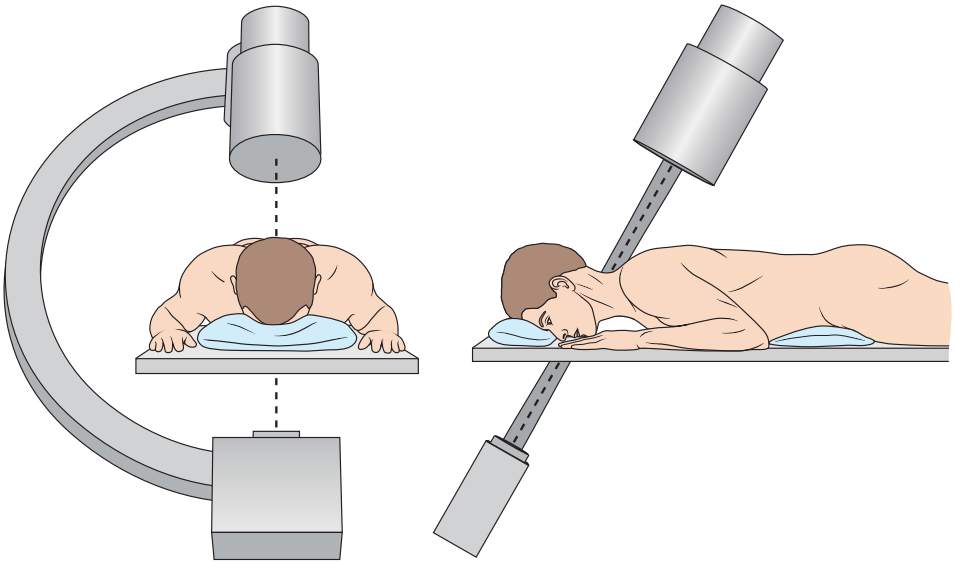


Figure 5-6.
Position for interlaminar cervical epidural injection. The patient is placed prone with a small headrest under the forehead to allow for air flow between the table and the patient's nose and mouth. The C-arm is angled 15 to 20 degrees caudally from the axial plane.

discussion of potential complications, particularly with regard to the transforaminal approach. Transforaminal epidural injections should be performed with appropriate image guidance to confirm correct needle position and spread of contrast before injecting a therapeutic substance; image guidance may be considered for interlaminar epidural injections."

There are numerous randomized controlled trials of varying methodologic quality that show more rapid resolution of acute radicular pain associated with acute lumbar disc herniation following epidural injection of steroids, and it is in this group that the evidence of efficacy is strongest. The use of this treatment for radicular pain associated with acute disc herniations occurring at the cervical and thoracic levels is common and most experts find this to be a reasonable extrapolation from the existing scientific evidence. The use of epidural injection of steroids to treat acute radicular pain associated with foraminal stenosis or neurogenic claudication associated with stenosis of the central spinal canal has been less well studied but remains common, again as an extrapolation from their usefulness in those with acute disc herniations. The use of epidural injection of steroids for the treatment of nonradicular spinal pain lacks scientific validation.

Cervical Epidural Injection

Positioning

The patient lies prone, facing the table, with a small headrest under the forehead to allow for air flow between the table and the patient's nose and mouth (Fig. 5-6). The C-arm is rotated 15 to 20 degrees caudally from the axial plane without any oblique angulation. This allows for good visualization of the interlaminar space and needle advancement between adjacent spinous processes (Figs. 5-7 and 5-8)

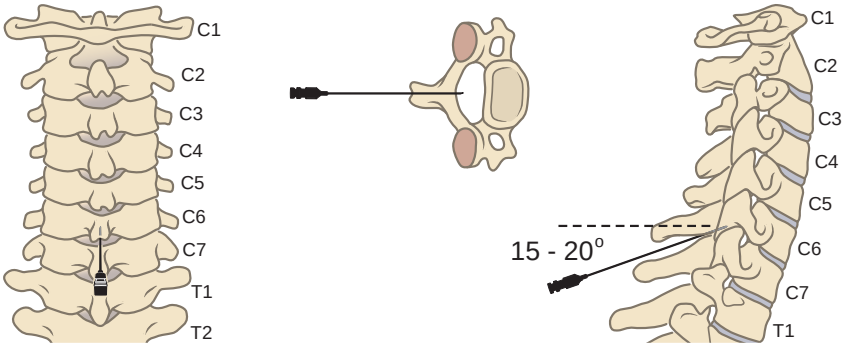
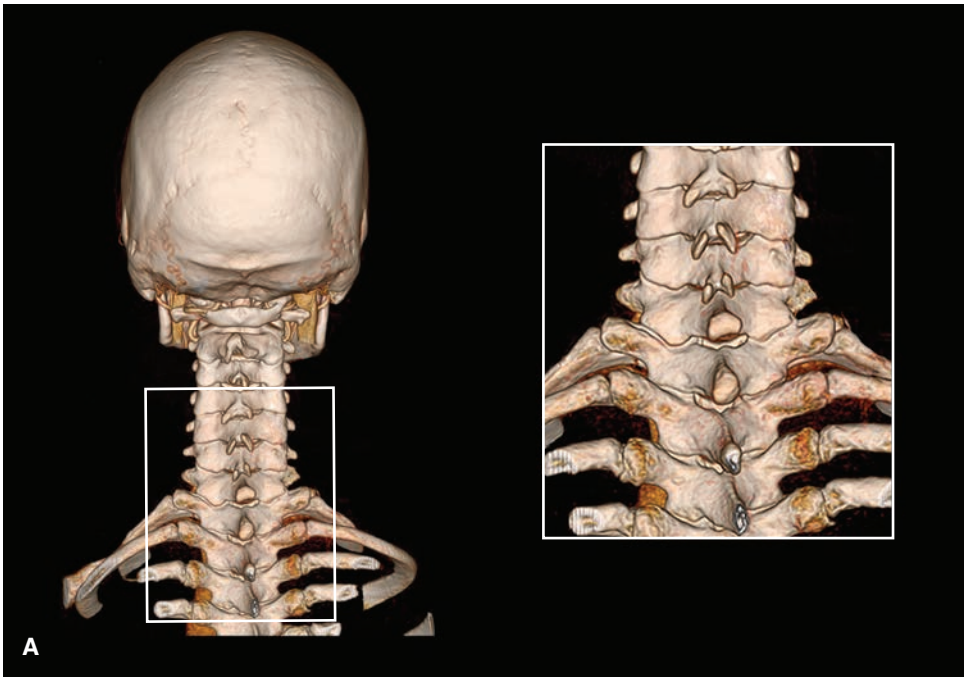
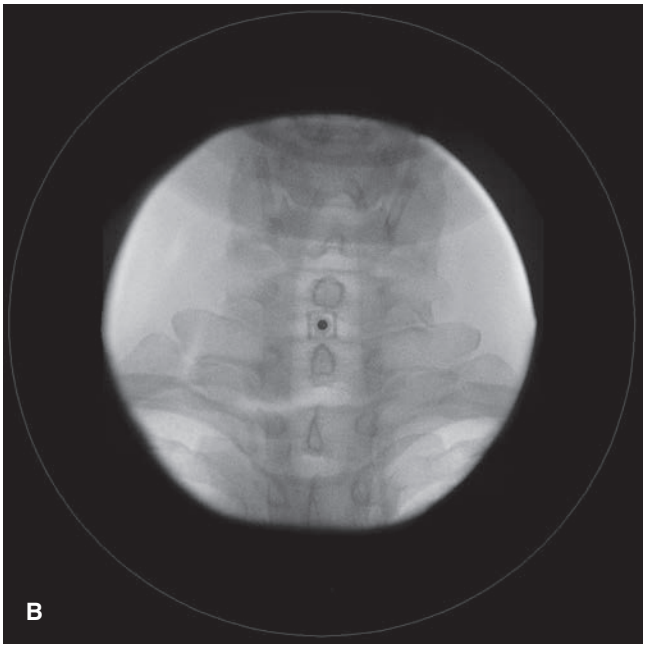


Figure 5-7.
Position and angle of needle entry for cervical interlaminar epidural injection. An 18- or 20-gauge Tuohy needle is advanced in the midline with 15 to 20 degrees of cranial angulation from the axial plane parallel to the spinous processes.

Block Technique

The skin and subcutaneous tissues overlying the interspace where the block is to be carried out are anesthetized with 1 to 2 mL of 1% lidocaine. The cervical interspaces with the largest interlaminar distance are typically found at C6/C7 and C7/T1. Because of the ease of entry, many practitioners will place the needle via one of these larger interspaces, regardless of the level of pathology, and rely on the flow of steroid in the epidural space to reach the level of pathology. The same technique can be carried out at all cervical





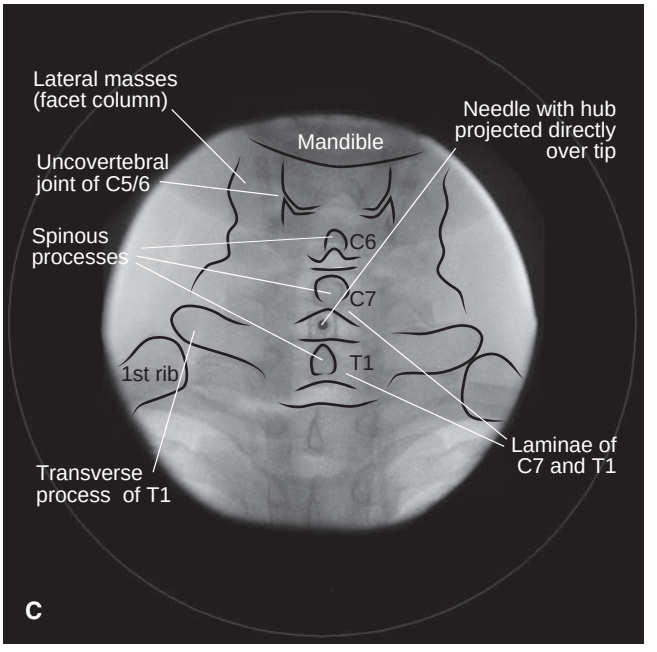


Figure 5-8.

A: Bony anatomy relevant to cervical interlaminar epidural injection. Three-dimensional reconstruction computed tomography of the cervical spine as viewed during the posterior approach used for cervical interlaminar injection. Inset matches the anatomic area in the radiographs shown in **(B)** and **(C)**. **B:** AP radiograph of the cervical spine during cervical interlaminar injection. A 20-gauge Tuohy needle is in position between the C7 and T1 laminae and spinous processes. The needle hub is projected directly over the needle tip and is positioned between the spinous processes. **C:** Labeled image.

interspaces at C3/C4 and below; interlaminar injection at the C2/C3 level and higher has not been described. An 18- or 20-gauge Tuohy needle is placed through the skin and advanced several centimeters until it is firmly seated in the interspinous ligament. An AP image is then taken, and the needle is redirected toward midline (see Fig. 5-8). A syringe containing 1 to 3 mL of preservative-free saline is attached to the needle, and the needle is slowly advanced in 1- to 2-mm increments until LOR occurs. Repeat images taken after every 0.5 to 1 cm of needle advancement will ensure the needle direction does not stray from midline. A firm grasp of the anatomy of adjacent structures and the proximity of the spinal cord are essential during cervical interlaminar epidural injection (Fig. 5-9). Use of an anterior oblique projection, 45 to 55 degrees oblique to either side of midline, allows the practitioner to visualize the laminae and posterior extent of the spinal canal as the needle is advanced (Fig. 5-10). The use of this projection is particularly useful in the obese patient, where the spinal canal is obscured by the bony and soft-tissue elements of the shoulders in the lateral radiographic view. After the needle tip enters the epidural space, the position is confirmed by injecting 1 to 1.5 mL of nonionic radiographic contrast (iohexol 180 mg per mL or iopamidol 200 mg per mL), and contrast spread is verified in the AP and lateral planes. Lateral imaging of the cervicothoracic junction and low cervical spine is hindered by the adjacent structures of the torso and arms (Fig. 5-11). When the automatic brightness control (ABC) feature on modern fluoroscopy units attempts to equalize the contrast distribution across such a wide range of radiographic opacity, the resulting image is too dark in areas of poor x-ray penetration where the shoulders overly the spinal canal and too light in areas of high x-ray penetration where air surrounds the lateral aspect of the spine above the shoulders. Nonetheless, even on seemingly poor quality images like that shown in Figure 5-11, the critical radiographic anatomic features that define the posterior aspect of the spinal canal can be clearly seen. At the anterior aspect of each spinous process, the cortex of the bone forms an arc that extends cephalad, and this arc takes the form of the letter "J" in the lateral projection.

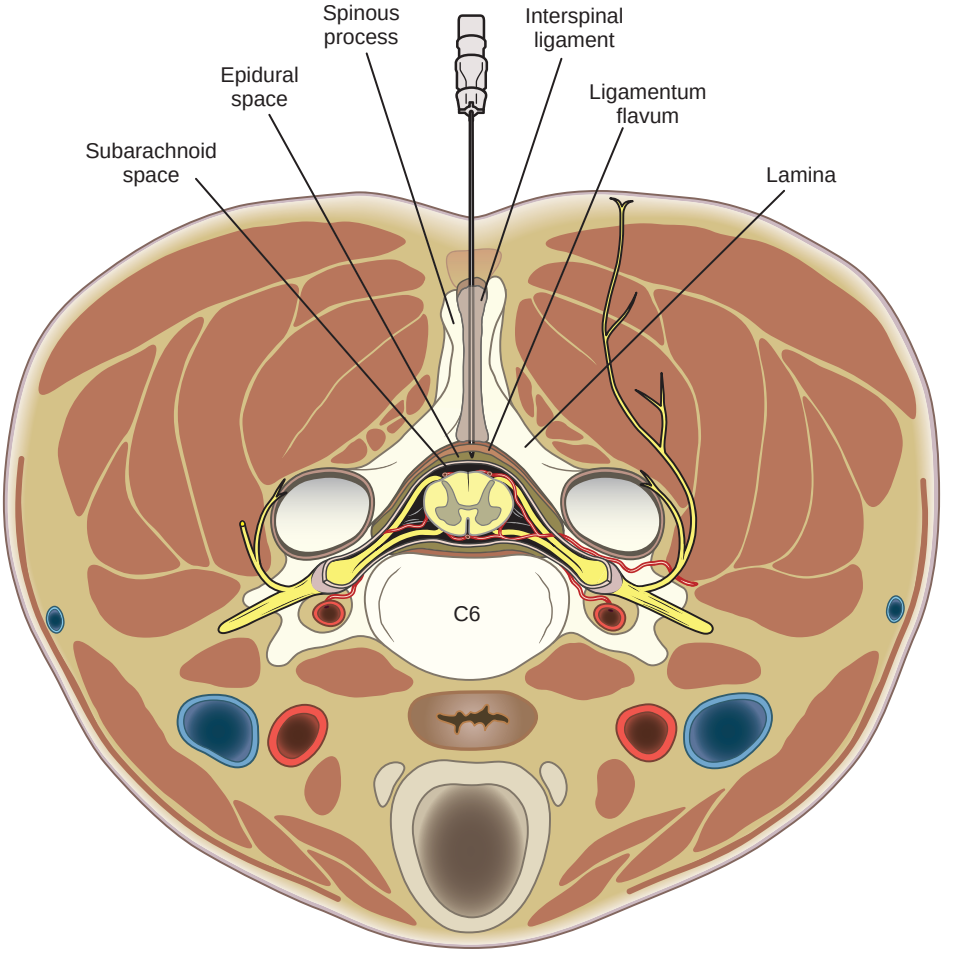
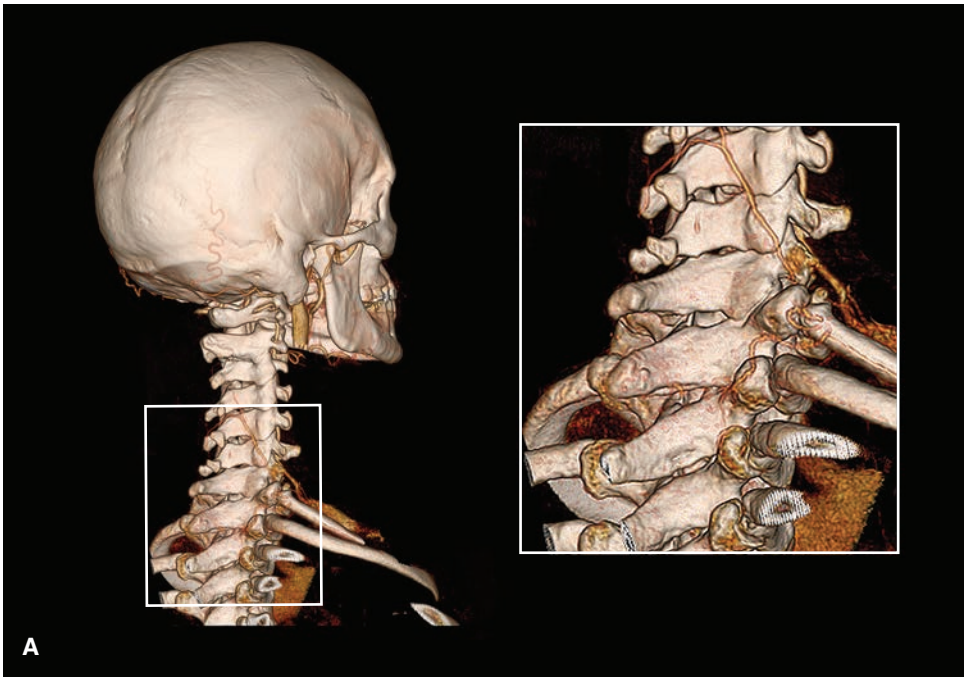
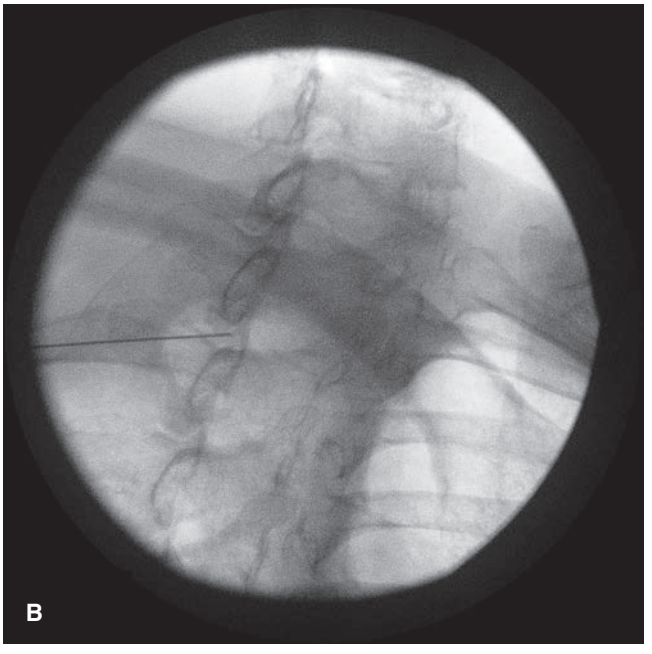


Figure 5-9.
Axial diagram of cervical interlaminar epidural injection. The epidural needle is advanced in the midline between spinous processes and traverses the ligamentum flavum to enter the dorsal epidural space in the midline. The normal cervical epidural space is ~3 mm wide (from the ligamentum flavum to the dura mater in the axial plane). Note the proximity of the underlying spinal cord during cervical epidural injection.





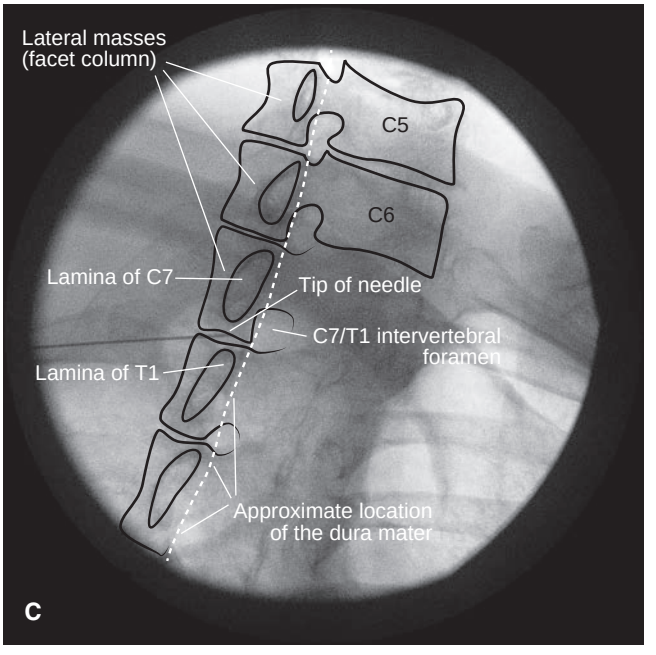


Figure 5-10.

A: Bony anatomy relevant to cervical interlaminar epidural injection. Three-dimensional reconstruction computed tomography of the cervical spine as viewed in an oblique projection. **Inset** matches the anatomic area in the radiographs shown in **(B)** and **(C)**. **B:** Anterior oblique radiograph of the cervical spine near the cervicothoracic junction during interlaminar cervical epidural injection. A 20-gauge Tuohy needle is in place in the C7/T1 interspace extending to the dorsal epidural space. The needle can be seen posterior to the posterior aspect of the laminae of C7 (superior to the needle) and T1 (inferior to the needle). The cortex of each lamina is clearly visible as an oval density superimposed on the facet column, just posterior to the intervertebral foramina. The use of the oblique projection allows the practitioner to clearly visualize the posterior extent of the spinal canal as the needle is advanced, even in the obese patient where little can be seen clearly in the lateral projection. **C:** Labeled image.

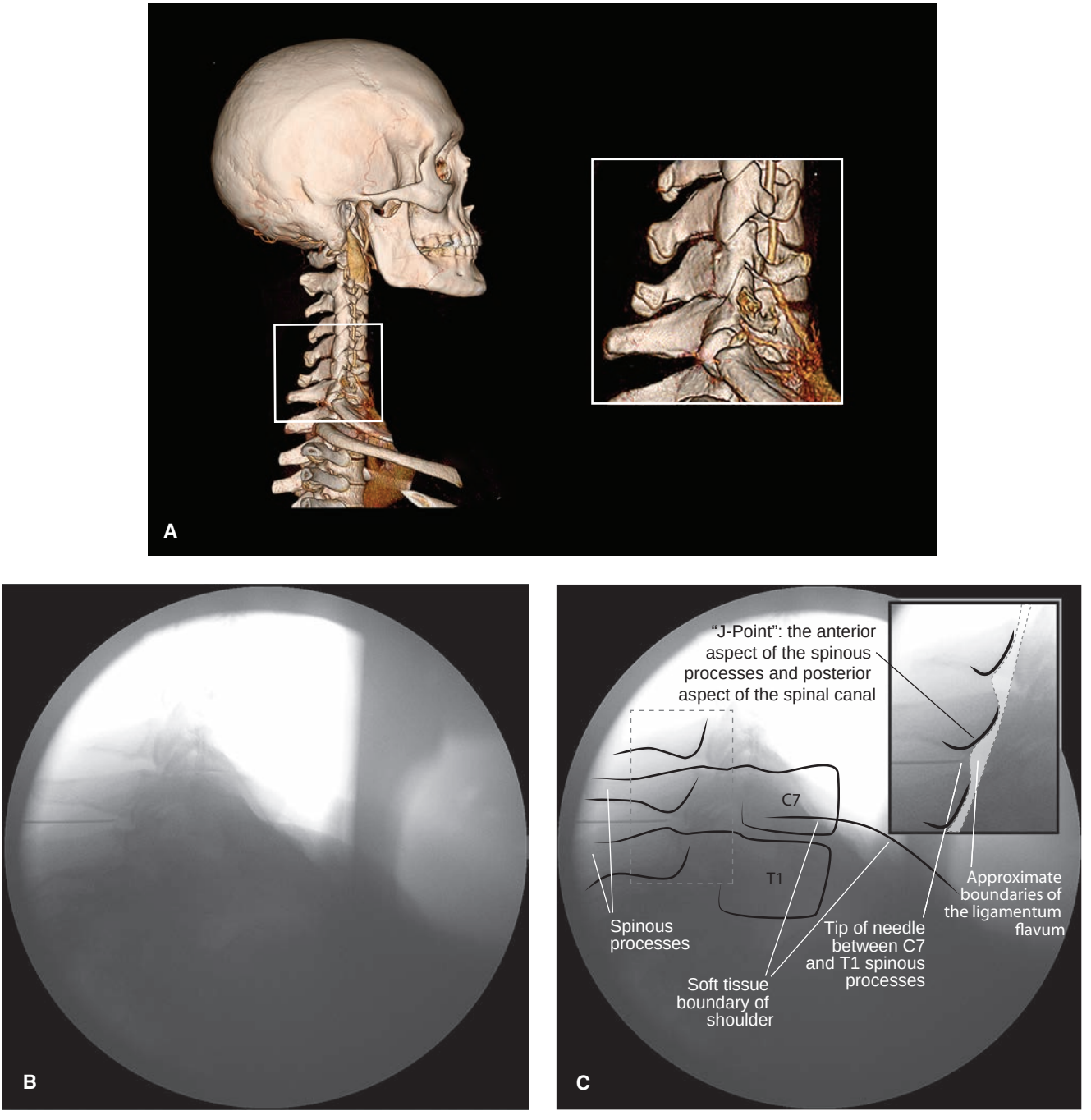


Figure 5-11.

A: Bony anatomy relevant to cervical interlaminar epidural injection. Three-dimensional reconstruction computed tomography of the cervical spine as viewed in the lateral projection. **Inset** matches the anatomic area in the radiographs shown in **(B–D)**. **B:** Lateral radiograph of the cervical spine near the cervicothoracic junction during interlaminar cervical epidural injection. A 22-gauge Tuohy needle is in place in the C7/T1 interspace extending toward the dorsal epidural space. **C:** Labeled image. The anterior most extent of the spinous process and the posterior most extent of the ligamentum flavum and spinal canal coincide with the "J-point" or the point where the inferior margin of the spinous process begins to arc in a cephalad direction, taking the appearance of the letter "J". The area outlined to the left of the image in the dashed box has been enlarged in the inset to the right, where the approximate borders of the ligamentum flavum have been outlined. ***(Cont.)***

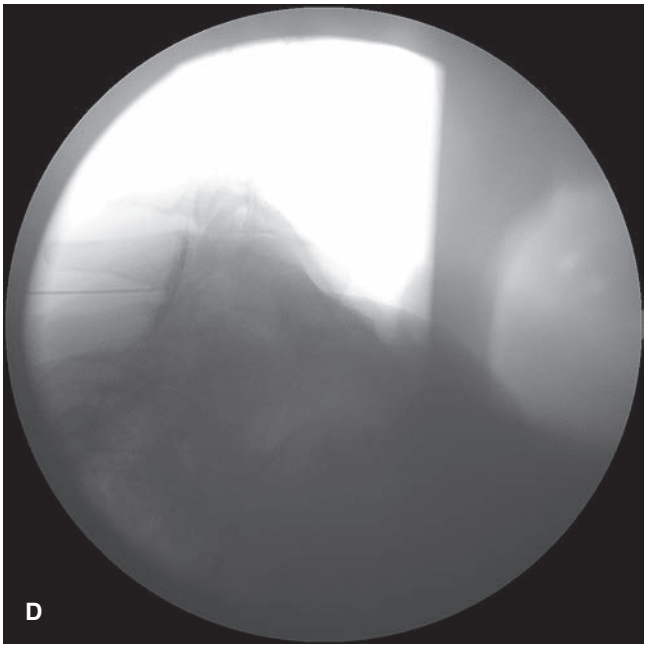


Figure 5-11. ***(Continued)***
D: The same lateral projection is shown with the needle in the epidural space after injection of 1 mL of radiographic contrast (iopamidol 200 mg per mL). The contrast extends in a linear stripe in a cephalad and caudad direction from the needle tip that outlines the dorsal (posterior) border of the dura mater.

The "J-point" is the point where the inferior margin of the spinous process begins to arc in a cephalad direction and coincides with the posterior most aspect of the ligamentum flavum (Fig. 5-11C). The needle tip can be safely advanced to this point in the lateral projection without any danger of entering the spinal canal. The needle is then advanced the last few millimeters through the ligamentum flavum and into the epidural space using the LOR technique. Once the needle tip is within the epidural space and contrast has been injected (Fig. 5-11D), a second lateral image taken just above the shoulders is often much simpler to interpret when trying to confirm epidural contrast flow (Fig. 5-12). Digital subtraction technology can also be extremely useful in ensuring injectate has spread to the level of pathology (Fig. 5-13). Once epidural needle position has been confirmed, a solution containing steroid diluted in preservative-free saline (80 mg of methyl prednisolone acetate or the equivalent diluted in 5 mL total volume) is injected, and the needle is removed.

Complications

Dural puncture with subsequent postdural puncture headache can occur during cervical interlaminar epidural injection. Although cervical epidural blood patch using a small volume of autologous blood has been described, most practitioners will manage postdural puncture headache following cervical epidural injection conservatively with fluids and oral analgesics. The incidence of headache following cervical dural puncture is lower than that following lumbar puncture, likely due to the diminished column of cerebrospinal fluid (CSF) cephalad to the point of dural puncture. Direct trauma to the spinal cord with catastrophic consequences (quadriplegia) has also been described, particularly in heavily sedated patients (Fig. 5-14). The level of sedation during this procedure should allow for direct conversation between the practitioner and the patient to ensure that the patient can report contact with neural elements before significant traumatic injury occurs. Caution should also be taken to avoid interlaminar epidural injection at any level where there is effacement of the epidural space (e.g., complete effacement of the epidural space and the CSF column surrounding the spinal cord within the thecal sac occurs in high-grade spinal stenosis, particularly that due to a large central or paramedian disc herniation). As with interlaminar epidural injection at all vertebral levels, epidural bleeding or infection can occur. Epidural hematoma or abscess can lead to significant spinal cord compression. Interlaminar injection should be avoided or postponed in those receiving anticoagulants.

Thoracic Epidural Injection

Positioning

The patient lies prone, with the head turned to one side (Fig. 5-15). The C-arm is rotated 40 to 50 degrees caudally from the axial plane without any oblique angulation. This allows for good visualization of the interlaminar space and needle advancement between adjacent spinous processes (Figs. 5-16 and 5-17).

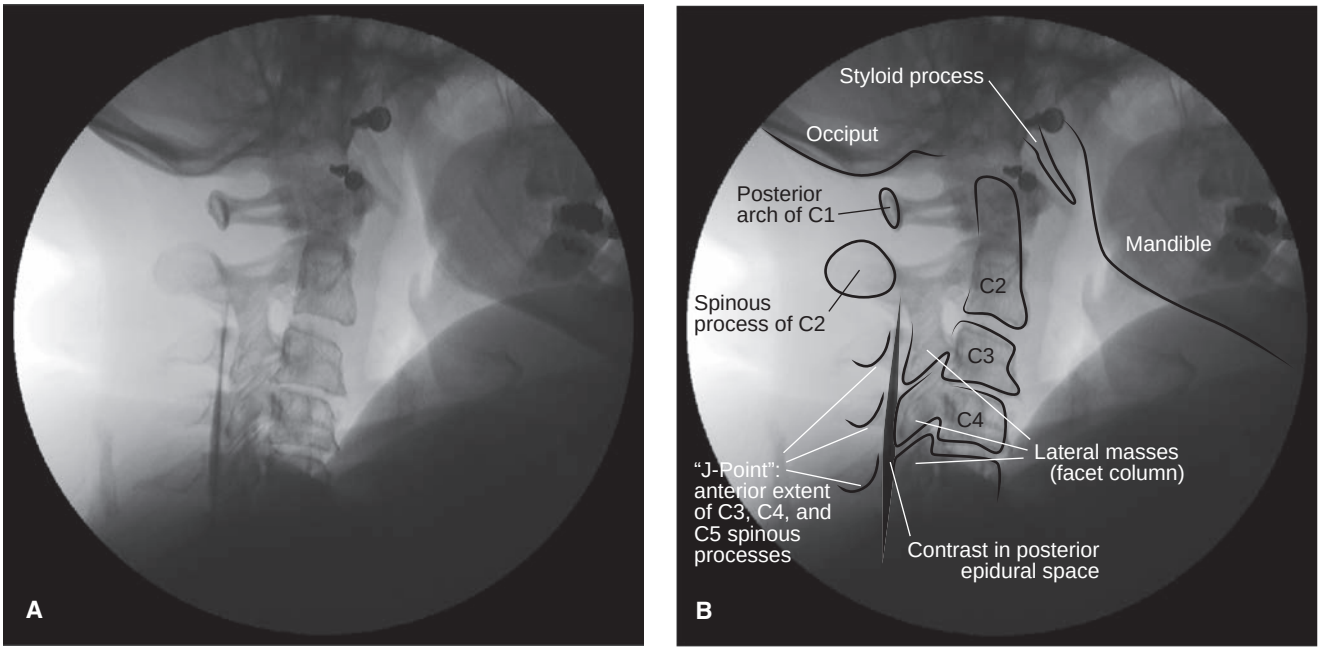


Figure 5-12.
Lateral radiograph of the upper cervical spine during interlaminar cervical epidural injection. **A:** Lateral radiograph of the superior cervical spine after injection of 1.5 mL of radiographic contrast at the C6/C7 level. The contrast can be seen as a thin stripe toward the posterior aspect of the spinal canal, adjacent to the anterior-most aspect of each spinous process. Although lateral radiographs near the cervicothoracic junction are difficult to interpret because of the overlying structures of the thorax and upper extremities, lateral radiographs of the superior cervical spine can be used to verify epidural placement. **B:** Labeled image.

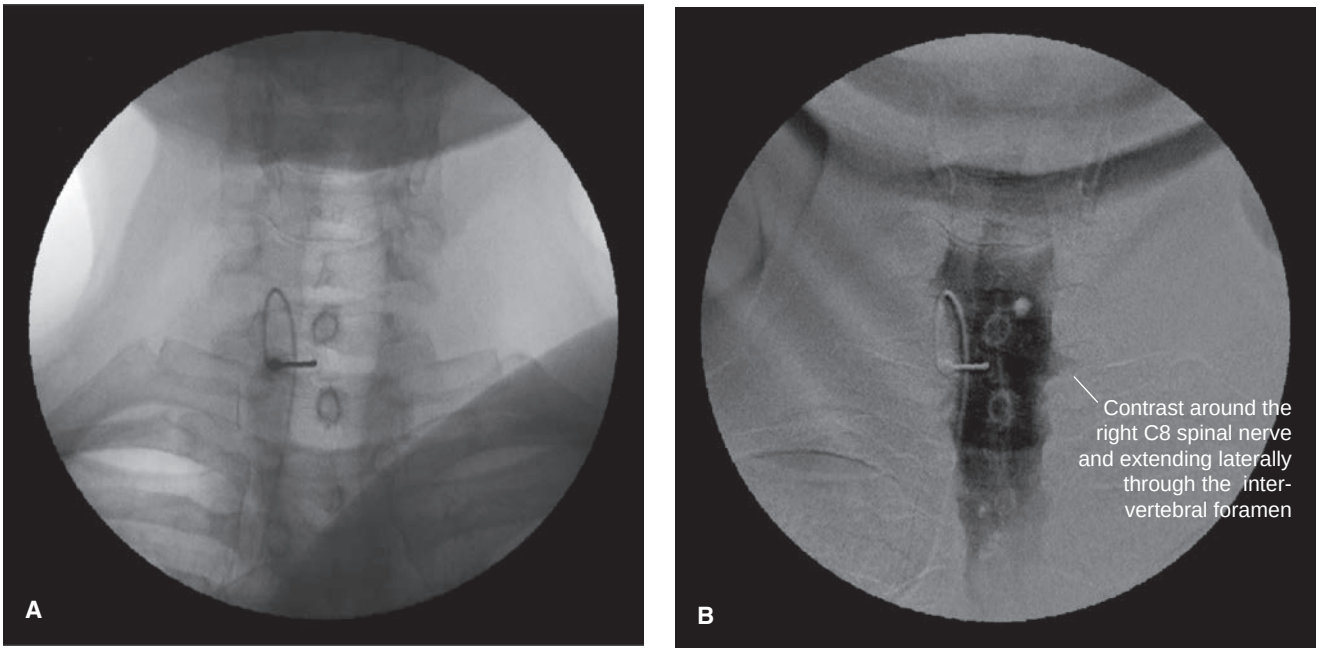


Figure 5-13.
Epidurogram following interlaminar cervical epidural steroid injection. **A:** AP radiograph showing the epidural needle in final position for contrast injection via flexible extension tubing. **B:** Final digital subtraction image following injection of 1.5 mL of radiographic contrast. Note the contrast spread nearly two vertebral levels above and below the level of injection and outlining the spinal nerves on both sides. Radiolucent area cephalad and to right of the needle tip is an air bubble in the contrast medium.

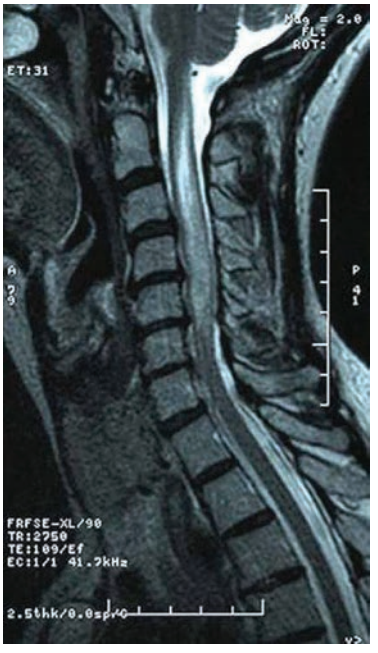


Figure 5-14.
MRI of the cervical spine demonstrating spinal cord injury sustained during cervical interlaminar epidural steroid injection. Sagittal T2-weighted MRI of the cervical spine taken several hours after a cervical epidural steroid injection performed using an interlaminar approach. The injection was performed in an unresponsive patient under deep sedation. The presence of high T2-weighted signal within the spinal cord suggests edema, most likely a result of needle entry and direct injection within the substance of the spinal cord. The patient suffered permanent, partial loss of sensory and motor function in all extremities.

Block Technique

The skin and subcutaneous tissues ~1 cm lateral and 1 cm caudal to the interspace where the block is to be carried out are anesthetized with 1 to 2 mL of 1% lidocaine. An 18- or 20-gauge Tuohy needle is placed through the skin and advanced several centimeters until it is firmly seated in tissue. An AP image is then taken and the needle is redirected toward the inferior margin of the lamina that bounds the inferior aspect of the interspace that is to be entered near the junction of the spinous process and the lamina (see Fig. 5-17). Although a midline approach can be used at low thoracic levels, the spinous processes are angled too steeply to allow for true coaxial needle placement at the midthoracic levels. Thus, the needle is directed toward the margin of the lamina. The needle is advanced in 3- to 4-mm increments and repeat images are taken. Care must be taken to keep the needle tip over the margin of the lamina until the bone is gently contacted. The periosteum should then be anesthetized with an additional 1 mL of 1% lidocaine and a syringe containing 1 to 3 mL of preservative-free saline attached to the needle. The needle is slowly advanced over the superior margin of the lamina and into the interlaminar space in 1- to 2-mm increments until LOR occurs. Because the needle is unlikely to lie within the interspinous ligament when using a paramedian approach, there will be little resistance to injection until the needle enters the interlaminar space and traverses the ligamentum flavum. A firm grasp of the anatomy of adjacent structures and the proximity of the spinal cord are essential during thoracic interlaminar epidural injection (Fig. 5-18). After the needle tip enters the epidural space, the position is confirmed by injecting 1 to 1.5 mL of nonionic radiographic contrast (iohexol 180 mg per mL), and contrast spread is verified in the AP and lateral planes. Lateral imaging of the thoracic spine is hindered by the overlying structures of the thorax (Fig. 5-19). Once epidural needle position has been confirmed, a solution containing steroid diluted in preservative-free saline (80 mg of methyl prednisolone acetate or the equivalent diluted in 5 mL total volume) is injected, and the needle is removed.

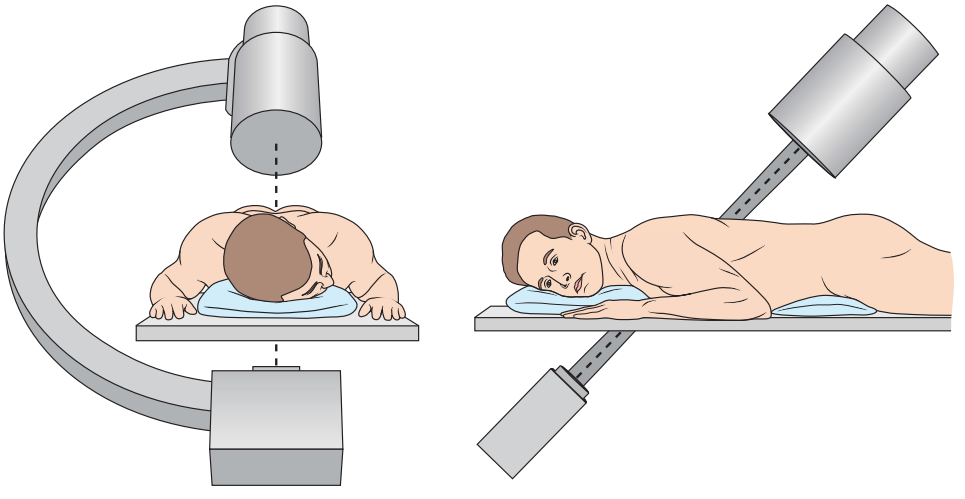


Figure 5-15.
Position for interlaminar thoracic epidural injection. The patient is placed prone with the head turned to one side. The C-arm is angled 40 to 50 degrees caudally from the axial plane.

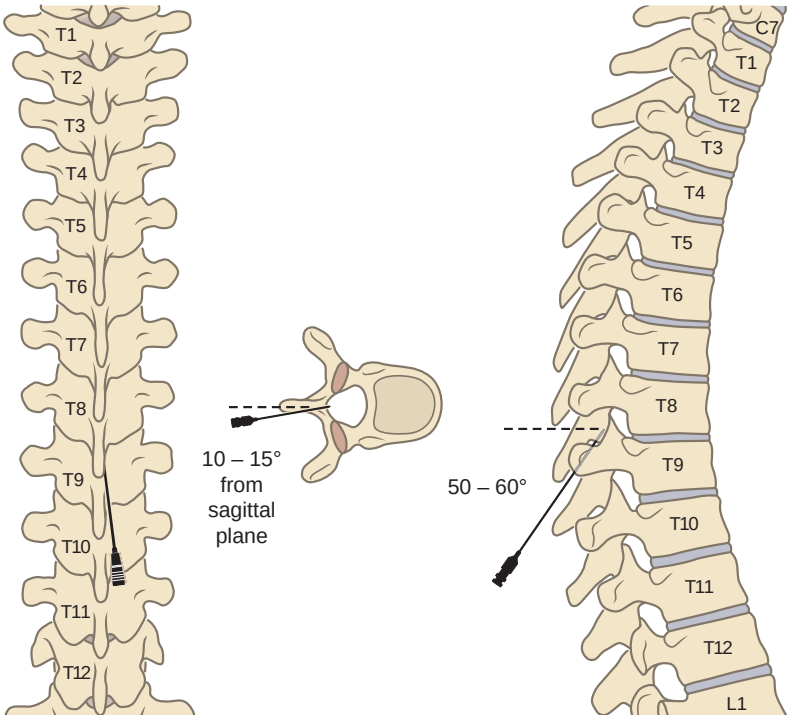


Figure 5-16.
Position and angle of needle entry for thoracic interlaminar epidural injection (paramedian approach). Starting ~1 cm below the interspace and 1 cm lateral to the spinous processes, an 18- or 20-gauge Tuohy needle is advanced 10 to 15 degrees toward midline with 50 to 60 degrees of cranial angulation from the axial plane.

Complications

Dural puncture with subsequent postdural puncture headache can occur during thoracic interlaminar epidural injection. Although thoracic epidural blood patch using a small volume of autologous blood has been described, most practitioners will manage postdural puncture headache following thoracic epidural injection conservatively with fluids and oral analgesics. The incidence of headache following thoracic dural puncture is high (50% or more of patients), approaching that following lumbar puncture. Direct trauma to the spinal cord with catastrophic consequences (quadriplegia) has also been described, particularly in heavily sedated patients. The level of sedation during this procedure should allow for direct conversation between the practitioner and the patient to ensure that the patient can report contact with neural elements before significant traumatic injury occurs. Caution should also be taken to avoid interlaminar epidural injection at any level where there is effacement of the epidural space (e.g., complete effacement of the epidural space and the CSF column surrounding the spinal cord within the thecal sac such as that which can occur in high-grade spinal stenosis, particularly that due to a large central or paramedian disc herniation). As with interlaminar epidural injection at all vertebral levels, epidural bleeding or infection can occur. Epidural hematoma or abscess can lead to significant spinal cord compression. Interlaminar injection should be avoided or postponed in those receiving anticoagulants.

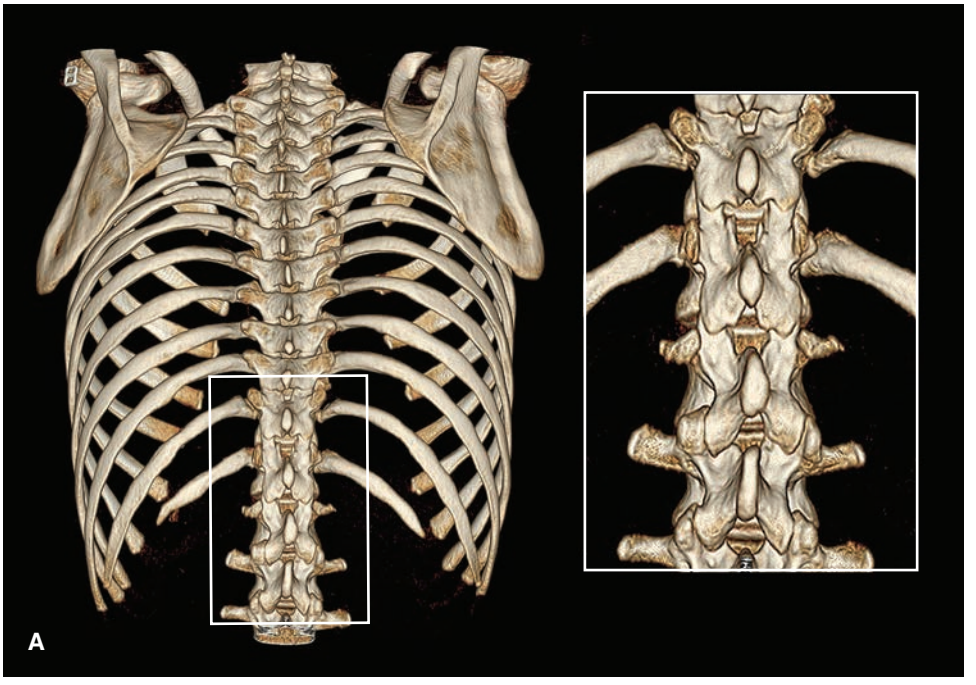
Lumbar Epidural Injection

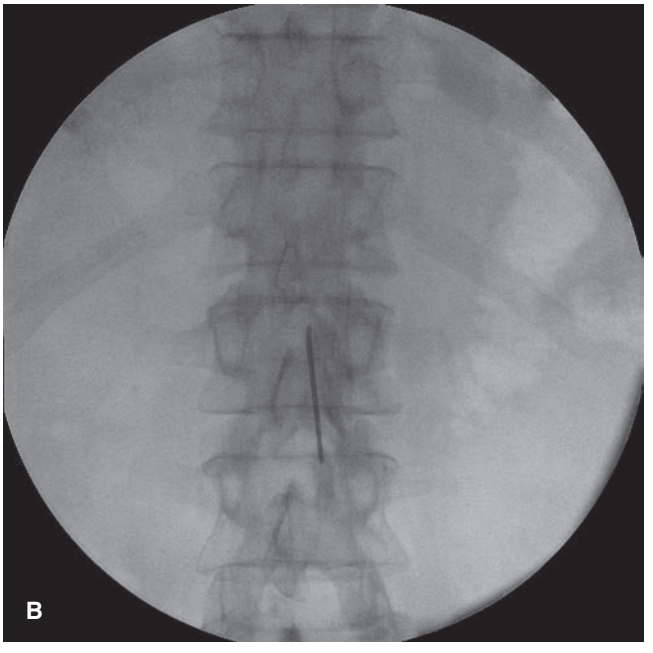
Positioning

The patient lies prone with the head turned to one side (Fig. 5-20). A pillow is placed under the mid and lower abdomen to reduce the lumbar lordosis and increase the separation between adjacent spinous processes. The C-arm is rotated 15 to 20 degrees caudally from the axial plane without any oblique angulation. This allows for good visualization of the interlaminar space and needle advancement between adjacent spinous processes (Figs. 5-21 and 5-22).

Block Technique

The skin and subcutaneous tissues overlying the interspace where the block is to be carried out are anesthetized with 1 to 2 mL of 1% lidocaine. An 18- or 20-gauge Tuohy needle is placed through the skin and advanced 1 to 2 cm until it is firmly seated in the interspinous ligament. An AP image is then taken, and the needle is directed toward midline (see Fig. 5-22). A firm knowledge of the anatomy of adjacent structures, as well as the proximity of the thecal sac and cauda equina, is essential during lumbar interlaminar epidural injection (Fig. 5-23). The fluoroscope is then moved to a lateral projection, and the needle is advanced anteriorly until it lies just posterior to the junction of the spinous process and the laminae (Fig. 5-24). A syringe containing 1 to 3 mL of preservative-free saline is attached to the needle, and the needle is





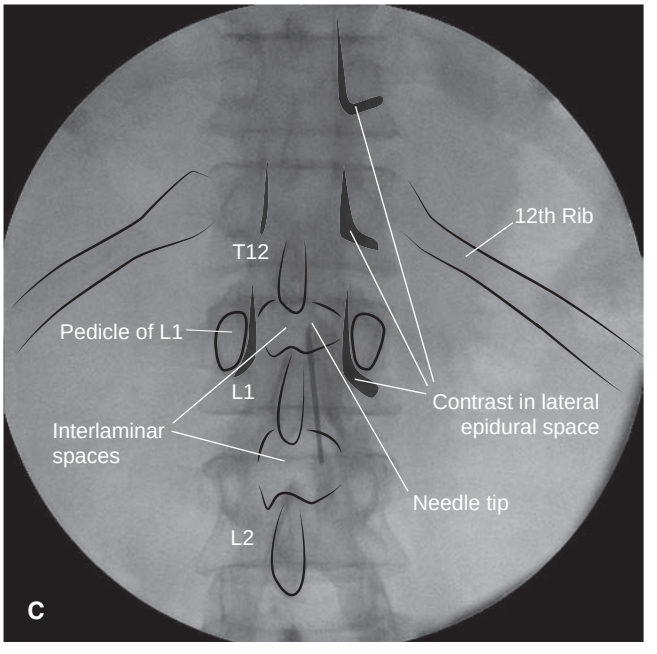


Figure 5-17.

A: Bony anatomy relevant to thoracic interlaminar epidural injection. Three-dimensional reconstruction computed tomography of the low thoracic spine as viewed from the posterior approach used for thoracic interlaminar injection. **Inset** matches the anatomic area in the radiographs shown in **(B)** and **(C)**. **B:** Anterior-posterior radiograph of the thoracic spine during thoracic interlaminar injection (paramedian approach). An 18-gauge Tuohy needle is in position between the T12 and L1 laminae just to the right of midline. The needle should first be advanced, keeping the needle tip over the superior margin of the lamina bounding the inferior aspect of the interspace to be entered (in this example, the superior margin of the lamina of L1 to the right of midline). The needle is advanced until it gently touches the lamina where it joins with the spinous process. Using the paramedian approach, contacting the margin of lamina allows determination of depth before entering the interspace and starting LOR to identify the epidural space. This paramedian approach is often necessary at thoracic levels because of the steep angulation of the spinous processes. With the paramedian approach, the LOR technique is unreliable until the needle is seated within the ligamentum flavum; at more superficial levels, there is little resistance to injection. **C:** Labeled image.

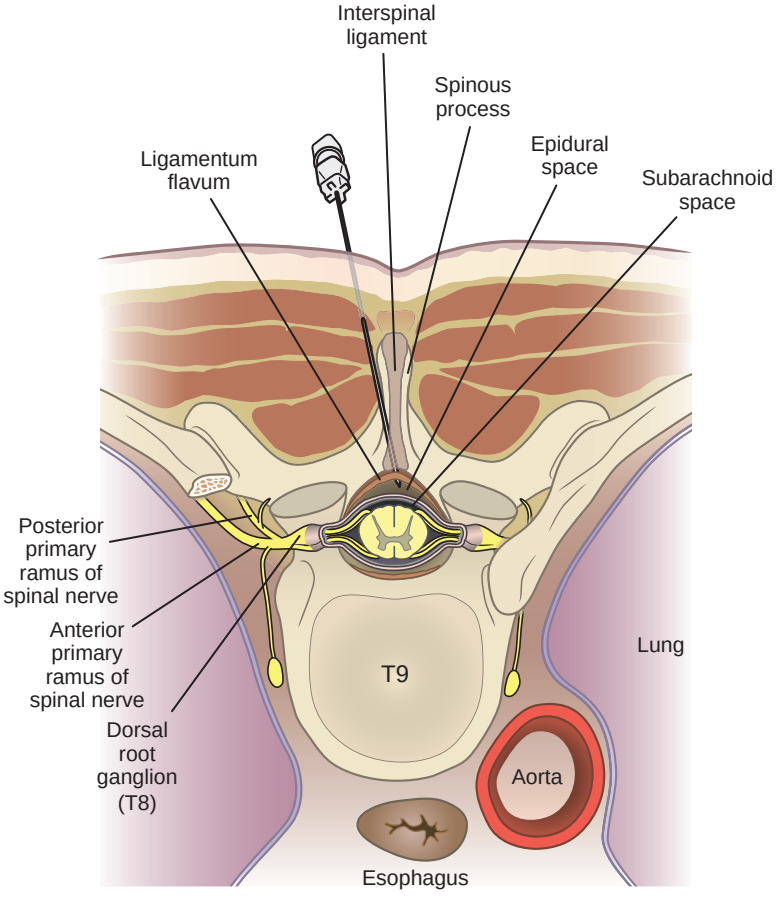


Figure 5-18.
Axial diagram of interlaminar thoracic epidural injection. The epidural needle is advanced toward the midline using a paramedian approach and traverses the ligamentum flavum to enter the dorsal epidural space in the midline. The normal epidural space is ~3 to 5 mm wide (from the ligamentum flavum to the dura mater in the axial plane). Note the proximity of the underlying spinal cord during thoracic epidural injection.

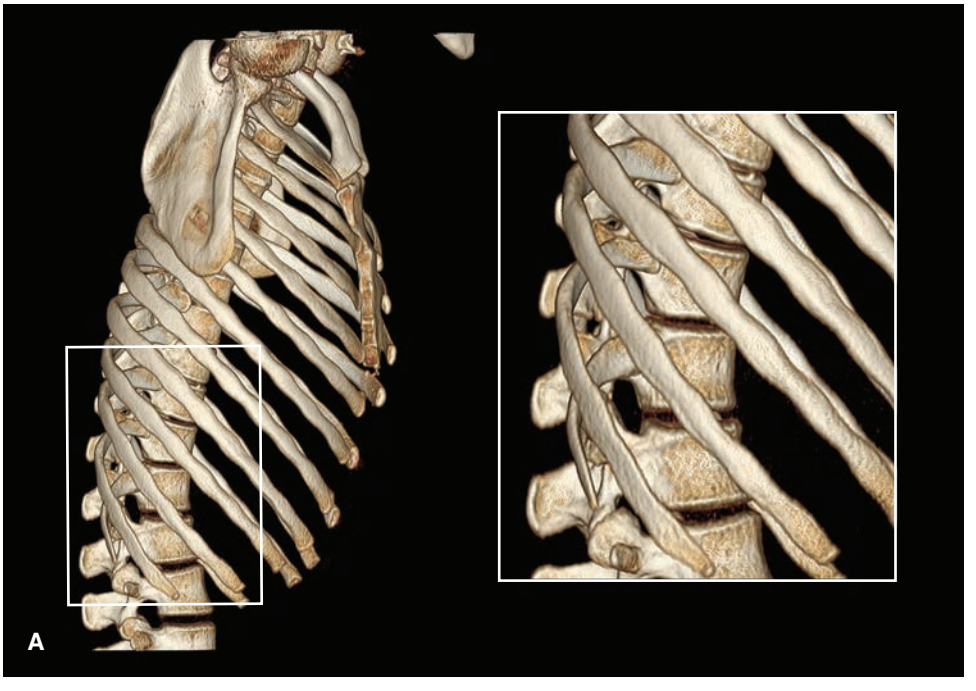


Figure 5-19.
A: Bony anatomy relevant to thoracic interlaminar epidural injection. Three-dimensional reconstruction computed tomography of the low thoracic spine as viewed in the lateral projection. **Inset** matches the anatomic area in the radiographs shown in **(B)** and **(C)**. ***(Cont.)***

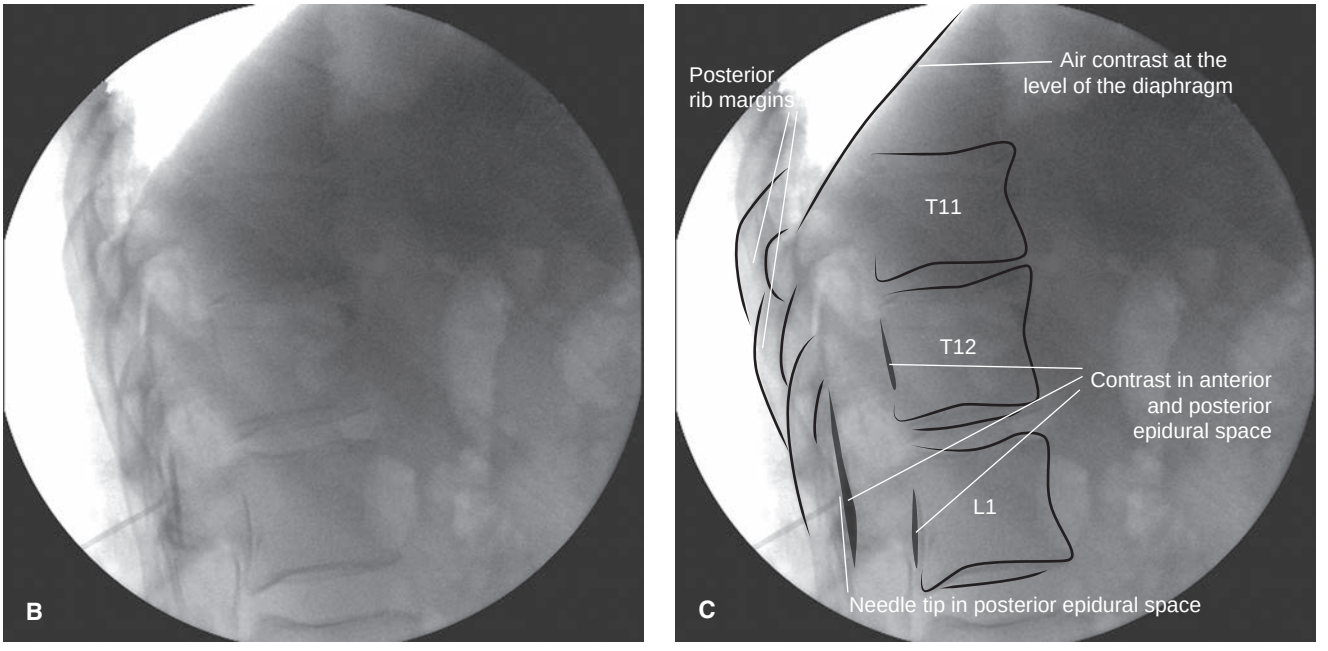


Figure 5-19. *(Continued)*

B: Lateral radiograph of the thoracic spine during interlaminar thoracic epidural injection. A Tuohy needle is in place in the T12/L1 interspace extending to the dorsal epidural space. One and one-half milliliters of radiographic contrast has been injected and can be seen in the posterior epidural space near the tip of the needle and as a thin stripe along the anterior epidural space adjacent to the vertebral bodies. Lateral radiographs of the thoracic spine are difficult to interpret because of the overlying structures of the thorax and the air contrast of the overlying lung fields. **C:** Labeled image.

slowly advanced in 1- to 2-mm increments until LOR occurs. After the needle tip enters the epidural space, the position is confirmed by injecting 1 to 1.5 mL of nonionic radiographic contrast (iohexol 180 mg per mL), and contrast spread is verified in the AP and lateral planes. Lateral imaging of the lower lumbar spine is hindered by the overlying iliac crests (Fig. 5-24); visualization can also be quite difficult in the obese patient. Once epidural needle position has been confirmed, a

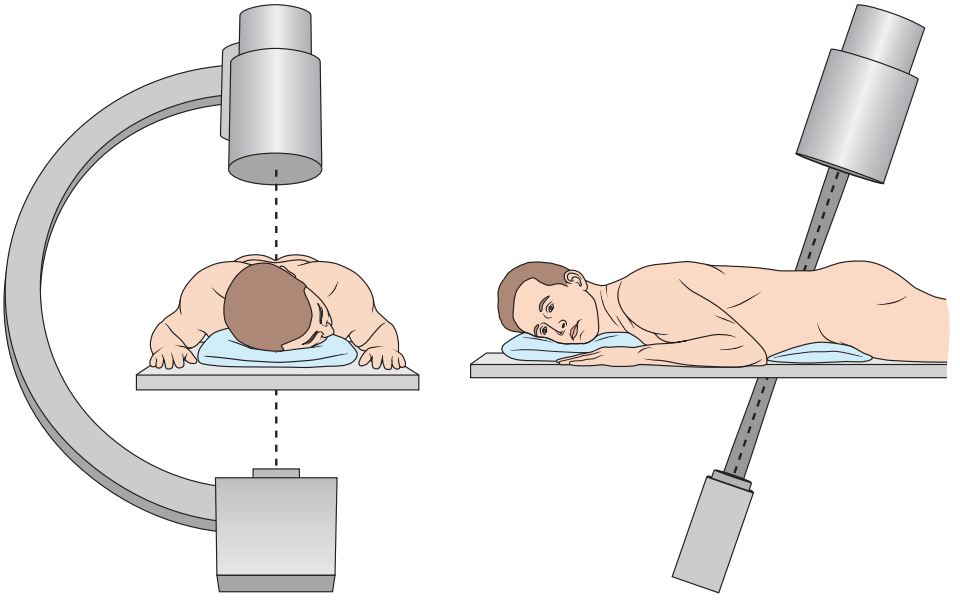


Figure 5-20.

Position for interlaminar lumbar epidural injection. The patient is placed prone with the head turned to one side. A pillow is placed under the mid and lower abdomen to reduce the lumbar lordosis and increase the distance between adjacent spinous processes. The C-arm is angled 15 to 20 degrees caudally from the axial plane.

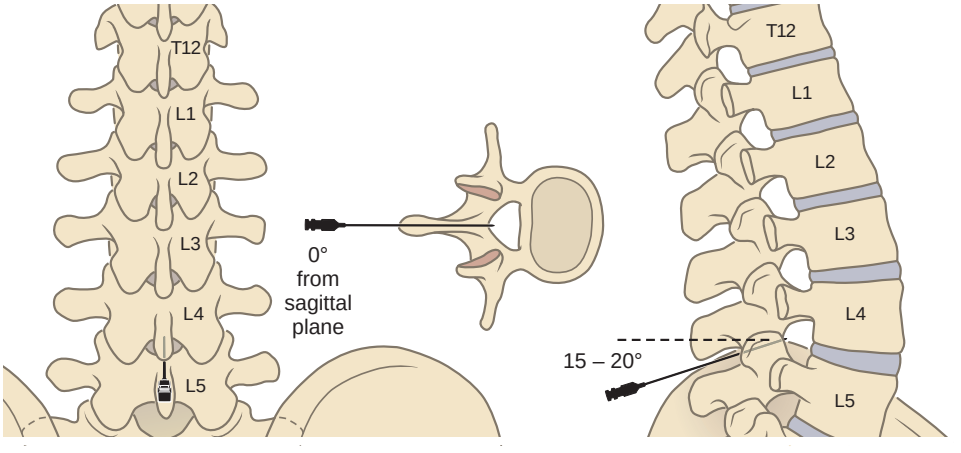


Figure 5-21.
Position and angle of needle entry for lumbar interlaminar epidural injection. An 18- or 20-gauge Tuohy needle is advanced in the midline with 15 to 20 degrees of cranial angulation from the axial plane parallel to the spinous processes.

solution containing steroid diluted in preservative-free saline (80 mg of methylprednisolone acetate or the equivalent diluted in 3 to 5 mL total volume) is injected, and the needle is removed. When larger injectate volumes are used, the solution spreads extensively in both the anterior and posterior aspects of the epidural space (Figs. 5-25 and 5-26). In patients with significant lumbar pathology (e.g., a herniated intervertebral disc), the injectate will tend to follow the path of least resistance, often flowing toward the side opposite the pathology.

Complications

Dural puncture with subsequent postdural puncture headache can occur during lumbar interlaminar epidural injection. The incidence of unintentional dural puncture may be higher in those with previous lumbar surgery, due to scarring within the epidural space and adhesion of the dura to the posterior elements. Epidural blood patch using autologous blood is a safe and effective treatment that relieves the headache symptoms promptly in the majority of those who

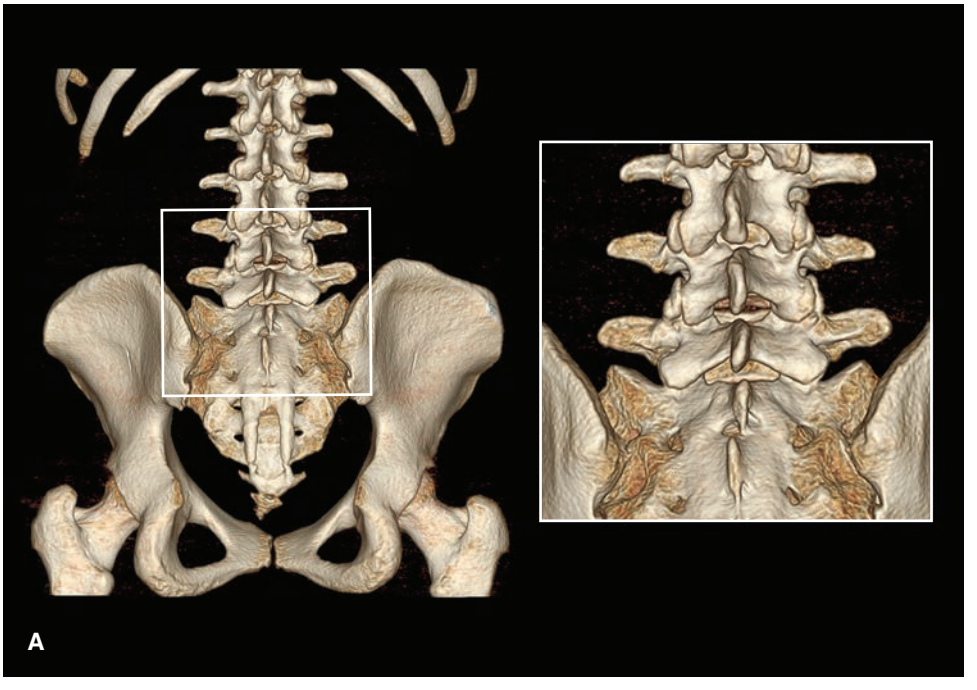


Figure 5-22.
A: Bony anatomy relevant to lumbar interlaminar epidural injection. Three-dimensional reconstruction computed tomography of the lumbar spine as viewed from the posterior approach used for lumbar interlaminar injection. **Inset** matches the anatomic area in the radiographs shown in **(B)** and **(C)**. ***(Cont.)***

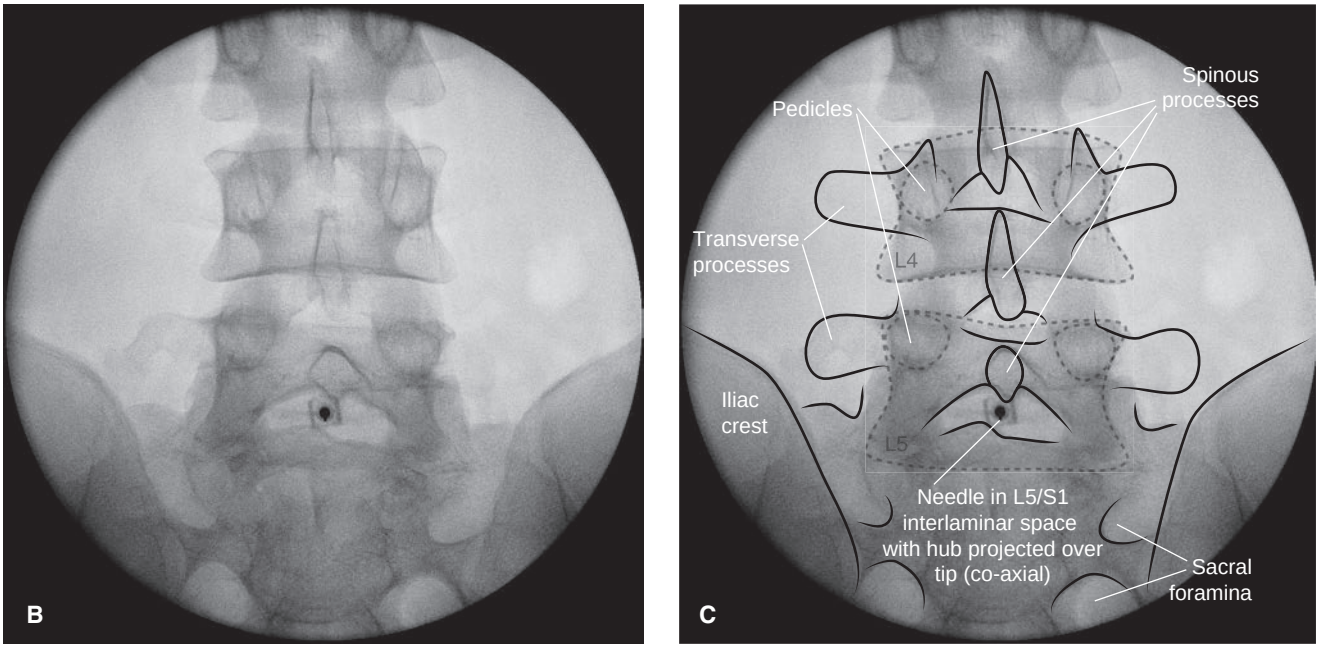


Figure 5-22. *(Continued)*
B: Anterior-posterior radiograph of the lumbar spine during interlaminar lumbar epidural injection. A 20-gauge Tuohy needle is in position between the L5 and S1 laminae with the hub projected directly over the needle tip. **C:** Labeled image.

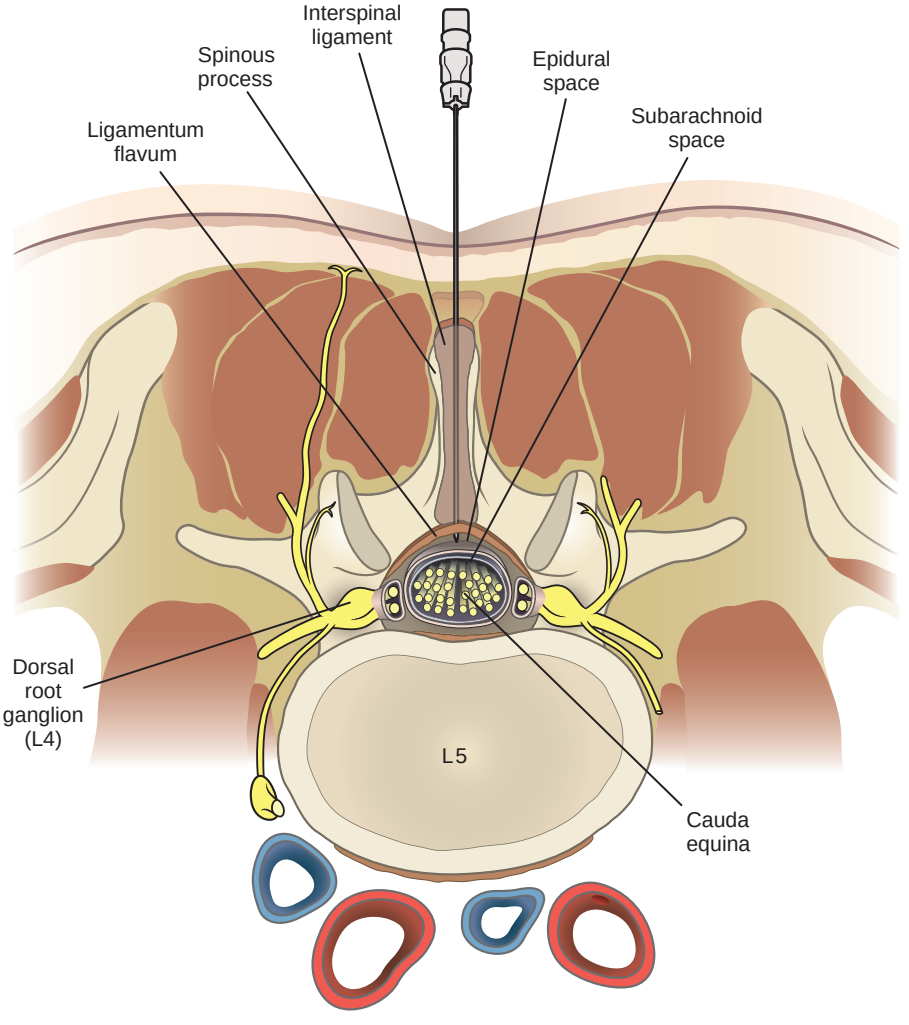


Figure 5-23.
Axial diagram of interlaminar lumbar epidural injection. The epidural needle is advanced in the midline between adjacent spinous processes to traverse the ligamentum flavum and enter the dorsal epidural space in the midline. The normal epidural space is ~4 to 6 mm wide (from the ligamentum flavum to the dura mater in the axial plane). Note the proximity of the underlying cauda equina during lumbar epidural injection.

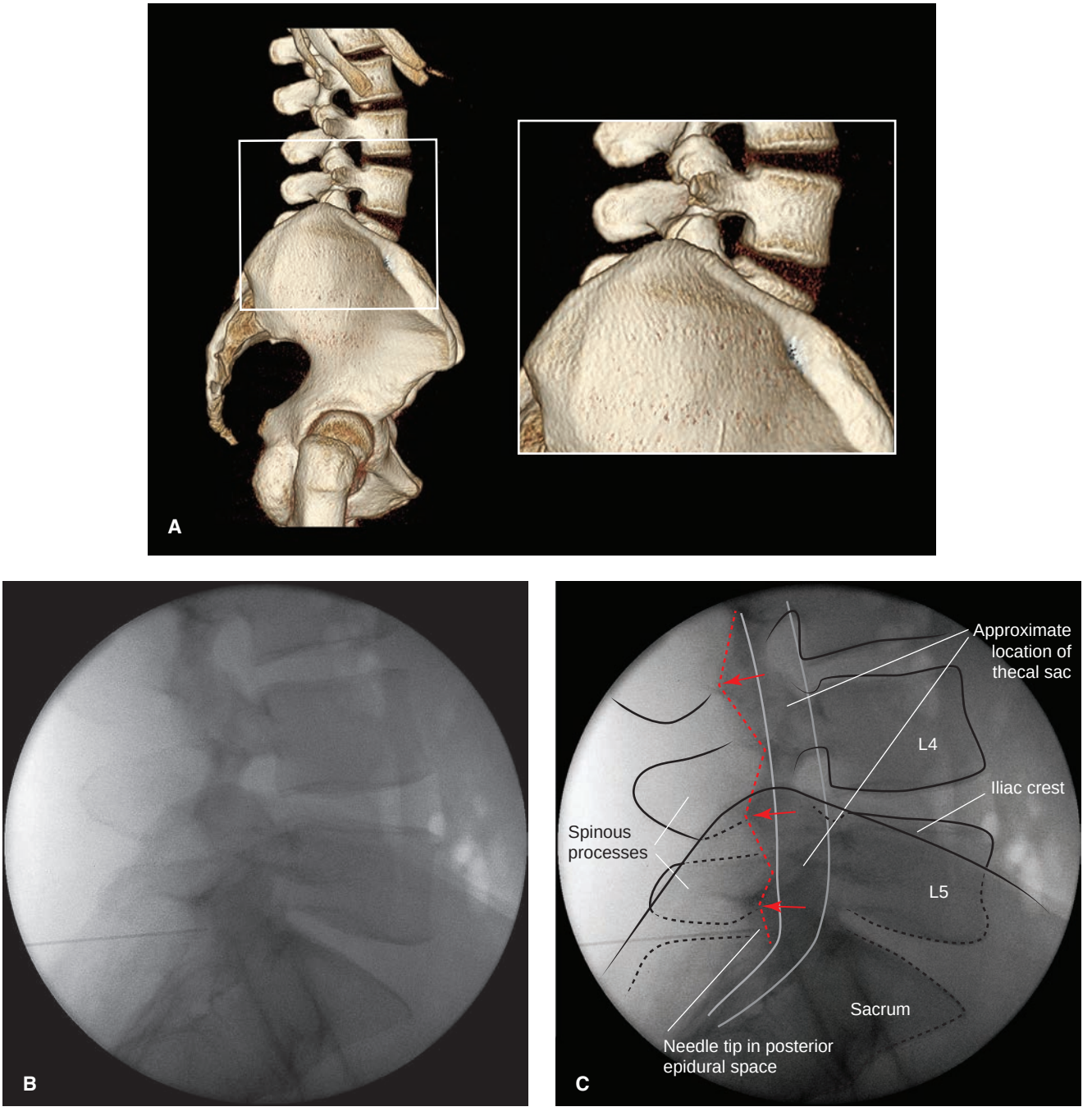


Figure 5-24.

A: Bony anatomy relevant to lumbar interlaminar epidural injection. Three-dimensional reconstruction computed tomography of the lumbar spine as viewed in the lateral projection. **Inset** matches the anatomic area in the radiographs shown in **(B)** and **(C)**. **B:** Lateral radiograph of the lumbar spine during interlaminar lumbar epidural injection. A Tuohy needle is in place in the L5/S1 interspace extending to the posterior epidural space. Clarity of lateral radiographs of the lumbar spine is often hindered by the overlying iliac crests. **C:** Labeled image. During lumbar interlaminar epidural injection, the needle can be safely advanced using the lateral radiograph to guide depth. The posterior-most extent of the ligamentum flavum lies just anterior to the junction of the spinous process with the laminae (*red arrows*). The needle can be safely advanced to this depth before starting the LOR technique during the last few millimeters of advancement through the ligamentum flavum to precisely identify the epidural space. The junction of the spinous process with the lamina can be easily identified in the lateral radiograph by following the inferior margin of the spinous processes anteriorly until the junction with the lamina is seen as a line that extends in an inferior and anterior direction (*dashed line*). The approximate location of the thecal sac is shown (*gray lines* indicate the approximate location of the anterior and posterior aspects of the dura mater).

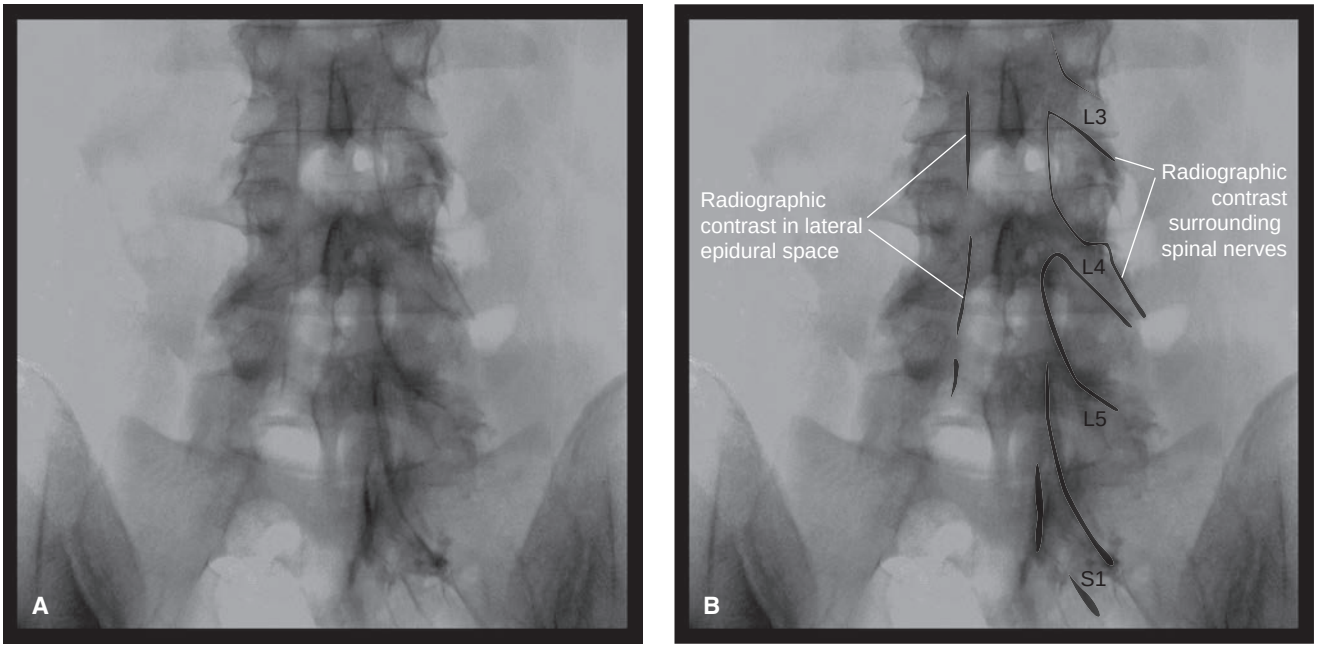


Figure 5-25.
Anterior-posterior epidurogram of the lumbosacral spine. **A:** When larger volumes of injectate are used (in this image, 10 mL of contrast-containing solution), the injectate spreads extensively within the anterior and posterior epidural space and exits the intervertebral foramina, surrounding the spinal nerves. However, in the presence of significant obstruction to flow, as in this patient with a right L4/L5 disc herniation and compression of the exiting right L4 spinal nerve, the injectate often follows the path of least resistance, exiting the foramina on the side *opposite* from the disc herniation. **B:** Labeled image showing the contours of the epidurogram. (Adapted from Rathmell JP, Torian D, Song T. Lumbar epidurography. *Reg Anesth Pain Med*. 2000;25:542, with permission.)

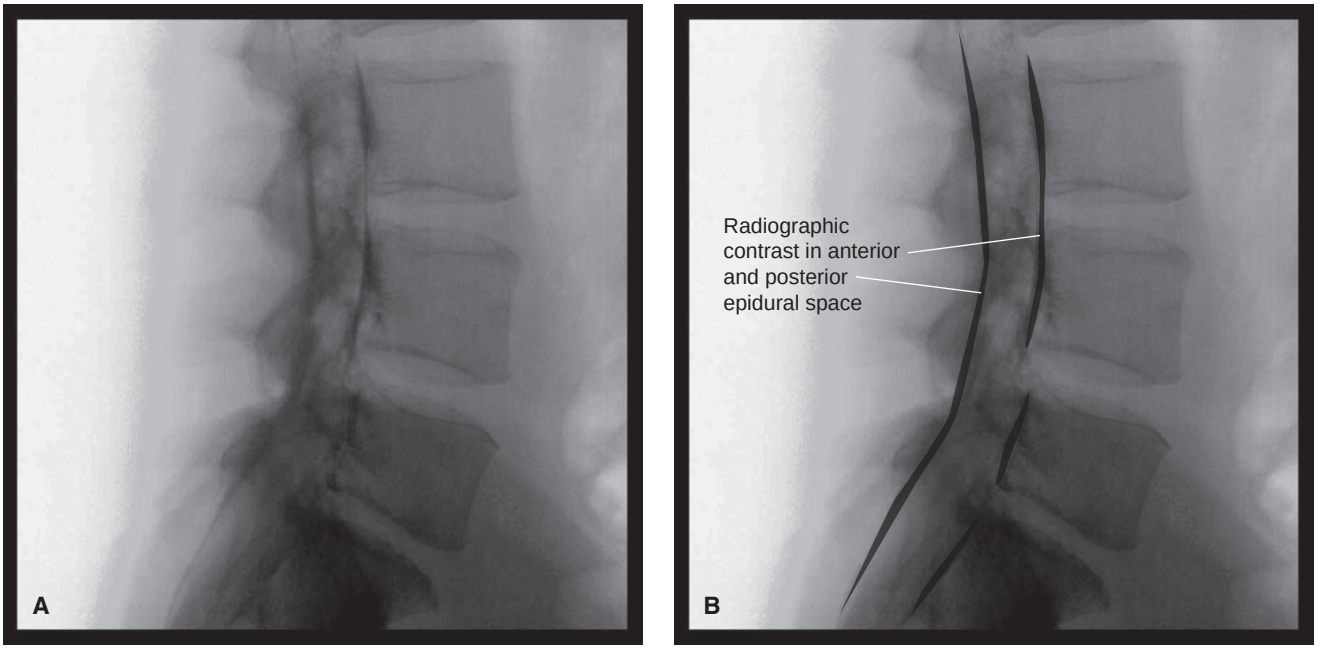


Figure 5-26.
A: Lateral epidurogram of the lumbosacral spine. When larger volumes of injectate are used (in this image, 10 mL of contrast-containing solution), the injectate spreads extensively within the anterior and posterior epidural space and has a characteristic *double line* or *railroad track* appearance. **B:** Labeled image showing the contours of the epidurogram. (Adapted from Rathmell JP, Torian D, Song T. Lumbar epidurography. *Reg Anesth Pain Med*. 2000;25:542, with permission.)

fail to improve after 24 to 48 hours of conservative treatment with fluids and oral analgesics. Direct trauma to the cauda equina or spinal nerves is unlikely during lumbar epidural injection when disciplined use of radiographic guidance is employed to ensure the needle tip does not stray from the midline. The level of sedation during this procedure should allow for direct conversation between the practitioner and the patient to ensure the patient can report contact with neural elements before significant traumatic injury occurs. As with interlaminar epidural injection at all vertebral levels, epidural bleeding or infection can occur. Epidural hematoma or abscess (Fig. 5-27) can lead to significant spinal cord compression. Interlaminar injection should be avoided or postponed in those receiving anticoagulants.

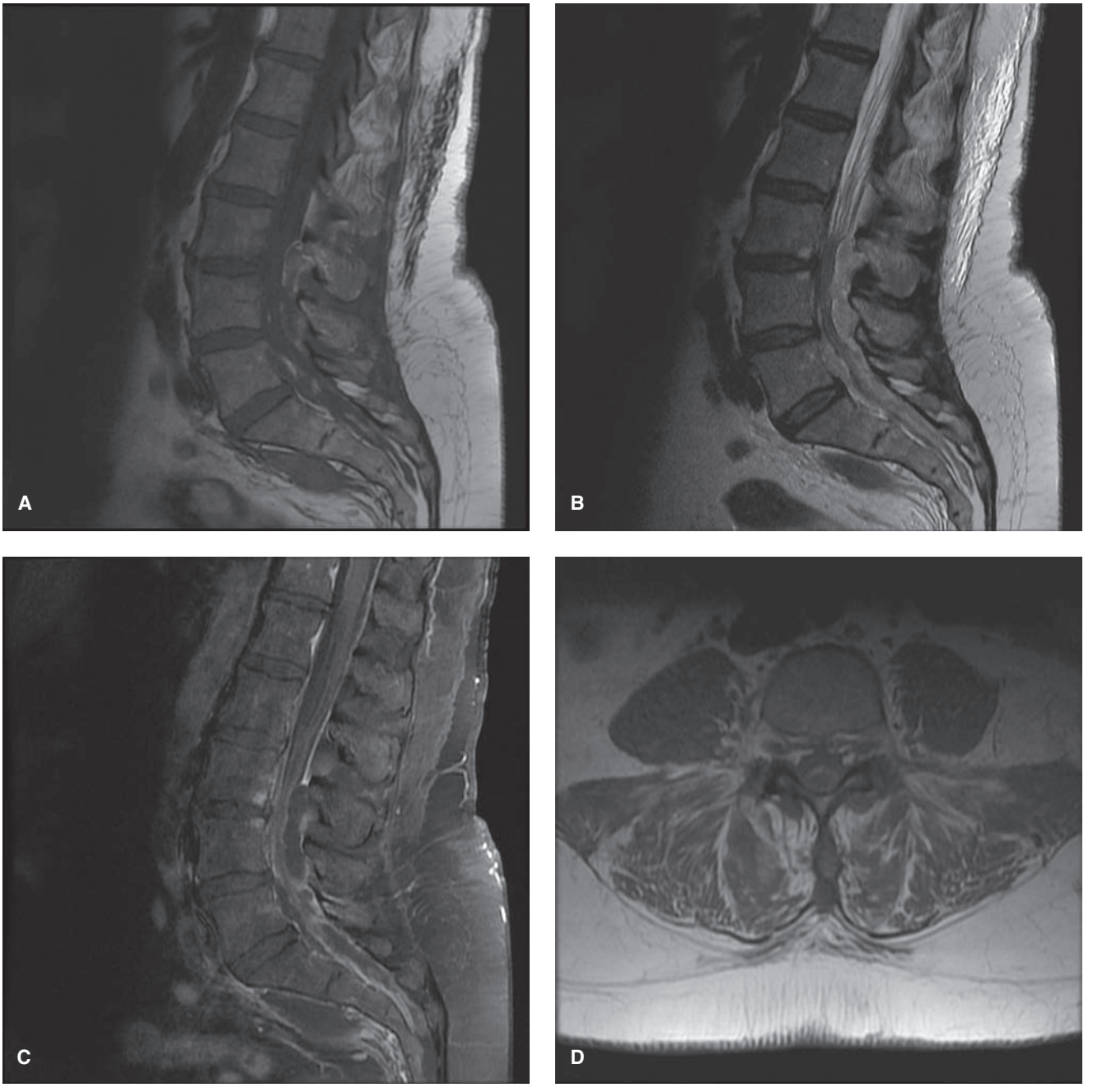


Figure 5-27.
MRI of the lumbosacral spine demonstrating a large spinal epidural abscess. **A:** Sagittal T1-weighted MRI of the lumbosacral spine taken 1 week following uneventful lumbar epidural steroid injection performed using an interlaminar approach. **B:** Sagittal T2-weighted image. **C:** Sagittal T1-weighted image following intravenous administration of gadolinium. **D:** Axial T1-weighted image at the level of L4 demonstrating significant anterior displacement of the thecal sac and extension of the infection to the paraspinous musculature on both sides of the spinous process. ***(Cont.)***

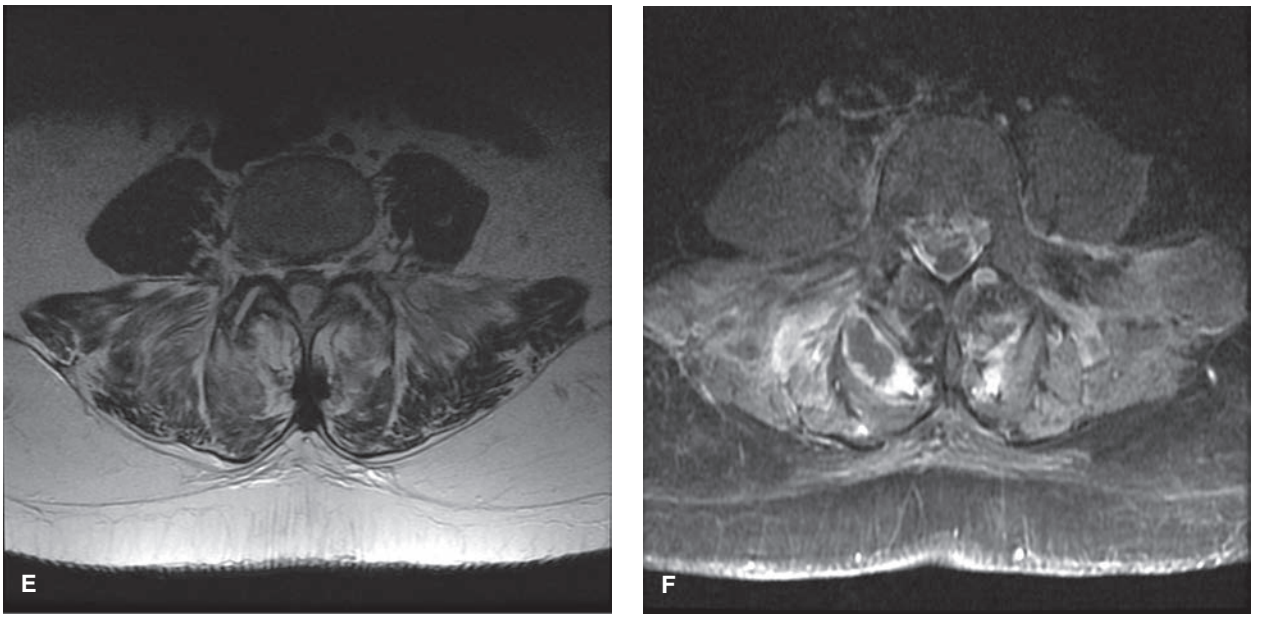


Figure 5-27. *(Continued)*
E: Axial T2-weighted image. **F:** Axial T1-weighted image following intravenous administration of gadolinium. Comparison of T1-weighted images before (**A and D**) and after (**C and F**) administration of intravenous gadolinium demonstrates significant enhancement consistent with a highly vascular inflammatory process. This patient presented 7 days after lumbar epidural steroid injection with worsening low back pain. She had no neurologic deficits and no fever. Laboratory evaluation demonstrated significant elevation in her white blood count (21.8 thousand per cm^3 with 92% neutrophils) and erythrocyte sedimentation rate. She underwent urgent lumbar laminectomy and evacuation of the abscess, followed by intravenous antibiotic administration and recovered fully and uneventfully.

Caudal Epidural Injection

Positioning

The patient lies prone with the head turned to one side (Fig. 5-28). The C-arm is rotated 20 to 30 degrees caudally from the axial plane without any oblique angulation. This allows for good visualization of the sacrum, sacral hiatus, and coccyx (Figs. 5-29 and 5-30).

Block Technique

The sacral hiatus is identified radiographically (see Fig. 5-30) and the overlying skin and subcutaneous tissues are anesthetized with 1 to 2 mL of 1% lidocaine. The sacral hiatus can be quite difficult to visualize radiographically in the AP projection. The approximate location can be identified by palpating the paired sacral corneae in the midline, near the superior extent of the gluteal cleft. An 18- or 20-gauge Tuohy needle can be used, but a smaller 22-gauge, 3.5-inch spinal needle is perfectly adequate. The needle is placed through the skin and advanced directly through the sacrococcygeal ligament. As the needle passes through the ligament, a distinct "pop" can be felt. Once the needle has passed through the sacrococcygeal ligament and into the caudal spinal canal, the angle of the needle is decreased to lie closer to the plane of the sacrum, and the needle is advanced into the caudal canal an additional 1 to 2 cm. A firm grasp of the anatomy of the sacral hiatus and the caudal epidural space is essential during caudal epidural injection (Figs. 5-29 and 5-31). AP and lateral radiographs confirm the needle's position within the caudal epidural space (Figs. 5-30 and 5-32), the caudal epidural space is generously supplied with veins, and intravascular needle placement can be ruled out by injecting 1 to 1.5 mL of nonionic radiographic contrast (iohexol 180 mg per mL) under live fluoroscopy. Once caudal epidural needle position has been confirmed, a solution containing steroid diluted in preservative-free saline (80 mg of methylprednisolone acetate or the equivalent diluted in at least 5 mL total volume) is injected, and the needle is removed. The caudal epidural space is distant from the usual sites of nerve root inflammation near the lumbosacral junction, thus a significant volume of injectate (at least 5 mL) is usually required to affect spread to the level of the lumbosacral junction.

Alternately, because the sacral hiatus is difficult to identify in the AP projection, many practitioners will begin this procedure with the fluoroscope in the lateral projection (Fig. 5-32). In the lateral projection, the sacral hiatus can be easily identified by following the posterior sacral plate to its inferior-most extent, which lies at the superior aspect of the sacral hiatus. The skin is anesthetized somewhat inferior to the sacral hiatus so that the trajectory of the needle from the skin's surface through the sacral hiatus is parallel to the anterior and posterior sacral plates as shown in Figure 5-32. The needle is advanced through the sacral hiatus and 1 to 2 cm into the caudal canal. One to

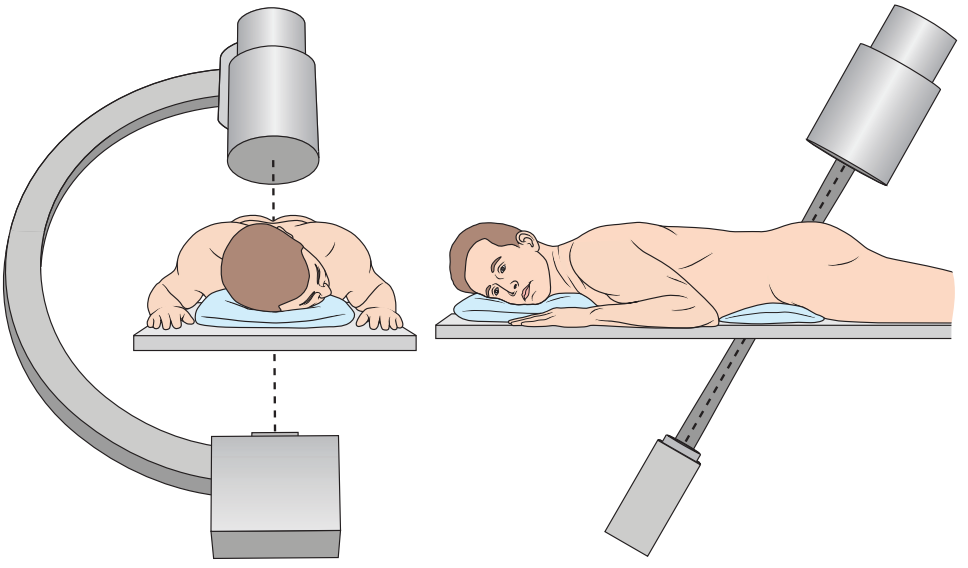


Figure 5-28.
Position for caudal epidural injection. The patient is placed prone with the head turned to one side. The C-arm is angled 20 to 30 degrees caudally from the axial plane. Alternately, many practitioners will begin caudal epidural injections with the fluoroscope positioned for lateral radiography from the start, as the position of the sacrococcygeal ligament can be readily identified in the lateral projection, while identifying the sacral hiatus in the AP projection can be difficult.

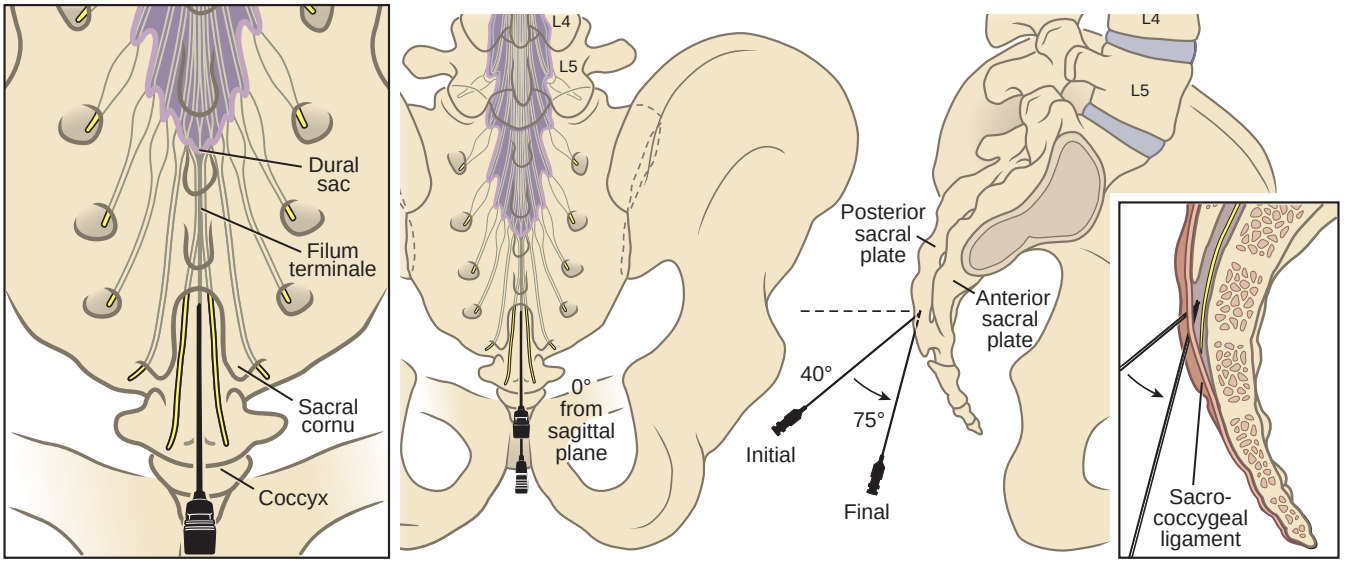
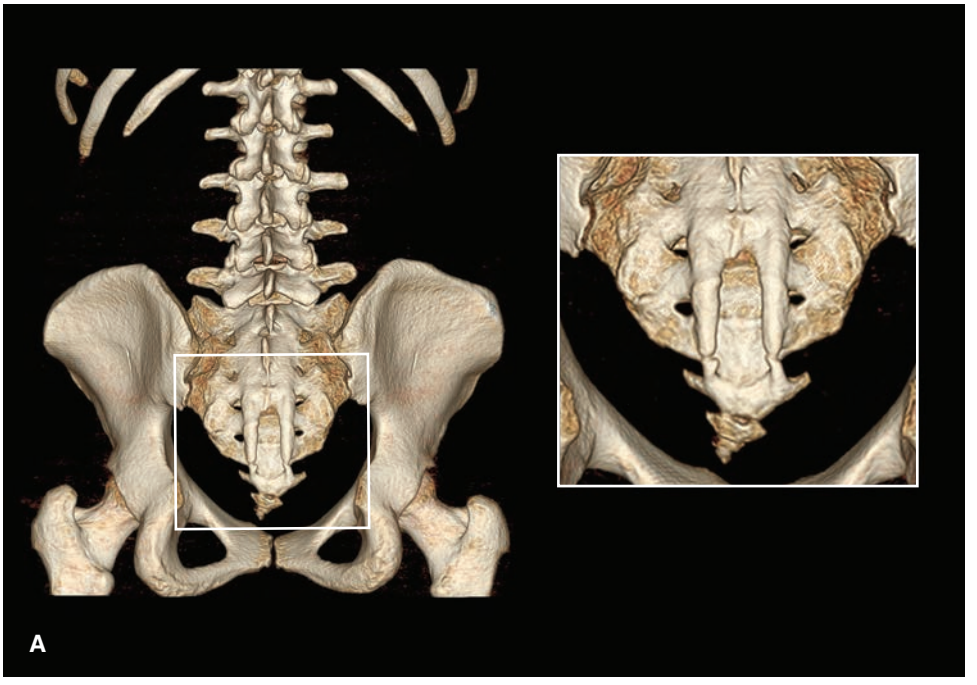
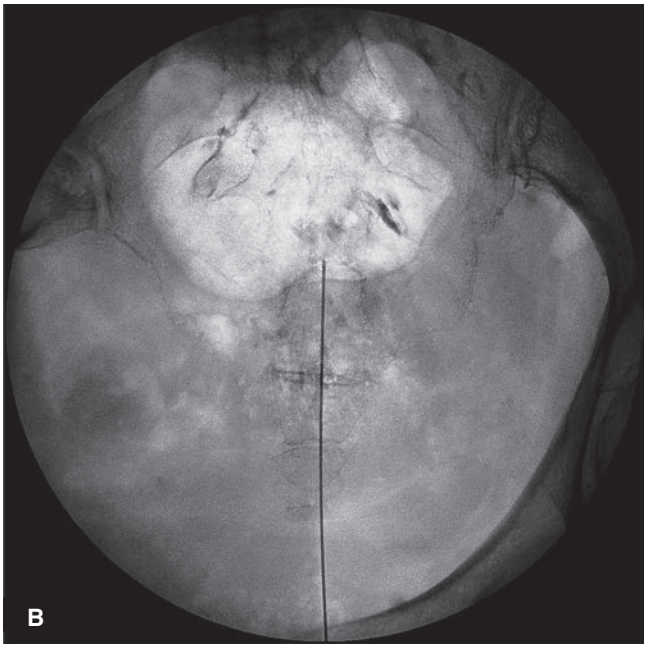


Figure 5-29.
Position and angle of needle entry for caudal epidural injection. A 22-gauge, 3.5-inch spinal needle (some practitioners prefer a 20-gauge Tuohy needle) is advanced in the midline overlying the sacral hiatus. A distinct "pop" is felt as the needle tip passes through the sacrococcygeal ligament. The angle of the needle is then increased (to 75 degrees or more from the axial plane) to lie closer to the plane of the sacrum, and the needle tip is advanced an additional 1 to 2 cm into the sacral spinal canal. Note the inferior termination of the thecal sac at approximately S2.





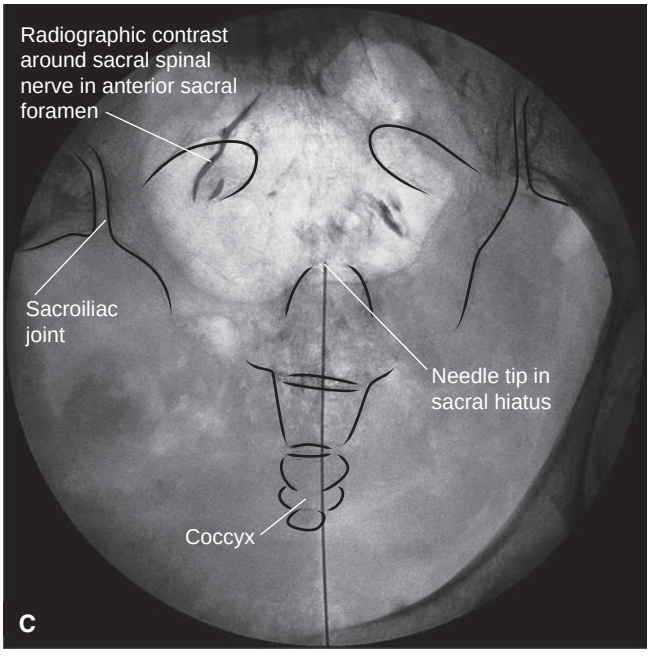


Figure 5-30.

A: Bony anatomy relevant to caudal epidural injection. Three-dimensional reconstruction computed tomography of the lumbosacral spine as viewed from the posterior approach used for caudal injection. **Inset** matches the anatomic area in the radiographs shown in **(B)** and **(C)**. **B:** Anterior-posterior radiograph of the sacrum during caudal epidural injection. A 22-gauge spinal needle is in position through the sacral hiatus in the midline and after injection of 2 mL of radiographic contrast. **C:** Labeled image.

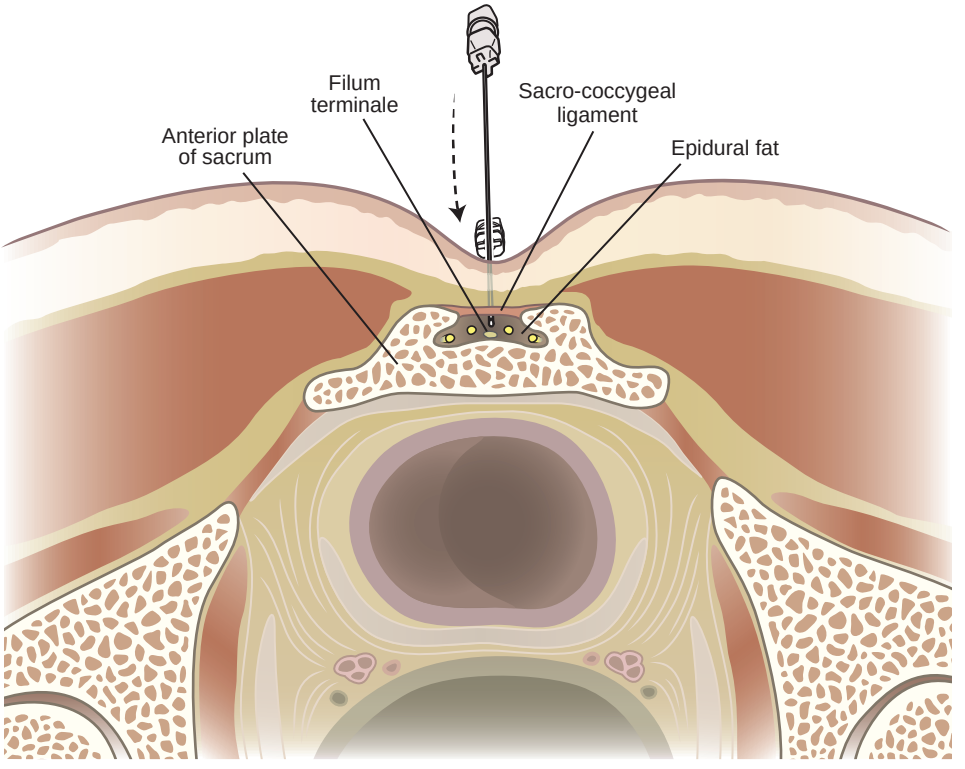


Figure 5-31.
Axial diagram of caudal epidural injection. The needle is advanced through the sacrococcygeal ligament. The angle is then increased to allow the needle to be advanced more cephalad within the epidural space.

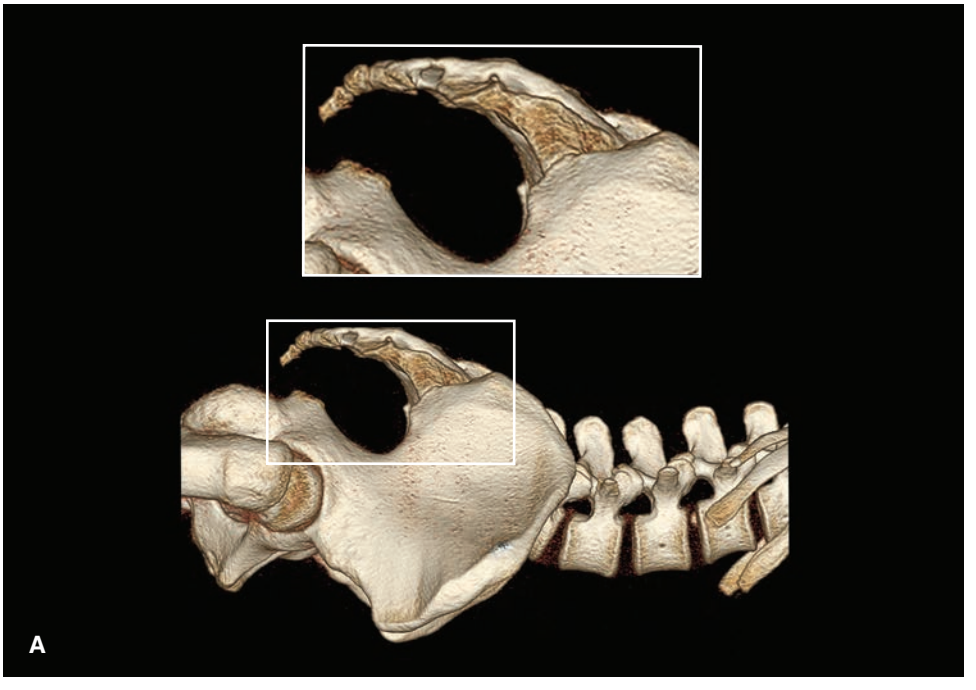


Figure 5-32.
A: Bony anatomy relevant to caudal epidural injection. Three-dimensional reconstruction computed tomography of the lumbosacral spine as viewed in the lateral projection. **Inset** matches the anatomic area in the radiographs shown in **(B–E)**. Lateral radiograph of the sacrum during caudal epidural injection. ***(Cont.)***

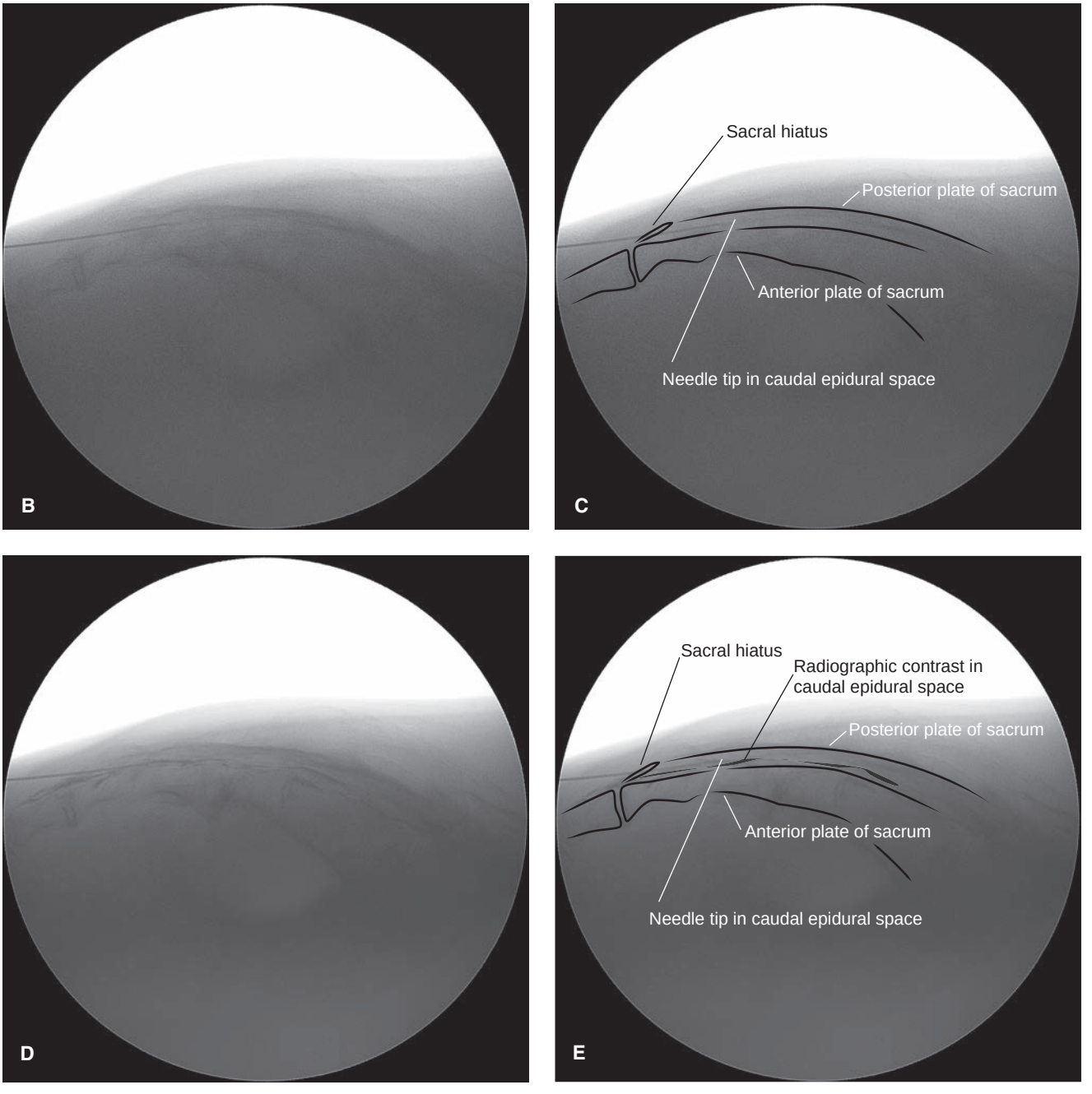


Figure 5-32. *(Continued)*
B: A 22-gauge spinal needle is in place through the sacrococcygeal ligament with the shaft parallel to the anterior sacral plate and after advancement 1 to 2 cm into the sacral canal. **C:** Labeled image. **D:** Same patient after injection of 2 mL of radiographic contrast. **E:** Labeled image after injection of 2 mL of radiographic contrast.

1.5 mL of nonionic radiographic contrast (iohexol 180 mg per mL) is injected under live fluoroscopy to rule out intravascular needle placement and establish that the needle is in position in the caudal epidural space. Once caudal epidural needle position has been confirmed, a solution containing steroid diluted in preservative-free saline (80 mg of methylprednisolone acetate or the equivalent diluted in at least 5 mL total volume) is injected, and the needle is removed.

Complications

Dural puncture with subsequent postdural puncture headache can occur during caudal epidural injection, but it should

occur only if the needle is advanced several centimeters or more cephalad within the caudal spinal canal. The thecal sac extends to the level of approximately S2, and the position can be approximated by palpating the adjacent posterior-superior iliac spines, which lie at approximately the same level. Direct trauma to the cauda equina or the spinal nerves is unlikely with the caudal approach. As with interlaminar epidural injection at all vertebral levels, epidural bleeding or infection can occur. Epidural hematoma or abscess can lead to significant compression of the cauda equina. Caudal epidural injection should be avoided or postponed in those receiving anticoagulants.

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CHAPTER 6

Transforaminal and Selective Spinal Nerve Injection

OUTLINE

Overview

Selective spinal nerve injection and transforaminal epidural injection can be performed using similar techniques. Indeed, the distinction between the two techniques is questionable because the fascial sheath surrounding the spinal nerves is contiguous with the dura mater within the epidural space. A solution injected around spinal nerve may well enter the epidural space, regardless of whether the needle tip is advanced through the intervertebral foramen prior to injection. Nonetheless, many practitioners reserve the term "selective spinal nerve injection" for injections that are performed with the needle tip adjacent to the spinal nerve, *outside* the intervertebral foramen, and the term "transforaminal injection" for injections that are performed with the needle tip *within* the intervertebral foramen. The rationale for injecting steroids is that they suppress inflammation of the nerve, which is believed to be the basis for radicular pain. The rationale for using a transforaminal route of injection rather than an interlaminar route is that the injectate is delivered directly onto the target nerve. This ensures the medication reaches the target area in maximum concentration at the site of the suspected pathology.

Level of Evidence

Quality of Evidence and Grading of Recommendation			
Grade of Recommendation/ Description	**Benefit vs. Risk and Burdens**	**Methodological Quality of Supporting Evidence**	**Implications**
RECOMMENDATION: *Transforaminal epidural steroid injections may be used as part of a multimodal treatment regimen to provide pain relief in selected patients with radicular pain or radiculopathy.*			
1C/strong recommendation, low-quality evidence	Benefits clearly outweigh risk and burdens	*For short-term relief of radicular pain (up to 6 mo):* II-1: Evidence obtained from well-designed controlled trials without randomization *For long-term relief of radicular pain (more than 6 mo):* II-2: Evidence obtained from well-designed cohort and case-control analytic studies from more than one research group	Strong recommendation but may change when higher quality evidence becomes available

Much of the rationale and scientific evidence for use of the transforaminal technique for administering epidural corticosteroids arises directly by extrapolation from the evidence for use of the interlaminar technique (see detailed discussion in Chapter 5). Use of the interlaminar technique was far more prominent until the last decade or so. This is likely a result of most injections in prior decades being performed by anesthesiologists, who were most familiar with identifying the epidural space using surface landmarks and a "blind" loss-of-resistance technique without the use of fluoroscopic guidance. With the emergence of widespread availability and expertise in fluoroscopic guidance, more precise needle placement directly adjacent to the spinal nerves directly in the area of inflammation became feasible. In recent years, a number of studies comparing the interlaminar and transforaminal routes of injection have been published, but our knowledge regarding the comparative effectiveness of the two approaches remains incomplete.

Available practice guidelines have not made any distinction between the interlaminar and transforaminal routes of injection, citing a dearth of available literature to guide any recommendation. Nonetheless, examination of the available observational studies and small number of randomized trials suggests that transforaminal epidural injections lead to a significant reduction in pain in patients with acute lumbar radicular pain when compared with observation alone or conservative management without injection therapy (evidence obtained from well-designed controlled trials without randomization leading to a strong recommendation for use of this treatment based on low-quality evidence). There is insufficient evidence to determine the efficacy of cervical transforaminal injection.

The available trials demonstrate more rapid resolution of acute radicular pain associated with acute lumbar disc herniation following epidural injection of steroids via the transforaminal route, and it is in this group that the evidence of efficacy is strongest. The use of this treatment for radicular pain associated with acute disc herniations occurring at the cervical and thoracic levels is common and most experts find this to be a reasonable extrapolation from the existing scientific evidence; however, the risks of the transforaminal route of injection at thoracic and cervical levels must be carefully weighed against the benefit (see further discussion below). Use of epidural steroid injections should include a specific discussion of potential complications, particularly with regard to the transforaminal approach. Transforaminal epidural injections should be performed with appropriate image guidance to confirm correct needle position and spread of contrast before injecting particulate steroid. The use of transforaminal epidural injection of steroids to treat acute radicular pain associated with foraminal stenosis or neurogenic claudication associated with stenosis of the central spinal canal has been less well studied but remains common, again as an extrapolation from their usefulness in those with acute disc herniations. The use of transforaminal epidural injection of steroids for the treatment of nonradicular spinal pain lacks scientific validation.

Cervical Transforaminal and Selective Nerve Root Injection

Anatomy

At typical cervical levels, the ventral and dorsal roots of the spinal nerves join in the vertebral canal to form the spinal nerve at the level of the intervertebral foramen. The foramen faces obliquely forward and lateral. Its roof and floor are formed by the pedicles of consecutive vertebrae. Its posterolateral wall is formed largely by the superior articular process of the lower vertebra and, in part, by the inferior articular process of the upper vertebra and the capsule of the zygapophysial joint formed between the two articular processes. The anteromedial wall is formed by the lower end of the upper vertebral body, the uncinate process of the lower vertebra, and the posterolateral corner of the intervertebral disc. Immediately lateral to the external opening of the foramen, the vertebral artery rises in a cephalad direction just anterior to the articular pillars of the zygapophysial joints (Fig. 6-1). The spinal nerve, in its dural sleeve, lies in the lower half of the foramen. The upper half is occupied by epiradicular veins. The ventral ramus of the spinal nerve issues from the intervertebral foramen, passing forward and lateral onto the transverse process. In strict anatomic terms, what has been termed "selective nerve root injection" would be more precisely termed "selective spinal nerve injection," as the technique is carried out at the level of the spinal nerve, not the more proximal ventral and dorsal nerve roots. However, the terms "selective nerve root injection" and "selective nerve root block" have permeated the published literature. Arterial branches arise from the vertebral arteries to supply the spinal nerves (radicular arteries) or the spinal cord via the anterior and posterior spinal arteries (medullary arteries) (see Fig. 6-1). Medullary and radicular arterial branches may also arise from the deep or ascending cervical arteries and traverse through the entire length of the foramen adjacent to the spinal nerve (see Fig. 6-1), and it is these spinal segmental arteries that are at risk for penetration during cervical transforaminal injection.

Patient Selection

The most common indication for selective nerve root injection is to place corticosteroid adjacent to an inflamed nerve root that is causing radicular symptoms. Nerve root inflammation may stem from an acutely herniated intervertebral disc causing nerve root irritation or other causes of nerve root impingement, such as isolated foraminal stenosis due to spondylitic spurring of the bony margins of the foramen. Selective spinal nerve injection with local anesthetic has also been employed diagnostically to determine which spinal nerve is causing symptoms when pathology exists at multiple vertebral levels. This information can prove helpful in planning surgical intervention.

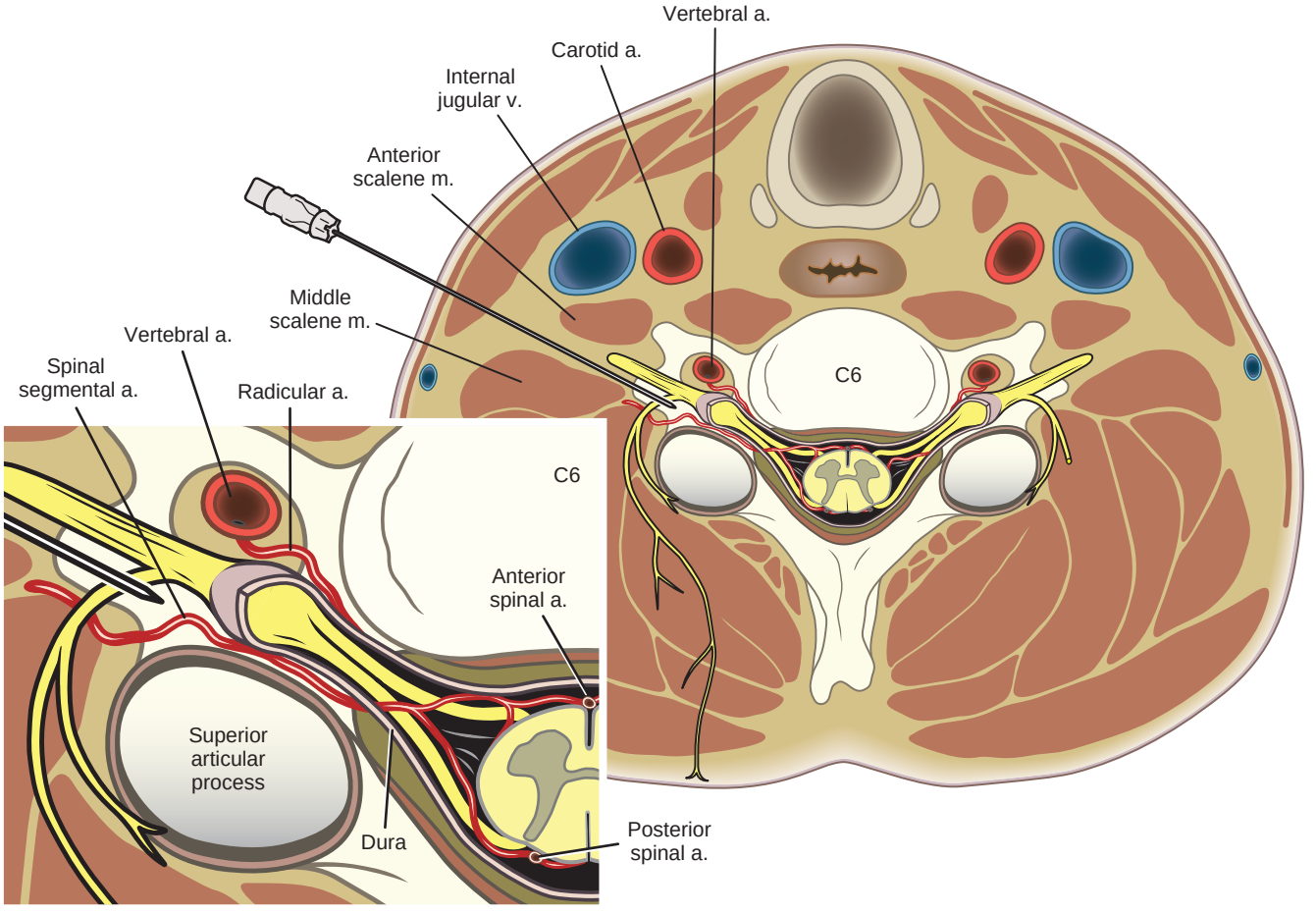


Figure 6-1.
Axial view of cervical transforaminal injection at the level of C6. The needle has been inserted along the axis of the foramen and is illustrated in final position within the posterior aspect of the foramen. Insertion along this axis avoids the vertebral artery, which lies anterior to the foramen, and the spinal nerve, which lies within the foramen angled anteriorly toward the interscalene groove. Spinal segmental arteries arise from the deep or ascending cervical artery, enter the foramen at variable locations, and often course through the foramen, penetrate the dura, and join the anterior or posterior spinal arteries that supply the spinal cord (**inset**). An arterial branch that joins the anterior spinal artery is termed a "spinal segmental" or "medullary" artery. Likewise, arterial branches arise variably from the vertebral artery to supply the nerve root itself (in this illustration, a branch to the nerve root or "radicular" artery is shown); similar branches from the vertebral artery often penetrate the dura to join the anterior or posterior spinal artery. There is great anatomic variation in the vascular supply in this region. The anatomic variant illustrated is shown to demonstrate how a needle can be placed within a small artery that provides critical reinforcing blood supply to the spinal cord during cervical transforaminal injection. Injection of particulate steroid directly into one of these vessels can lead to catastrophic spinal cord injury. (Anatomic descriptions are based on cadaveric dissections carried out in our laboratory. Detailed data appear in Hoeft MA, Rathmell JP, Monsey RM, et al. Cervical transforaminal injection and the radicular artery: Variation in anatomical location within the intervertebral foramina. *Reg Anesth Pain Med.* 2006;3:270–274.)

Positioning

The patient lies supine, facing directly forward (Fig. 6-2). The C-arm is rotated 45 to 65 degrees lateral oblique until the neural foramina are clearly visualized (Fig. 6-3). The patient may also be asked to rotate the head away from the side of injection. Although this facilitates access to the side of the neck, the neural foramina and bony elements of the cervical spine will no longer be aligned. This may prove confusing to the inexperienced practitioner.

Block Technique

A 22- or 25-gauge, 3.5-inch spinal or blunt-tipped needle can be used in all patients; some manufacturers provide similar needles in shorter lengths, and a 2.5-inch needle is sufficient for all but the most obese patients. To avoid the vertebral artery and the exiting nerve root, the needle is advanced toward the posterior aspect of the intervertebral foramen midway between the superior and the inferior limits of the foramen (see Fig. 6-3). Care is taken to

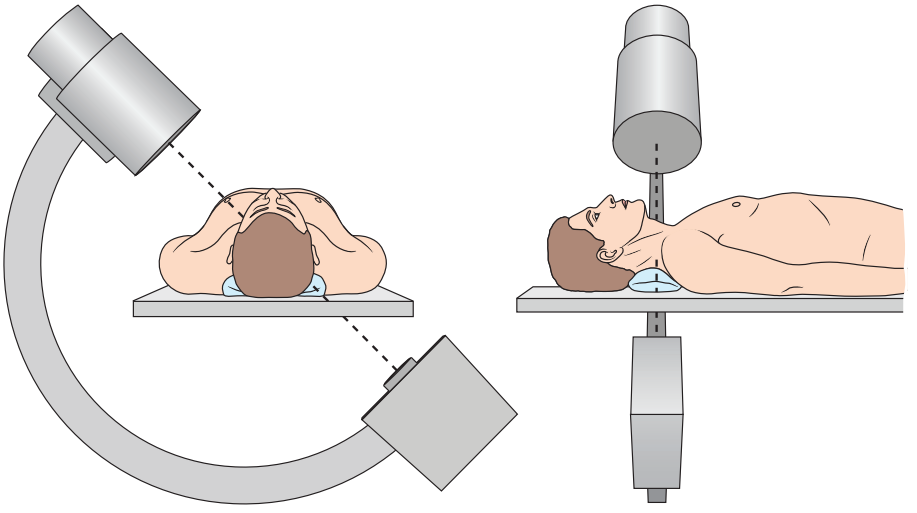
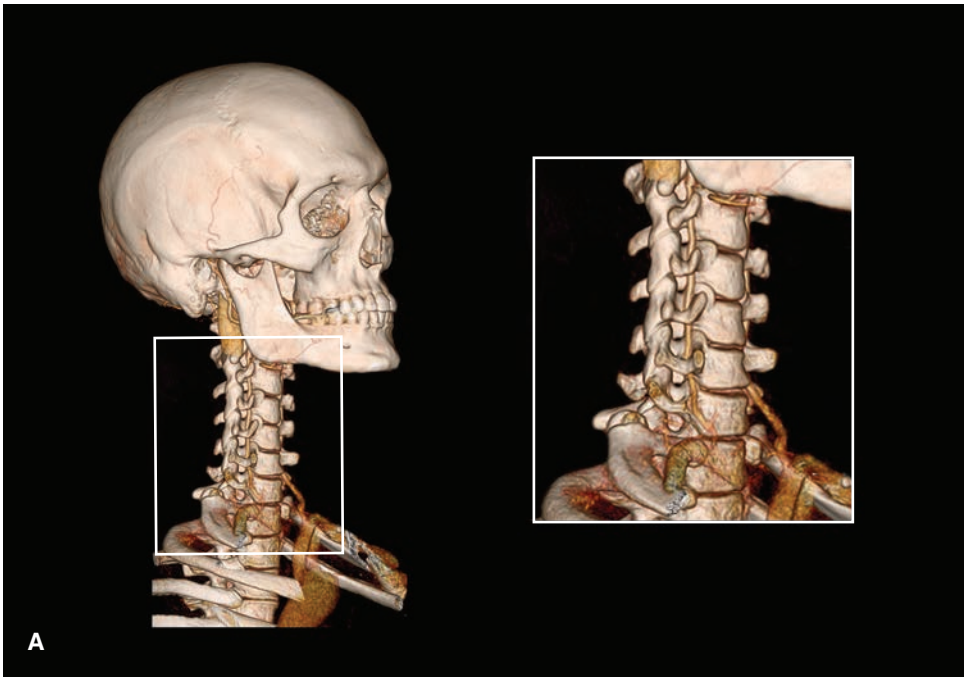


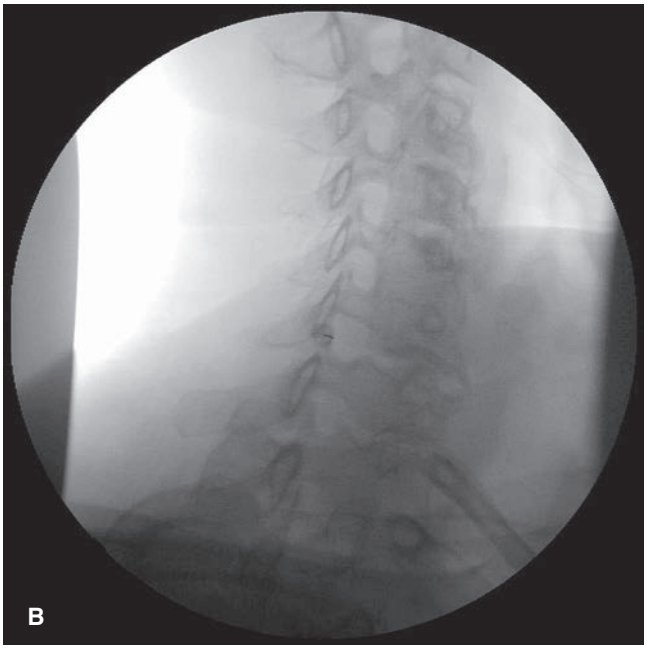
Figure 6-2.
Patient position for cervical transforaminal injection. The patient is positioned supine with C-arm axis rotated obliquely 45 to 65 degrees until the intervertebral foramina are clearly visualized. Most C-arms are limited in their ability to rotate obliquely to the side opposite the mobile base (the limit is typically 45 to 55 degrees). When performing cervical transforaminal injection on the side opposite the base unit, the limits of oblique angulation can be overcome by placing a foam wedge beneath the patient to angle them toward the side of the base unit, thereby gaining an additional degree of oblique angulation toward the opposite side. The limits of oblique angulation can also be overcome by inverting the C-arm so the x-ray source is above the patient and the image intensifier below; however, this results in a dramatic increase in radiation exposure to both the patient and the operator (see Fig. 2-6).

be sure the needle tip remains superimposed on the bone of the facet column during advancement. The depth when the needle is in final position is frequently just 1 to 2 inch from the skin's surface. Thus, extreme care must be taken to assure that the needle is not advanced too deeply before the first fluoroscopy image is taken. This poses some difficulty when using the coaxial technique, as the needle will not remain seated in the tissue along the intended axis until it has been advanced sufficiently. When the needle is first placed in the superficial tissues then released by the operator to take the first radiograph, the needle will flop to one side under its own weight. In order to keep the needle on axis for coaxial placement, the needle can be grasped with a small clamp and aimed accurately. The use of a clamp allows the operator to keep the needle in a coaxial orientation and take radiographs without his or her hands in the x-ray field. In this way, the superior articular process of the facet just posterior to the foramen is first contacted, preventing needle advancement through the foramen and into the spinal canal. Once the needle contacts the facet, it is then walked anteriorly into the foramen and advanced no more than an additional 2 to 3 mm. The depth is then assessed by obtaining an image in the posterior-anterior (PA) plane (Fig. 6-4). To avoid direct trauma to the spinal cord and intrathecal injection, the needle should be advanced no further than halfway across the facet column. When the needle is in final position, the stylette is removed and a short length of flexible IV extension tubing is attached. The use of this flexible extension assures that the final needle position is not altered by placing and removing syringes directly to the needle's hub. One to two milliliters of radiocontrast is then injected under "live" or real-time fluoroscopy to ensure the needle tip lies in close proximity to the nerve root without any intravascular or intrathecal spread (Fig. 6-4D). The solution containing local anesthetic and/or steroid can then be injected safely (40 mg of triamcinolone acetonide or the equivalent and 0.5 to 1 mL of 1% lidocaine). In recent years, many practitioners have switched to the routine use of the nonparticulate steroid, dexamethasone sodium phosphate to completely avoid the risk of particulate steroid embolization, typically in a dose of 4 mg.

Complications

A firm grasp of the anatomy of adjacent vascular and neural structures is essential to avoid complications during cervical selective nerve root injection (see Fig. 6-1 **inset**). Direct intravascular injection into the vertebral artery may produce generalized seizures when local anesthetic is used or cerebral ischemia when particulate steroid solutions are used. Direct injection of particulate steroid into a medullary artery supplying the spinal cord can lead to catastrophic spinal cord infarction. Needle positioning toward the posterior aspect of the foramen and advancing the needle in a plane parallel to the nerve root rather than toward the anterior aspect of the foramen reduces the risk of entering the vertebral artery. However, the use of radiographic contrast injected during "live" or "real-time" fluoroscopy, with or without digital subtraction, to visualize final needle position and detect any hint of intravascular injection is the only means to accurately verify that injectate is not injected within an artery (Fig. 6-5). Based on animal studies, use





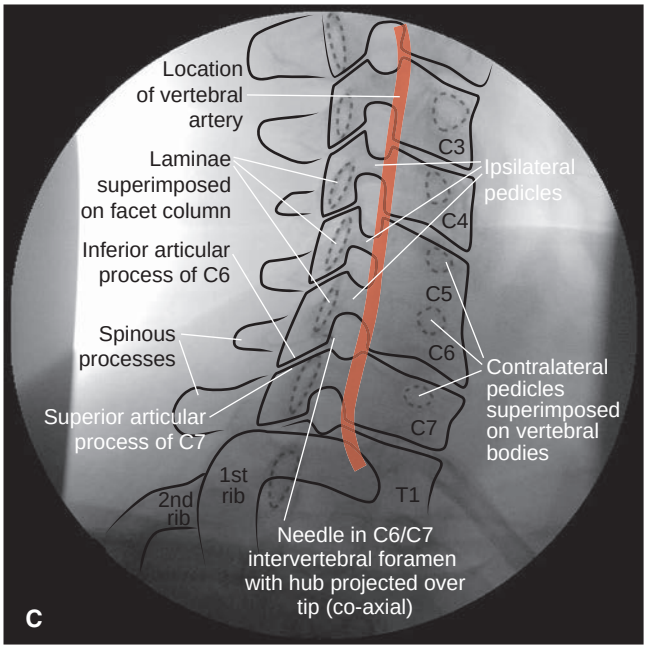
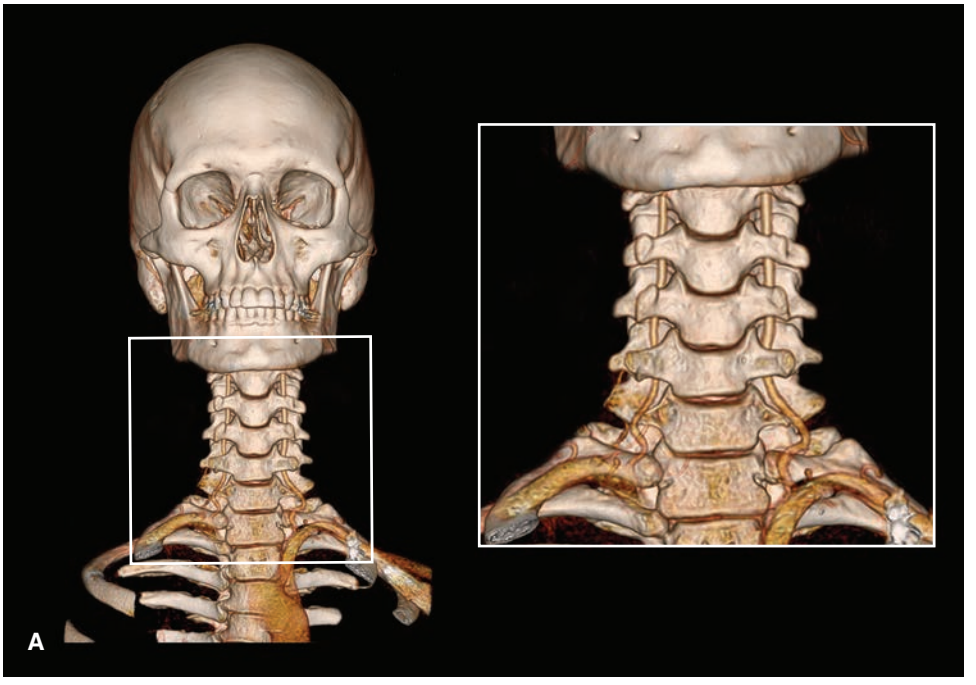
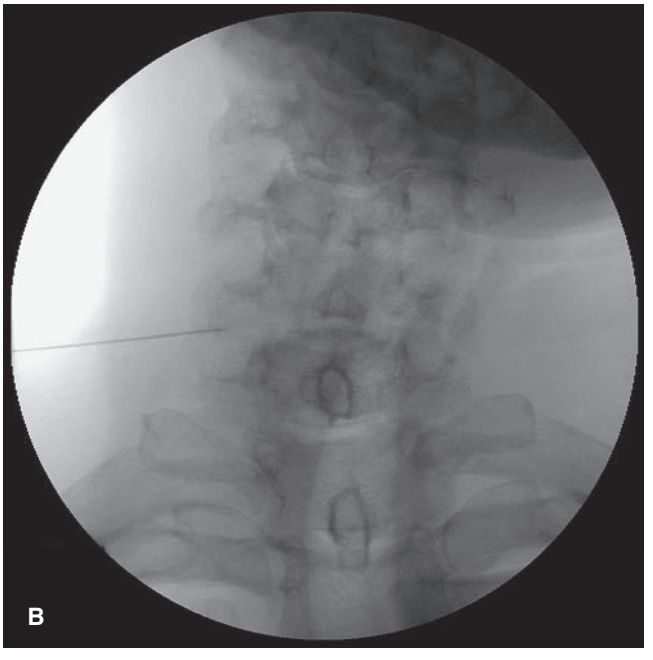


Figure 6-3.

A: Bony anatomy relevant to cervical transforaminal injection. Three-dimensional reconstruction computed tomography of the cervical spine as viewed from the anterior oblique approach used for cervical transforaminal injection. **Inset** matches the anatomic area in the radiographs shown in **(B)** and **(C)**. **B:** Right oblique view of the cervical spine during right C6/C7 transforaminal injection. The needle is in proper position in the posterior aspect of the foramen for right C6/C7 transforaminal injection (C7 nerve root). Note that this patient has had a prior C5/C6 interbody fusion, and it is difficult to discern a disc space between these two vertebrae. **C:** Labeled image. The approximate position of the vertebral artery near the anterior aspect of the intervertebral foramina is shown in red.





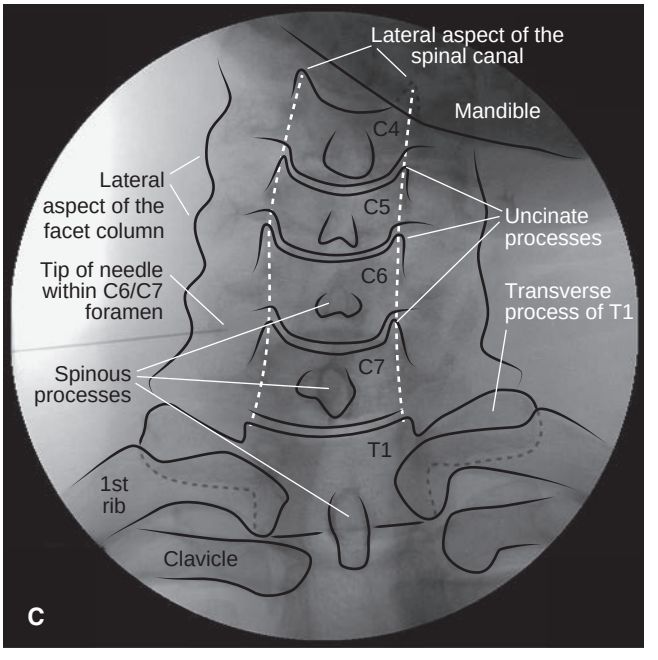


Figure 6-4.

A: Bony anatomy relevant to cervical transforaminal injection. Three-dimensional reconstruction computed tomography of the cervical spine as viewed in the anterior-posterior projection. **Inset** matches the anatomic area in the radiographs shown in **(B)** and **(C)**. **B:** PA view of the cervical spine during C6/C7 transforaminal injection. The needle is in proper position within the right C6/C7 intervertebral foramen (C7 nerve root). Note that this patient has had a prior C5/C6 interbody fusion, and it is difficult to discern a disc space between these two vertebrae. **C:** Labeled image. The approximate position of the lateral-most aspect of the spinal canal where the lateral reflection of the thecal sac lies can be estimated fairly precisely by drawing an imaginary line through the uncinate processes of the vertebral bodies (*white dashed lines*). ***(Cont.)***

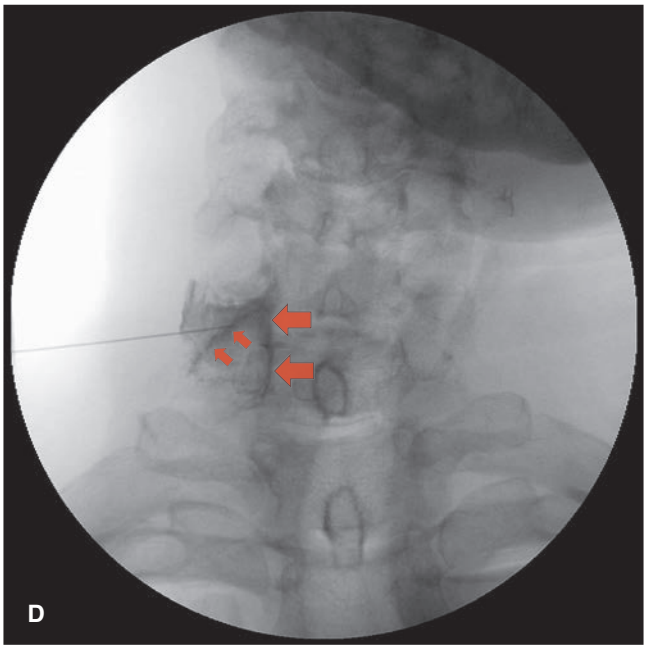


Figure 6-4. (*Continued*)
D: PA view of the cervical spine during C6/C7 transforaminal injection after contrast injection. The needle is in final position within the right C6/C7 intervertebral foramen after injection of 1 mL of radiographic contrast medium (iohexol 180 mg per mL). Contrast outlines the spinal nerve (*small arrows*) and extends along the lateral aspect of the epidural space below the foramen (*large arrows*).

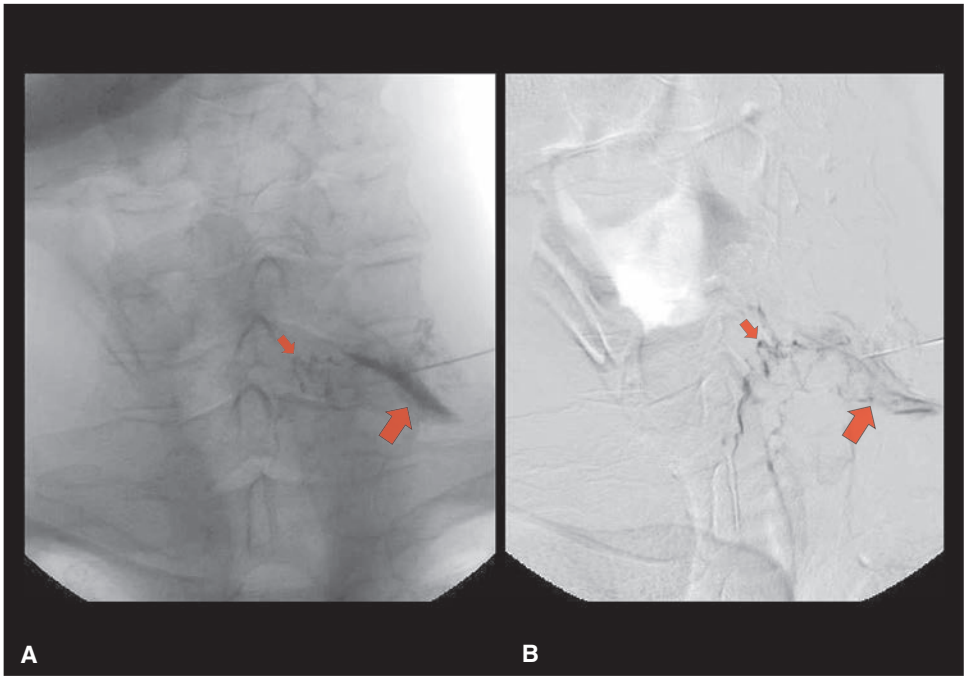


Figure 6-5.
PA view of the cervical spine during C7/T1 transforaminal injection, including a digital subtraction sequence after contrast injection. An anteroposterior view of an angiogram obtained after injection of contrast medium, prior to planned transforaminal injection of corticosteroids. **A:** Image as seen on fluoroscopy. The needle lies in the left C7/T1 intervertebral foramen. Contrast medium outlines the spinal nerve (*large arrow*). The radicular artery appears as a thin tortuous line of contrast passing medially from the site of injection (*small arrow*). **B:** Digital subtraction angiogram reveals that the radicular artery (*small arrow*) extends to the midline to join the anterior spinal artery and much of the contrast is located in the correct location surrounding the spinal nerve (*large arrow*). (Reprinted from Rathmell JP, Aprill C, Bogduk N. Cervical transforaminal injection of steroids. *Anesthesiology*. 2004;100:1597, with permission.)

of the nonparticulate steroid, dexamethasone, appears to remove the risk of embolization and ischemic neural injury to the brain and spinal cord; however, the comparative efficacy of dexamethasone when compared to depot steroid preparations awaits further study. Subarachnoid injection may also occur if the needle is advanced too medially and pierces the dural cuff as it extends laterally onto the exiting nerve root. Direct trauma to the exiting nerve root or the spinal cord itself may also occur.

Lumbar Transforaminal and Selective Nerve Root Injection

Anatomy

At typical lumbar levels, the ventral and dorsal roots of the spinal nerves descend in the vertebral canal to form the spinal nerves in their intervertebral foramina (Figs. 6-6 to 6-8). The foramen faces laterally. Its roof and floor are formed by the pedicles of adjacent vertebrae. Its posterior wall is formed largely by the superior articular process of the lower vertebra and, in part, by the inferior articular process of the upper vertebra and the capsule of the zygapophysial joint between the two articular processes. The anterior wall is formed by the vertebral body and the intervertebral disc. The spinal nerve, in its dural sleeve, lies in the anterior and superior portion of the foramen, just inferior to the pedicle. Spinal segmental arteries arise from the aorta and the iliac vessels and accompany the spinal nerve and its roots to the spinal cord. The location of the lumbar spinal segmental arteries is highly variable, but they can be present on either side as low as the L5/S1 interspace. The largest of the spinal segmental arteries is called the artery of Adamkiewicz and enters the spinal canal from the left side between T9 and L1 in 80% of individuals. However, the artery of Adamkiewicz can enter the spinal canal anywhere from T7 to L4.

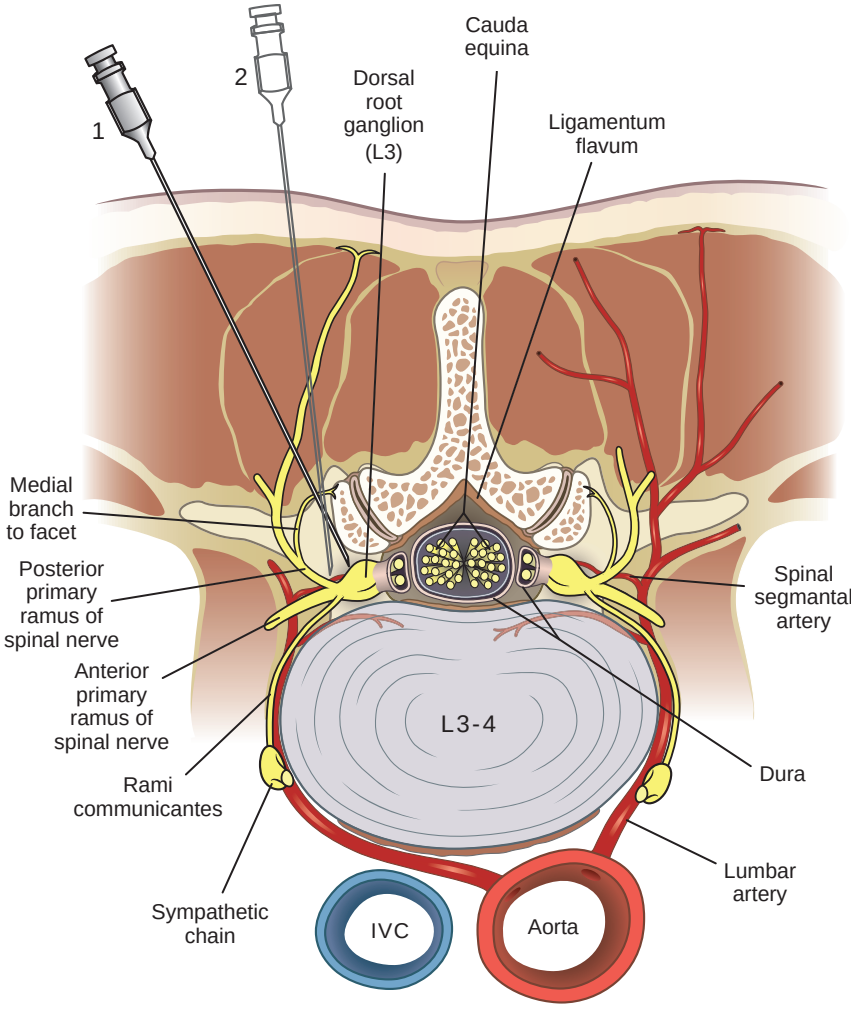


Figure 6-6.
Axial view of lumbar transforaminal and selective nerve root injection. The anatomy and proper needle position (axial view) for right (*1*) L3/L4 transforaminal injection and (*2*) L3 selective spinal nerve injection.

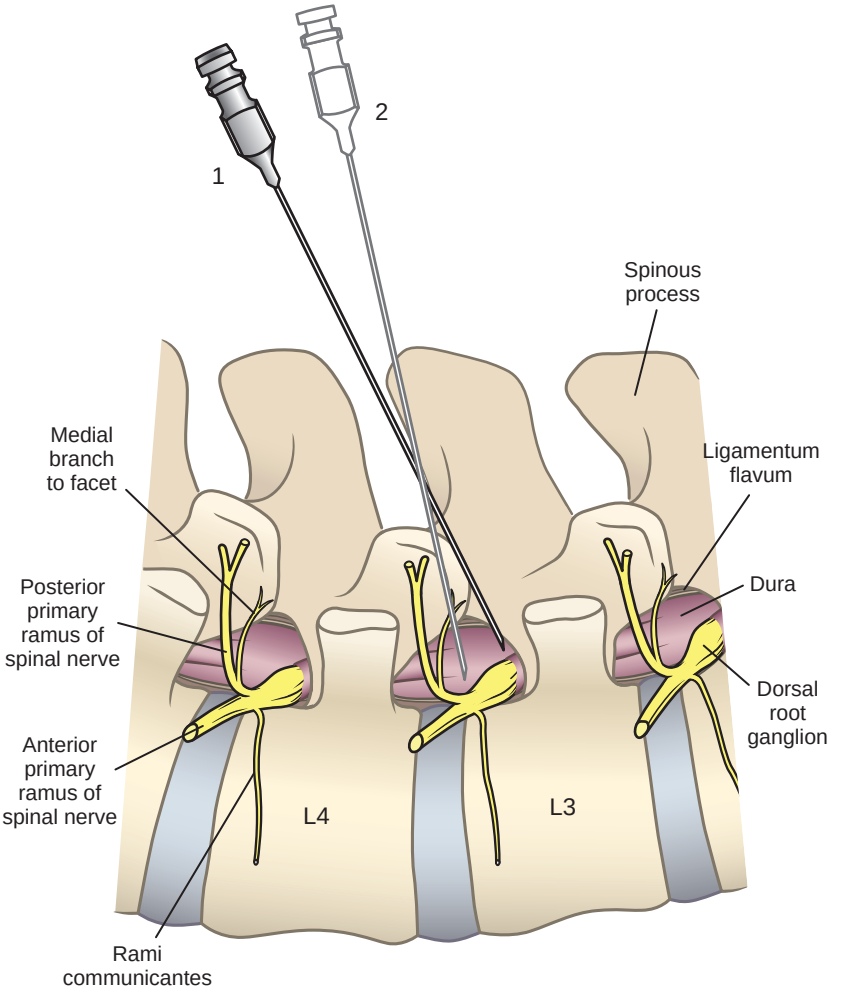


Figure 6-7.
Lateral view of lumbar transforaminal and selective nerve root injection. Anatomy and proper needle position (lateral view) for right (*1*) L3/L4 transforaminal injection and (*2*) L3 selective spinal nerve injection.

The artery typically enters the foramen along its ventral aspect within the superior half of the foramen. The final needle position during selective nerve root or transforaminal injection lies in close proximity to both the spinal nerve and the spinal segmental artery.

Patient Selection

The most common indication for selective spinal nerve or transforaminal injection is to place corticosteroid adjacent to an inflamed nerve that is causing radicular symptoms. Spinal nerve inflammation may stem from an acutely herniated intervertebral disc causing nerve irritation or other causes of nerve impingement, such as isolated foraminal stenosis due to spondylitic spurring of the bony margins of the foramen. Selective spinal nerve injection with local anesthetic has also been employed diagnostically to determine which spinal nerve is causing symptoms when pathology exists at multiple vertebral levels. This information can prove helpful in planning surgical intervention.

Positioning

The patient lies supine, facing directly forward (Fig. 6-9). The C-arm is rotated 20 to 30 degrees lateral oblique to allow direction of the needle toward the superolateral aspect of the intervertebral foramen (Fig. 6-10). A somewhat less oblique approach will result in a final needle position slightly lateral to the intervertebral foramen (see Figs. 6-7 and 6-8) and has been advocated by some practitioners as a means of limiting spread of the injectate to a single nerve root. However, even small volumes of injectate will often be seen to track along the spinal nerve to enter the lateral epidural space.

Block Technique

A 22- or 25-gauge, 3.5-inch spinal needle is sufficient in length for patients of average build, whereas a 5-inch needle may be needed in obese patients. To avoid the spinal nerve, the needle is advanced toward the superior aspect of the intervertebral foramen, just inferior to the pedicle and inferolateral to the pars interarticularis (see Figs. 6-8 and 6-11).

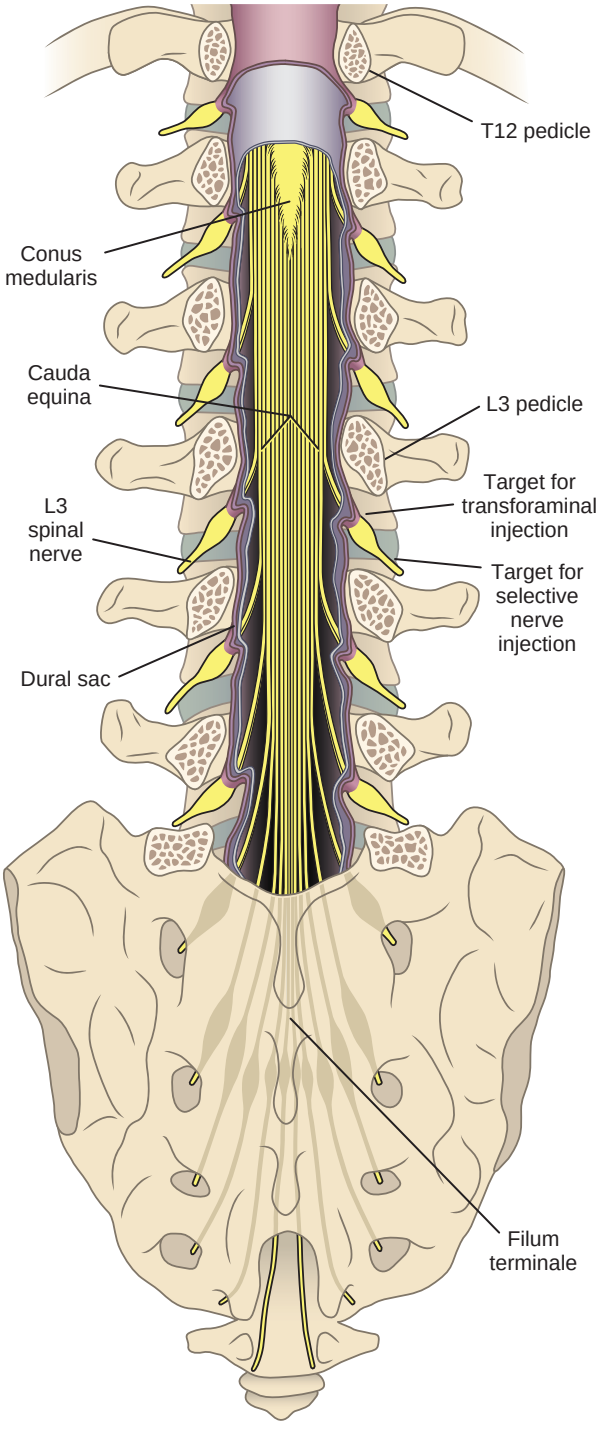


Figure 6-8.
Coronal view of lumbar transforaminal and selective nerve root injection. Anatomy and injection target points (coronal view) for L3/L4 transforaminal injection and L3 selective spinal nerve injection.

The needle tip can be advanced using a coaxial technique, and the tip first seated on the inferolateral margin of the pars interarticularis. This serves as an effective depth marker. Once this bony margin is contacted, the C-arm is rotated to a lateral view (Fig. 6-12), and the needle is slowly advanced toward the anterior and superior aspect of the foramen. If a paresthesia is reported by the patient at any time during needle advancement, the needle should be withdrawn slightly, and the position confirmed with radiographic contrast. With the needle in final position, 1 to 2 mL of radiographic contrast is injected under "live" or "real-time" fluoroscopy in the AP plane to ensure the needle tip lies in close proximity to the nerve without any intravascular or intrathecal spread (Fig. 6-13). The injectate containing local anesthetic and/or steroid can then be injected safely. Obtaining a final lateral image will allow assessment of the extent of spread of the injectate (Fig. 6-11D).

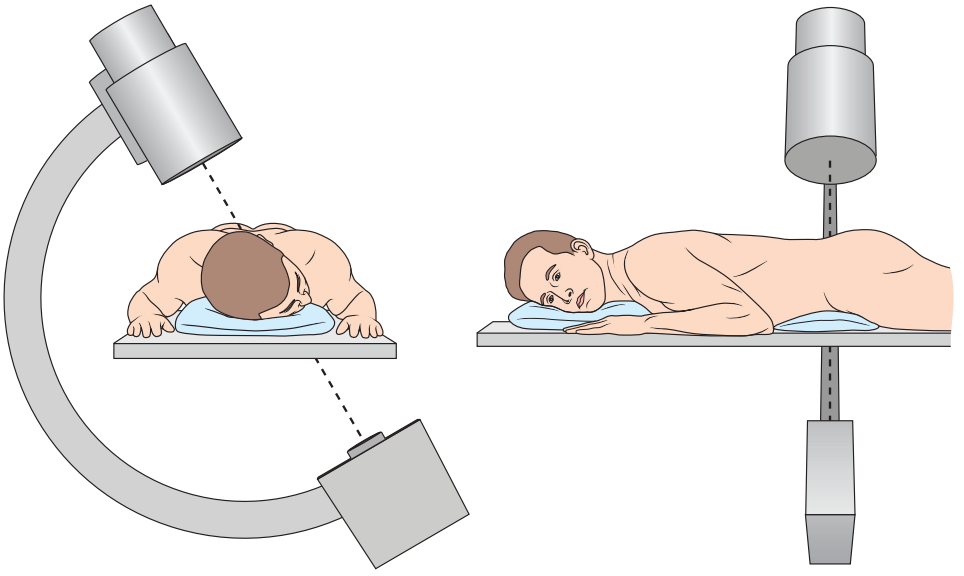


Figure 6-9.
Patient position for lumbar transforaminal and selective spinal nerve injection. The patient is positioned supine with C-arm axis rotated obliquely 20 to 30 degrees until the facet joint and pars interarticularis are clearly visualized.

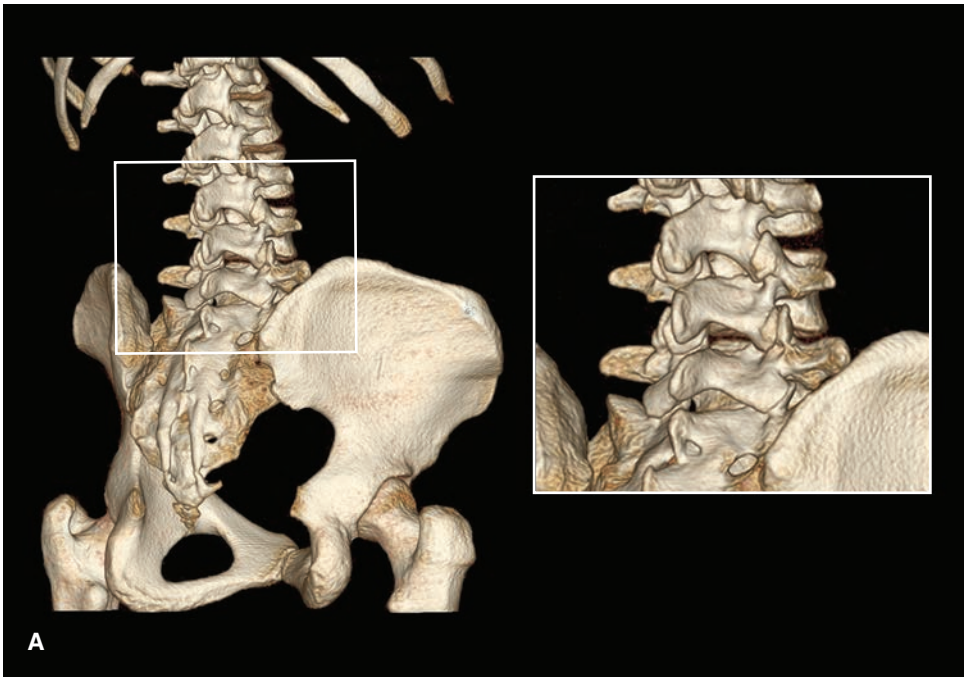


Figure 6-10.
A: Bony anatomy relevant to lumbar transforaminal injection. Three-dimensional reconstruction computed tomography of the lumbar spine as viewed in the left oblique projection used for needle insertion. **Inset** matches the anatomic area in the radiographs shown in **(B)** and **(C)**. *(Cont.)*

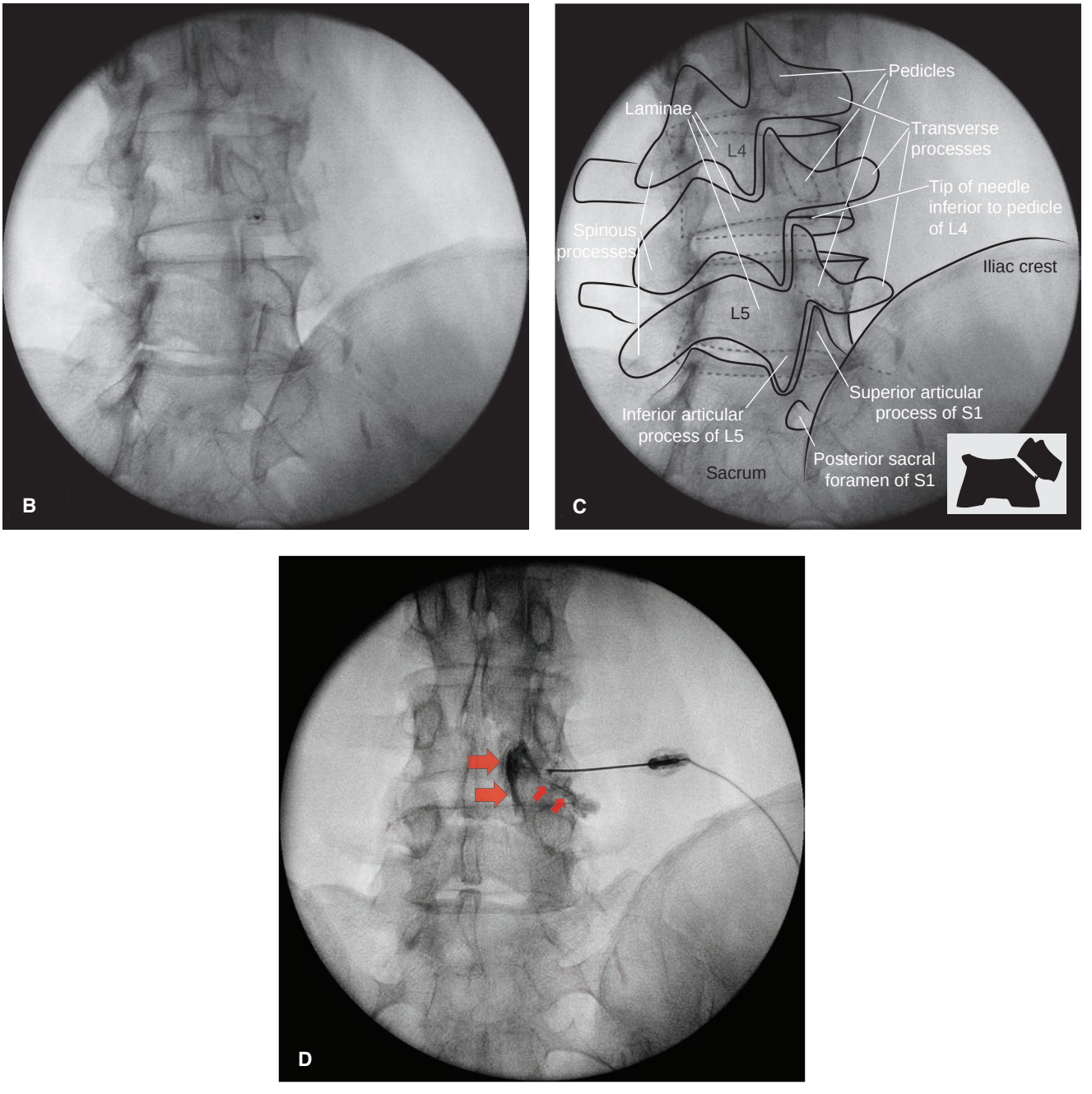
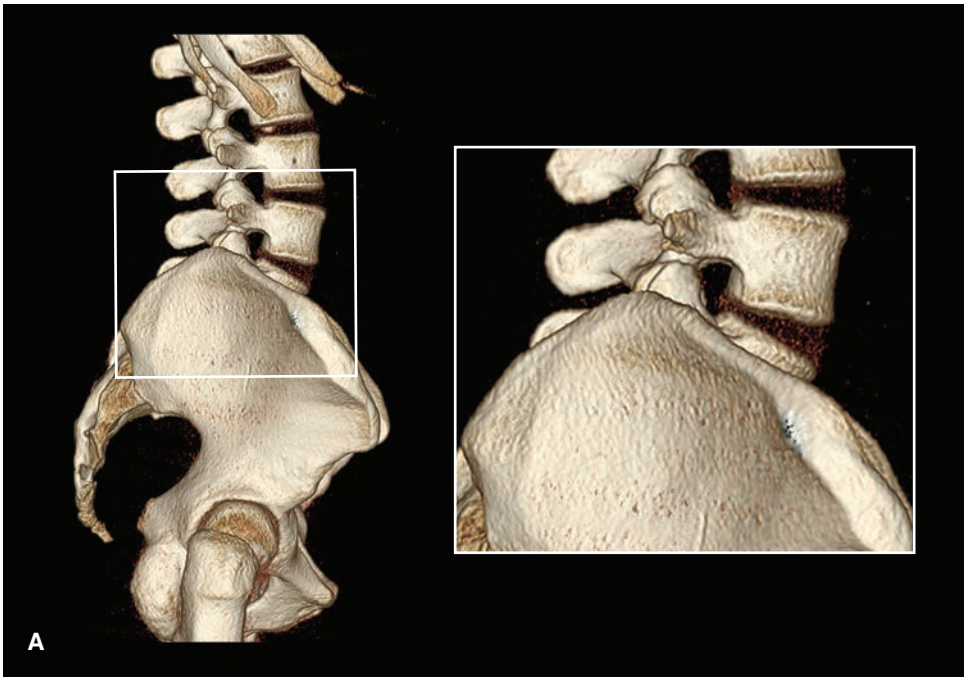
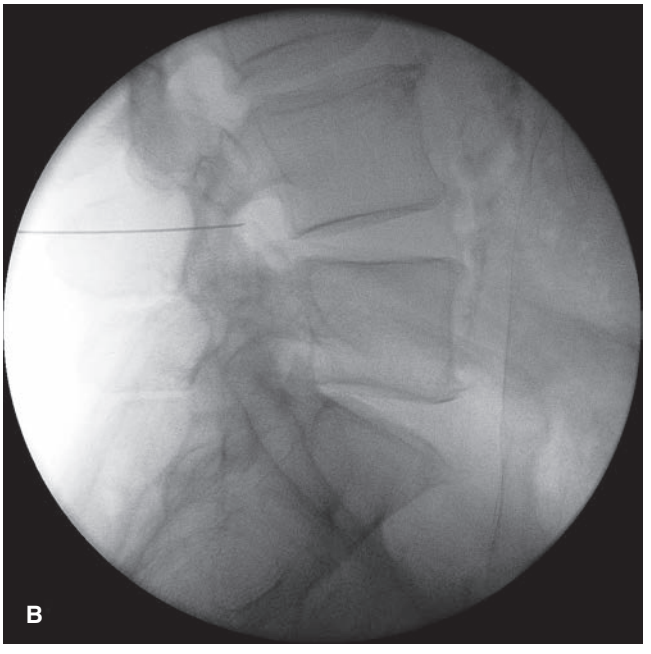


Figure 6-10. (*Continued*)

B: Left oblique radiograph with the needle in final position for right L4/L5 transforaminal injection. The needle tip lies directly inferior to the pedicle and inferolateral to the pars interarticularis. **C:** Labeled image. The contour of the posterior bony elements of the spine on the oblique projection takes a shape similar to the silhouette of a Scottish terrier or "Scotty dog". Following this contour around its perimeter, the front leg of the dog is the inferior articular process of the vertebra, the snout is the transverse process, the ear is the superior articular process, the back is the superior margin of the lamina, the buttocks and hind leg is the spinous process, and the belly of the dog is the inferior margin of the lamina. Compare the outlined areas of the radiograph with the contour of an actual Scottish terrier shown in the **inset** in the lower right corner of this image. **D:** Anterior-posterior radiograph with the needle in final position for right L4/L5 transforaminal injection after injection of 1 mL of radiographic contrast medium (iopamidol 200 mg per mL). Contrast outlines the spinal nerve (*small arrows*) and extends along the lateral aspect of the epidural space (*large arrows*).





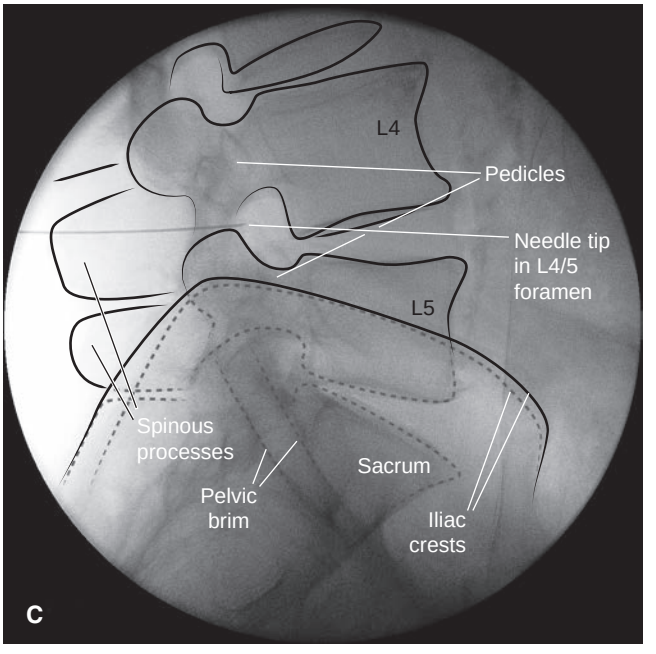


Figure 6-11.

A: Bony anatomy relevant to lumbar transforaminal injection. Three-dimensional reconstruction computed tomography of the lumbar spine as viewed in lateral projection used for needle insertion. **Inset** matches the anatomic area in the radiographs shown in **(B–D)**. **B:** Lateral radiograph with the needle in final position for right L4/L5 transforaminal injection. The needle tip lies directly inferior to the pedicle within the posterior and superior aspect of the L4/L5 intervertebral foramen. **C:** Labeled image. ***(Cont.)***

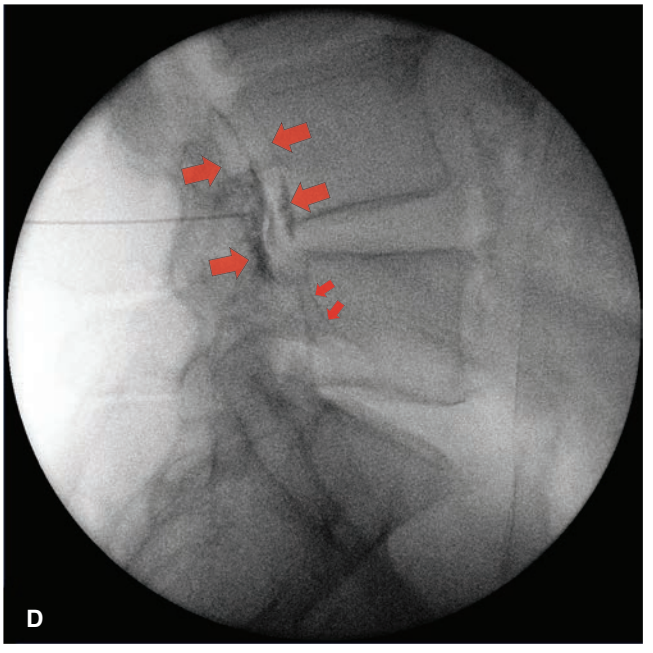


Figure 6-11. *(Continued)*
D: Lateral radiograph with the needle in final position for right L4/L5 transforaminal injection after injection of 1 mL of radiographic contrast medium (iopamidol 200 mg per mL). Contrast outlines the spinal nerve (*small arrows*) and extends along the anterior and posterior aspects of the epidural space (*large arrows*).

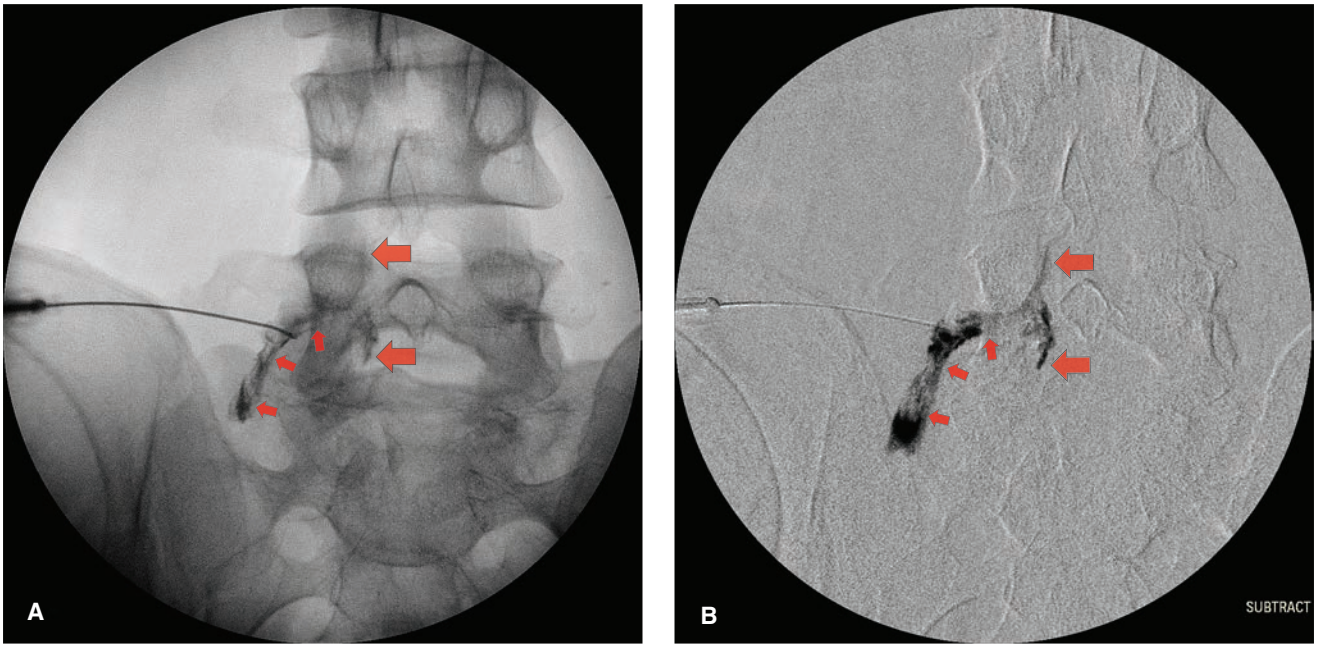


Figure 6-12.
A: Anterior-posterior radiograph of the lumbar spine following lumbar transforaminal injection, after contrast injection. The needle is in final position for left L5/S1 transforaminal injection following injection of 1.5 mL of radiographic contrast. The needle tip lies inferior and slightly lateral to the pedicle, just inferior to the spinal nerve, and contrast surrounds the spinal nerve along its course (*small arrows)*, extending to the right lateral epidural space beneath the pedicle (*large arrows*). **B:** Same image shown in **(A)** as seen using digital subtraction.

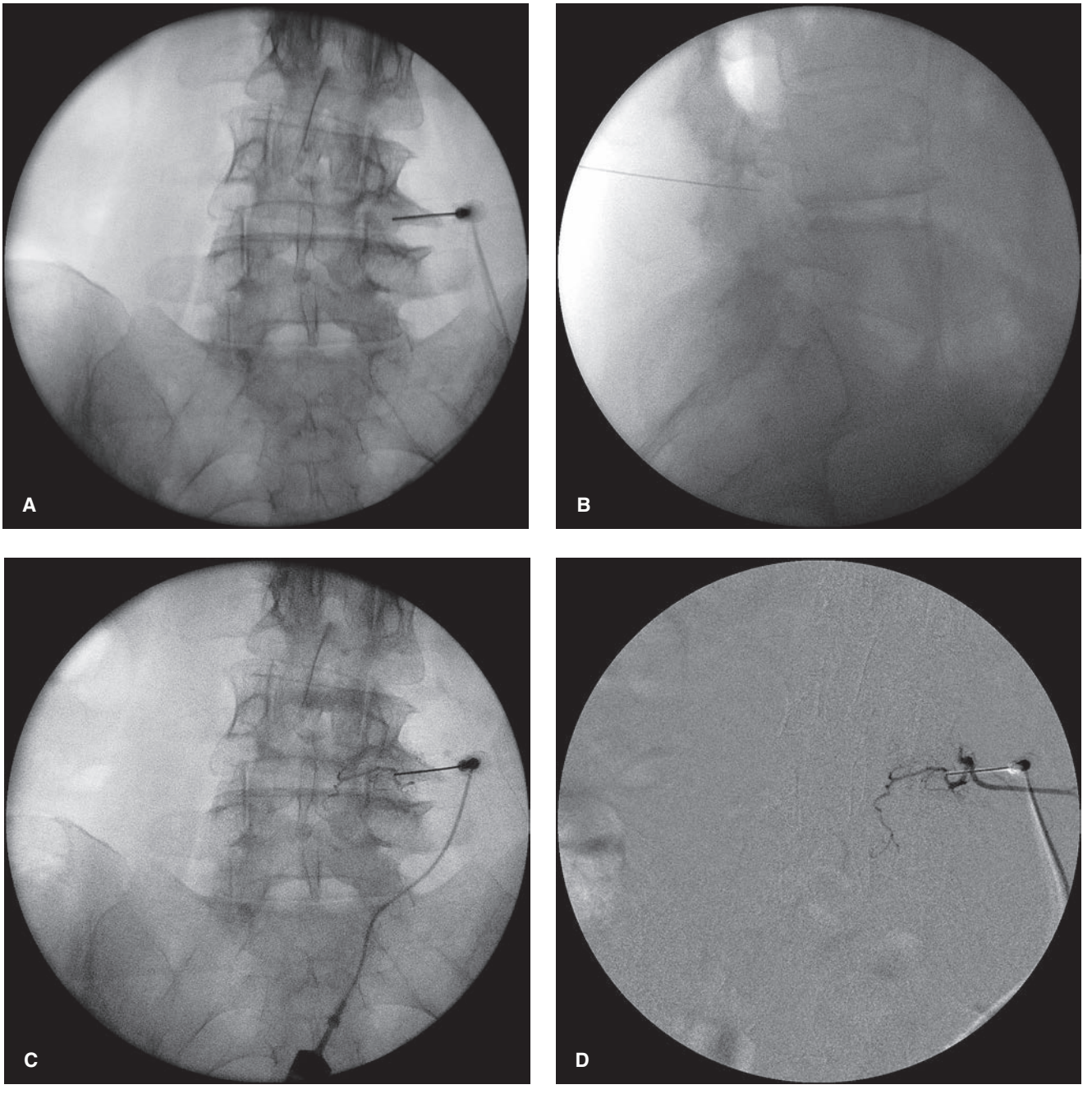


Figure 6-13.
Lumbar transforaminal injection and use of digital subtraction to identify intra-arterial needle location. **A:** Anterior-posterior radiograph of the lumbar spine with the needle in final position for right L4/L5 transforaminal injection. **B:** Lateral radiograph of the lumbar spine with the needle in final position for right L4/L5 transforaminal injection. **C:** Anterior-posterior radiograph of the lumbar spine with the needle in final position for right L4/L5 transforaminal injection acquired during active injection of radiographic contrast demonstrating intra-arterial contrast injection. **D:** Same image shown in **(C)** as seen using digital subtraction.

Complications

A firm grasp of the anatomy of adjacent vascular and neural structures is essential to avoid complications during lumbar selective spinal nerve and transforaminal injection (see Fig. 6-7). Direct injection of particulate steroid into a spinal segmental artery supplying the spinal cord can lead to catastrophic spinal cord infarction. Needle positioning toward the posterior aspect of the foramen reduces the risk of entering the spinal segmental artery. Particular care should be taken when performing transforaminal injection on the left between T9 and L1 because the artery of Adamkiewicz, the largest of the spinal segmental arteries,

lies between these levels in the majority of individuals. The use of radiographic contrast injected during "live" or "real-time" fluoroscopy to visualize final needle position and detect any hint of intravascular injection is the only means to accurately verify that injectate is not injected within an artery. Subarachnoid injection may also occur if the needle is advanced too medially and pierces the dural cuff as it extends laterally onto the exiting nerve root. Direct trauma to the exiting nerve root or the spinal cord itself may also occur.

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CHAPTER 7

Facet Injection: Intra-articular Injection, Medial Branch Block, and Radiofrequency Treatment

OUTLINE

Overview

Intra-articular facet injection has been largely supplanted by radiofrequency treatment techniques for facet-related pain. Clinical experience and a limited number of published observational studies suggest that the intra-articular injection of local anesthetic and steroid leads to relief of facet-related pain that is limited in duration. In contrast, radiofrequency treatment is safe and modestly effective in producing longer term pain relief in the same group of patients (see "Facet Medial Branch Block and Radiofrequency Treatment"). Nonetheless, an understanding of facet-related pain syndromes and the methods for placing medication directly within the facet joint may still prove useful for those practitioners who are unable to provide radiofrequency treatment.

Osteoarthritis of the spine is ubiquitous and an inevitable part of aging. The cascade that leads to degeneration of the intervertebral discs causes progressive disc dehydration and loss of disc height. Typically first appearing in the third decade of life, disc degeneration leads to increased mobility of adjacent vertebrae and heightened shear forces on the facet joints themselves. This can lead to a pattern of pain over the axis of the spine that increases with movement, particularly with flexion and extension, but produces little or no pain radiating toward the extremities. In the past, the only available treatment for those with debilitating facet-related pain was segmental fusion of the spine to completely arrest motion within the painful portion of the spine.

The majority of patients will have pain that is gradual in onset and can be localized only to a general region of the spinal axis (i.e., high or low cervical spine, high or low thoracic spine, or high or low lumbar spine). However, a subgroup of patients will present with sudden onset of pain, often associated with trauma in the form of sudden flexion or hyperextension of the spine in the affected region. Diagnostic studies are typically unrevealing, either showing no abnormalities or facet arthropathy at multiple levels. In those with pain of sudden onset, it may be possible to isolate one or more facets that are causing the pain. It is in these instances with sudden onset of well-localized pain that intra-articular facet injection with local anesthetic and steroid can prove most beneficial.

Anatomy

The zygapophysial or "facet" joints are paired structures that lie posterolaterally on the bony vertebrae at the junction of the lamina and pedicle medially, and the base of the transverse process laterally. The facet joints are true joints, with opposing cartilaginous surfaces and a true synovial lining, and they are subject to the same inflammatory and degenerative processes that affect other synovial joints throughout the body. The facet joint articular processes are named for the vertebra to which they belong. Thus, each vertebra has a superior articular process and an inferior articular process. This nomenclature can be confusing because the superior articular process of a given vertebra actually forms the inferior portion of each facet joint. The paired facet joints, along with the vertebral bodies and intervertebral discs, form the three weight-bearing support columns that distribute the axial load on the vertebral column while allowing for movement in various planes.

The structure and location of the facet joints is distinct in the cervical, thoracic, and lumbar regions (Fig. 7-1). The cervical facet joints are oriented nearly parallel to the axial plane where the atlas (C1) articulates with the occiput and become gradually more steeply angulated in a cephalad-to-caudad direction at lower cervical levels. The orientation of the cervical facet joints in a plane close to the axial plane

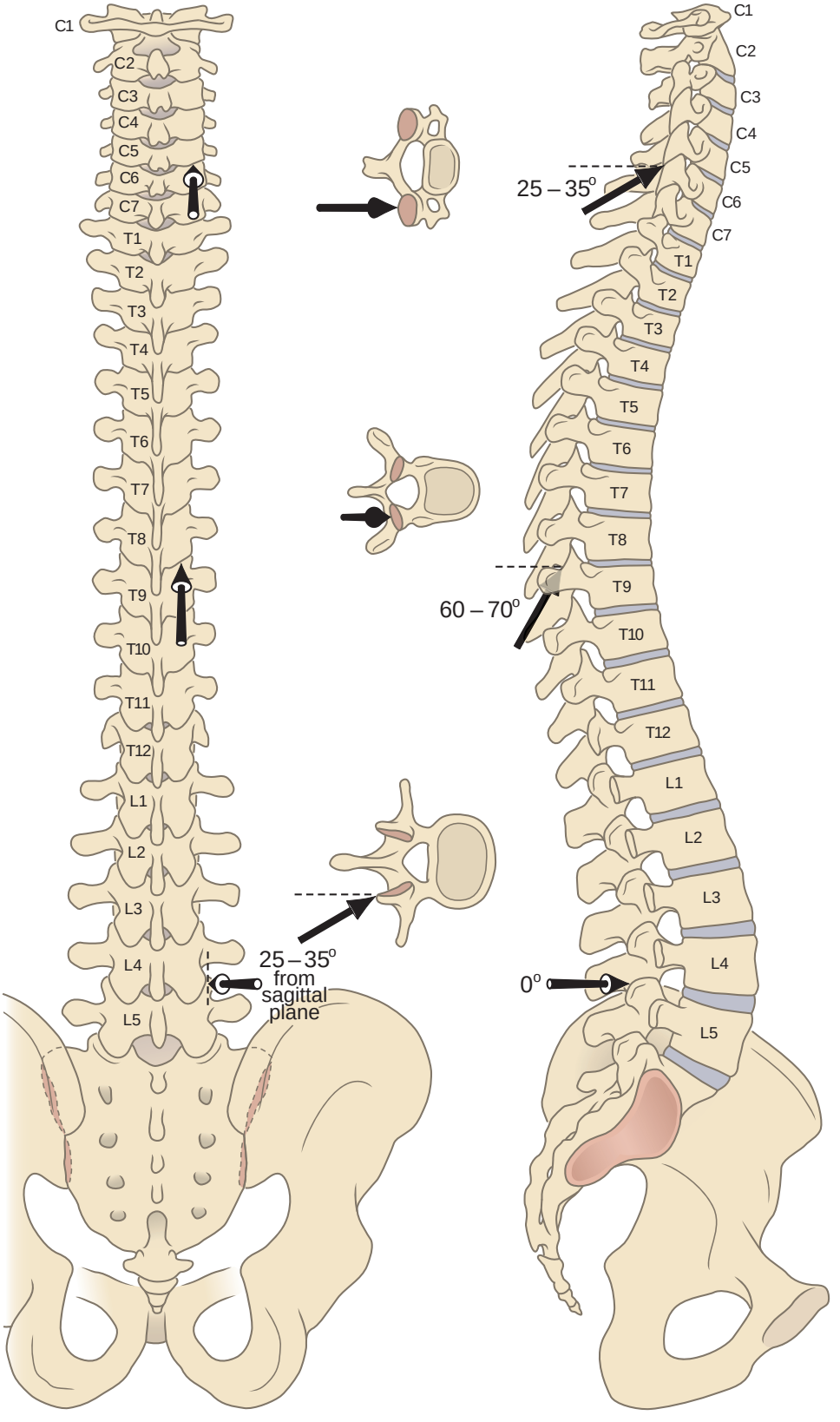


Figure 7-1.
Anatomy of the facet joints. The plane of orientation of the facet joints varies significantly among cervical, thoracic, and lumbar levels. The axis of the joints and the plane of entry for intra-articular injection are shown for typical cervical, thoracic, and lumbar facet joints.

allows for a great degree of rotation of the neck, as well as flexion and extension. The thoracic facet joints become even more steeply angulated, approaching the frontal plane. At midthoracic levels, the inferior articular process of the vertebra forming the superior portion of each thoracic facet joint lies directly posterior to the superior articular process, forming the inferior portion of each joint. This allows for some degree of flexion and extension, but limited rotation of the spinal column in the thorax. The steeply angled cephalad-to-caudad orientation of the thoracic facets also makes intra-articular injection difficult or impossible. The lumbar facet joints are angled with a somewhat oblique orientation, allowing for flexion, extension, and rotation that is greater than that in the thorax but less than in the cervical region. The orientation of the facet joints and the optimal angle of needle insertion for intra-articular facet injection are illustrated in Figure 7-1.

The sensory innervation to the facet joints is anatomically predictable, and the sensory nerves are easily accessible from the dorsal surface of the body. The spinal nerve at each level traverses the intervertebral foramen and divides into anterior and posterior primary rami. The anterior ramus contains the majority of sensory and motor fibers at each vertebral level. The posterior primary ramus, in turn, divides into a lateral branch that provides innervation to the paraspinous musculature and a small, variable sensory branch to the skin overlying the spinous processes; the medial branch of the posterior primary ramus courses over the base of the transverse process where it joins with the superior articular process of the facet joint and courses along the articular process to supply sensation to the joint. Each facet joint receives sensory innervation from the medial branch nerve at the same vertebral level, as well as from a descending branch from the vertebral level above; thus, two medial branch nerves must be blocked to anesthetize each facet joint, for example, medial branch blocks at the base of the L4 and L5 transverse processes are needed to anesthetize the L4/L5 facet joint. The specific course of the medial branch nerves and cannula position for radiofrequency treatment at specific spinal levels is discussed in the following sections.

Patient Selection

Patients with facet-related pain are difficult to distinguish from those with other causes of axial spinal pain. Some patients will present with sudden onset of pain following a significant flexion-extension (whiplash) injury, but more common is an insidious onset over months to years. Patients with myofascial or discogenic pain and, in the low back, those with sacroiliac dysfunction present with similar symptoms. Nonetheless, certain features can be helpful in differentiating facet-related pain from other causes of spinal pain. The pain caused by facet arthropathy is most pronounced over the axis of the spine itself and is typically maximal directly in the region of the most affected joints. The pain tends to be exacerbated by movement, particularly extension of the spine, which forces the inflamed articular surfaces of the facet joints together. However, axial spinal pain at rest or worsening with forward flexion or rotation of the spine is also a common feature. The most important historical feature is a predominance of axial spinal pain; those patients who report that the predominance of their pain is in the extremities are more likely to have acute or chronic radicular pain than facet-related pain. The quality of the pain is typically deep and aching, and waxes and wanes with activity. Burning or stabbing qualities suggest neuropathic pain rather than facet arthropathy. Diagnostic studies are often unrevealing. Patients with significant facet-related pain may have unremarkable plain radiographs and/or imaging studies of the spine, or they may have facet arthropathy at multiple levels. Patient selection for facet injection or radiofrequency treatment is empiric and relies on excluding other causes of pain and the presence of a pattern of pain that is consistent with facet-related pain.

The pattern of pain caused by abnormalities in specific facet joints has been established by injecting a mild irritant (usually hypertonic saline) into specific facet joints in healthy volunteers and then recording the pattern of pain produced. This information is shown in Figures 7-2 to 7-4 for the cervical, thoracic, and lumbar regions, respectively. The levels to be treated are chosen by correlating the patient's report of pain to these pain diagrams. Occasionally, a patient will present with evidence of facet arthropathy and a pattern of pain that corresponds to a single level, but this is uncommon. Most patients will have more diffuse pain that can only be narrowed to a specific region. Treatment should be directed to the joint or joints that most closely match the pattern of referred pain that has been established for each joint and that typically requires treatment at more than one level.

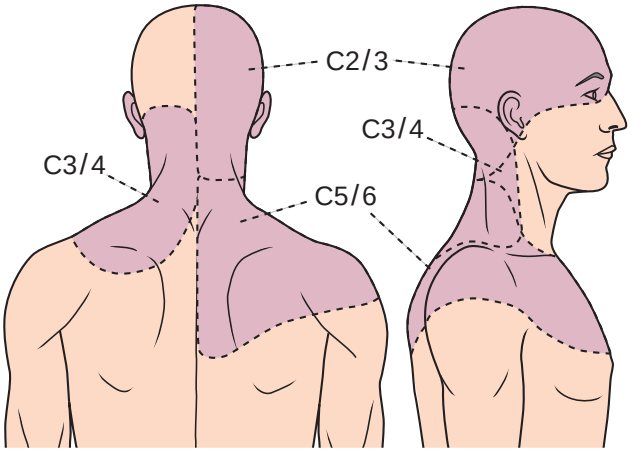


Figure 7-2.
Patterns of pain produced by cervical facet joints. Typical pain patterns produced by specific cervical facet joints are illustrated. Data are derived from intra-articular injection in healthy volunteers. (Data from Bogduk N, Marsland A. The cervical zygapophysial joints as a source of neck pain. *Spine*. 1988;13:615.)

Level of Evidence

Quality of Evidence and Grading of Recommendation			
Grade of Recommendation/Description	**Benefit vs. Risk and Burdens**	**Methodological Quality of Supporting Evidence**	**Implications**
RECOMMENDATION: *Intra-articular facet injections and therapeutic medial branch blocks may be used for symptomatic relief of facet-related pain.*			
2B/weak recommendation, moderate-quality evidence	Benefits closely balanced with risks and burden	II-2: randomized controlled trials (RCTs) with important limitations (inconsistent results, methodological flaws, indirect, or imprecise) and strong evidence from observational studies	Weak recommendation, best action may differ depending on circumstances or patients' or societal values
RECOMMENDATION: *Radiofrequency ablation: Conventional (e.g., 80°C) or thermal (e.g., 67°C) radiofrequency ablation of the medial branch nerves to the facet joint should be performed for low back (medial branch) pain when previous diagnostic or therapeutic injections of the joint or medial branch nerve have provided temporary relief. Conventional radiofrequency ablation may be performed for neck pain.*			
1B/strong recommendation, moderate-quality evidence	Benefits clearly outweigh risk and burdens, or vice versa	I: RCTs with important limitations (inconsistent results, methodological flaws, indirect, or imprecise) and strong evidence from observational studies	Strong recommendation, can apply to most patients in most circumstances without reservation

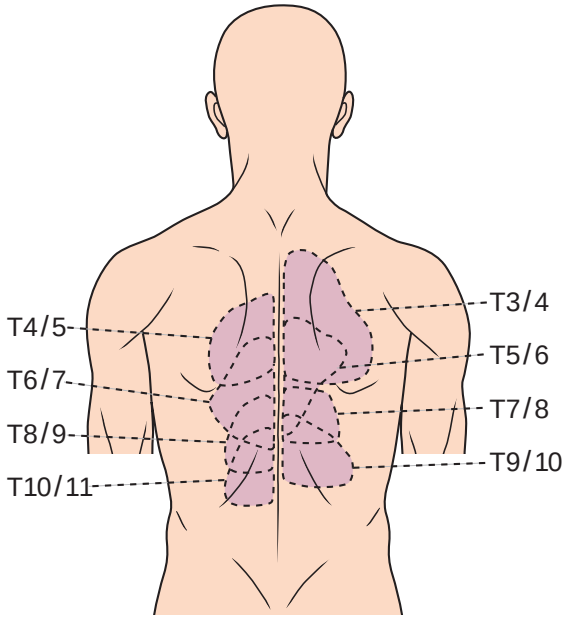


Figure 7-3.
Patterns of pain produced by thoracic facet joints. Typical pain patterns produced by specific thoracic facet joints are illustrated. Data are derived from intra-articular injection in healthy volunteers. (Adapted from Dreyfuss P, Tibiletti C, Dreyer S. Thoracic zygapophyseal joint pain patterns. *Spine*. 1994;19:809, with permission.)

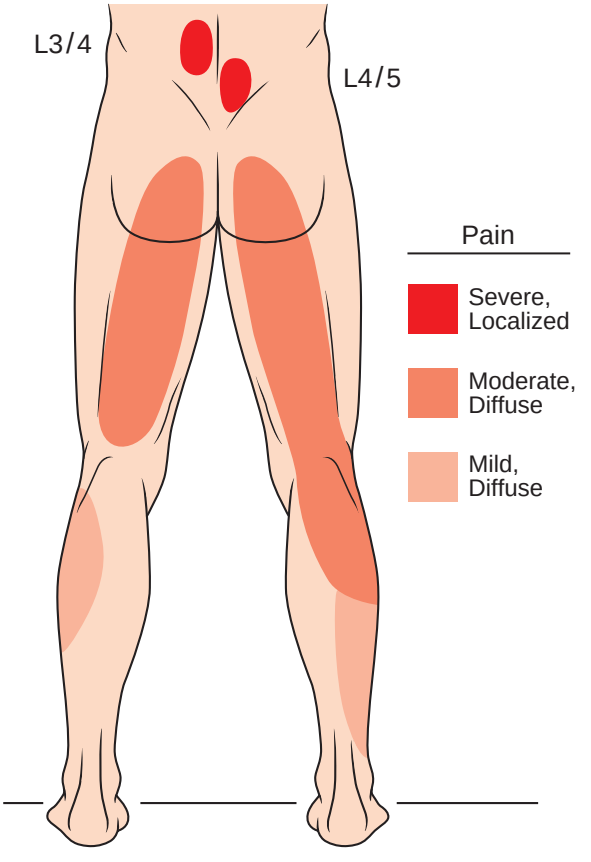


Figure 7-4.
Patterns of pain produced by lumbar facet joints. Typical pain patterns produced by specific lumbar facet joints are illustrated. Data are derived from intra-articular injection in healthy volunteers. (Adapted from Boas RA. Facet joint injections. In: Stanton-Hicks MA, Boas RA, eds. *Chronic Low Back Pain*. New York: Raven Press; 1982:202, with permission.)

There has been an exponential rise in the use of spinal injections of all kinds during the past decade in the United States, while the prevalence of acute pain associated with various spinal disorders has changed little. The overuse of facet injections, including intra-articular injections and radiofrequency treatment, has been singled out as a significant area of concern. Several organizations have closely examined the scientific literature and made evidence-based guidelines regarding the use of this treatment. The available RCTs examining facet injections and radiofrequency treatment are limited, and we will discuss each in turn.

The American Pain Society (APS) Low Back Pain Guideline Panel published a report in 2009, concluding, "In patients with persistent nonradicular low back pain, facet joint corticosteroid injection…[is] not recommended (strong recommendation, moderate-quality evidence). There is insufficient evidence to adequately evaluate benefits of therapeutic medial branch block [and] radiofrequency denervation…for nonradicular low back pain." Facet joint injections were not recommended by this group specifically because randomized trials consistently found them to be no more effective than sham therapies.

Subsequently, the American Society of Anesthesiologists (ASA) Task Force on Chronic Pain Management published A 2010 Practice Guideline, offering the following recommendations: (1) "Intra-articular facet joint injections may be used for symptomatic relief of facet-mediated pain."; (2) "Medial branch blocks may be used for the treatment of facet-mediated spine pain."; and (3) "Radiofrequency ablation: Conventional (e.g., 80°C) or thermal (e.g., 67°C) radiofrequency ablation of the medial branch nerves to the facet joint should be performed for low back (medial branch) pain when previous diagnostic or therapeutic injections of the joint or medial branch nerve have provided temporary relief. Conventional radiofrequency ablation may be performed for neck pain…" The ASA Task Force recommendations appear to be at odds with those put forward by the APS Low Back Pain Guideline Panel. The ASA Task Force deliberately included observational studies and expert opinion in its overall analysis. Indeed randomized trials demonstrate little benefit for use of intra-articular injections, while well-conducted observational studies suggest a more significant effect in treating chronic axial low back pain. Observational trials of the use of medial branch blocks with local anesthetic alone, without subsequent radiofrequency treatment, have been encouraging, but randomized trials are lacking. When examining the available trials for use of radiofrequency facet treatment, the ASA Task Force accepted the availability of one or more randomized trial as an acceptable level of evidence to recommend use of this treatment. Nonetheless, the overall level of evidence supporting the efficacy of facet injections and radiofrequency treatment is limited and additional, large-scale clinical trials are desperately needed. Guidance on the optimal frequency for repeating these interventions as well as the efficacy of using multiple repeated treatments over time is lacking entirely.

Intra-articular Facet Injection Versus Radiofrequency Treatment

How to select between intra-articular facet injection and diagnostic medial branch blocks followed by radiofrequency treatment is still a question that is frequently posed by practitioners. Limited outcome studies of intra-articular injection, particularly at the cervical level, have demonstrated only transient pain relief lasting from days to weeks in most patients. In contrast, in those patients who obtain significant pain relief from diagnostic blocks of the medial branch nerves to the facet, radiofrequency treatment can produce significant pain reduction that is somewhat longer lasting (typically 50% or more reduction in pain lasting at least 3 months after treatment). Based on this improved efficacy and a long track record of safety, many practitioners have all but abandoned intra-articular injections in favor of radiofrequency treatment. Intra-articular injection remains of some value in those patients who have had recent onset of pain that is discrete in location and suggests involvement of a single facet joint. Intra-articular injection is also a reasonable alternative when the expertise or equipment for radiofrequency treatment is not available, but it will provide only transient symptomatic relief in those with facet-related pain who have failed conservative treatment. While observational studies have suggested that use of medial branch blocks with local anesthetic alone can provide sustained pain relief in some individuals, transient pain relief lasting only hours to days after injection is more common than not.

Intra-articular Facet Injection

Cervical Intra-articular Facet Injection

Positioning

The patient lies prone, facing the table with a small headrest under the forehead to allow for air flow between the table and the patient's nose and mouth (Fig. 7-5). The C-arm is rotated 25 to 35 degrees caudally from the axial plane without any oblique angulation. This brings the axis of the x-rays in line with the axis of the facet joints and allows for visualization of the joints (Fig. 7-6). Although the cervical facet joints can also be entered from a lateral approach with the patient lying on his or her side, advancing a needle using radiographic guidance in the anterior-posterior (AP) plane allows the operator to directly see the position of the spinal canal at all times and avoid medial needle deviation that could lead to spinal cord injury (Figs. 7-7 and 7-8).

Block Technique

The skin and subcutaneous tissues overlying the facet joint where the block is to be carried out are anesthetized with 1 to 2 mL of 1% lidocaine. The cervical level is easily

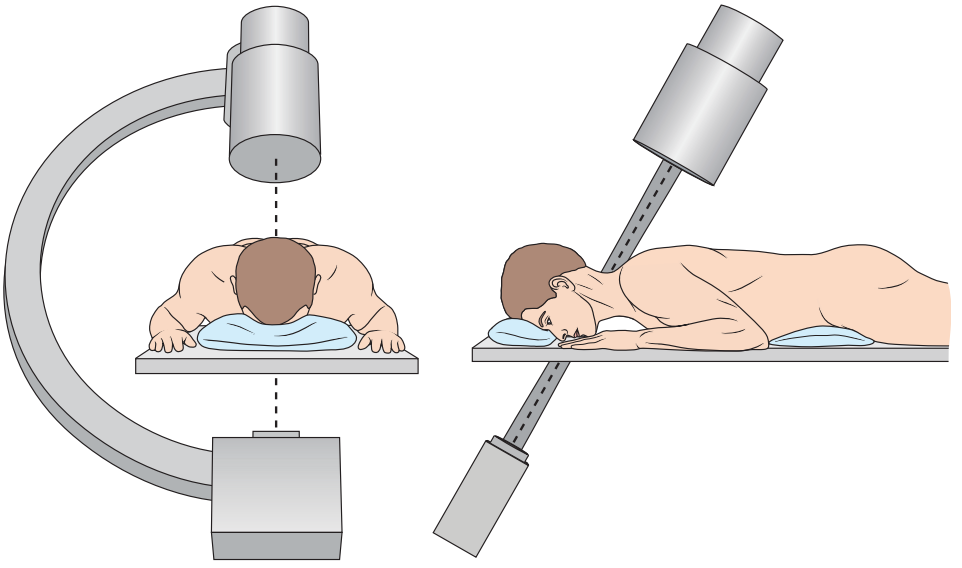


Figure 7-5.
Position for intra-articular cervical facet joint injection. The patient is placed prone with a small headrest under the forehead to allow for air flow between the table and the patient's nose and mouth. The C-arm is angled 25 to 35 degrees caudally from the axial plane.

identified by counting upward from the T1 level, where the vertebra is distinguished by the presence of a large transverse process that articulates with the first rib (see Fig. 7-6). A 22- or 25-gauge, 3.5-inch spinal needle is placed through the skin and advanced until it is seated in the tissues in a plane that is coaxial with the axis of the x-ray path (see Fig. 7-6). The needle is adjusted to remain coaxial and advanced toward the joint space using repeat images after every 2 to 4 mm of needle advancement. Once the surface of the joint space is contacted, a lateral radiograph is

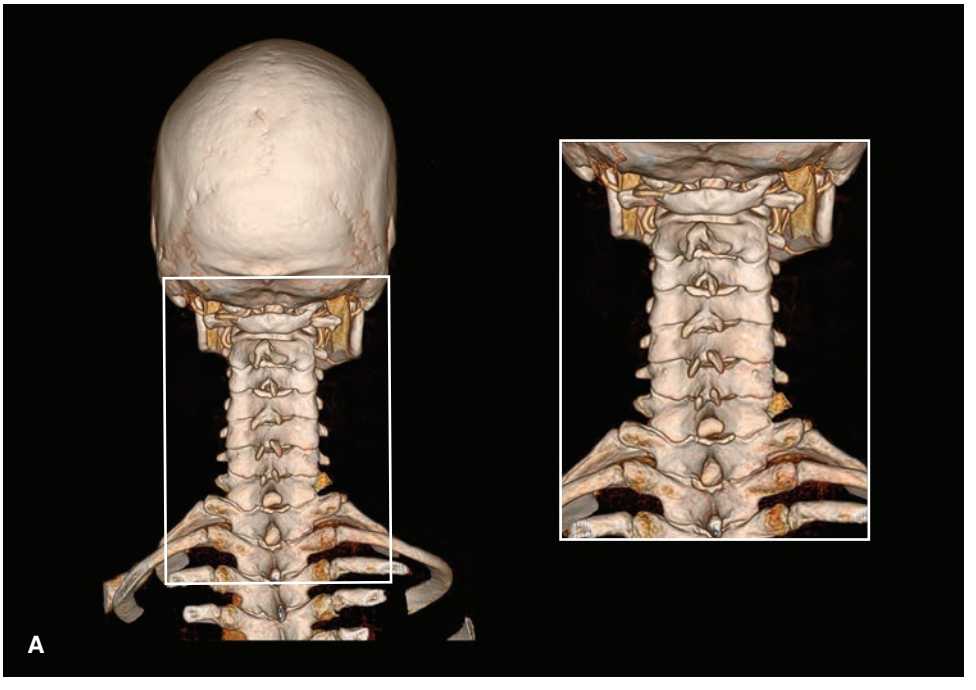


Figure 7-6.
A: Bony anatomy relevant to cervical intra-articular facet injection. Three-dimensional reconstruction computed tomography of the cervical spine as viewed from the posterior approach used for cervical intra-articular facet injection. **Inset** matches the anatomic area in the radiographs shown in **(B)** and **(C)**. ***(Cont.)***

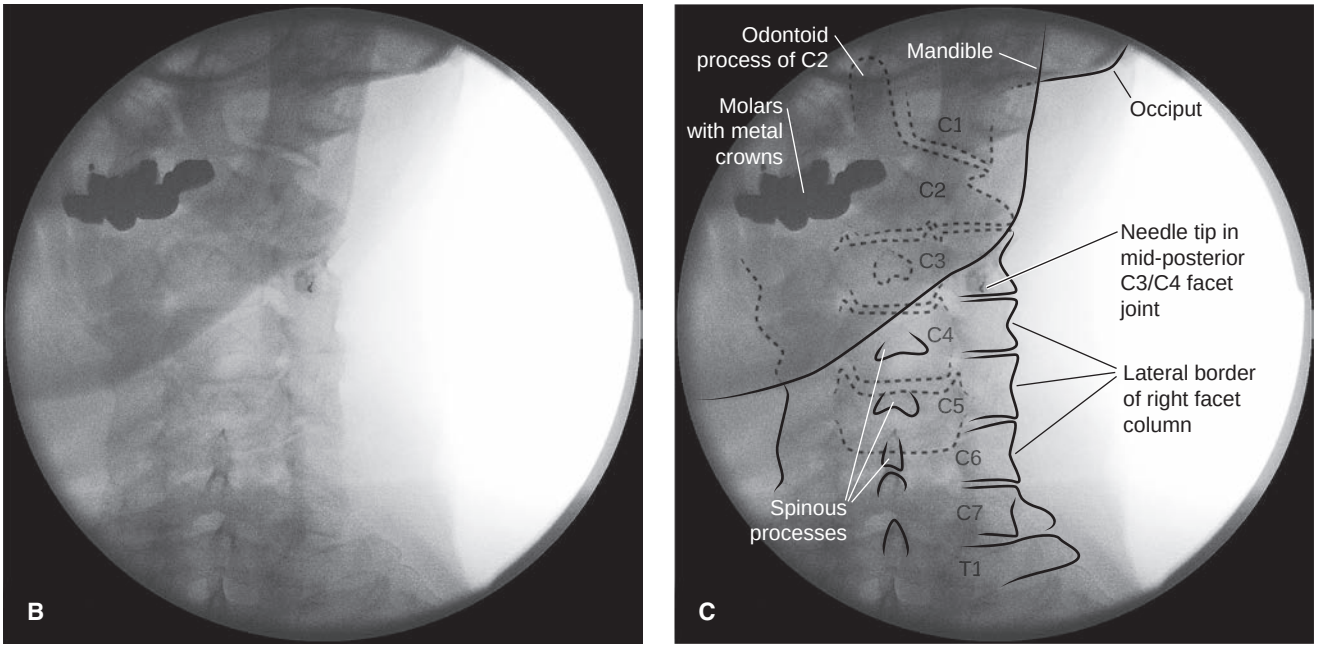


Figure 7-6. ***(Continued)***
B: AP radiograph of the cervical spine during intra-articular cervical facet injection. A 22-gauge spinal needle is in position in the left C3/C4 facet joint. **C:** Labeled image.

obtained (Fig. 7-9), and the needle is advanced just slightly to penetrate the posterior joint capsule. The needle should not be advanced into the joint between articular surfaces; this serves no purpose and is likely to abrade the articular surfaces and lead to worsened pain once the local anesthetic block subsides. Although intra-articular location of the needle tip can be confirmed with radiographic contrast, this is unnecessary if the needle location is correct in both AP and lateral planes. The facet joint itself holds only limited volume (typically ~0.5 mL), and thus, placing contrast in the joint limits the ability to place local anesthetic and steroid within the joint. Once needle position has been confirmed, a solution containing steroid and local anesthetic is placed. A total dose of 80 mg of methylprednisolone acetate or the equivalent should be divided over all the joints to be injected, but more than 40 mg per joint is probably unnecessary. Using concentrated steroid (40 or 80 mg per mL) allows 1:1 mixture with local anesthetic (0.5% bupivacaine) to provide some immediate pain relief.

Atlantoaxial (C1/C2) Facet Injection

Degenerative joint disease involving the atlantoaxial joint is not uncommon, and techniques to inject this

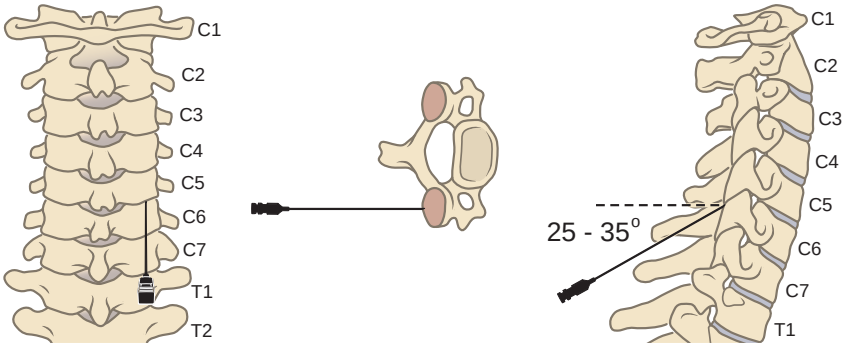


Figure 7-7.
Position and angle of needle entry for intra-articular cervical facet injection. A 22-gauge spinal needle is advanced in the sagittal plane overlying the facet joint with 25 to 35 degrees of caudad angulation from the axial plane.

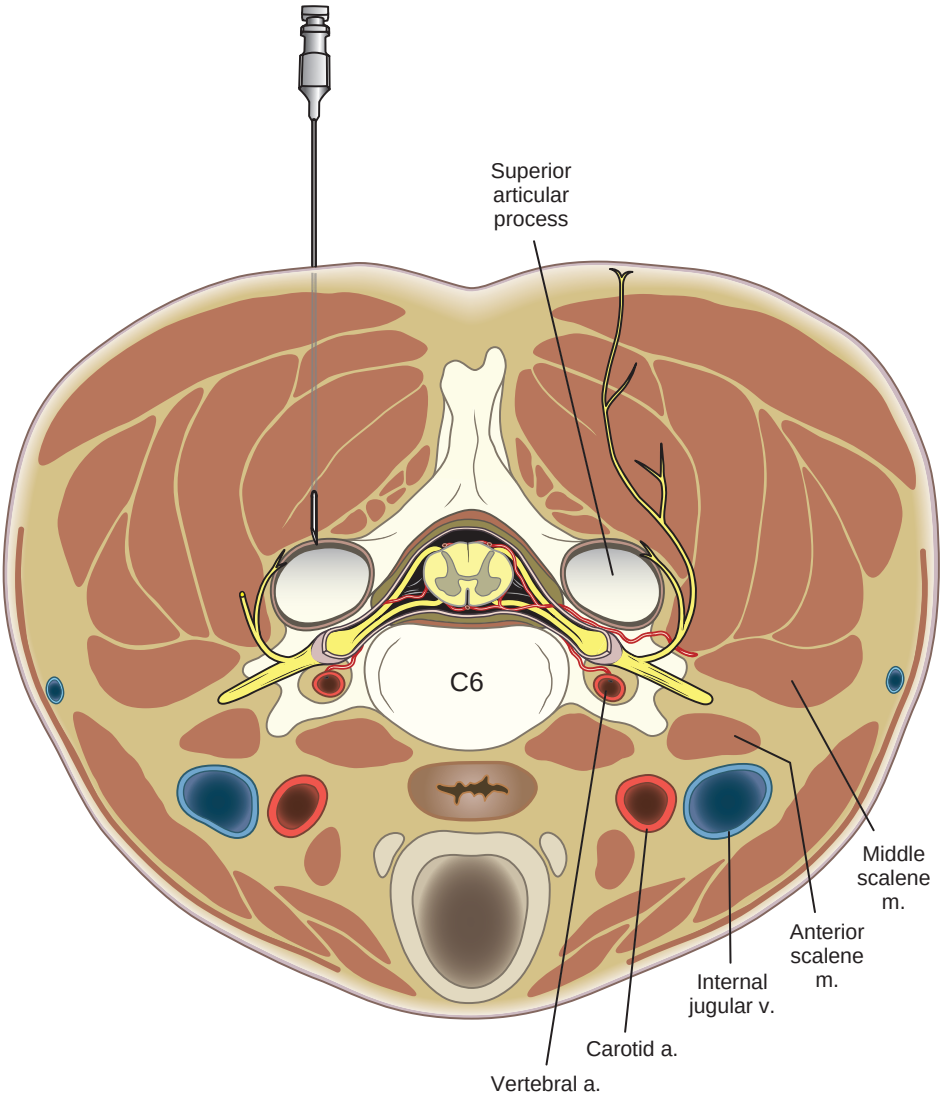
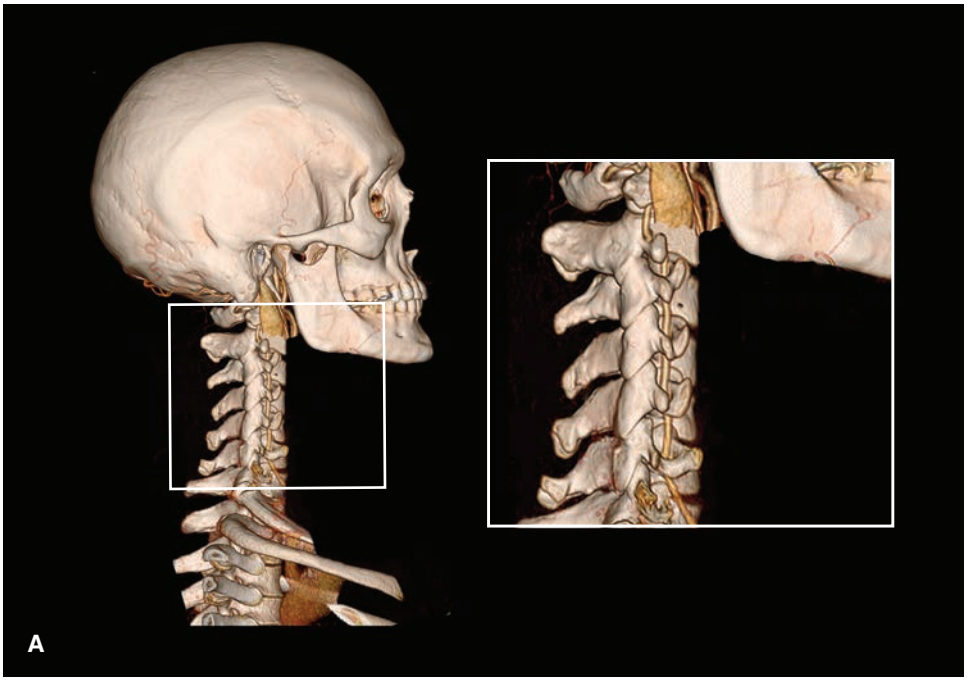
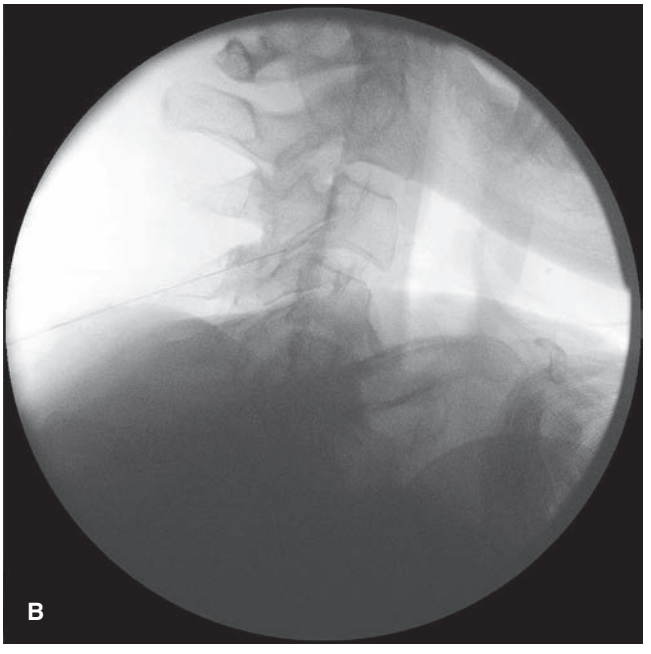


Figure 7-8.
Axial diagram of intra-articular cervical facet injection. The needle is advanced in the sagittal plane to enter the posterior aspect of the facet joint. Although the cervical facet joint can be entered from a lateral approach, using the posterior approach and radiographic guidance allows the operator to directly visualize the position of the spinal canal at all times. If the needle strays medially, the direction can be immediately corrected before dural puncture or injury to the spinal cord. When a needle is placed using a lateral approach, anterior deviation can also lead to penetration of the vertebral artery; the vertebral artery is protected by the facet column when a posterior approach is used.

joint are well described. However, there is no evidence that injection of the atlantoaxial joint can produce anything more than modest, short-term pain reduction. At the same time, recent reports of massive stroke following intra-arterial injection of particulate steroid during the conduct of atlantoaxial injection have appeared (see Fig. 4-4). *Thus many practitioners have abandoned the use of this technique entirely*. The technique is discussed here briefly to make readers aware of the relevant anatomy that makes intra-articular injection of the atlantoaxial joint particularly hazardous. The vertebral artery lies in close apposition to the lateral aspect of the atlantoaxial joint, while the dorsal root ganglion and spinal nerve of C2 lie directly over the medial and midportion of the joint (Fig. 7-10A). Block of the atlantoaxial joint is performed in a manner similar to that described for intra-articular injection of more inferior cervical facet joints. The patient in positioned prone with the head in a neutral position and the mouth opened as far as possible to allow good visualization of the lateral elements of C1 and C2 in the anteroposterior projection (Fig. 7-10B and C). To avoid contact with the C2 spinal nerve medially and





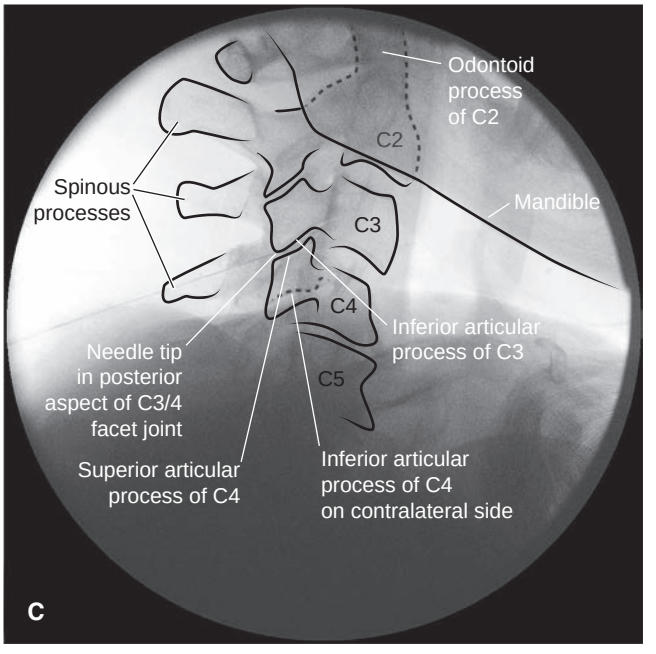


Figure 7-9.

A: Bony anatomy relevant to cervical intra-articular facet injection. Three-dimensional reconstruction computed tomography of the cervical spine as viewed in the lateral projection. **Inset** matches the anatomic area in the radiographs shown in **(B)** and **(C)**. **B:** Lateral radiograph of the cervical spine during intra-articular cervical facet injection. A 22-gauge spinal needle is in place in the posterior aspect of the C3/C4 facet joint. **C:** Labeled image.

penetration of the vertebral artery laterally, the needle is directed to the lateral third of the joint in the AP projection. Once the surface of the joint space is contacted, a lateral radiograph is obtained (Fig. 7-10D and E), and the needle is advanced just slightly to penetrate the posterior joint capsule. It is imperative that intra-arterial location of the needle tip is identified before injection of steroid, thus injection of a small volume of radiographic contrast under live fluoroscopy with or without digital subtraction is essential, for example, 0.5 to 1 mL of iopamidol 41%. There is no published evidence regarding efficacy of particulate versus nonparticulate steroid

for atlantoaxial joint injection. Nonetheless, given the close proximity of the vertebral artery and the potentially catastrophic consequences of intra-arterial injection, strong consideration of use of nonparticulate steroid should be given, for example, 4 mg of dexamethasone sodium phosphate.

Thoracic Intra-articular Facet Injection

Positioning

Thoracic intra-articular facet injection is not commonly employed. The plane of the thoracic facet joints is steeply angled, nearing the frontal plane. Even with steep

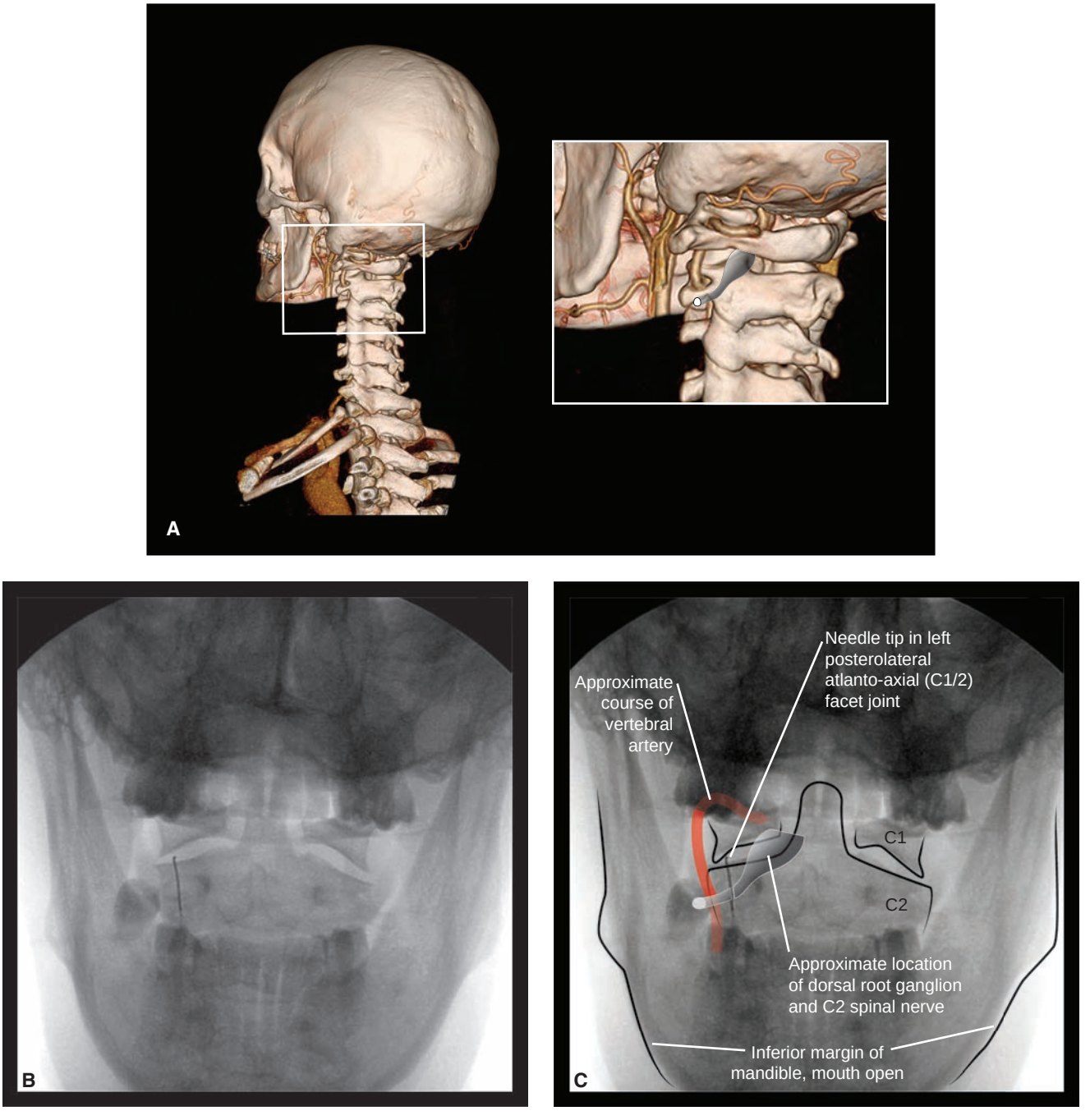


Figure 7-10.

A: Bony anatomy relevant to cervical intra-articular facet injection of the atlantoaxial (C1/C2) facet joint. Three-dimensional reconstruction computed tomography of the cervical spine as viewed in the oblique projection. **Inset** illustrates the position of the vertebral artery; the approximate position of the C2 dorsal root ganglion and spinal nerve is shown. **B:** AP radiograph of the cervical spine during intra-articular atlantoaxial (C1/C2) facet injection. A 22-gauge spinal needle is in position in the lateral third of the left atlantoaxial facet joint. **C:** Labeled AP image showing the approximate position of the vertebral artery and the C2 dorsal root ganglion and spinal nerve. ***(Cont.)***

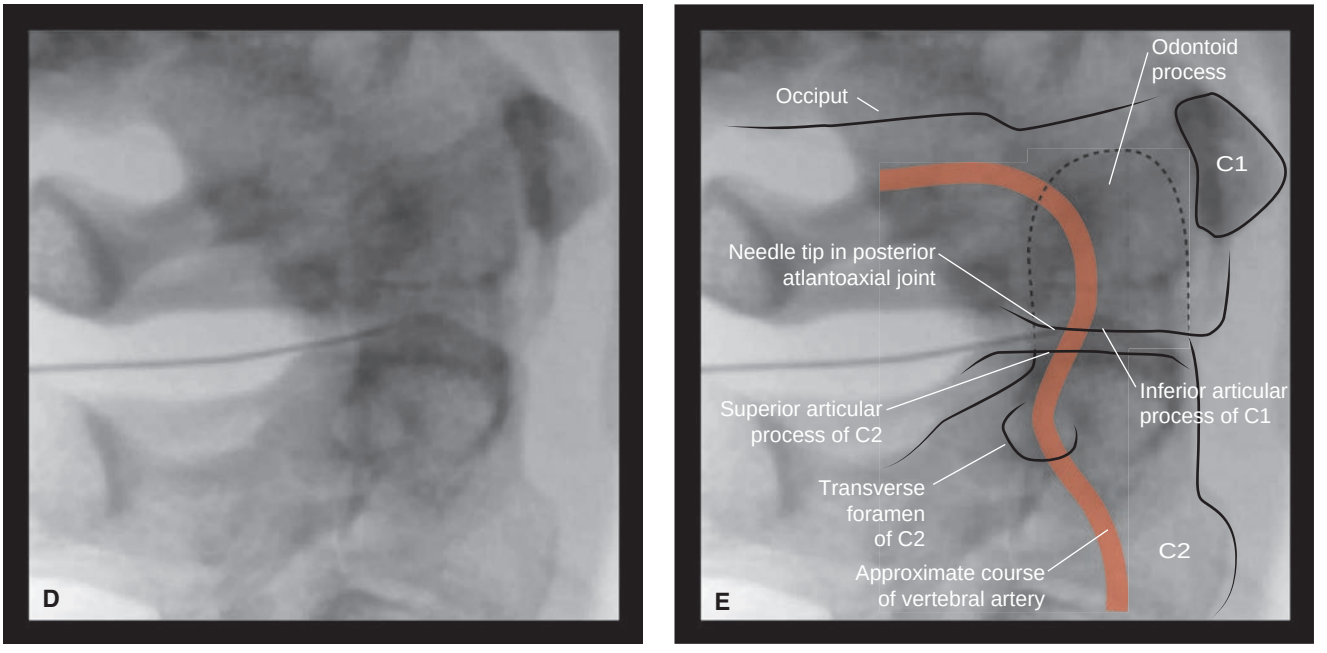


Figure 7-10. *(Continued)*

D: Lateral radiograph of the cervical spine during intra-articular atlantoaxial (C1/C2) facet injection. A 22-gauge spinal needle is in position in the posterior atlantoaxial facet joint. **E:** Labeled lateral image showing the approximate position of the vertebral artery. (Radiographs in Fig. 7-10 **(B–E)** are reproduced with permission from Aprill C, Axinn MJ, Bogduk N. Occipital headaches stemming from the lateral atlanto-axial (C1-C2) joint. *Cephalalgia*. 2002;22:15–22.)

angulation of the C-arm, the joint space cannot be visualized directly, but rather it must be inferred from the position of adjacent structures. The patient is positioned prone with the head turned to one side. The C-arm is angled 50 to 60 degrees in a caudad direction from the axial plane (Fig. 7-11). The plane of the mid- and lower thoracic facet joints lies at an angle of 60 to 70 degrees from the axial plane, but further angulation of the C-arm is impractical without the image intensifier resting against the patient's back. This angle allows visualization of structures adjacent to the facet joint from which the position of the joint can be inferred (Fig. 7-12). The inferior articular process

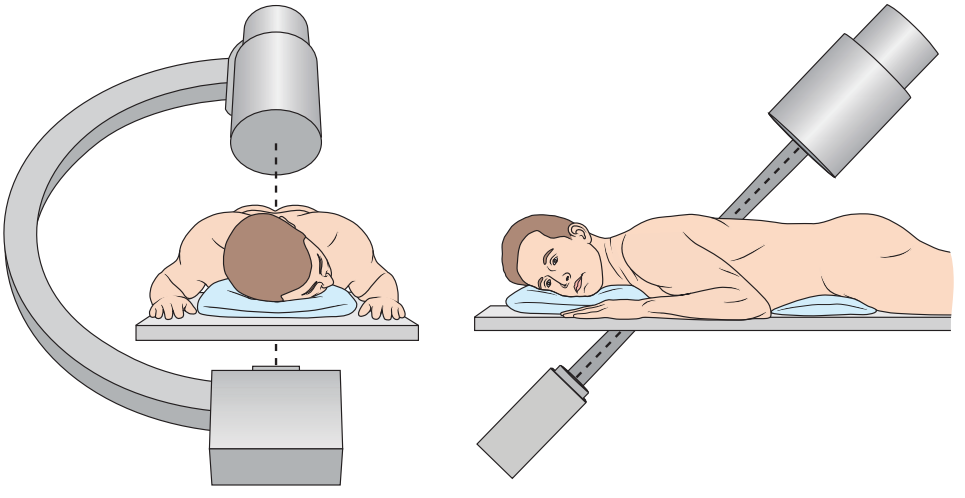


Figure 7-11.

Position for intra-articular thoracic facet joint injection. The patient is placed prone with the head turned to one side. The C-arm is angled 50 to 60 degrees caudally from the axial plane.

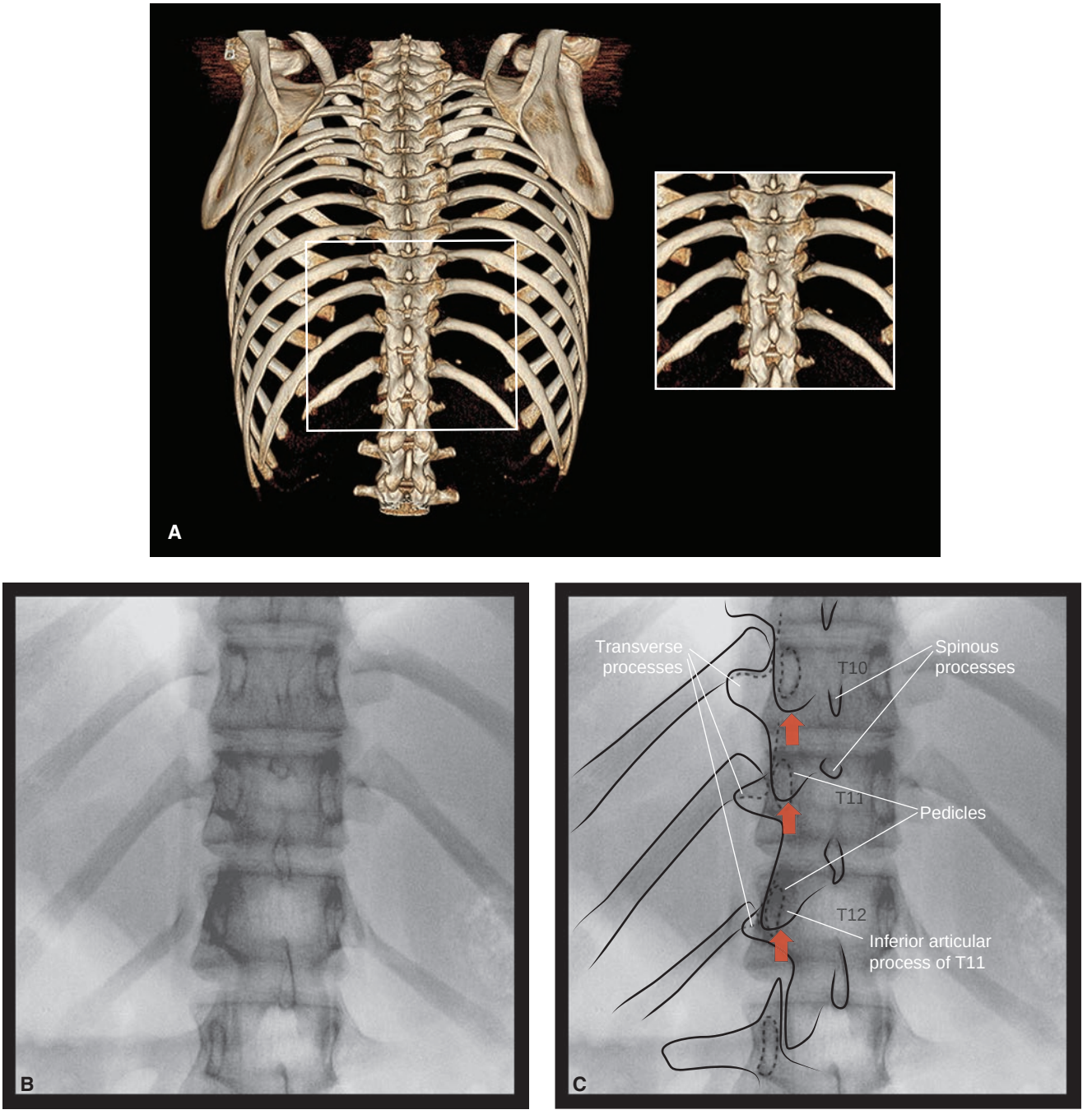


Figure 7-12.

A: Bony anatomy relevant to thoracic intra-articular facet injection. Three-dimensional reconstruction computed tomography of the thoracic spine as viewed from the posterior approach used for thoracic intra-articular facet injection. **Inset** matches the anatomic area in the radiographs shown in **(B)** and **(C)**. **B:** AP radiograph of the thoracic spine. Because of their steep angle, the thoracic facet joints cannot be seen directly but must be inferred from the position of adjacent structures. The superior aspect of each joint (inferior articular process) lies posteriorly (*arrows*), directly over the inferior aspect of the joint (superior articular process). This position can be inferred by following the inferior margin of the lamina from the spinous process laterally. **C:** Labeled image.

(superior aspect of the joint) lies posteriorly, directly over the superior articular process (inferior aspect of the joint). The needle tip is advanced toward the inferior aspect of the joint (Figs. 7-12 and 7-13).

Block Technique

The skin and subcutaneous tissues overlying the facet joint where the block is to be carried out are anesthetized with 1 to 2 mL of 1% lidocaine. The thoracic level is easily identified by counting upward from the T12 level, where the 12th and lowest rib joins the T12 vertebra (see Fig. 7-12). A 22-gauge, 3.5-inch spinal needle is placed through the skin and advanced until it is seated in the tissues in a plane that is coaxial with the axis of the x-ray path. The needle is adjusted to remain coaxial and advanced toward the inferior margin of the joint space (see Fig. 7-12). Because of the joint's steep angle, the needle can be advanced only into the inferior- and posterior-most extent of the joint (see Fig. 7-14). Lateral radiography is difficult to interpret due to the overlying structures of the thorax (Fig. 7-15). The facet joint itself holds only limited volume (typically <1 mL), and placing contrast in the joint limits the ability to place local anesthetic and steroid within the joint. Once the needle position has been confirmed, a solution containing steroid and local anesthetic is placed. A total dose of 80 mg of methylprednisolone acetate or the equivalent should be divided over all the joints to be injected, but more than 40 mg per joint is probably unnecessary. Using concentrated steroid (40 or 80 mg per mL) allows 1:1 mixture with local anesthetic (0.5% bupivacaine) to provide some immediate pain relief.

Lumbar Intra-articular Facet Injection

Positioning

The patient is positioned prone with the head turned to one side. The C-arm is angled obliquely 25 to 35 degrees from the sagittal plane and without caudal angulation (Fig. 7-16). This angle allows direct visualization of the facet joint (Figs. 7-17 to 7-19).

Block Technique

The skin and subcutaneous tissues overlying the facet joint where the block is to be carried out are anesthetized with 1 to 2 mL of 1% lidocaine. The lumbar level is easily identified by counting upward from the sacrum (see Fig. 7-17). A 22-gauge, 3.5-inch spinal needle is placed through the skin and advanced until it is seated in the tissues in a plane that is coaxial with the axis of the x-ray path. The needle is adjusted to remain coaxial and advanced toward the joint space (see Fig. 7-15). The facet joint itself holds only limited volume (typically <1.5 mL), and placing contrast in the

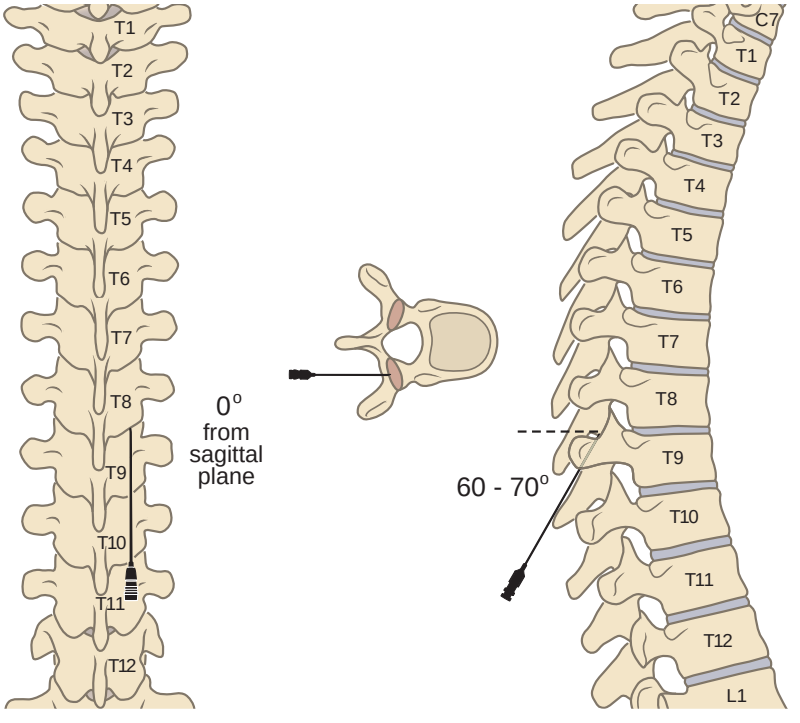


Figure 7-13.
Position and angle of needle entry for intra-articular thoracic facet injection. A 22-gauge spinal needle is advanced in the sagittal plane overlying the facet joint with 60 to 70 degrees of caudad angulation from the axial plane.

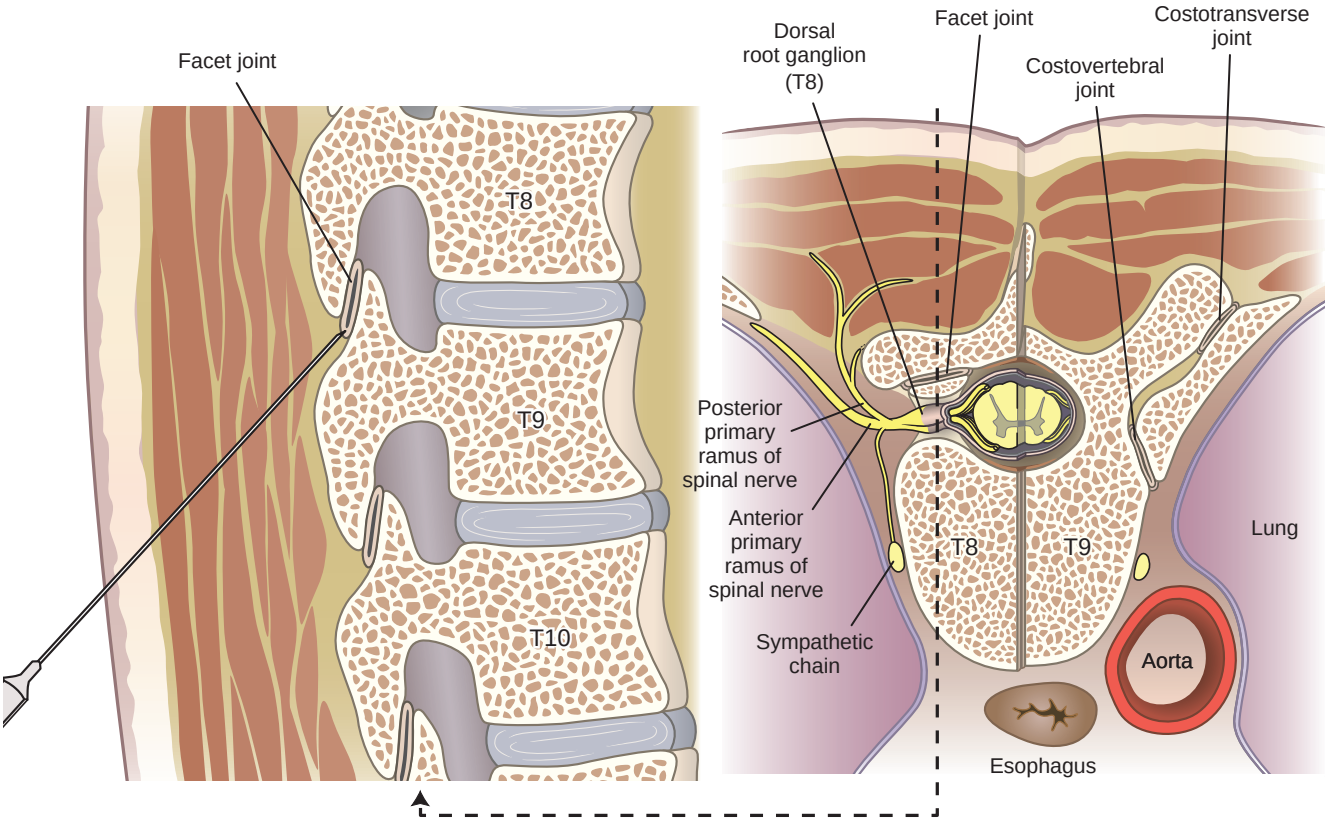


Figure 7-14.
Axial and sagittal diagrams of intra-articular thoracic facet injection. Axial panel (*right*): The needle is advanced in the sagittal plane to enter the posterior and inferior aspect of the facet joint. Sagittal panel (left): Because of the steep angle of the thoracic facet joints, the needle tip will only penetrate the posterior- and inferior-most aspect of the joint.

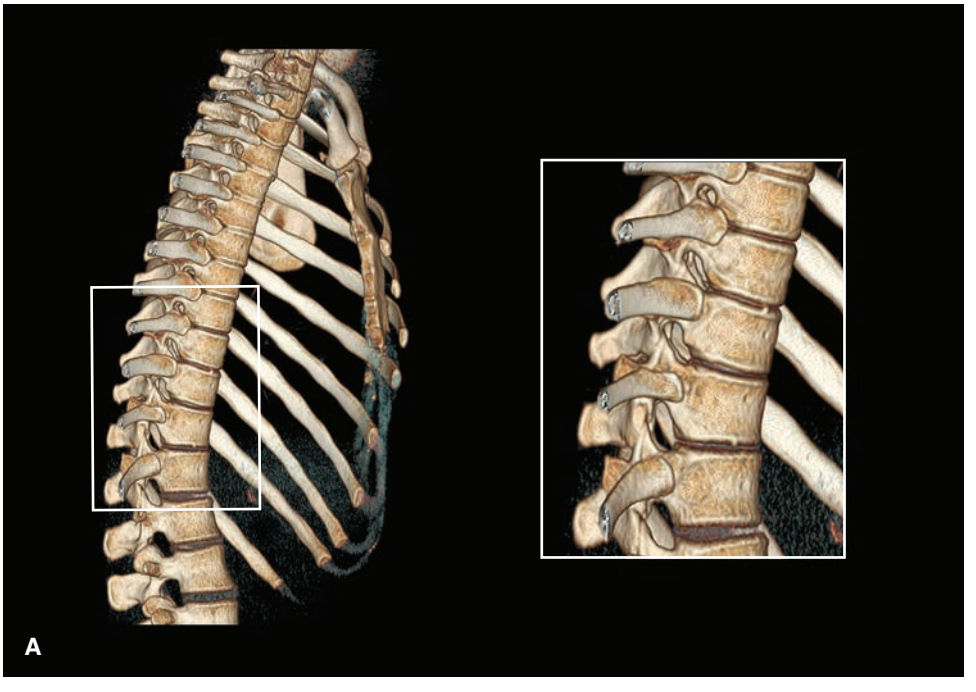


Figure 7-15.
A: Bony anatomy relevant to thoracic intra-articular facet injection. Three-dimensional reconstruction computed tomography of the thoracic spine as viewed in the lateral projection; the bony elements of the right lateral hemithorax have been removed to allow better visualization of the spine. **Inset** matches the anatomic area in the radiographs shown in **(B)** and **(C)**. *(Cont.)*

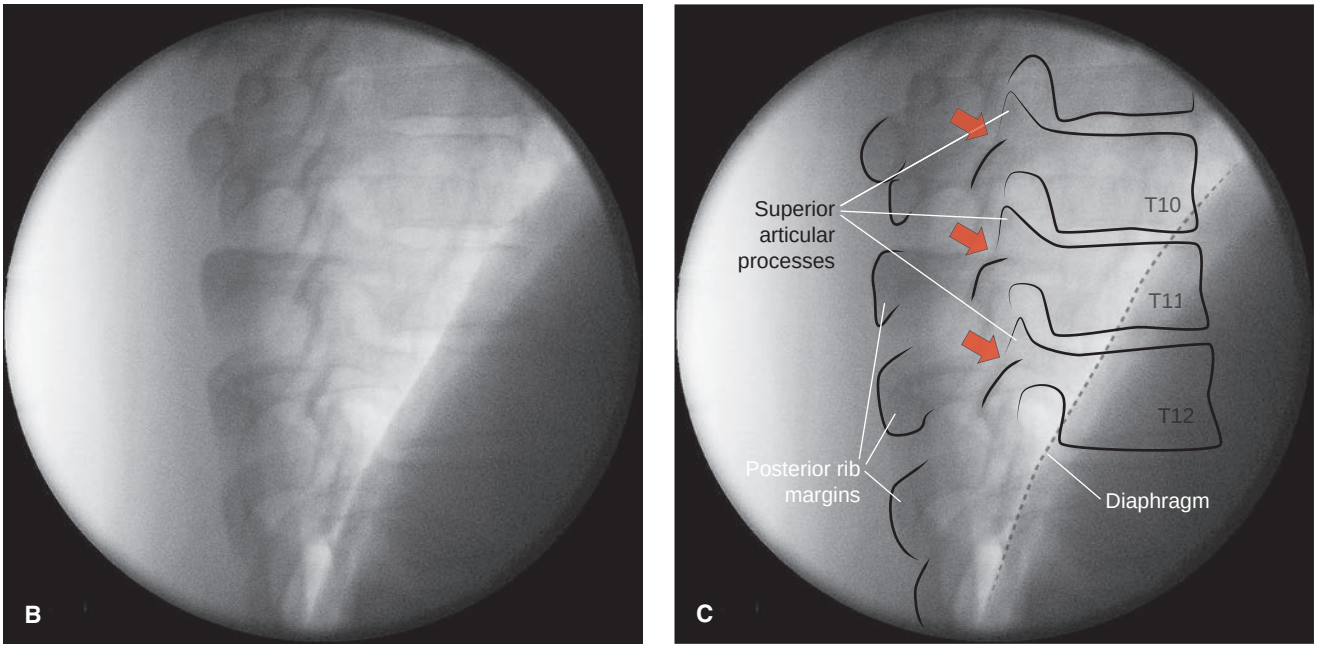


Figure 7-15. ***(Continued)***
B: Lateral radiograph of the thoracic spine. The thoracic superior articular processes can be identified in the lateral radiograph by following the contour of the superior end plate of each vertebra posteriorly toward the intervertebral foramen. The inferior aspect of each joint lies posteriorly (*arrows*), where the transverse process joins the superior articular process. **C:** Labeled image.

joint limits the ability to place local anesthetic and steroid within the joint. Nonetheless, intra-articular injection of contrast is commonly carried out at the lumbar levels. The articular space is z-shaped, with the superior recess extending slightly lateral to the axis of the articular surfaces, and the inferior recess extending slightly medial to the axis of the articular surfaces (we do not routinely inject contrast). Once needle position has been confirmed, a solution containing steroid and local anesthetic is placed. A total dose of 80 mg of methylprednisolone acetate or the equivalent should be divided over all the joints to be injected, but more than 40 mg per joint is probably unnecessary. Using

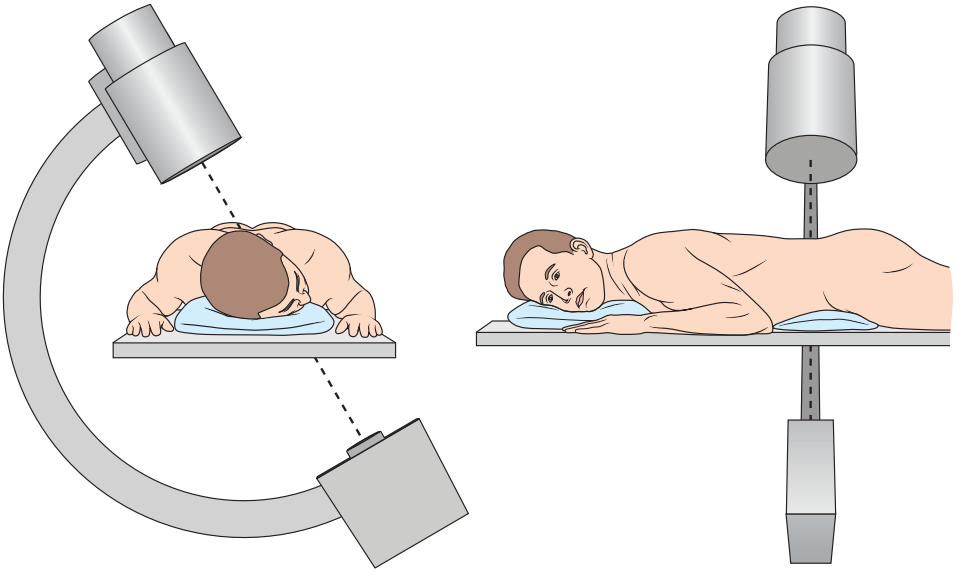


Figure 7-16.
Position for intra-articular lumbar facet joint injection. The patient is placed prone with the head turned to one side. The C-arm is angled 25 to 35 degrees from the sagittal plane parallel to the axial plane.

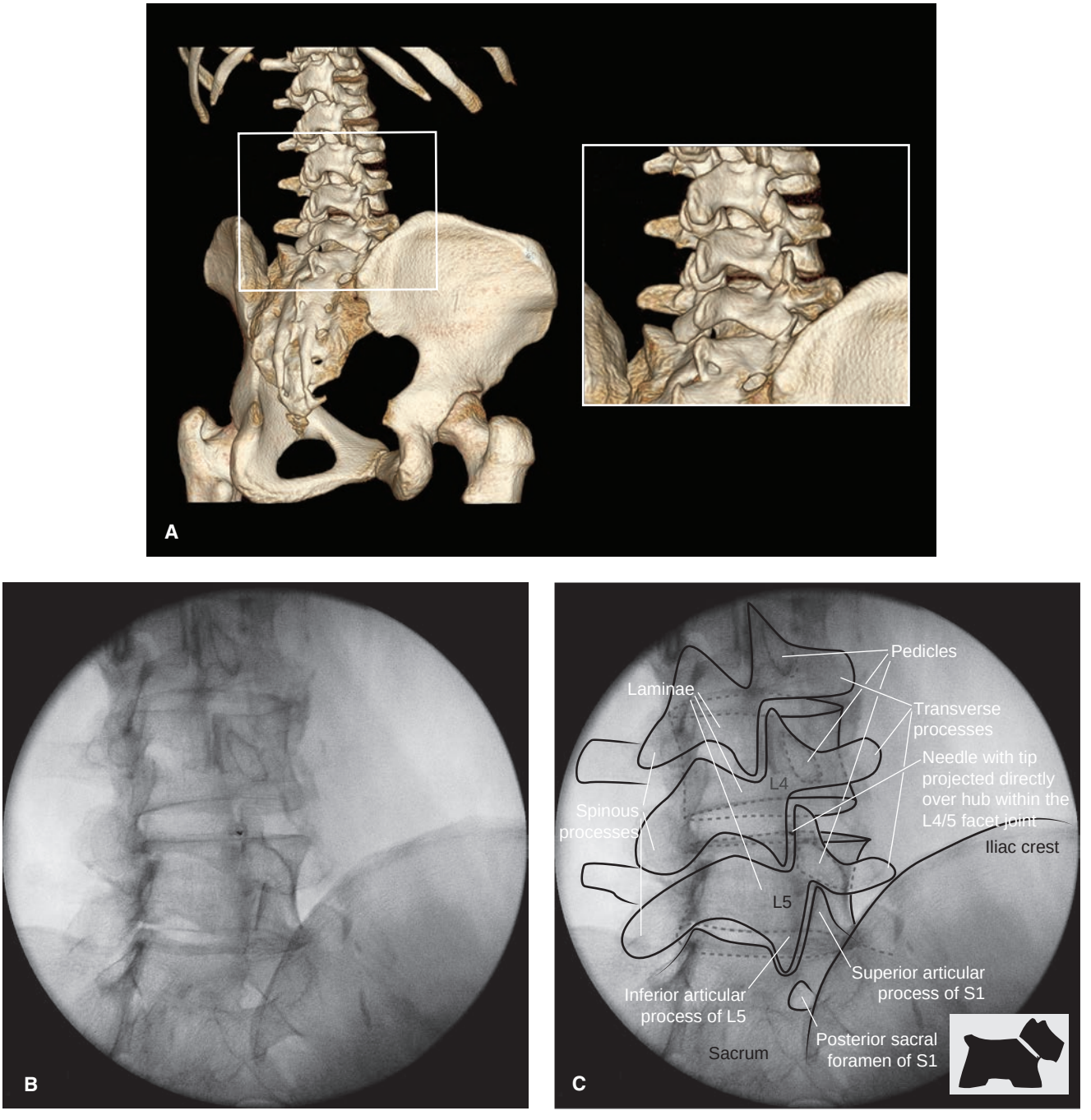


Figure 7-17.

A: Bony anatomy relevant to lumbar intra-articular facet injection. Three-dimensional reconstruction computed tomography of the lumbar spine as viewed in the left oblique projection used for needle insertion. **Inset** matches the anatomic area in the radiographs shown in **(B)** and **(C)**. **B:** Left oblique radiograph with needle in final position for right L4/L5 intra-articular facet injection. The needle's hub is projected directly over the tip (coaxial) and lies directly over the L4/L5 facet joint. **C:** Labeled image. The contours of the posterior bony elements of the spine on the oblique projection take a shape similar to the silhouette of a Scottish terrier or "Scotty dog". Following this contour around its perimeter, the front leg of the dog is the inferior articular process of the vertebra, the snout is the transverse process, the ear is the superior articular process, the back is the superior margin of the lamina, the buttocks and hind leg is the spinous process, and the belly of the dog is the inferior margin of the lamina. Compare the outlined areas of the radiograph with the contour of an actual Scottish terrier shown in the **inset** in the lower right corner of this image.

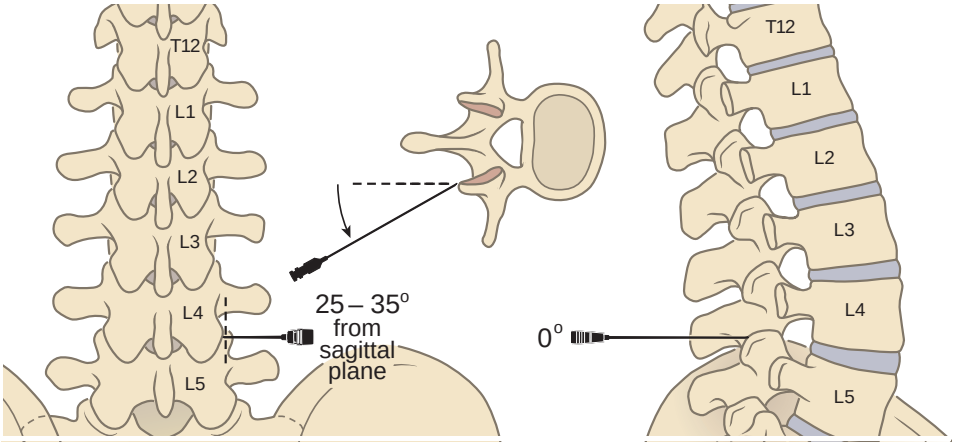


Figure 7-18.
Position and angle of needle entry for intra-articular lumbar facet injection. A 22-gauge spinal needle is advanced in the axial plane overlying the facet joint with 25 to 35 degrees of oblique angulation from the sagittal plane.

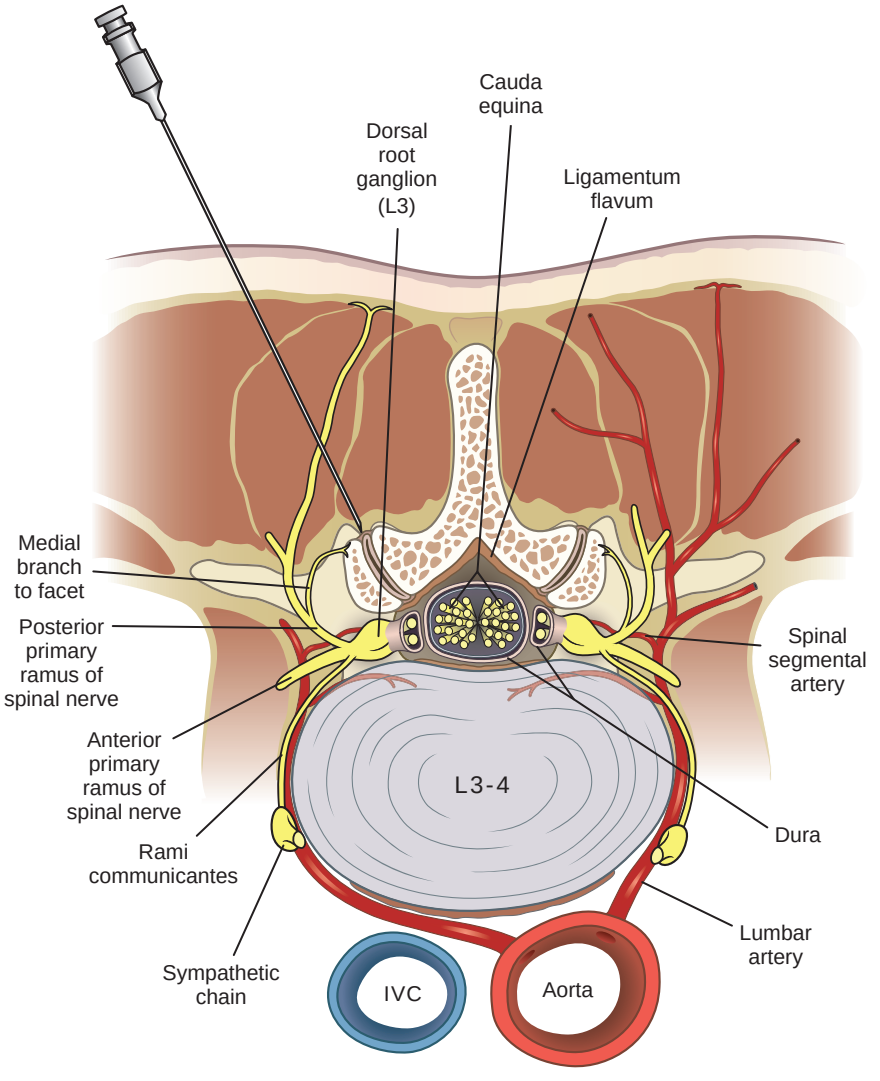


Figure 7-19.
Axial diagram of intra-articular lumbar facet injection. The axis of the facet joint lies 25 to 35 degrees from the sagittal plane. Note the innervation to the facet joint.

concentrated steroid (40 or 80 mg per mL) allows 1:1 mixture with local anesthetic (0.5% bupivacaine) to provide some immediate pain relief.

Complications of Intra-articular Facet Injection

Complications associated with intra-articular facet injection are uncommon. The most likely adverse effect is an exacerbation of pain. This is frequent when intra-articular cervical facet injection is carried out and the needle is advanced within the joint space. The joint space is narrow, and advancing the needle within the joint can abrade the articular surfaces, causing increased pain. This exacerbation is usually self-limited. Infection can also occur, leading to abscess within the paraspinous musculature, but the incidence is exceedingly low. Bleeding complications have not been associated with intra-articular facet injection.

Facet Medial Branch Block and Radiofrequency Treatment

In those patients who receive only temporary relief from therapeutic intra-articular facet injections or who have pain that is more diffuse, requiring treatment at numerous levels, radiofrequency treatment can produce significant, enduring pain relief. Many investigators have pointed to the need for controlled diagnostic injections to determine who will respond to radiofrequency treatment. Despite the value of placebo-controlled injections (i.e., comparative blocks with saline versus local anesthetic on different occasions), this is impractical in most clinical settings. Most practitioners rely on a single set of diagnostic local anesthetic blocks to the medial branch nerves at the levels of suspected pathology to determine who should receive radiofrequency treatment. Those who report significant pain relief, usually defined as 50% or greater pain reduction lasting the average duration of the local anesthetic, go on to radiofrequency treatment. Similarly, transient pain relief with intra-articular injection of local anesthetic can also be used as a reasonable prognostic test before proceeding with radiofrequency treatment.

Conventional radiofrequency treatment produces a small area of tissue coagulation surrounding the active tip of an insulated cannula (Fig. 7-20). When the tip of the radiofrequency cannula is placed in close proximity to a neural structure, the lesion encompasses the nerve causing denervation. The most commonly used cannulae for facet treatment are 22-gauge SMK (Sluijter-Mehta Kanüle) and come in 5-, 10-, and 15-cm lengths with an active tip (noninsulated area where coagulation occurs) of 4, 5, or 10 mm; their placement is similar to placing a Quincke needle. For all but the most obese patients, the 10-cm cannulae with 5-mm active tips are used. In more recent years, pulsed radiofrequency treatment has come into frequent use. Pulsed radiofrequency produces voltage fluctuations at the tip of the cannula that are similar in magnitude to those produced during conventional radiofrequency treatment (40 to 50 V at 300 kHz). By applying the radiofrequency energy in intermittent pulses, the voltage energy can be delivered without heating of the tissue or resultant tissue coagulation. Pulsed radiofrequency has been shown to produce significant changes in gene expression within the dorsal horn of experimental animals, but evidence for the clinical efficacy of this approach is still lacking. The key

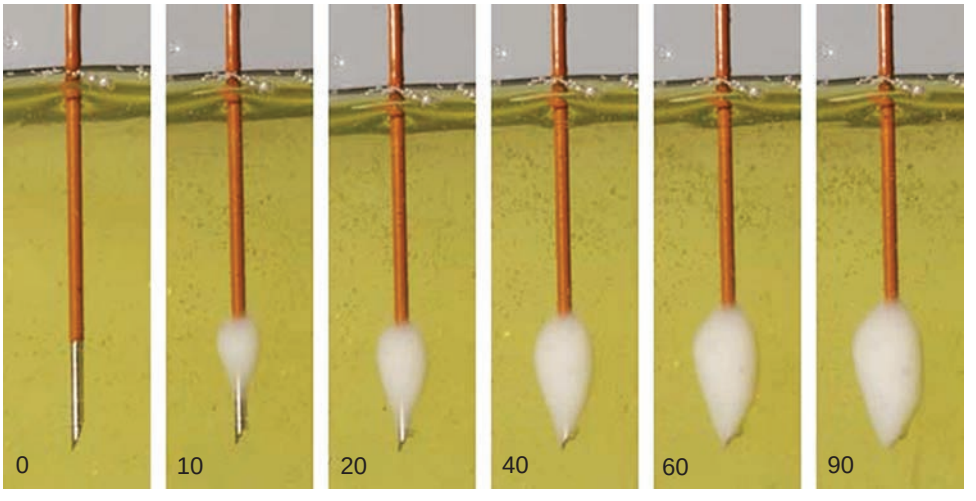


Figure 7-20.
Conventional radiofrequency lesion. A 10-cm SMK radiofrequency cannula with a 5-mm active tip is immersed in egg white and a lesion is carried out at 80°C for 90 seconds. The size of the lesion is maximal near the midportion of the active tip, with little coagulation at the tip of the needle. Thus, for optimal application of conventional radiofrequency treatment, the shaft of the needle's active tip must be placed adjacent to the target. The size of the lesion is near maximal by 60 seconds of treatment, changing little in size thereafter.

concept when using conventional versus pulsed radiofrequency is to understand where the lesion or pulsed radiofrequency energy will occur relative to the active tip. The lesion produced by conventional radiofrequency is along the shaft of the needle surrounding the active tip (see Fig. 7-20). There is scant tissue destruction at the tip of the needle; thus, the shaft of the active tip of the cannula must be placed along the course of the nerve. In contrast, the highest density of voltage change during pulsed radiofrequency emanates directly from the tip of the radiofrequency cannula; thus, the tip of the needle should be directed along the course of the nerve to be treated. Techniques for both conventional and pulsed radiofrequency treatment will be discussed.

Cervical Medial Branch Block and Radiofrequency Treatment

Positioning

The medial branch nerves to the facets course across the articular pillar, midway between the superior and inferior articular processes (Fig. 7-21). The nerves can be anesthetized by placing a needle from a posterior approach (see Fig. 7-21) or a lateral approach (Figs. 7-22 and 7-23). For patients, the lateral approach is more comfortable because they can lie on one side rather than face down, and the needle must traverse less tissue en route to the target. However, when the needles are inserted from a lateral approach, they are directed toward the spinal cord. Even

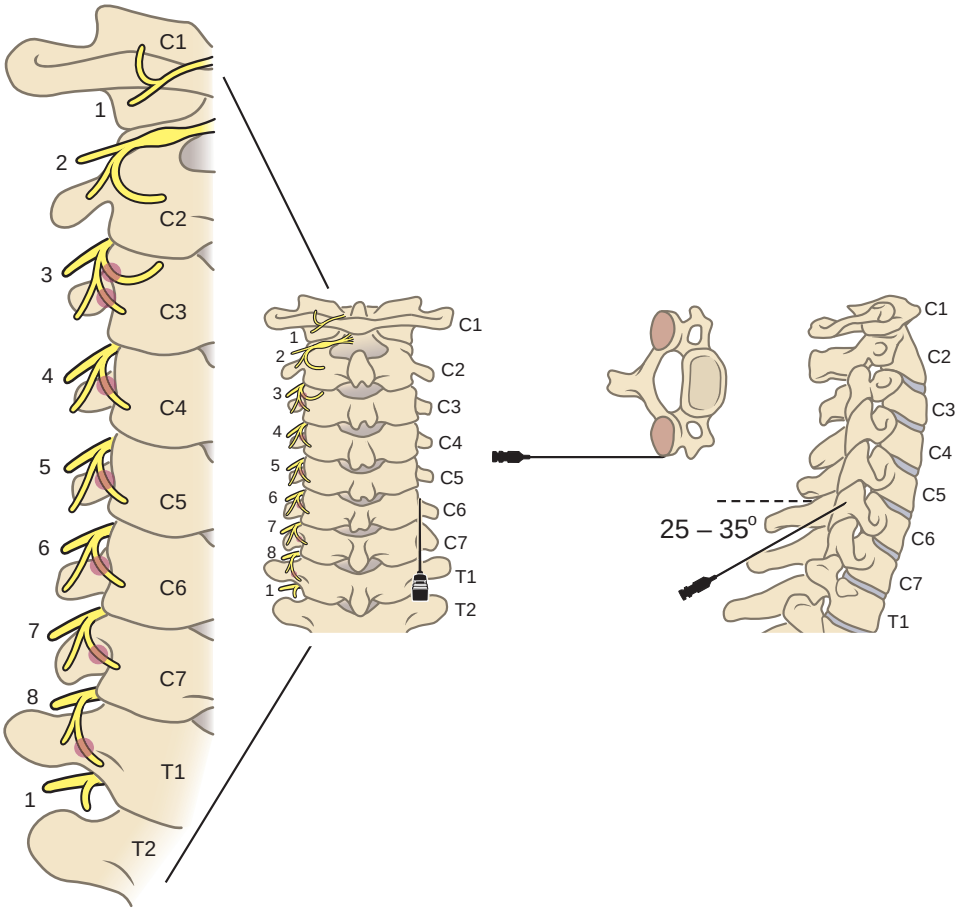


Figure 7-21.
Position and angle of needle entry for cervical medial branch blocks and radiofrequency treatment (posterior approach). A 22- or 25-gauge, 3.5-inch spinal needle (or 22-gauge, 10-cm SMK radiofrequency cannula with a 5-mm active tip) is advanced in a plane 25 to 35 degrees caudal to the axial plane toward the midpoint between superior and inferior articular processes of the facet to be treated. This point appears as an invagination or "waist," where the lateral margin of the facet column dips medially between articular surfaces. The target points for radiofrequency treatment are illustrated to the left. Note that treatment of the third occipital nerve requires that an additional cannula is placed toward the superior aspect of the C3 articular pillar overlying the C2/C3 facet joint.

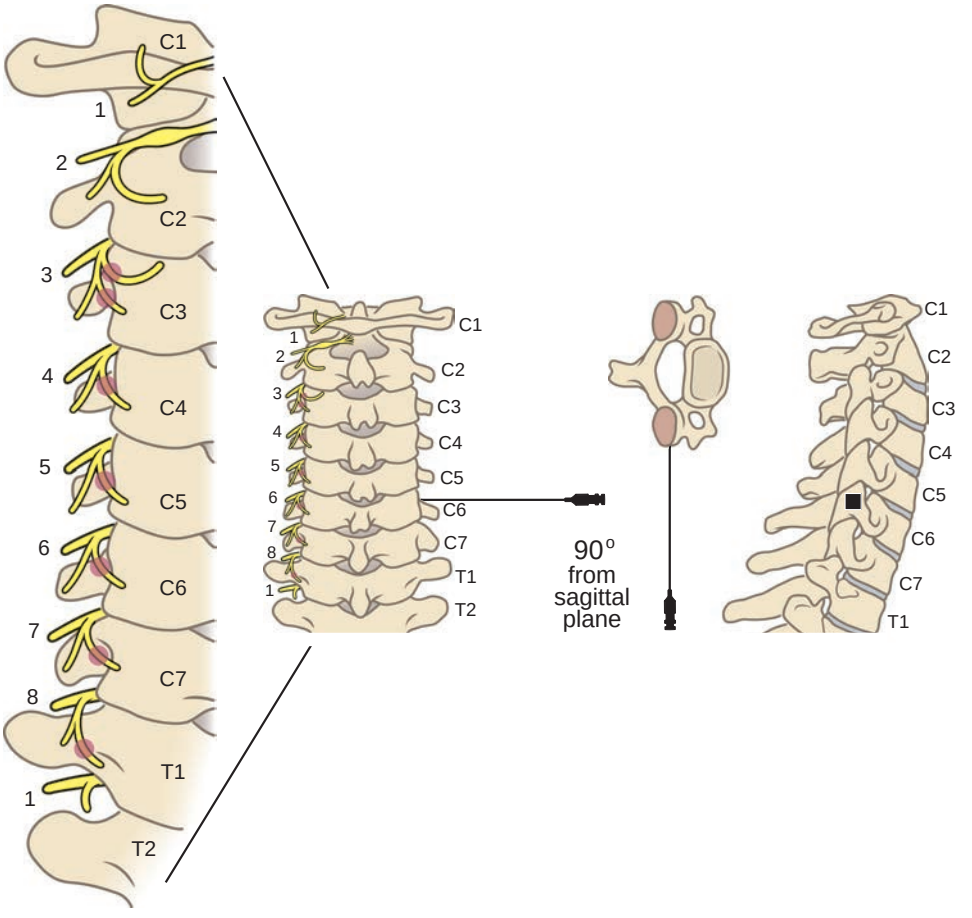


Figure 7-22.
Position and angle of needle entry for cervical medial branch blocks and radiofrequency treatment (lateral approach). A 22- or 25-gauge, 2- to 2.5-inch spinal needle (or 22-gauge, 5-cm SMK radiofrequency cannula with a 5-mm active tip) is advanced in the axial plane toward the midpoint between superior and inferior articular processes, and midway between the anterior and posterior borders of the facet column of the level to be treated. This point is in the center of the trapezoid that corresponds to the articular pillar of each vertebra when viewed from the side. The target points for radiofrequency treatment are illustrated to the left. Note that treatment of the third occipital nerve requires that an additional cannula is placed toward the superior aspect of the C3 articular pillar overlying the C2/C3 facet joint.

slight rotation of the neck can cause confusion among the left and right articular pillars and lead to needle entry into the spinal canal. For performing diagnostic medial branch blocks, either approach is adequate because the local anesthetic will be deposited in the same location with both approaches. For conventional radiofrequency treatment, the cannulae should be placed using a posterior approach because this will allow the entire length of the 5-mm active tip to align with the nerve along the lateral surface of the articular pillar. For pulsed radiofrequency treatment, the cannulae can be placed from a lateral approach because the voltage fluctuations are maximal at the tip of the cannula.

Positioning for the Posterior Approach

The patient lies prone, facing the table with a small headrest under the forehead to allow for air flow between the table and the patient's nose and mouth (Fig. 7-24). The C-arm is rotated 25 to 35 degrees caudally from the axial plane without any oblique angulation. This brings the axis of the x-rays in line with the axis of the facet joints and allows for good visualization of the articular pillars (Fig. 7-25).

Positioning for the Lateral Approach

The patient lies in the lateral decubitus position with a pillow under the neck that minimizes lateral flexion of the

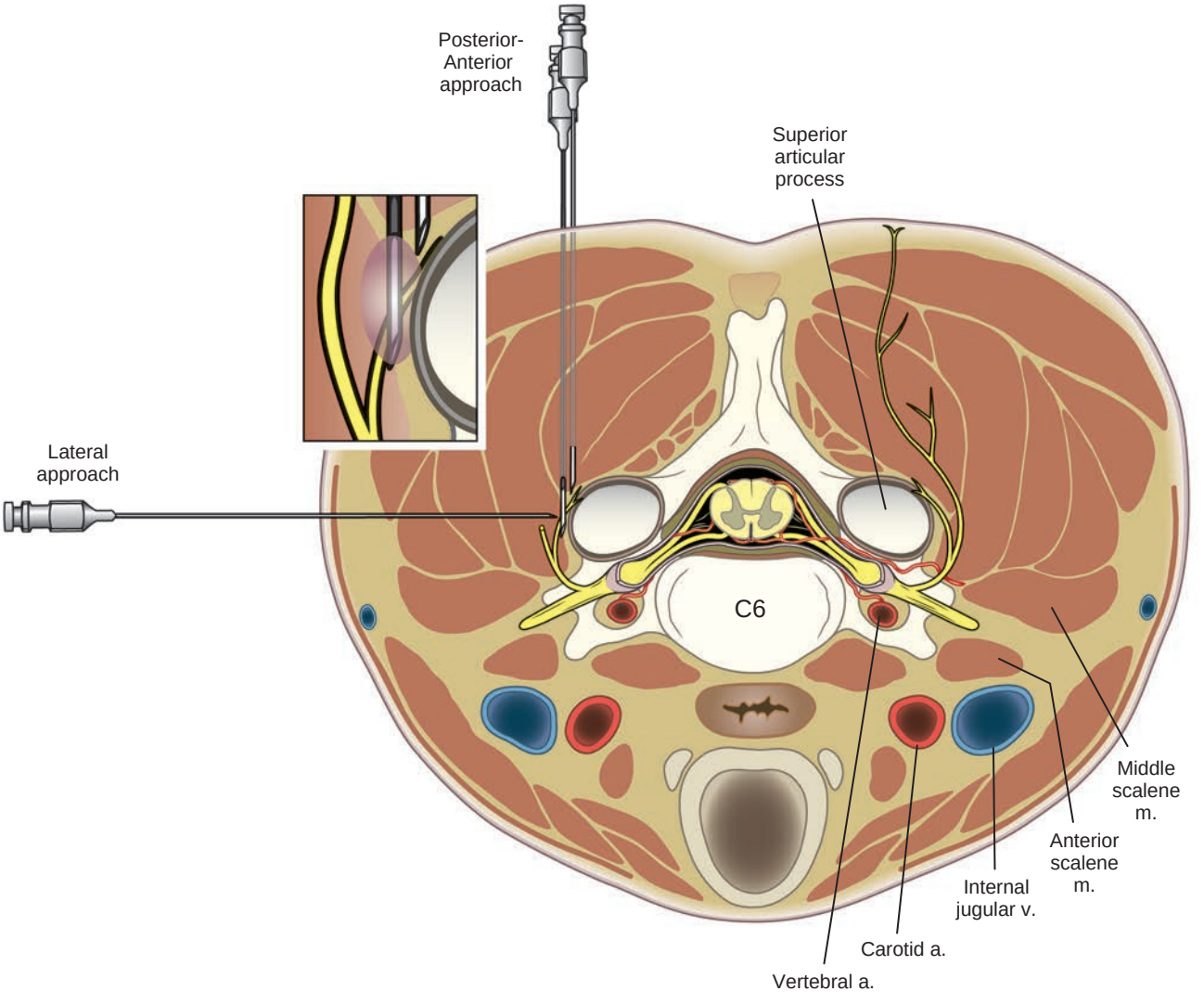


Figure 7-23.
Axial diagram of cervical medial branch nerve blocks and radiofrequency treatment. When needles are placed from a lateral approach, they are directed toward the spinal canal, and care must be taken to keep the needle tip over the bony facet target at all times as the needle is advanced. When a posterior approach is used, the needle is first seated on the lateral margin of the facet column. Local anesthetic can be placed without advancing the needle any further for diagnostic medial branch blocks. For conventional radiofrequency treatment, the cannulae must be walked off the lateral margin of the facet column and advanced 2 to 3 mm to place the active tip along the course of the medial branch nerve (**inset**).

neck to either side (Fig. 7-26). The C-arm is placed directly over the patient's neck without rotation or angulation. Care must be taken to ensure the left and right articular pillars are aligned directly over one another (Fig. 7-27). This is a point of great confusion among practitioners who are inexperienced with radiographic anatomy of the cervical spine. Even a small degree of rotation can place the left and right facet joints in significantly different locations on lateral radiographs. It is difficult to discern the left side from the right, and if a needle is advanced toward the contralateral facet target in error, the needle can easily pass into the spinal canal.

Block Technique: Diagnostic Medial Branch Blocks

The skin and subcutaneous tissues overlying the facet target where the block is to be carried out are anesthetized with 1 mL of 1% lidocaine. The cervical level can be identified by counting upward from T1 (T1 is identified in the AP view by its large transverse process that articulates with the head of the first rib) or downward from C2 (C2 can be identified by its odontoid process in the AP view and its large spinous process in the lateral view). A 22- or 25-gauge, 3.5-inch spinal needle is placed through the skin and advanced until it is seated in

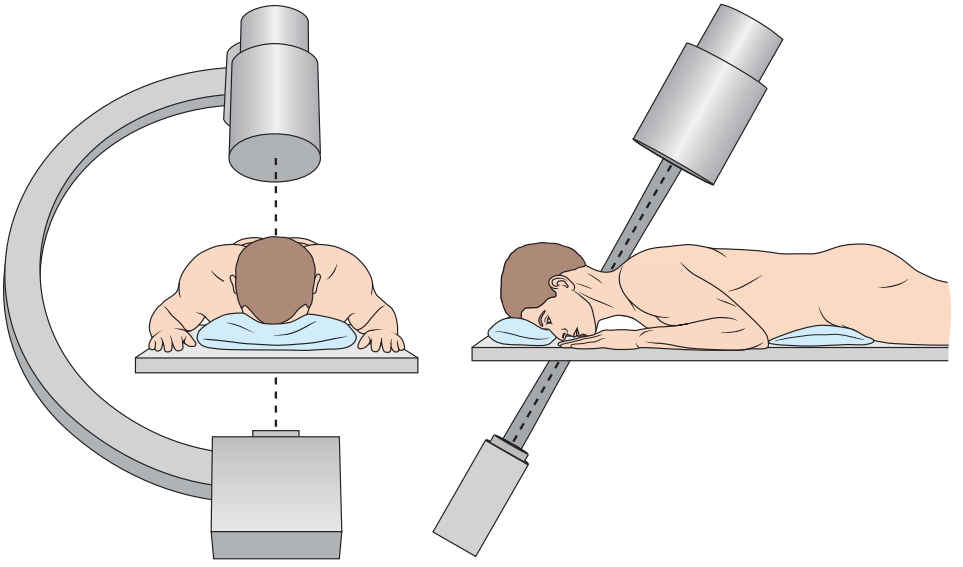


Figure 7-24.
Position for cervical medial branch blocks and radiofrequency treatment (posterior approach). The patient is placed prone with a small headrest under the forehead to allow for air flow between the table and the patient's nose and mouth. The C-arm is angled 25 to 35 degrees caudally from the axial plane.

the tissues in a plane that is coaxial with the axis of the x-ray path. The needle is adjusted to remain coaxial and advanced toward the facet target in the middle of the articular pillar, midway between superior and inferior articular surfaces of the vertebra. This appears as an invagination or "waist" on AP radiographs (see Fig. 7-25) and as a trapezoid on lateral radiographs (Fig. 7-27). From the posterior approach, the needle is gently seated on the lateral margin of the facet column in the middle of the "waist"; from a lateral approach, the needle tip is seated in the middle of the trapezoid

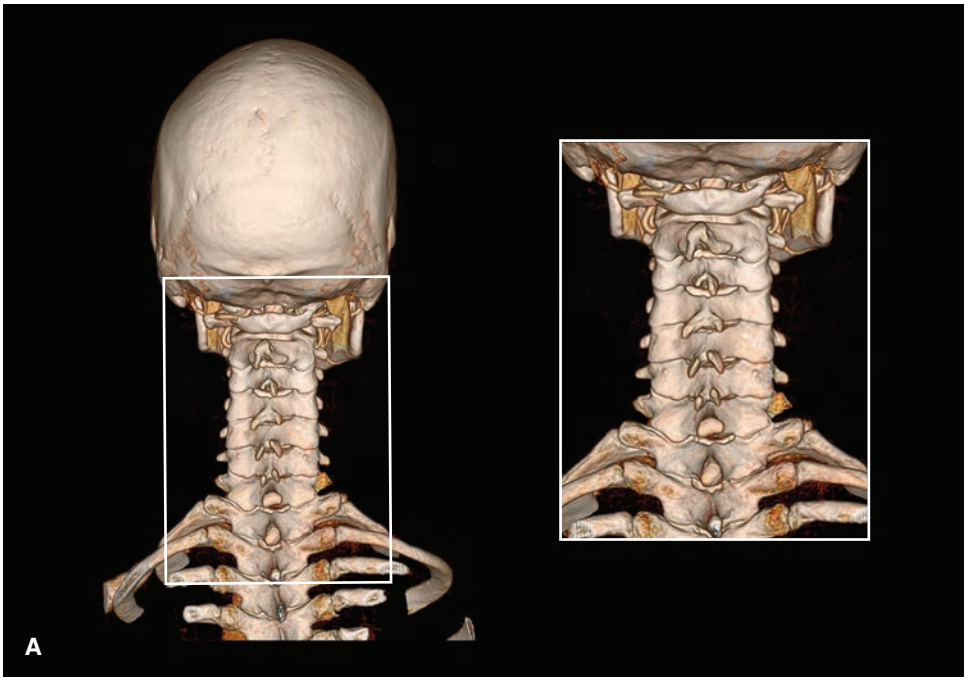


Figure 7-25.
A: Bony anatomy relevant to cervical facet medial branch block or radiofrequency treatment. Three-dimensional reconstruction computed tomography of the cervical spine as viewed in the AP projection used for needle insertion (posterior approach). **Inset** matches the anatomic area in the radiographs shown in **(B)** and **(C)**. *(Cont.)*

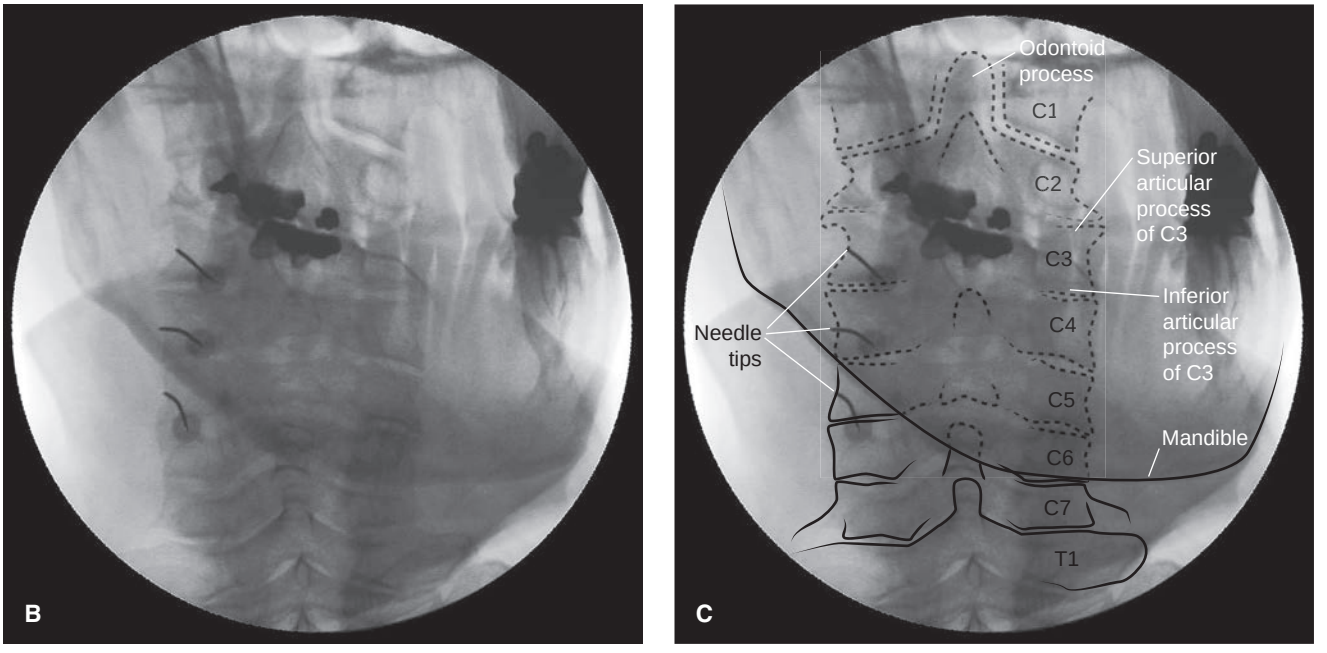


Figure 7-25. *(Continued)*

B: AP radiograph of the cervical spine during cervical medial branch block or radiofrequency treatment (posterior approach). Three radiofrequency cannulae are in place in the middle of the facet pillar at C3, C4, and C5 on the left, midway between superior and inferior articular processes at each level. The caudad angulation of 25 to 35 degrees brings the facet joints into clear view and allows placement of the cannulae along the course of the medial branch nerves. **C:** Labeled image.

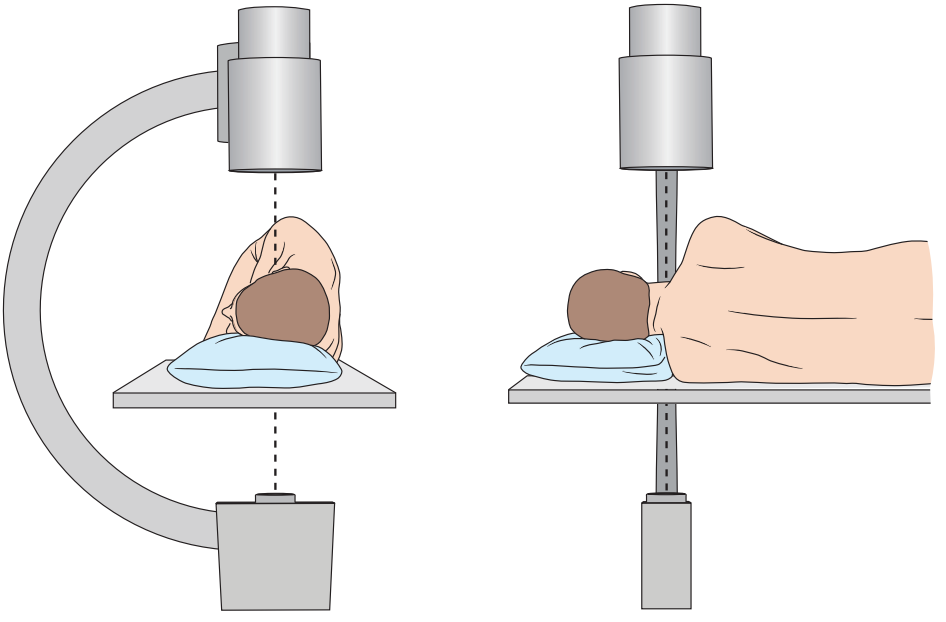


Figure 7-26.

Position for cervical medial branch blocks and radiofrequency treatment (lateral approach). The patient is placed on his or her side with a pillow under the head. The pillow should keep the cervical spine in alignment without lateral flexion to either side. The C-arm is placed directly over the patient's neck in the axial plane without angulation. Note how the dependent shoulder extends cephalad and is often projected in the image overlying the cervical spine.

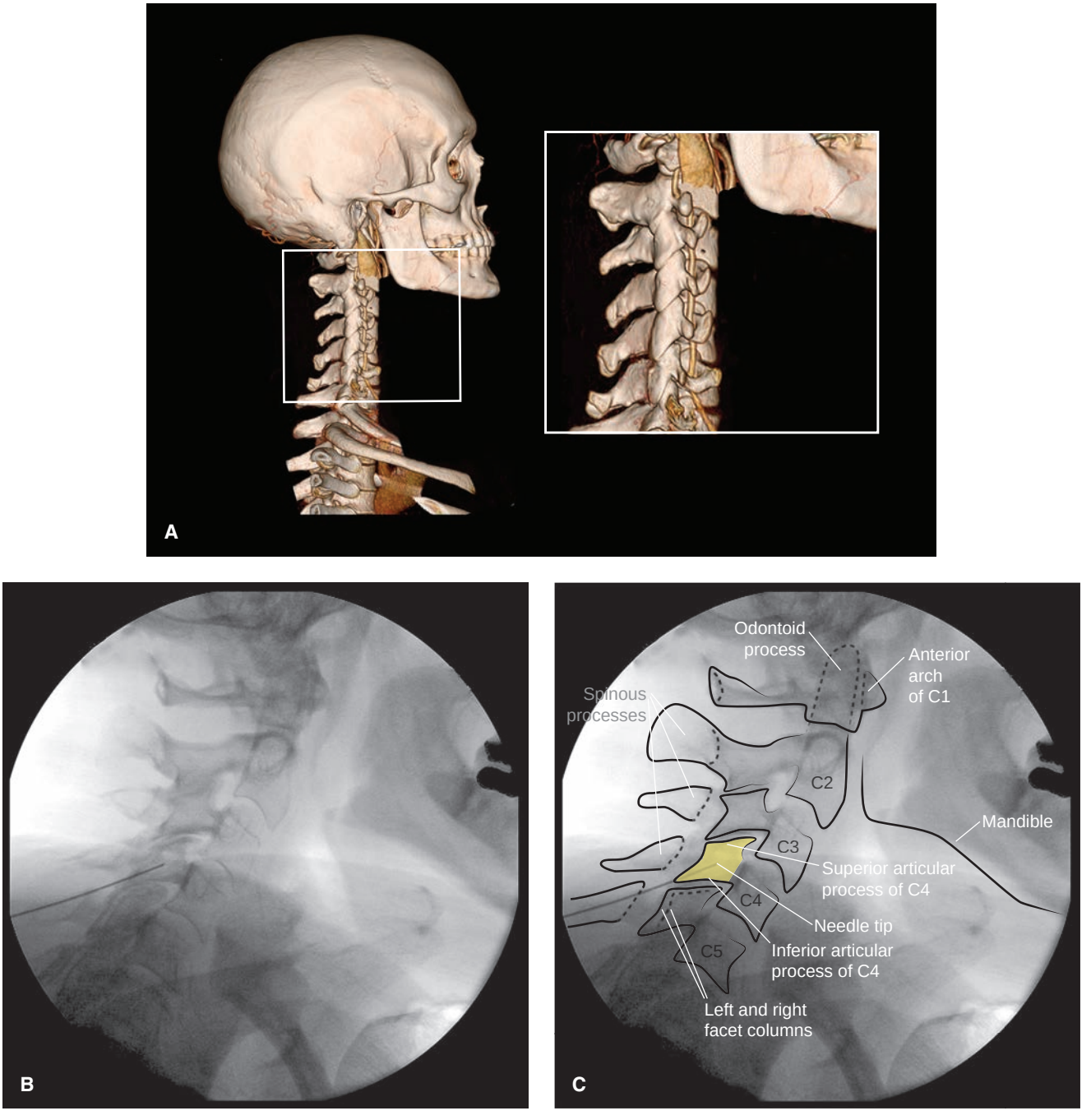


Figure 7-27.

A: Bony anatomy relevant to cervical facet medial branch block or radiofrequency treatment. Three-dimensional reconstruction computed tomography of the cervical spine as viewed in the lateral projection used for needle insertion (lateral approach) or final positioning of the needles using the posterior approach. **Inset** matches the anatomic area in the radiographs shown in **(B–E)**. **B:** Lateral radiograph of the cervical spine during cervical medial branch block (posterior approach). There is poor alignment of the left and right facet columns toward the inferior extent of the image. A single needle is seated in the middle of the articular pillar of C4, midway between superior and inferior articular processes and midway between the anterior and the posterior borders of the facet column. The margins of the lateral elements of each vertebra form a trapezoid in the lateral radiographic projection (yellow shading). The approximate location of the medial branch nerve is in the middle of this trapezoid. When needles are placed from a lateral approach, great care must be taken to align the left and right facet columns so that they are superimposed. Even small degrees of rotation place the left and right facets in different locations, as seen in the inferior part of the image, where the left and right C6 facet pillars are not aligned. It is difficult to distinguish the left from the right facet on a lateral radiograph, and if they are not superimposed, there is danger that a needle advanced from a lateral approach could be directed in error toward the contralateral facet and enter the spinal canal. **C:** Labeled image. ***(Cont.)***

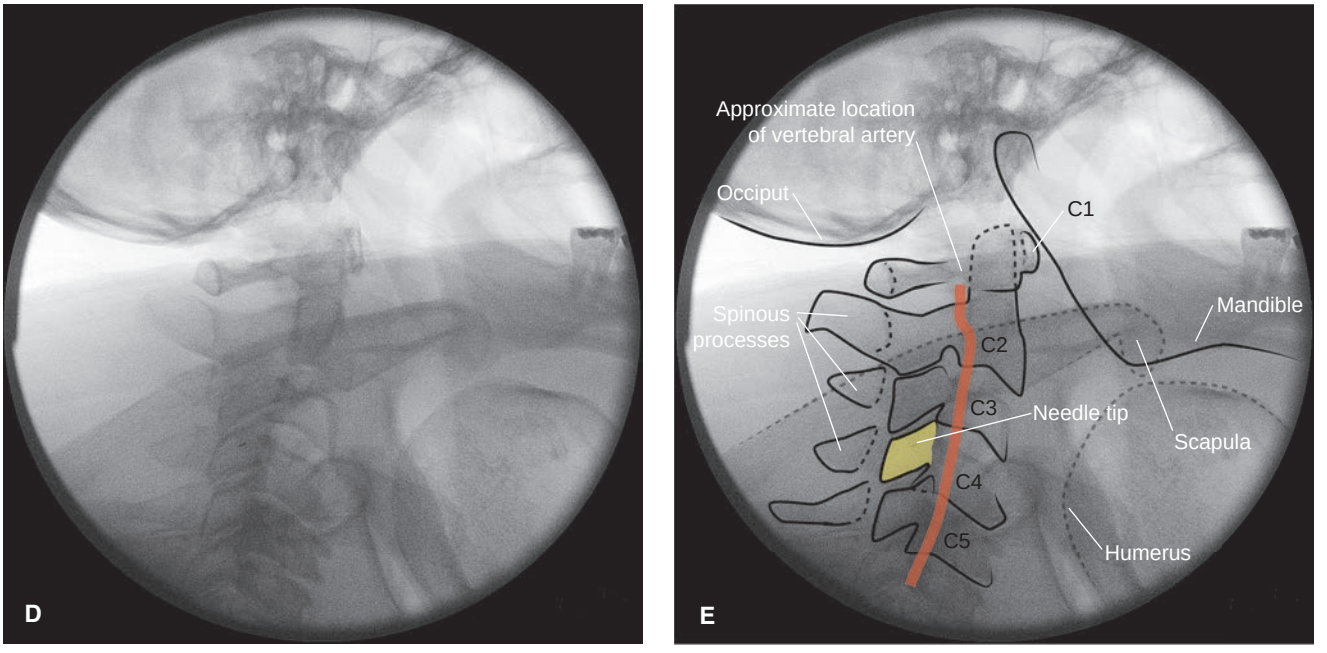


Figure 7-27. *(Continued)*
D: Lateral radiograph of the cervical spine during cervical medial branch block (lateral approach). A single needle is seated in the middle of the articular pillar of C4, midway between superior and inferior articular processes and midway between the anterior and the posterior borders of the facet column. The margins of the lateral elements of each vertebra form a trapezoid in the lateral radiographic projection (yellow shading). The approximate location of the medial branch nerve is in the middle of this trapezoid. The approximate location of the vertebral artery, just anterior to the intervertebral foramina and overlying the posterior aspect of the vertebral bodies, is shown. When medial branch blocks are performed using a lateral approach, care must be taken to avoid needle deviation too anteriorly, where the needle can pass through the intervertebral foramen and into the spinal canal or penetrate the vertebral artery. **E:** Labeled image.

(see Figs. 7-21 to 7-23). Needle position is confirmed with AP and lateral radiographs (see Figs. 7-25 and 7-28). Once needle position has been confirmed, a small volume of local anesthetic is placed at each level and the needles are removed (0.5 mL of 2% lidocaine or 0.5% bupivacaine). The patient is instructed to assess his or her degree of pain relief in the hours immediately following the diagnostic blocks.

Block Technique: Radiofrequency Treatment

Radiofrequency cannulae are placed using a technique identical to that described for medial branch blocks. For conventional radiofrequency treatment, 10-cm SMK cannulae with 5-mm active tips are used and placed from a posterior approach. Once the lateral margin of the facet column is contacted, the needle is walked laterally off the facet and advanced 2 to 3 mm to position the active tip along the course of the medial branch nerve (see Figs. 7-21 and 7-23). Proper testing for sensory-motor dissociation is conducted (the patient should report pain or tingling during stimulation at 50 Hz at <0.5 V and have no motor stimulation to the affected myotome at 2 Hz at no less than three times the sensory threshold or 3 V). Thereafter, great care must be taken to prevent any movement of the cannulae. Each level is anesthetized with 0.5 mL of 2% lidocaine, and lesions are created at 80°C for 60 to 90 seconds.

For pulsed radiofrequency treatment, 5-cm cannulae with 5-mm active tips are inserted from a lateral approach. The tip is placed in the center of the trapezoid of the target facet, midway between articular surfaces, and midway between the anterior and the posterior extent of the facet column (see Figs. 7-22 , 7-23, and 7-27 D and E). Proper testing for sensory thresholds is conducted (the patient should report pain or tingling during stimulation at 50 Hz at <0.5 V). Each level is then treated with pulsed radiofrequency adequate to maintain voltage fluctuations of 40 to 45 V for 120 seconds, without exceeding a tip temperature of 42°C. Local anesthesia is not needed for pulsed radiofrequency treatment, but it may be placed before the cannulae are removed.

Thoracic Medial Branch Block and Radiofrequency Treatment

Positioning

The medial branch nerves typically cross the superolateral corners of the transverse processes and then pass medially and inferiorly across the posterior surfaces of the transverse processes (Figs. 7-29 and 7-30). At midthoracic

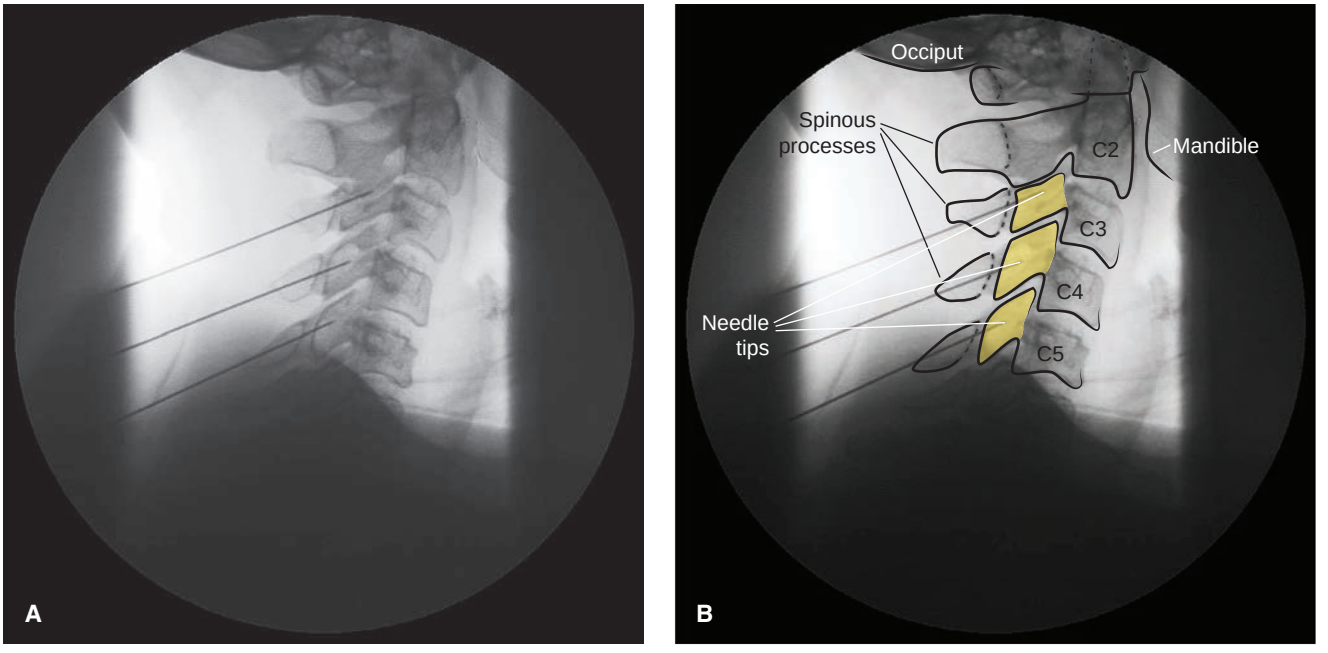


Figure 7-28.
Lateral radiograph of the cervical spine during cervical medial branch block or radiofrequency treatment (posterior approach). **A:** Three radiofrequency cannulae are in place in the middle of the facet pillar at C3, C4, and C5 on the left, midway between superior and inferior articular processes, and midway between the anterior and the posterior borders of the facet column. The margins of the lateral elements of each vertebra form a trapezoid in the lateral radiographic projection (yellow shading). The approximate location of the medial branch nerve is in the middle of this trapezoid. The caudad angulation of 25 to 35 degrees allows placement of the cannulae along the course of the medial branch nerves, parallel to the articular surfaces. **B:** Labeled image.

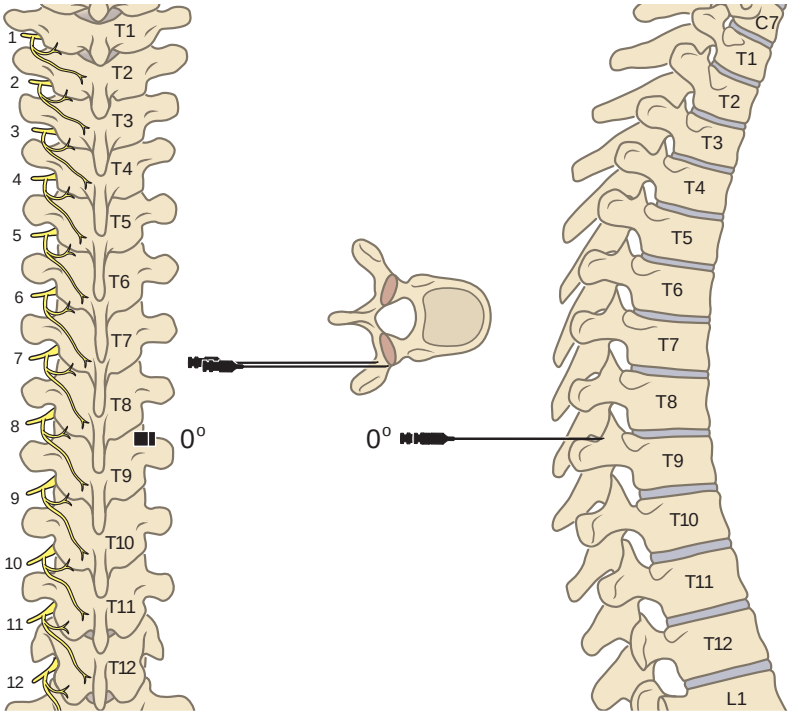


Figure 7-29.
Position and angle of needle entry thoracic medial branch blocks and radiofrequency treatment. A 22-gauge, 3.5-inch spinal needle (or 22-gauge, 5-cm SMK radiofrequency cannula with a 5-mm active tip) is advanced in the axial plane toward the superolateral margin of the transverse process. The target points for radiofrequency treatment are illustrated to the left.

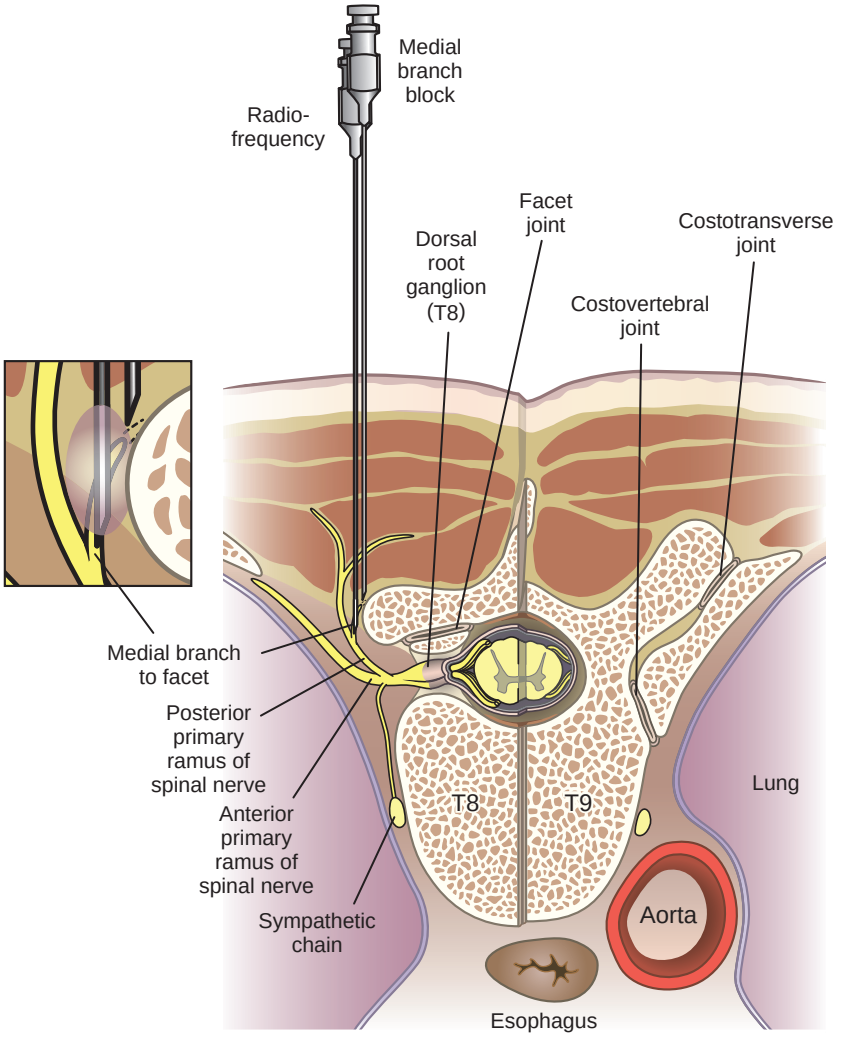


Figure 7-30.
Axial diagram of thoracic medial branch nerve blocks and radiofrequency treatment. A 22-gauge, 3.5-inch spinal needle (or 22-gauge, 5-cm SMK radiofrequency cannula with a 5-mm active tip) is advanced in the axial plane toward the superolateral margin of the transverse process. For conventional radiofrequency treatment, the cannulae must be walked off the superior margin of the transverse process and advanced 2 to 3 mm to place the active tip along the course of the medial branch nerve (**inset**).

levels (T5–T8), the curved course remains the same, but the inflection occurs at a point superior to the superolateral corner of the transverse process. The patient lies prone, with the head turned to one side (Fig. 7-31). The C-arm is positioned over the thoracic spine without angulation. The transverse processes of the thoracic vertebrae are best seen from this angle at both high (Fig. 7-32) and low (Fig. 7-33) thoracic levels.

Block Technique: Diagnostic Medial Branch Blocks

The skin and subcutaneous tissues overlying the facet target where the block is to be carried out are anesthetized with 1 mL of 1% lidocaine. The thoracic level can be identified by counting downward from T1 (T1 is identified in the AP view by its large transverse process that articulates with the head of the first rib) or upward from T12 (T12 articulates with the most inferior rib). A 22-gauge, 3.5-inch spinal needle is placed through the skin and advanced until it is seated in the tissues in a plane that is coaxial with the axis of the x-ray path. The needle is adjusted to remain coaxial and advanced toward the superolateral margin of the transverse process (see Figs. 7-32 and 7-33) and is seated on the bony margin. Once the needle is in position, a small volume of local anesthetic is placed at each level, and the needles are removed (0.5 mL of 2% lidocaine

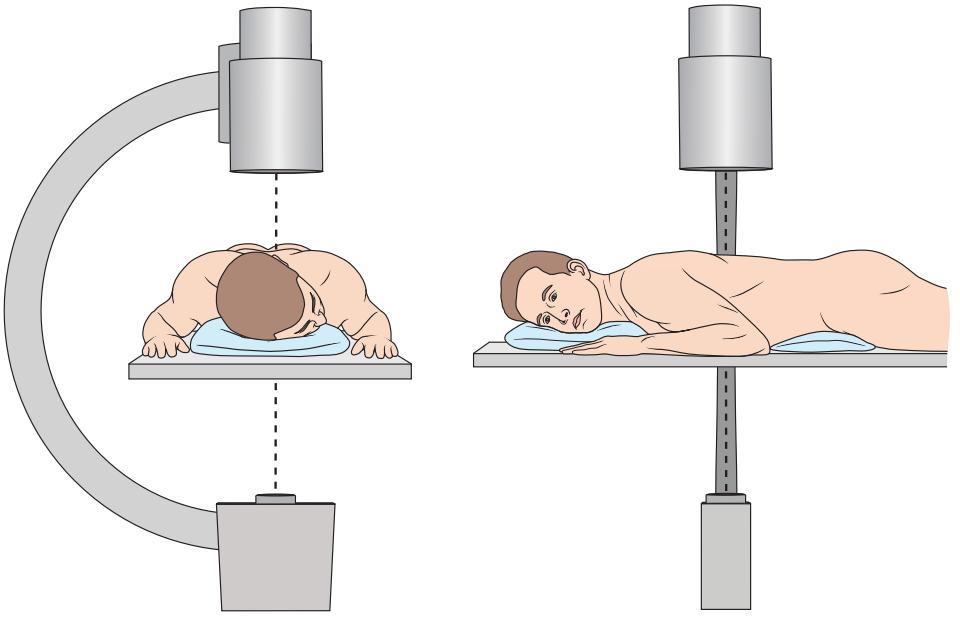


Figure 7-31.
Position for thoracic medial branch blocks and radiofrequency treatment. The patient is placed prone with the head turned to one side. The C-arm is positioned over the thoracic spine in a direct AP plane without angulation.

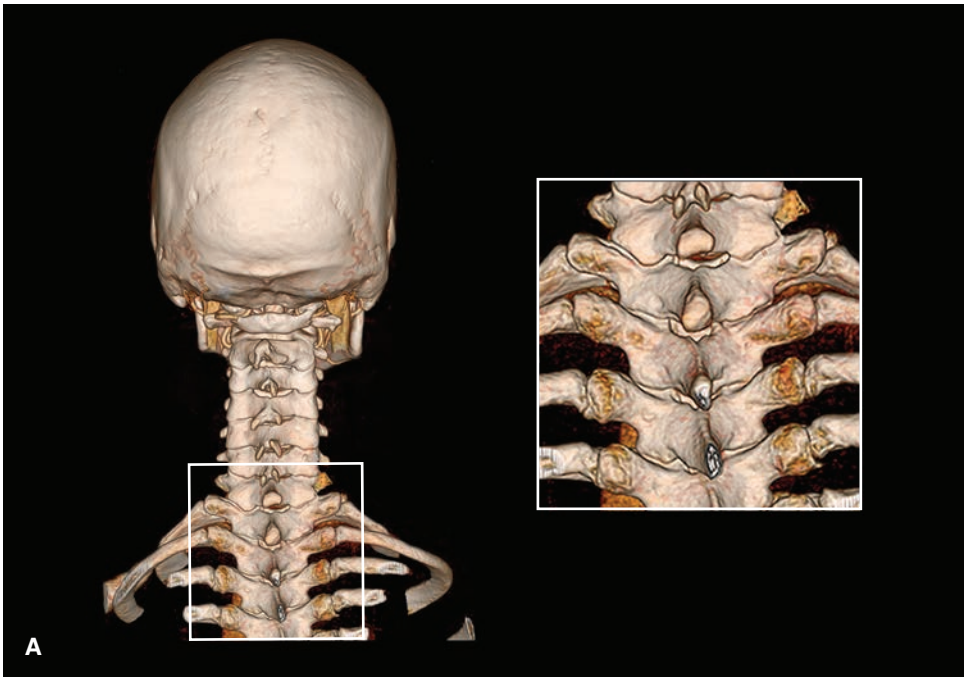


Figure 7-32.
A: Bony anatomy relevant to thoracic facet medial branch block or radiofrequency treatment. Three-dimensional reconstruction computed tomography of the high thoracic spine as viewed in the posterior approach used for needle insertion. **Inset** matches the anatomic area in the radiographs shown in **(B)** and **(C)**. *(Cont.)*

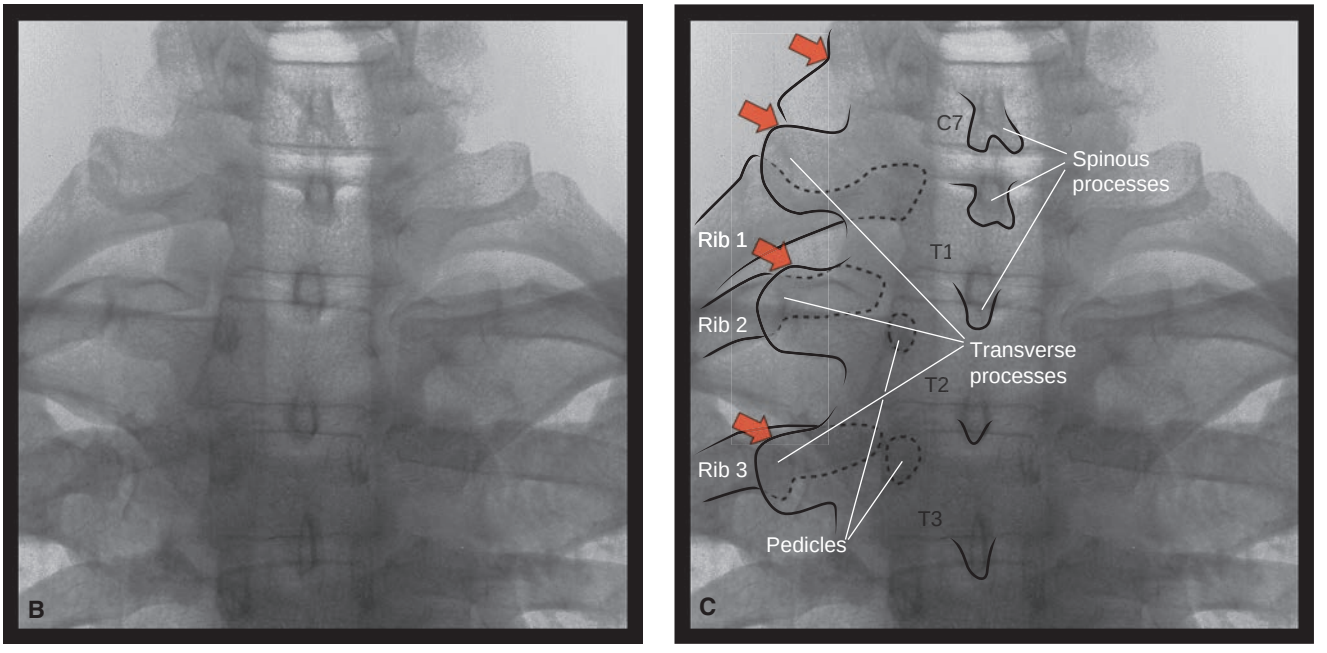


Figure 7-32. *(Continued)*

B: AP radiograph of the high thoracic spine. The transverse processes are prominent at high thoracic levels. The base of the transverse process joins the superior articular process just superolateral to the pedicle. **C:** Labeled image. The *arrows* indicate the targets for medial branch nerve blocks or radiofrequency treatment at the C7 to T3 levels on the left.

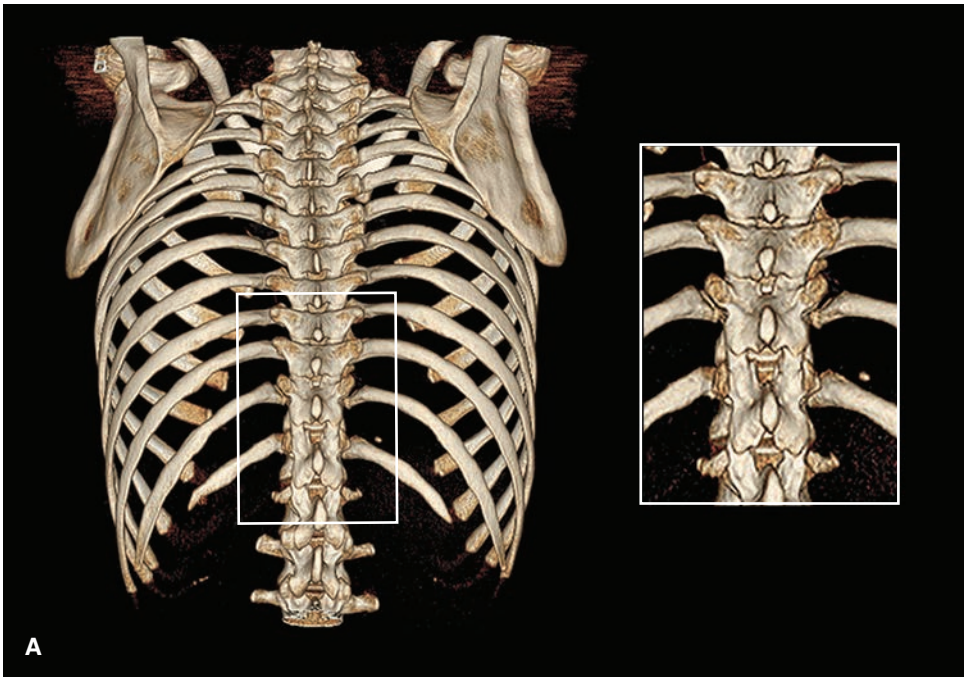


Figure 7-33.

A: Bony anatomy relevant to thoracic facet medial branch block or radiofrequency treatment. Three-dimensional reconstruction computed tomography of the low thoracic spine as viewed in the posterior approach used for needle insertion. **Inset** matches the anatomic area in the radiographs shown in **(B)** and **(C)**. *(Cont.)*

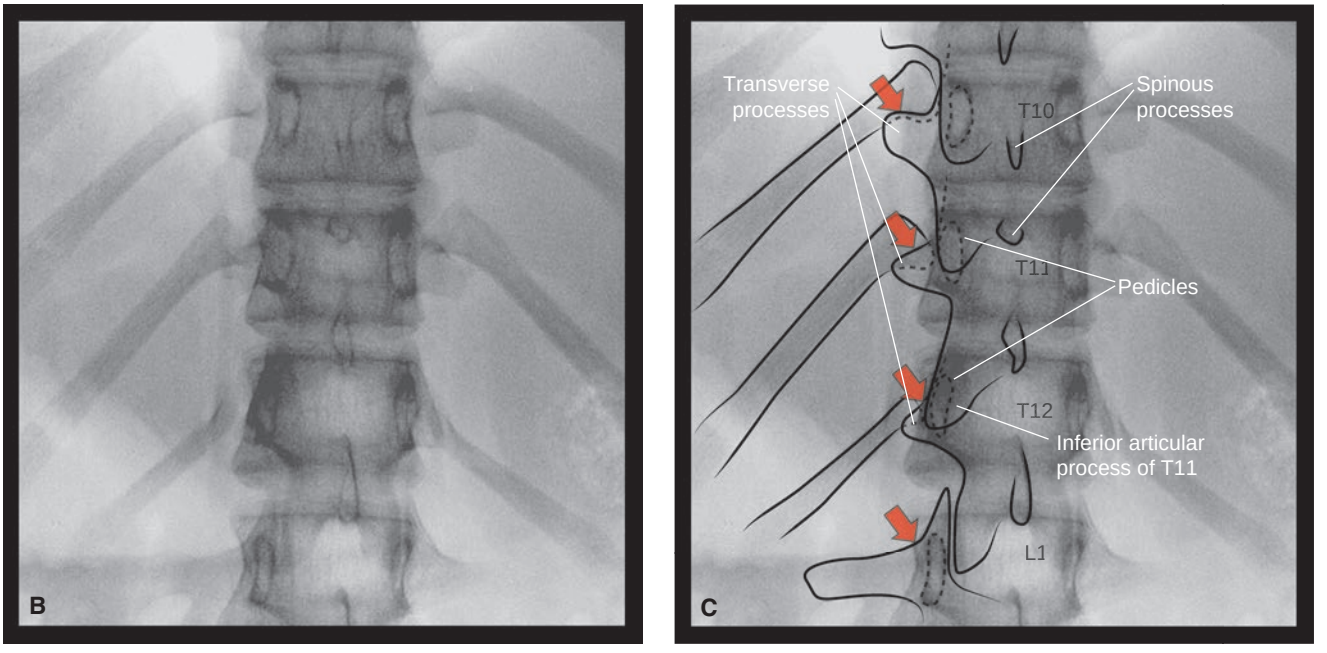


Figure 7-33. ***(Continued)***
B: AP radiograph of the low thoracic spine. The transverse processes are less prominent at low thoracic levels and often difficult to see at all at T12. The base of the transverse process joins the superior articular process just superolateral to the pedicle, and the pedicle is used as a landmark to locate the target for injection. **C:** Labeled image. The *arrows* indicate the targets for medial branch nerve blocks or radiofrequency treatment at T10 to L1 levels on the left.

or 0.5% bupivacaine). The patient is instructed to assess his or her degree of pain relief in the hours immediately following the diagnostic blocks.

Block Technique: Radiofrequency Treatment

Radiofrequency cannulae are placed using a technique identical to that described for medial branch blocks. For conventional radiofrequency treatment, 10-cm SMK cannulae with 5-mm active tips are used (5-cm cannulae are sufficient in length in all but obese patients). Once the needle is seated against the superior margin of the transverse process, the cannula is walked superolaterally off the transverse process and advanced 2 to 3 mm to position the active tip along the course of the medial branch nerve (Figs. 7-30 and 7-34). A lateral radiograph can be used to assure that the needle tip is in position at the base of the superior articular process and has not been advanced anteriorly into the intervertebral foramen (Fig. 7-35). Proper testing for sensory-motor dissociation is conducted (the patient should report pain or tingling during stimulation at 50 Hz at <0.5 V and have no motor stimulation to the affected myotome of the chest wall at 2 Hz at no less than three times the sensory threshold or 3 V). Thereafter, great care must be taken to prevent any movement of the cannulae. Each level is anesthetized with 0.5 mL of 2% lidocaine, and lesions are created at 80°C for 60 to 90 seconds. Cannula placement for thoracic pulsed radiofrequency treatment is carried out in the same manner.

Lumbar Medial Branch Block and Radiofrequency Treatment

Positioning

The medial branch nerves to the lumbar facets course over the base of the transverse process, where they join with the superior articular processes (Figs. 7-36 and 7-37). The medial branch nerve lies in the groove between the transverse process and the superior articular process, which slopes inferolaterally. The patient lies prone, with the head turned to one side (Fig. 7-38). A pillow is placed under the lower abdomen in an effort to tilt the pelvis backward and swing the iliac crests posteriorly away from the lumbosacral junction. The C-arm is positioned over the lumbar spine with 25 to 35 degrees of oblique angulation so the facet joints, as well as the junction between the transverse process and the superior articular process, are clearly seen (Fig. 7-39). For medial branch blocks, the needle can be advanced in the axial plane without caudal angulation (see Fig. 7-36). However, for radiofrequency treatment, the C-arm should be angled 25 to 30 degrees caudal to the axial

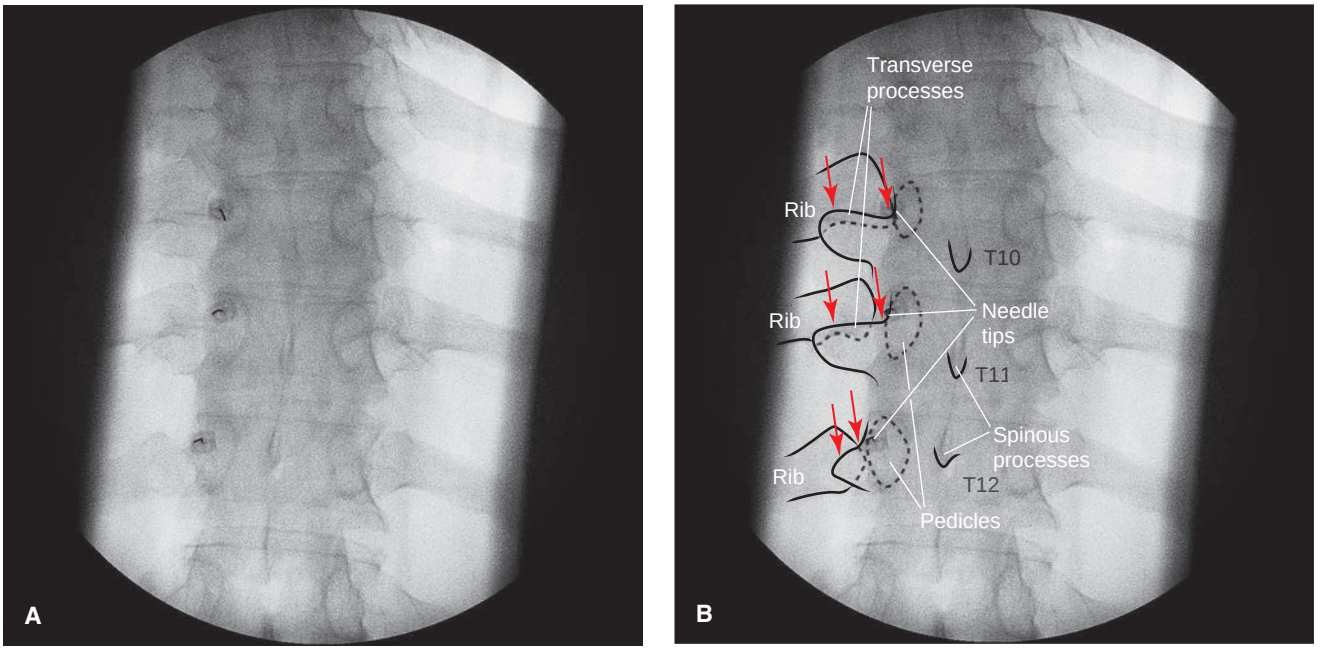


Figure 7-34.

AP radiograph of the thoracic spine during medial branch blocks of the thoracic facets. **A:** Three 25-gauge, 3.5-inch spinal needles are in place along the superolateral margin of the left T10, T11, and T12 transverse processes, where they join the superior articular process at each level. **B:** Labeled image. The *arrows* indicate the range, from medial to lateral extremes, where the medial branch nerves may pass over the superior margin of the transverse process (based on anatomic dissection studies). Unlike the very predictable location of the nerve near the junction of the transverse process and superior articular process at lumbar spinal levels, the position of the nerve is less predictable at thoracic levels.

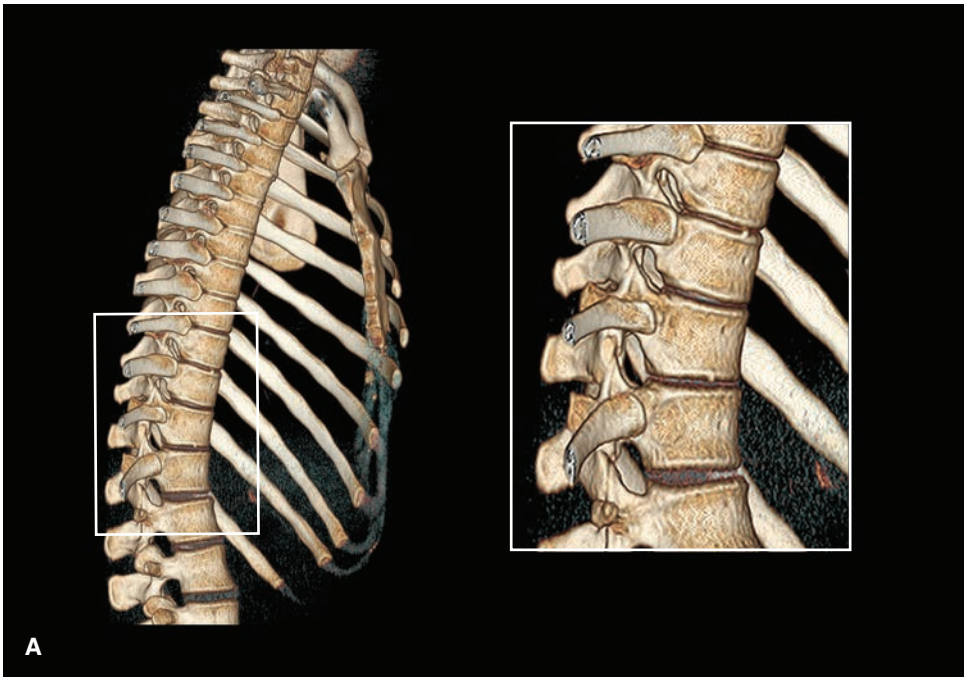


Figure 7-35.

A: Bony anatomy relevant to thoracic facet medial branch block or radiofrequency treatment. Three-dimensional reconstruction computed tomography of the low thoracic spine as viewed in the lateral projection used to verify final needle position; the bony elements of the right lateral hemithorax have been removed to allow better visualization of the spine. **Inset** matches the anatomic area in the radiographs shown in **(B)** and **(C)**.*(Cont.)*

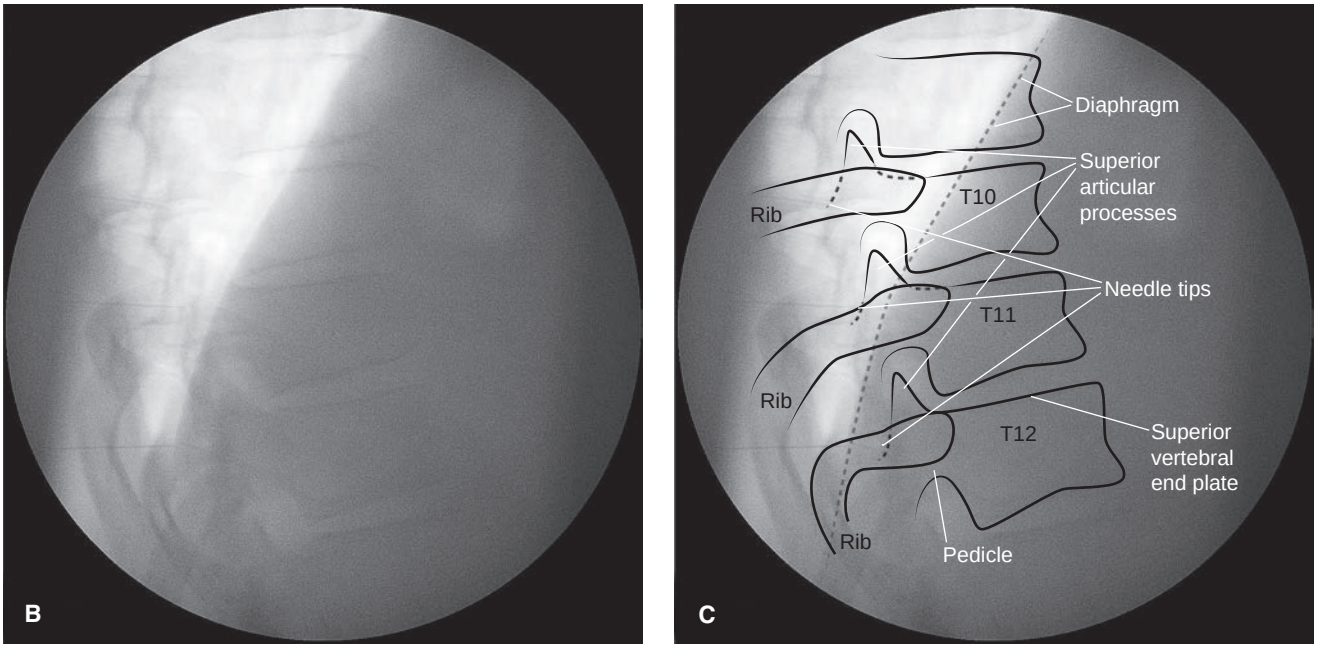


Figure 7-35. *(Continued)*

B: Lateral radiograph of the thoracic spine during medial branch blocks of the thoracic facets. Three 25-gauge, 3.5-inch spinal needles are in place along the superolateral margin of the left T10, T11, and T12 transverse processes, where they join the superior articular process at each level. **C:** Labeled image. Interpretation of the lateral radiograph is complicated by the dramatically differing contrast within the abdomen and pelvis as well as the multiple confluences of shadows due to the overlying ribs. Nonetheless, discerning the location of the superior articular surface is simple: identify the superior end plate of the vertebral body at the level of interest, and follow the margin posteriorly until the posterior margin of the vertebral body joins the pedicle (the structures have been labeled on T12). The superior margin of the pedicle forms the inferior border of the intervertebral foramen. Follow the superior border of the pedicle posteriorly and it will slope upward where it joins the superior articular process of the facet joint. The superior extent of the superior articular process is easily identified as notch along the posterior margin of the intervertebral foramen. The articular surface is then easily identified as a line sloping in a posterior and inferior direction. The junction of the superior articular process and the transverse process is behind the overlying rib; the tips of each needle are located at this junction in the image.

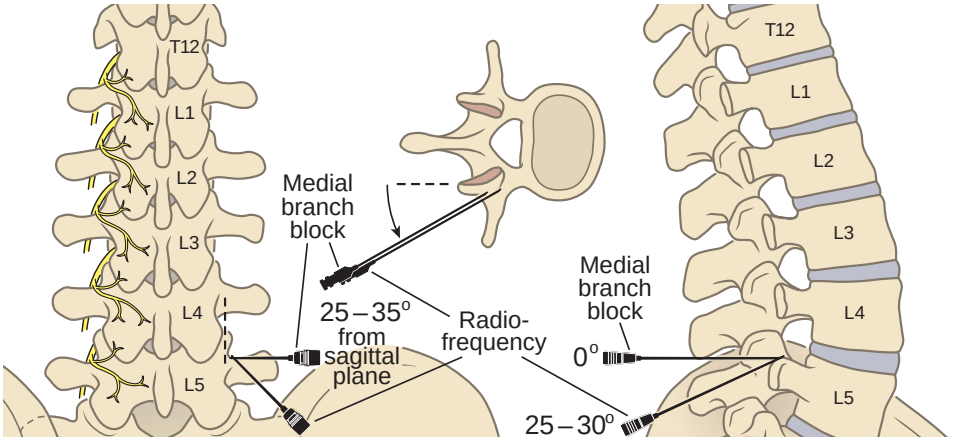


Figure 7-36.

Position and angle of needle entry for lumbar medial branch blocks and radiofrequency treatment. A 22-gauge, 3.5-inch spinal needle (or 22-gauge, 10-cm SMK radiofrequency cannula with a 5-mm active tip) is advanced toward the base of the transverse process, where it joins with the superior articular process. Cannulae placement for conventional radiofrequency treatment should be carried out with 25 to 30 degrees of caudal angulation of the C-arm to bring the axis of the active tip parallel to the course of the medial branch nerve in the groove between the transverse process and the superior articular process. The target points for radiofrequency treatment are illustrated to the left.

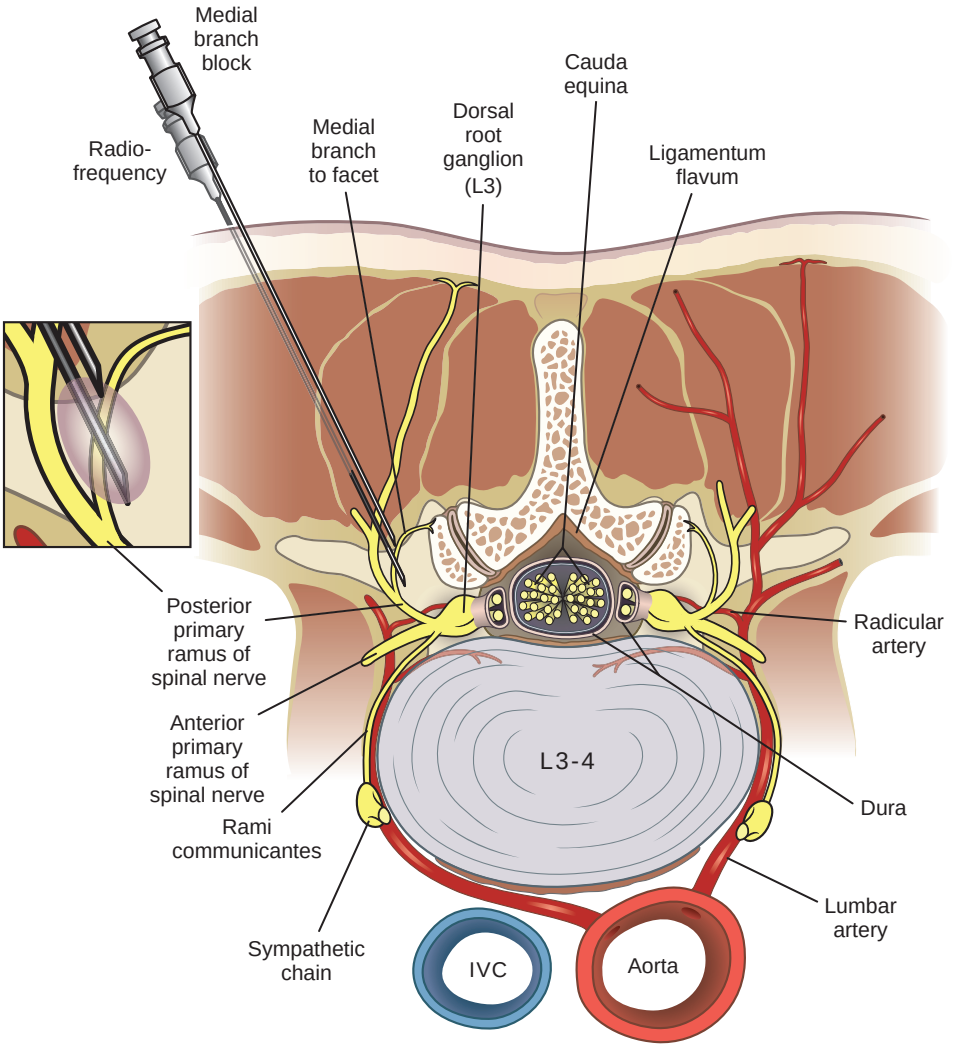


Figure 7-37.
Axial diagram of lumbar medial branch nerve blocks and radiofrequency treatment. A 22-gauge, 3.5-inch spinal needle (or 22-gauge, 10-cm SMK radiofrequency cannula with a 5-mm active tip) is advanced toward the base of the transverse process, where it joins with the superior articular process. Cannulae placement for conventional radiofrequency treatment should be carried out with 25 to 30 degrees of caudal angulation of the C-arm to bring the axis of the active tip parallel to the course of the medial branch nerve in the groove between the transverse process and the superior articular process. For conventional radiofrequency treatment, the cannulae must be walked off the superior margin of the transverse process and advanced 2 to 3 mm to place the active tip along the course of the medial branch nerve (**inset**).

plane so the active tip of the radiofrequency cannulae will be parallel to the medial branch nerve within the groove between the transverse process and the superior articular process as it slopes inferomedially (see Fig. 7-36).

Block Technique: Diagnostic Medial Branch Blocks

The skin and subcutaneous tissues overlying the facet target where the block is to be carried out are anesthetized with 1 mL of 1% lidocaine. The lumbar level can be identified by counting upward from the sacrum. A 22-gauge, 3.5-inch spinal needle is placed through the skin and advanced until it is seated in the tissues in a plane that is coaxial with the axis of the x-ray path. The needle is adjusted to remain coaxial and advanced toward the base of the transverse process, where it joins the superior articular process (see Figs. 7-36 to 7-39) and is seated on the bony margin. Once the needle is in position, a small volume of local anesthetic is placed

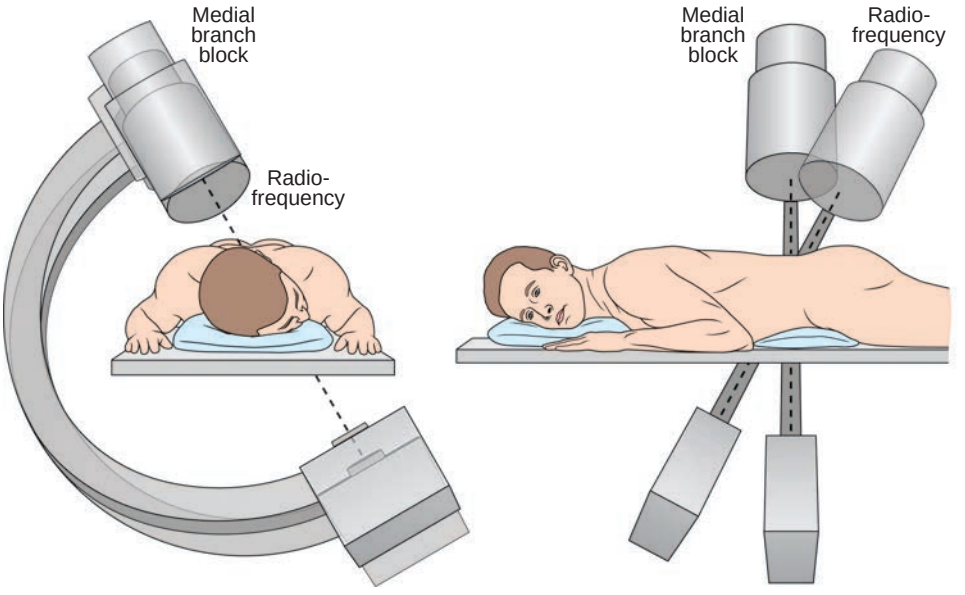


Figure 7-38.
Position for lumbar medial branch blocks and radiofrequency treatment. The patient is placed prone with the head turned to one side. The C-arm is positioned over the lumbar spine with 25 to 35 degrees of oblique angulation so the facet joints themselves and the junction between the transverse process and the superior articular process are clearly seen. For medial branch blocks, the needle can be advanced in the axial plane without caudal angulation. However, for radiofrequency treatment, the C-arm should be angled 25 to 30 degrees caudal to the axial plane so the active tip of the radiofrequency cannulae will be parallel to the medial branch nerve in the groove between the transverse process and the superior articular process.

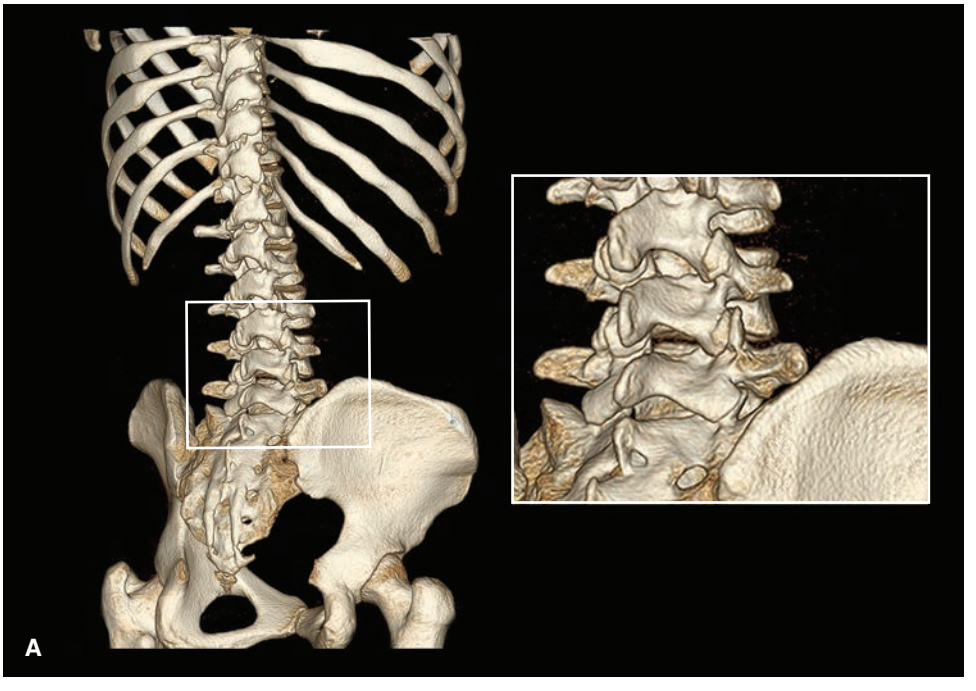


Figure 7-39.
A: Bony anatomy relevant to lumbar medial branch blocks and radiofrequency treatment. Three-dimensional reconstruction computed tomography of the lumbar spine as viewed in the left oblique projection used for needle insertion. **Inset** matches the anatomic area in the radiographs shown in **(B)** and **(C)**. *(Cont.)*

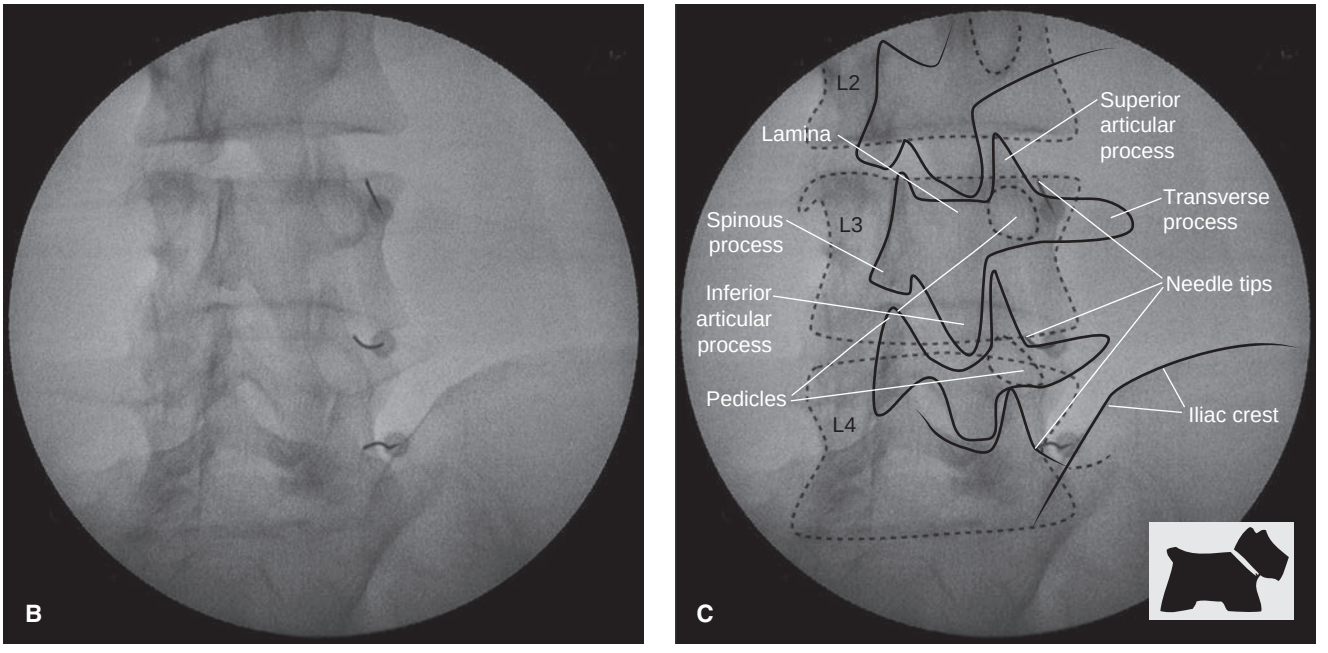


Figure 7-39. *(Continued)*
B: Oblique radiograph of the lumbar spine during lumbar radiofrequency treatment of the lumbar facet joints. Three radiofrequency cannulae are in place at the base of the transverse processes and superior articular processes at the L3, L4, and L5 levels on the right. Note the presence of a transitional vertebra at L5, with sacralization of the L5 vertebra (thin laminar arch and absence of a discernable inferior articular process at L5, yet clear segmentation of the L5 vertebral body on the lateral image shown in Fig. 7-41). **C:** Labeled image. The contours of the posterior bony elements of the spine on the oblique projection take a shape similar to the silhouette of a Scottish terrier or "Scotty dog". Following this contour around its perimeter, the front leg of the dog is the inferior articular process of the vertebra, the snout is the transverse process, the ear is the superior articular process, the back is the superior margin of the lamina, the buttocks and hind leg is the spinous process, and the belly of the dog is the inferior margin of the lamina. Compare the outlined areas of the radiograph with the contour of an actual Scottish terrier shown in the **inset** in the lower right corner of this image.

at each level, and the needles are removed (0.5 mL of 2% lidocaine or 0.5% bupivacaine). The patient is instructed to assess his or her degree of pain relief in the hours immediately following the diagnostic blocks.

Block Technique: Radiofrequency Treatment

Radiofrequency cannulae are placed using a technique identical to that described for medial branch blocks; however, the C-arm is angled 25 to 30 degrees caudal to the axial plane so the active tip of the radiofrequency cannulae will be parallel to the medial branch. For conventional radiofrequency treatment, 10-cm SMK cannulas with 5-mm active tips are used. Once the needle is seated against the superior margin of the transverse process, where it joins the superior articular process of the facet, the cannula is walked off the superior margin of the transverse process and advanced 2 to 3 mm to position the active tip along the course of the medial branch nerve (Figs. 7-36, 7-37, and 7-39 to 7-41). Proper testing for sensory-motor dissociation is conducted (the patient should report pain or tingling during stimulation at 50 Hz at <0.5 V and have no motor stimulation to the affected myotome of the lower extremity at 2 Hz at no less than three times the sensory threshold or 3 V). Thereafter, great care must be taken to prevent any movement of the cannulae. Each level is anesthetized with 0.5 mL of 2% lidocaine, and lesions are created at 80°C for 60 to 90 seconds. Cannula placement for lumbar pulsed radiofrequency treatment is carried out in the same manner.

Complications of Medial Branch Block and Radiofrequency Treatment

Complications associated with diagnostic medial branch nerve blocks are uncommon and similar to those following intra-articular facet injection. Unlike intra-articular

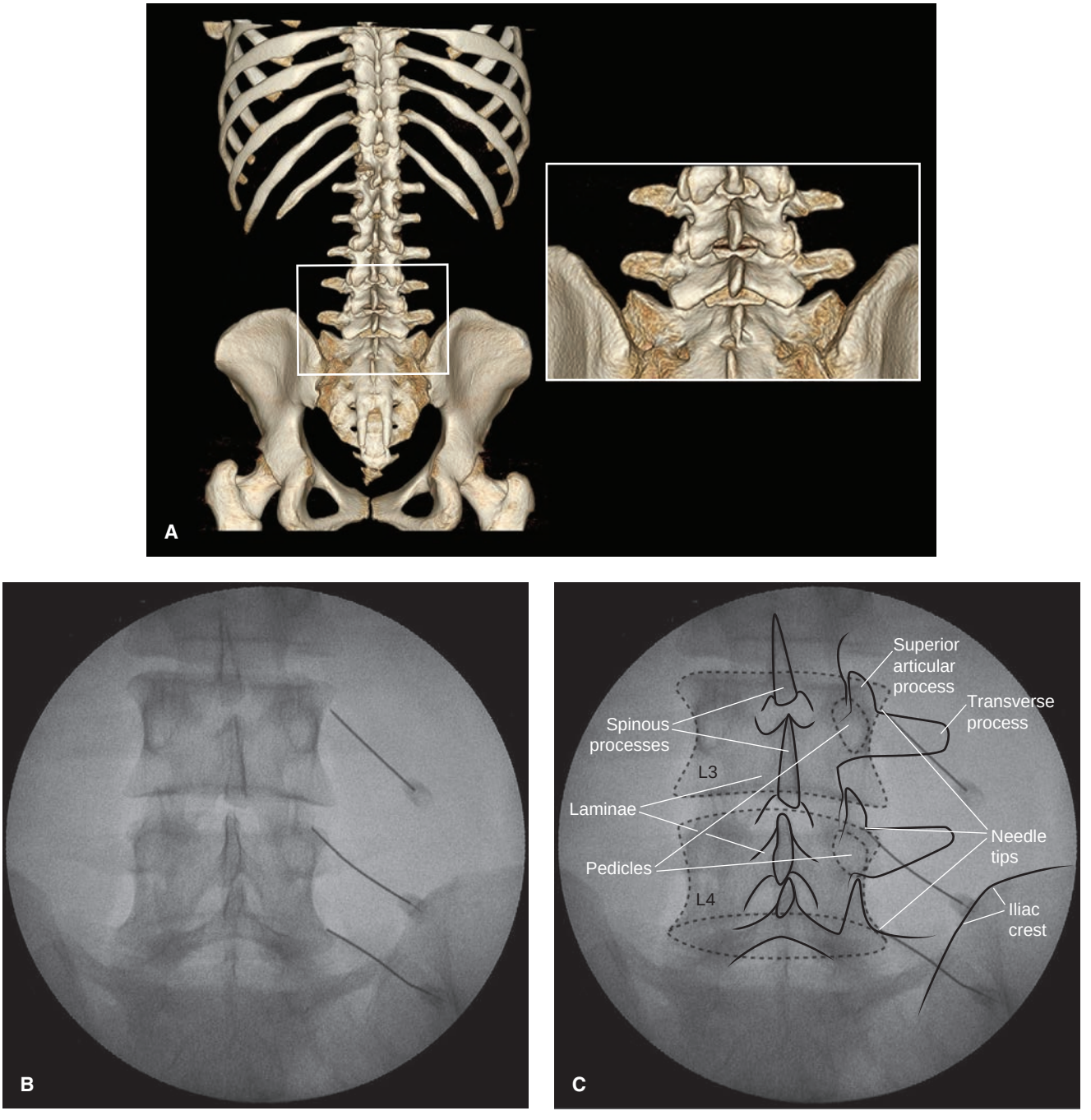


Figure 7-40.

A: Bony anatomy relevant to lumbar medial branch blocks and radiofrequency treatment. Three-dimensional reconstruction computed tomography of the lumbar spine as viewed in the AP projection. **Inset** matches the anatomic area in the radiographs shown in **(B)** and **(C)**. **B:** AP radiograph of the lumbar spine during lumbar radiofrequency treatment of the lumbar facet joints. Three radiofrequency cannulae are in place at the base of the transverse processes and superior articular processes at the L3, L4, and L5 levels on the right. Note the angle of the entering cannulae. There is a transitional vertebra at L5, with sacralization of the L5 vertebra (thin laminar arch and absence of a discernable inferior articular process at L5, yet clear segmentation of the L5 vertebral body on the lateral image shown in Fig. 7-41). **C:** Labeled image.

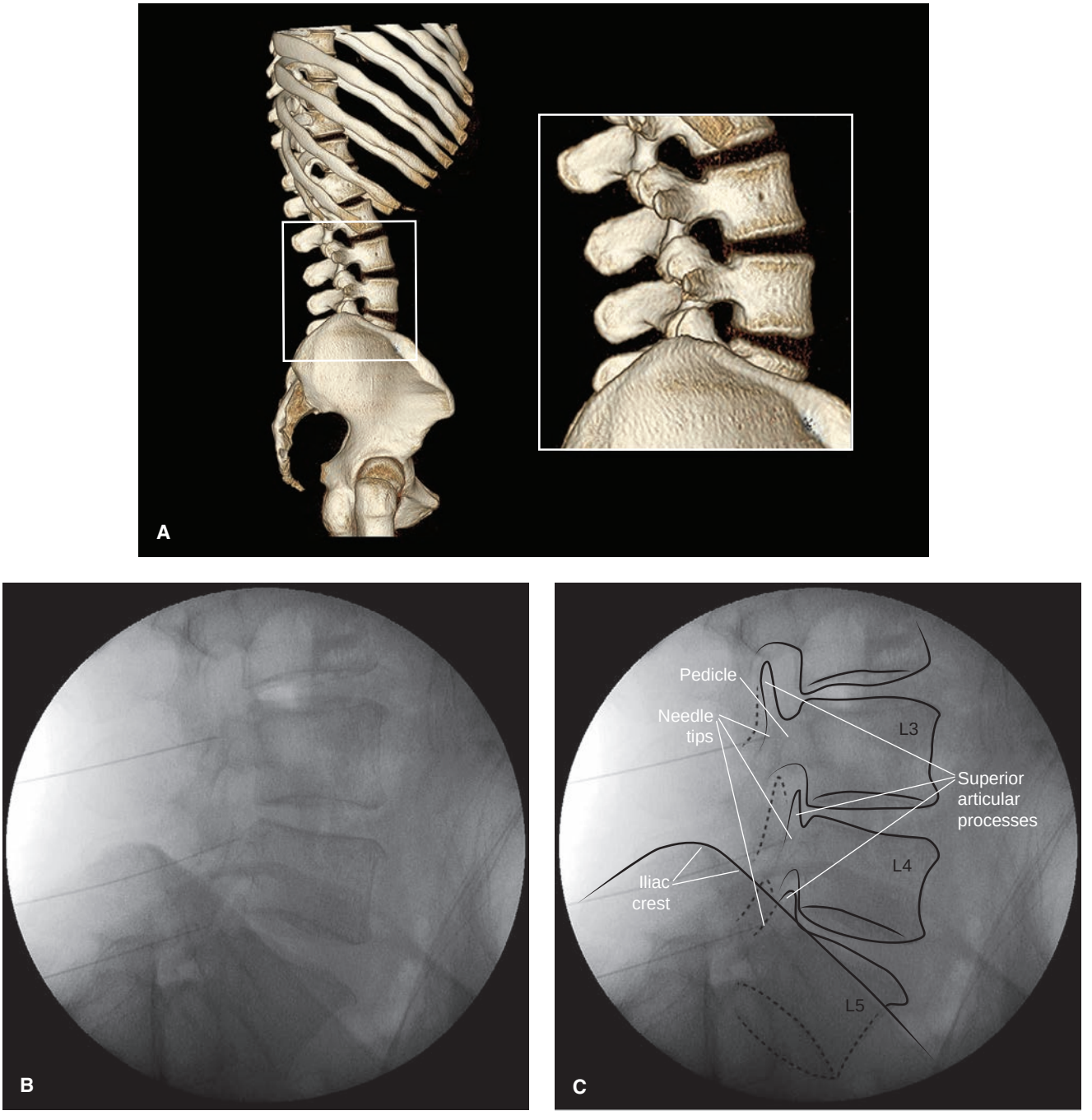


Figure 7-41.

A: Bony anatomy relevant to lumbar medial branch blocks and radiofrequency treatment. Three-dimensional reconstruction computed tomography of the lumbar spine as viewed in the lateral projection. **Inset** matches the anatomic area in the radiographs shown in **(B)** and **(C)**. **B:** Lateral radiograph of the lumbar spine during lumbar radiofrequency treatment of the lumbar facet joints. Three radiofrequency cannulae are in place at the base of the transverse processes and superior articular processes at the L3, L4, and L5 levels on the right. Note the angle of the entering cannulae and their distance from the intervertebral foramina. **C:** Labeled image. Discerning the location of the superior articular surface is simple: identify the superior end plate of the vertebral body at the level of interest and follow the margin posteriorly until the posterior margin of the vertebral body joins the pedicle. The superior margin of the pedicle forms the inferior border of the intervertebral foramen. There is significant rotation at the L4 and L5 vertebral levels in this image, but the left and right foramina are well aligned at the L3 level. Follow the superior border of the pedicle posteriorly and it will slope upward where it joins the superior articular process of the facet joint. The superior extent of the superior articular process is easily identified as notch along the posterior margin of the intervertebral foramen. The articular surface is then easily identified as a line sloping in a posterior and inferior direction. The junction of the superior articular process and the transverse process cannot be identified precisely in the lateral projection (the oblique view is used for this purpose), but the position of the needle tip relative to the margin of the transverse process is easily determined and adjusted in the AP direction.

injection, it is unusual for medial branch blocks to cause an exacerbation of pain. Patients should be warned to expect mild pain at the injection site lasting a day or two after the procedure. Radiofrequency treatment of the facets is also associated with few complications. Although conventional radiofrequency produces actual tissue destruction, injury to the spinal nerves is uncommon. This is likely due to the physiologic testing before each lesion. As long as proper sensory and motor testing are carried out before each lesion is created, there is little chance that the active tip of the cannula will be close enough to the anterior primary ramus of the nerve root to cause injury. Exacerbation of pain following conventional radiofrequency treatment is common, and patients should be instructed to expect an increase in pain similar in character to their usual pain that will last from several days to a week or more. A smaller group of patients will report uncomfortable dysesthesia, usually in the form of a sunburned feeling of the skin overlying the spinous processes at the level of treatment often accompanied by allodynia (pain to light touch in the area). This adverse effect is more common following cervical radiofrequency treatment and usually subsides over several weeks. These dysesthesia likely stem from partial denervation of the lateral branch of the posterior primary ramus, which supplies a variable region of cutaneous innervation overlying the spinous processes. Likewise, some patients will report a small patch of complete sensory loss in this same region. Injury to the spinal nerve with new-onset radicular pain with or without radiculopathy (nerve dysfunction in the distribution of the spinal nerve in the form of sensory or motor loss) has been reported following radiofrequency treatment, but it is rare when physiologic testing is employed. Pulsed radiofrequency treatment does not produce tissue destruction; thus, it is not surprising that most patients will have no worsening of their pain following treatment or a transient, mild exacerbation that is short lived. Painful dysesthesia and other consequences of nerve injury do not occur with pulsed radiofrequency treatment. It is precisely because of this lack of neural destruction and associated adverse effects that pulsed radiofrequency treatment has become so popular among practitioners. If controlled trials emerge to support the efficacy of pulsed radiofrequency treatment, it will rapidly replace conventional radiofrequency. In the past decade, pulsed radiofrequency gained rapid popularity, but the majority of practitioners have returned to routine use of conventional, thermal radiofrequency treatment, as controlled trials have failed to demonstrate the benefit of using the pulsed technique for most applications.

SUGGESTED READINGS

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CHAPTER 8

Sacroiliac Joint Injection

OUTLINE

Overview

Pain arising from the sacroiliac (SI) joint is common and difficult to distinguish from other causes of pain in the area of the lumbosacral junction. SI joint dysfunction typically presents with localized pain in the lower back or upper buttock overlying the SI joint. Pain may be referred to the posterior thigh, but pain extending below the knee is unusual. In most cases, the etiology is unclear, and the onset is gradual over months to years. Trauma, infection, and tumor are uncommon causes of SI joint pain. The inflammatory arthropathies associated with ankylosing spondylitis, Reiter's syndrome, and inflammatory bowel diseases are also infrequent but well-established causes of SI-related pain. Intra-articular injection of the SI joint with local anesthetic and steroid can provide short-term pain relief and assist diagnostically in establishing the source of low back pain. Radiofrequency treatments for SI-related pain have been devised but are only modestly effective in a fraction of treated patients. A long-term solution to SI-related pain is one of the needs unmet by our current armamentarium.

Anatomy

The SI joints are paired structures formed by the sacrum medially and the ilium of the pelvis laterally. The SI joints are the principal load-bearing structures that connect the vertebral elements of the spine with the pelvis and lower extremities. The majority of the connection between the sacrum and the ilium is in the form of a dense fibrocartilaginous connection, rather than a true synovial joint. The bulk of the true joint space is limited to the anterior portion of the apposing surfaces of the SI connection. There is a small portion of the synovial joint space that extends to the posterior- and inferior-most extent of the SI apposition, and it is from this point that access for intra-articular injection is gained. The superior extent of the SI joint lies anterior to the iliac crest, and the joint is difficult to access superior to the posterior-superior iliac spine (Fig. 8-1). The plane of the SI joint is variable from individual to individual; at the inferior extent of the joint where SI injection is carried out, the joint lies with 0 to 30 degrees of oblique angulation from the sagittal plane.

The sensory innervation to the SI joints is extensive, arising from branches of both the lumbar plexus anteriorly and the L5 dorsal ramus and S1 to S3 lateral branches posteriorly. Only the posterior aspect of the joint can be accessed with safety and ease percutaneously, and radiofrequency treatments have been devised to treat this portion of the SI joint.

Patient Selection

Patients with SI-related pain are difficult to distinguish from those with other causes of axial spinal pain, tending to report pain location over the SI joints to either side of midline near the lumbosacral junction (Fig. 8-2). Physical examination may reveal localized tenderness over the joint, and Patrick's test (or the Flexion, ABduction, External Rotation [FABER] test) may reproduce pain in the area of the SI joint positive (Table 8-1). Degenerative change of the joint on radiography is uncommon and nonspecific; most patients with SI-related pain have normal SI joint appearance on radiography. Resolution

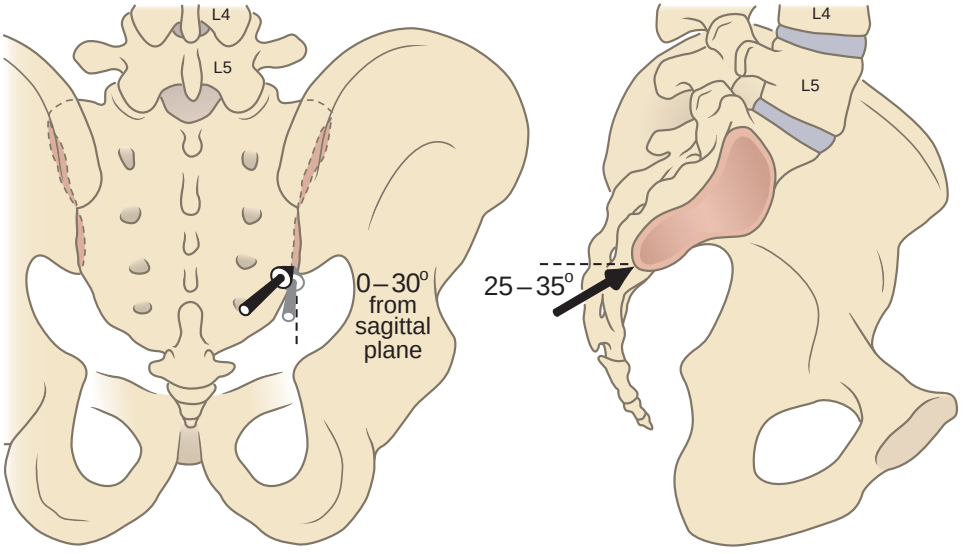


Figure 8-1.
Anatomy of the SI joints. The SI joints are largely stiff fibrocartilaginous connections, with the true synovial joint lying largely in the anterior aspect of the junction between the sacrum and the ilium. The true joint space extends to the inferior and posterior extent of the SI apposition, where it is accessible to injection. The plane of the posterior-inferior portion of the SI joint is variable, lying with 0 to 30 degrees of oblique angulation from the sagittal plane. The anterior portion of the joint arcs laterally. Accessing the joint is facilitated by a caudad-cephalad approach of 25 to 35 degrees to avoid the overlying posterior-superior iliac spine and iliac crest.

of pain following intra-articular injection of local anesthetic under fluoroscopic or computed tomography (CT) guidance is the best diagnostic tool available. Similar to facet joint pain, definitive diagnosis is hindered by the significant placebo effect of diagnostic injection. Treatment for SI joint pain remains inadequate and controversial. Currently, periodic intra-articular injection of steroid with local anesthetics is the most common therapy for SI joint pain but typically provides only transient relief.

Level of Evidence

Quality of Evidence and Grading of Recommendation			
Grade of Recommendation/Description	**Benefit vs. Risk and Burdens**	**Methodological Quality of Supporting Evidence**	**Implications**
RECOMMENDATION: *Intra-articular SI joint may be used for symptomatic relief of SI-related pain.*			
2B/weak recommendation, moderate-quality evidence	Benefits closely balanced with risks and burden	II-2: Randomized controlled trials (RCTs) with important limitations (inconsistent results, methodologic flaws, indirect, or imprecise) and strong evidence from observational studies	Weak recommendation, best action may differ depending on circumstances or patients' or societal values
RECOMMENDATION: *Radiofrequency ablation: Water-cooled lateral branch nerve radiofrequency ablation of the sacral segments may be used for SI joint–related pain when previous diagnostic or therapeutic injections of the joint or lateral branch nerves have provided temporary relief. There is insufficient evidence to support the routine use of conventional (e.g., 80°C, bipolar technique) radiofrequency ablation of the SI joints.*			
2C/weak recommendation, low-quality or very low-quality evidence	Uncertainty in the estimates of benefits, risks, and burden; benefits, risk, and burden may be closely balanced	II-3: Observational studies or case series	Very weak recommendations; other alternatives may be equally reasonable

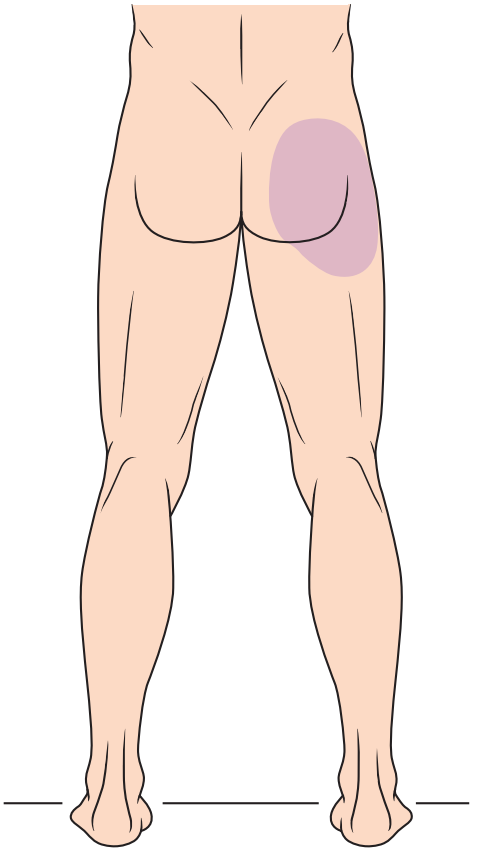


Figure 8-2.
Pattern of pain produced by SI joint dysfunction. The typical pain pattern produced by the SI joint is illustrated.

The available randomized controlled trials examining SI injections and radiofrequency treatment are limited. The American Pain Society (APS) Low Back Pain Guideline Panel published a report in 2009 and concluded that there was insufficient evidence to adequately evaluate the benefits of local anesthetic, corticosteroid injections, or radiofrequency treatment for the treatment of persistent nonradicular low back pain. Due to lack of available evidence, no recommendation for or against the use of SI joint injections was made by this group. Subsequently, the American Society of Anesthesiologists (ASA) Task Force on Chronic Pain Management published A 2010 Practice Guideline, offering the following recommendations: (1) "Sacroiliac joint injections may be considered for symptomatic relief of sacroiliac joint pain."; and (2) "…water-cooled radiofrequency ablation may be used for chronic sacroiliac joint pain.". Both groups highlight the limited evidence that is currently available to make any recommendations regarding the best means to diagnose and treat sacroiliac-related pain. In establishing the diagnosis, the features gleaned from the patient history overlap with the symptoms from a myriad of other causes for persistent nonradicular low back pain. Use of provocative maneuvers on physical examination is unreliable (Table 8-1). The gold standard for establishing the diagnosis has been pain relief with the intra-articular placement of local anesthetic, but this too is plagued by the large proportion of patients who report pain relief with the intra-articular injection of (saline) placebo. Thus, use of placebo-controlled, comparative injections is the only certain means to establish the diagnosis, and this is impractical in most clinical settings. Despite the limited evidence for long-term efficacy, the use of intra-articular SI joint injections using local anesthetic and corticosteroid remains commonplace. The use of radiofrequency treatment of the L5 dorsal ramus and the S1 to S3 lateral branches is still emerging. Detailed anatomic studies have recently appeared to guide accurate treatment and small controlled trials of water-cooled radiofrequency treatment suggest modest efficacy for this new approach.

Intra-articular Sacroiliac Joint Injection

Positioning

The patient lies prone, with the head turned to one side (Fig. 8-3). The C-arm is rotated 25 to 35 degrees caudally from the axial plane to place the posterior-superior iliac spine and the iliac crest cephalad along the line of

Table 8–1
Provocative Tests for SI Pain

Patrick's or FABER (Flexion, ABduction, External Rotation) test. The knee is flexed and the lateral malleolus of the ankle placed on the contralateral patella. The knee is then slowly lowered toward the examination table in external rotation. Pain caused by hip disease (e.g., osteoarthritis of the hip) is produced by this maneuver and is reported to radiate to the groin along the inguinal ligament. During the same maneuver, the examiner presses over the flexed knee while stabilizing the contralateral side of the pelvis over the anterior-superior iliac spine. This stresses the SI joint, and report of pain over the SI joint should raise suspicion of SI joint etiology.

Gaenslen's test. An alternate test for pain arising from the SI joint, Gaenslen's test, is performed by placing the patient supine along the edge of the examination table. One leg is placed over the edge of the examination table and lowered toward the floor in hyperextension, while the pelvis is held stable. Pain related to the SI joint is reproduced by this maneuver.

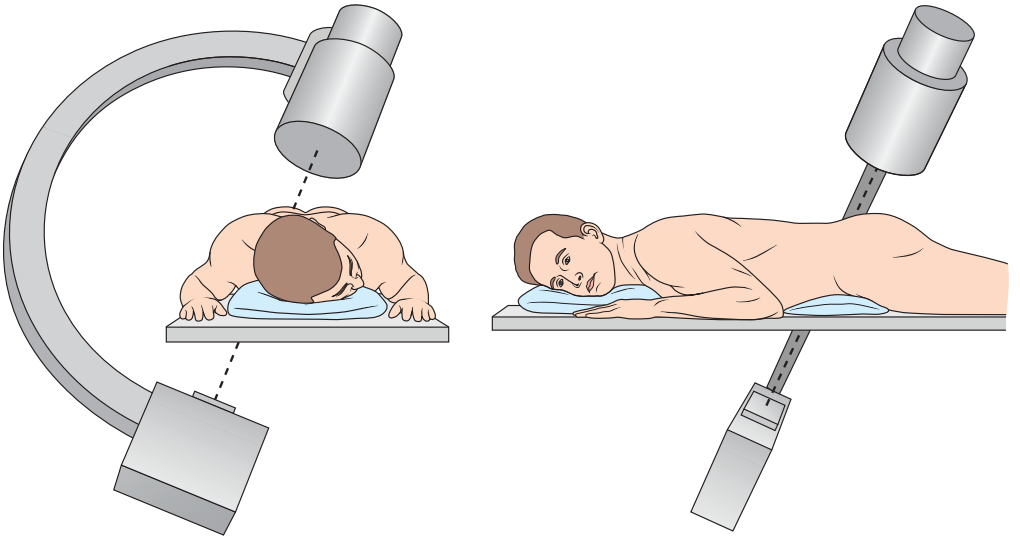


Figure 8-3.
Position for intra-articular SI joint injection. The patient is placed prone with the head turned to one side. The C-arm is angled 25 to 35 degrees caudally from the axial plane and 0 to 30 degrees obliquely until the posterior-inferior aspect of the joint is clearly visible.

the SI joint. The C-arm is then rotated obliquely 0 to 30 degrees until the posterior-inferior aspect of the SI joint is clearly visible (Fig. 8-4). Two features of the SI joint are important to recognize. First, the SI joint is curvilinear, often arcing somewhat laterally toward the anterior aspect (Fig. 8-5). This can lead to confusing overlying shadows of the anterior and posterior portion of the joint (Figs. 8-4 and 8-5). The second important feature is the overlying iliac crest that can block entry to the SI joint (Figs. 8-5 to 8-7). To avoid placing a needle on the iliac crest rather than in the SI joint itself, use caudal angulation of the C-arm and limit injection to the inferior aspect of the joint.

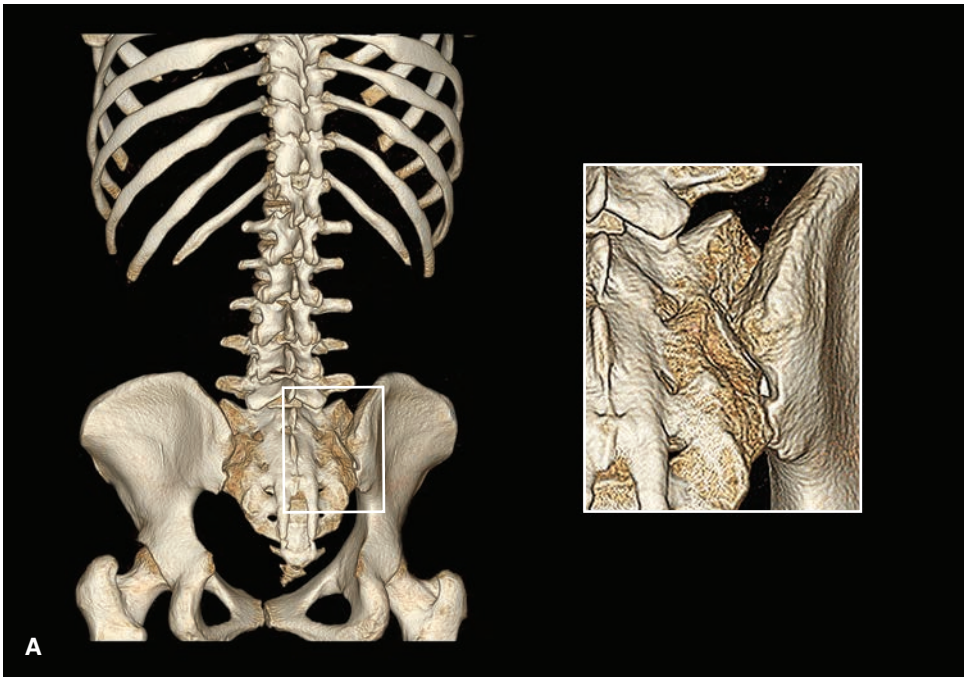


Figure 8-4.
A: Bony anatomy relevant to SI joint injection. Three-dimensional reconstruction CT of the lumbar spine as viewed in the anterior oblique projection used to perform SI injection. **Inset** matches the anatomic area in the radiographs shown in **(B)** and **(C)**. *(Cont.)*

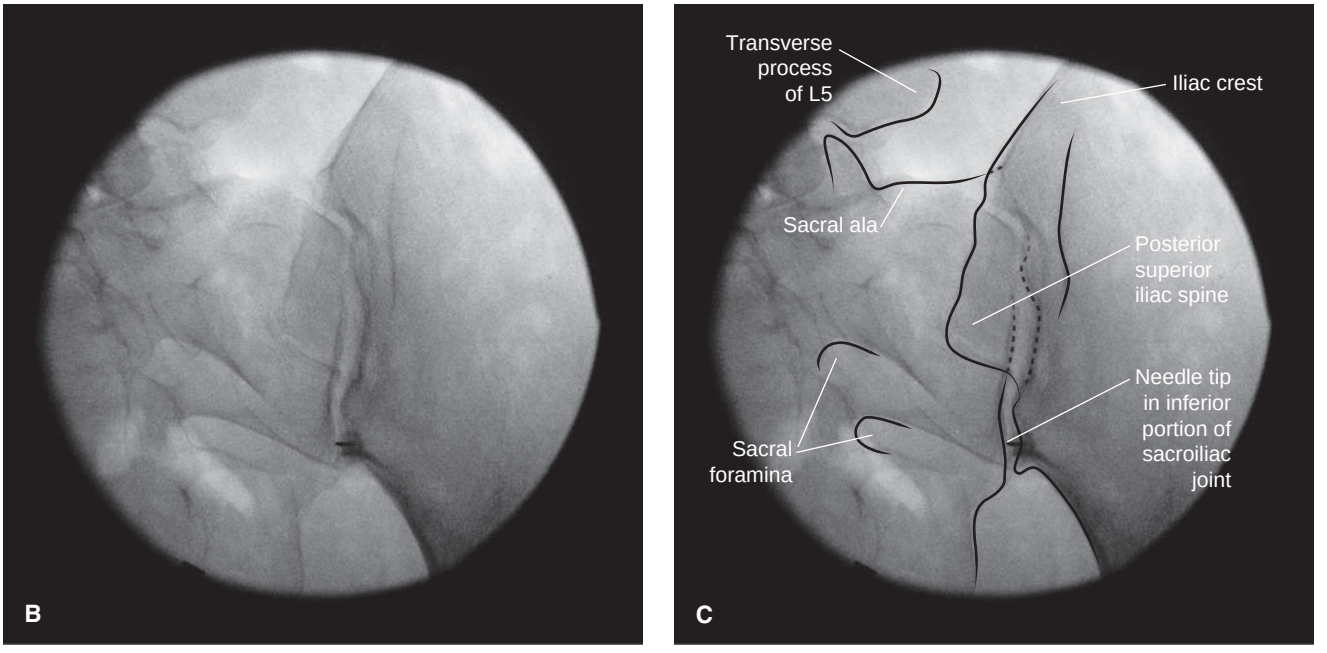


Figure 8-4. ***(Continued)***

B: Anterior-posterior radiograph of the SI joint during intra-articular SI joint injection. A 22-gauge spinal needle is in position in the posterior-inferior aspect of the right SI joint. **C:** Labeled image. Note that the superior portion of the SI joint (*dashed lines*) is obscured by the overlying posterior superior iliac spine.

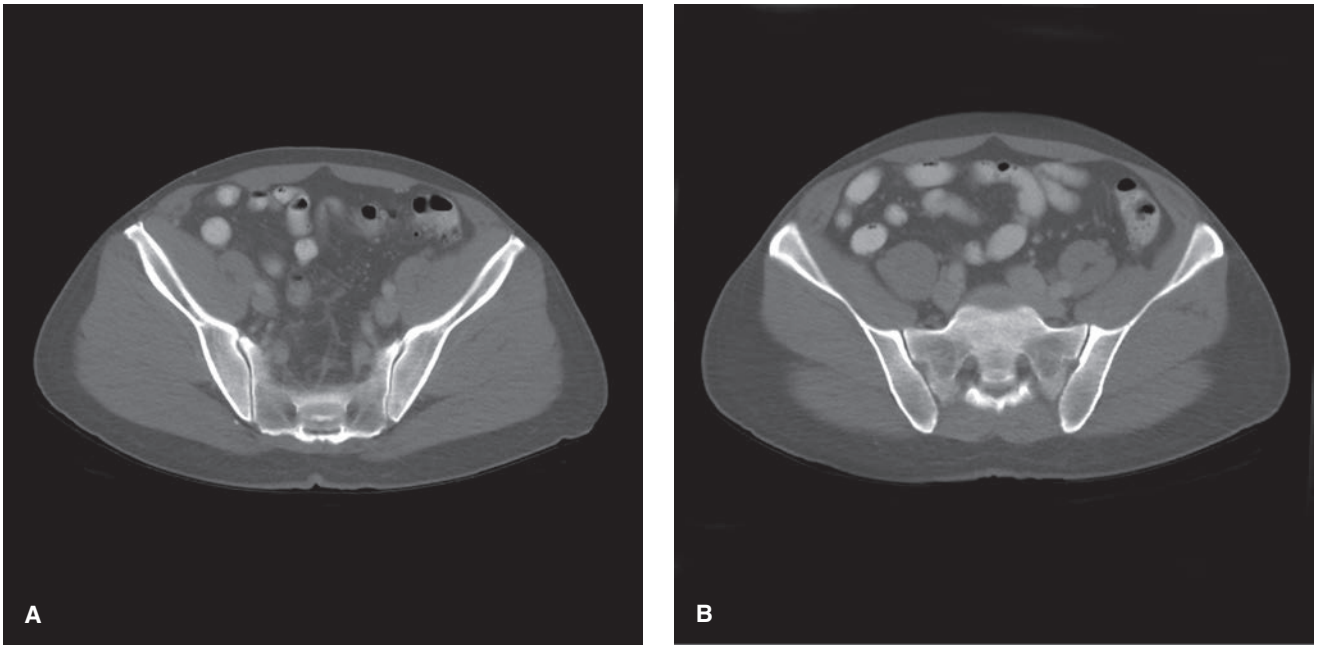


Figure 8-5.

Axial CT of the pelvis. This is a study performed after administration of both oral and intravenous radiographic contrast for evaluation of intra-abdominal pathology. The images are shown here to illustrate the anatomy of the normal SI joint. **A:** Axial CT near the inferior extent of the SI joint where the joint can be easily accessed. Note that the plane of the joint angles slightly in an anterolateral to posteromedial direction. **B:** Axial CT near the superior extent of the SI joint where the joint cannot be easily accessed due to the overlying posterior-superior iliac spine and the iliac crest.

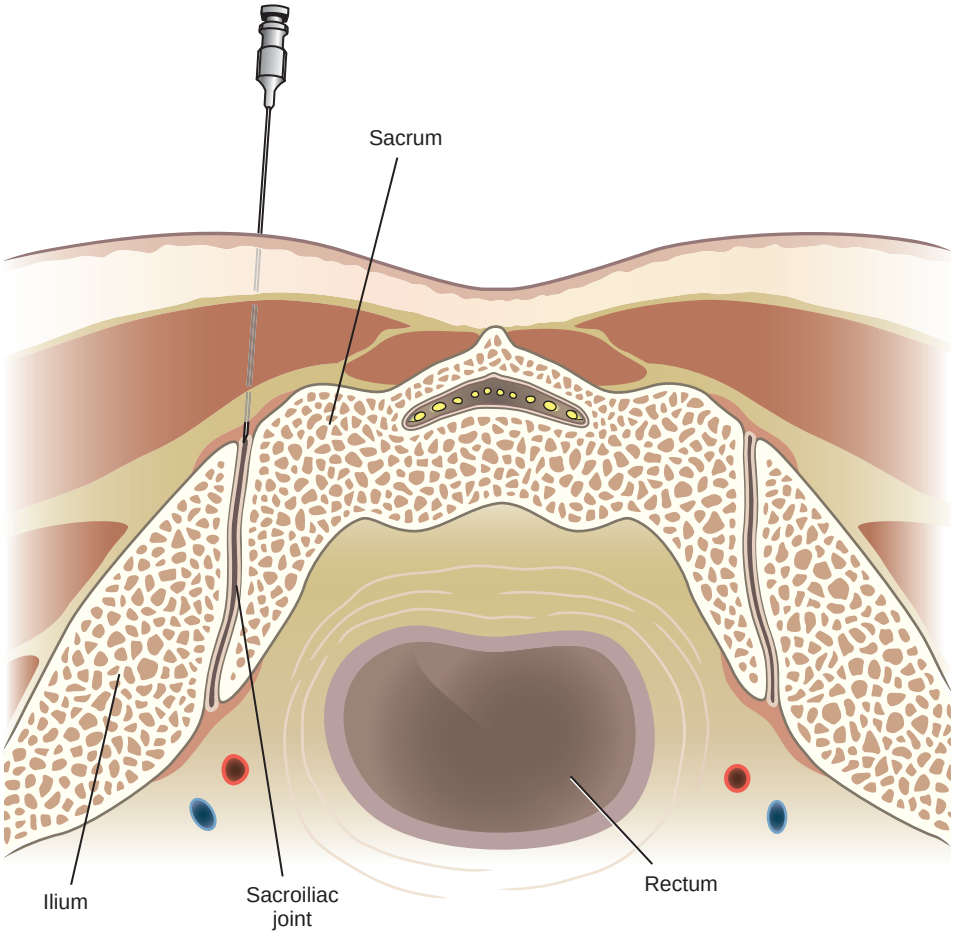


Figure 8-6.
Axial diagram of intra-articular SI joint injection. The needle enters the posterior-inferior aspect of the SI joint. The anterior portion of the SI joint arcs laterally and can often be seen as a second line on radiographs that can be confused for the posterior aspect of the joint.

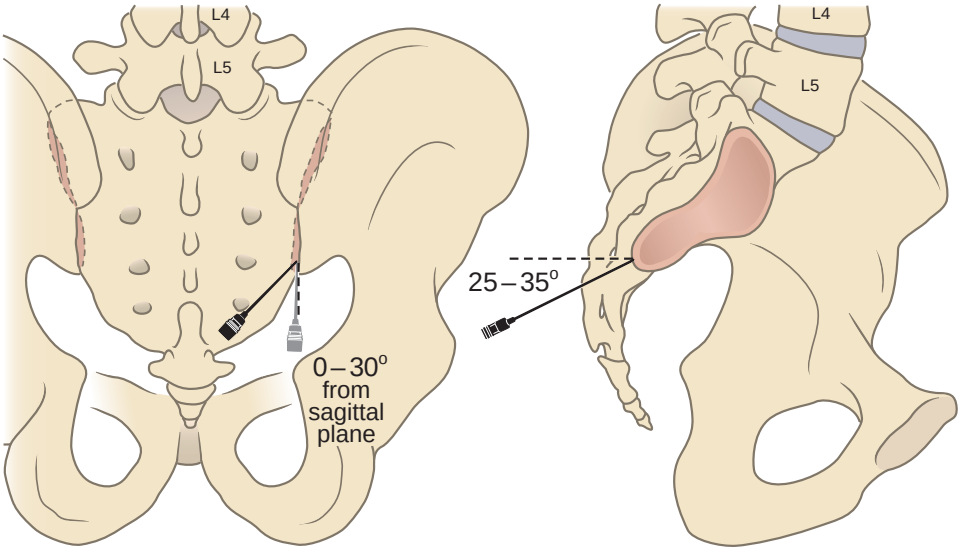


Figure 8-7.
Position and angle of needle entry for intra-articular SI joint injection. A 22-gauge spinal needle is advanced from 25 to 35 degrees caudad-cephalad to avoid the overlying posterior-superior iliac spine. The axis of the SI joint varies from person to person with 0 to 30 degrees of oblique angulation toward the side opposite the joint to be injected.

Block Technique

The skin and subcutaneous tissues overlying the SI joint where the block is to be carried out are anesthetized with 1 to 2 mL of 1% lidocaine. A 22-gauge, 3.5-inch spinal needle is placed through the skin and advanced until it is seated in the tissues in a plane that is coaxial with the axis of the x-ray path (see Fig. 8-4). The needle is adjusted to remain coaxial or angled in a slightly cephalad direction toward the inferior aspect of the joint and advanced toward the joint space using repeat anterior-posterior images after every 2 to 4 mm of needle advancement. Once the surface of the joint space is contacted, the needle is advanced just slightly to penetrate the posterior joint capsule. As the needle enters the joint space, the tip often curves slightly, following the contour of the surface of the ilium. In older patients and those with significant osteoarthritis, it may be difficult or impossible to penetrate into the joint space and only periarticular infiltration can be carried out. In most instances, there is no need for contrast injection to confirm needle location. The SI joint itself often holds only limited volume (typically <2 mL), and placing contrast in the joint limits the ability to place local anesthetic and steroid. A typical SI arthrogram is shown in Figure 8-8. A total dose of 80 mg of methylprednisolone acetate or the equivalent can be administered or divided between both SI joints if bilateral injection is necessary. Using concentrated steroid (40 or 80 mg per mL) allows 1:1 mixture with local anesthetic (0.5% bupivacaine) to provide immediate pain relief.

Complications of Intra-articular Sacroiliac Injection

Complications associated with intra-articular SI joint injection are uncommon. The most likely adverse effect is an exacerbation of pain in the days following resolution of the local anesthetic effect, likely owing to distention of inch the SI joint during the injection procedure. This exacerbation is usually mild and self-limited. Infection can also occur, leading to abscess within the presacral musculature, but the incidence is exceedingly low. Bleeding complications have not been associated with intra-articular SI injection.

Radiofrequency Treatment of the Sacroiliac Joint

In those patients who receive only temporary relief from therapeutic intra-articular SI joint injections, there are limited treatment options available. Fusion of the joint is a major undertaking and has met with mixed results. In more recent years, several investigators have applied radiofrequency treatment to the SI joints in efforts to attain long-lasting pain relief. The sensory innervation to the SI joints is extensive, arising from branches of both the lumbar plexus anteriorly and the L5 dorsal ramus and S1 to S3 lateral branches posteriorly. Only the posterior aspect of the joint can be accessed with safety and

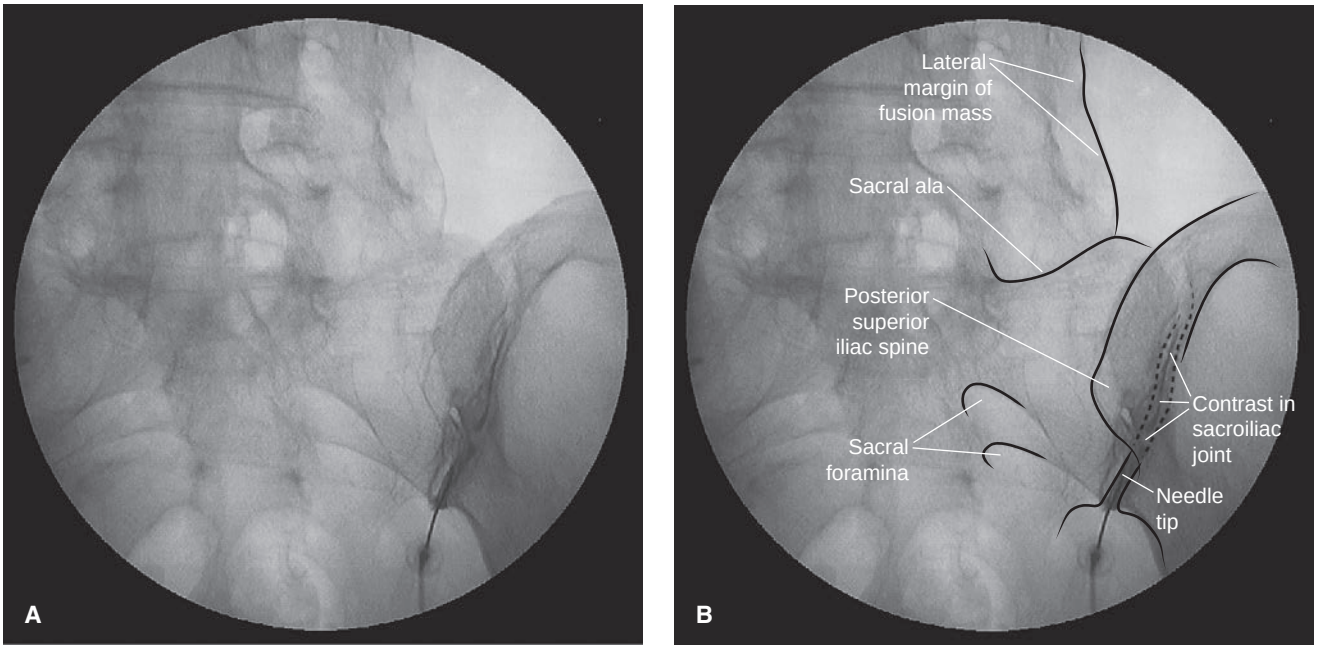


Figure 8-8.
Anterior-posterior radiograph of the SI joint during intra-articular SI joint injection following contrast injection. **A:** A 22-gauge spinal needle is in position in the posterior-inferior aspect of the right SI joint, and 1.5 mL of radiographic contrast (iohexol 180 mg per mL) has been injected. Contrast extends to the superior portion of the joint. **B:** Labeled image.

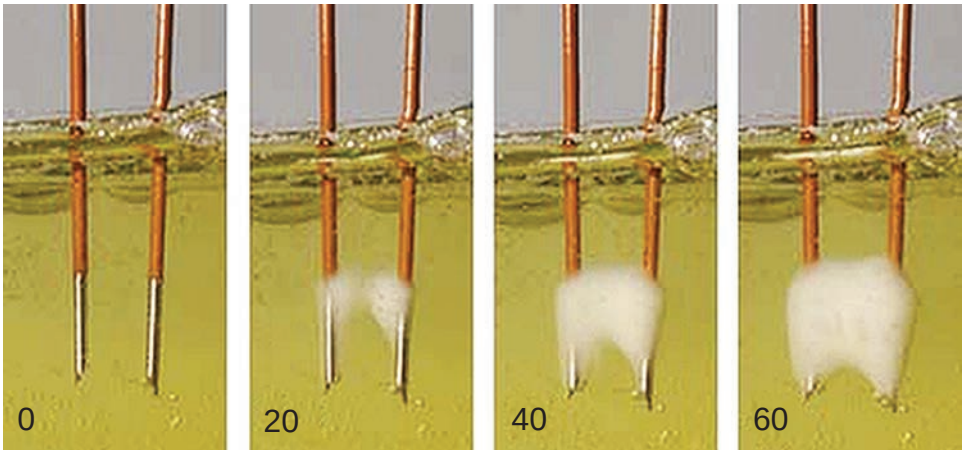


Figure 8-9.
Bipolar radiofrequency lesion. Two 10-cm SMK radiofrequency cannulae with 5-mm active tips are immersed in egg white, and a lesion is carried out at 90°C for 90 seconds. The lesion is maximal in size by 90 seconds of treatment and bridges between the two cannulae form only if they remain <6 mm apart. If the cannulae are spaced more than 6 mm apart, two discrete unipolar lesions are created. (Full data appear in Pino C, Hoeft M, Hofsess C, et al. Morphologic analysis of bipolar radiofrequency lesions: implications for denervation of the sacroiliac joint. *Reg Anesth Pain Med*. 2005;30:335–338.)

ease percutaneously, and radiofrequency treatments have been devised to treat this portion of the SI joint. Several techniques have been described; however, only preliminary results of efficacy have been reported. The two best described techniques will be covered in turn below: bipolar lesioning and cooled radiofrequency lesioning of the lateral branch sacral nerves.

Denervation of the posterior portion of the joint can be affected by producing a strip-like lesion along the posterior aspect of the joint, from the posterior-inferior portion of the joint cephalad to the posterior-superior iliac spine, the point above which access to the joint is obstructed by the overlying iliac crest. Using the bipolar lesion technique, denervation is accomplished by creating a strip lesion along the posterior aspect of the joint capsule. This is done by using two radiofrequency cannulae positioned parallel to one another, no more than 5 to 6 mm apart along the posterior aspect of the joint. One of the two cannulae is attached to the electrode port of the radiofrequency generator, and the other cannula is attached to the ground (reference) port. The resulting lesion extends between the two cannulae (Fig. 8-9). By placing the cannulae sequentially one above the other along the posterior portion of the SI joint, a strip lesion is created. Denervation of the posterior portion of the joint can also be affected by placing specific lesions to directly treat the medial branch nerves at the L4 and L5 levels as well as the lateral branch nerves at the S1, S2, and S3 levels (see detailed description below). In small case series and one controlled trial, this treatment has shown significant efficacy (about one-third of patients will receive 50% or greater pain reduction lasting an average of 12 months).

Positioning

The patient lies prone, with the head turned to one side (see Fig. 8-3). The C-arm is rotated 25 to 35 degrees caudally from the axial plane to place the posterior-superior iliac spine and the iliac crest cephalad along the line of the SI joint. The C-arm is then rotated obliquely 0 to 30 degrees toward the side opposite that to be treated until the posterior-inferior aspect of the SI joint is clearly visible (see Fig. 8-4). Two features of the SI joint are important to recognize. First, the SI joint is curvilinear, often arcing somewhat laterally toward the anterior aspect. This can lead to confusing overlying shadows of the anterior and posterior portion of the joint (see Fig. 8-10). The second important feature is the overlying iliac crest that can block access to the SI joint (see Fig. 8-5). Using caudal angulation of the C-arm and limiting injection to the inferior aspect of the joint are used to avoid placing a needle on the iliac crest rather than in the SI joint itself.

Block Technique: Bipolar Lesioning

The skin and subcutaneous tissues overlying the SI joint where the block is to be carried out are anesthetized with 1 to 2 mL of 1% lidocaine. Three 10-cm SMK cannulae with 5-mm active tips are used for bipolar radiofrequency lesioning. The first cannula is placed at the inferior-most aspect of the joint, and then a second cannula is placed 5 to 6 mm above the first cannula (Fig. 8-10). Care should be taken to ensure the cannulae are at the same depth so the active

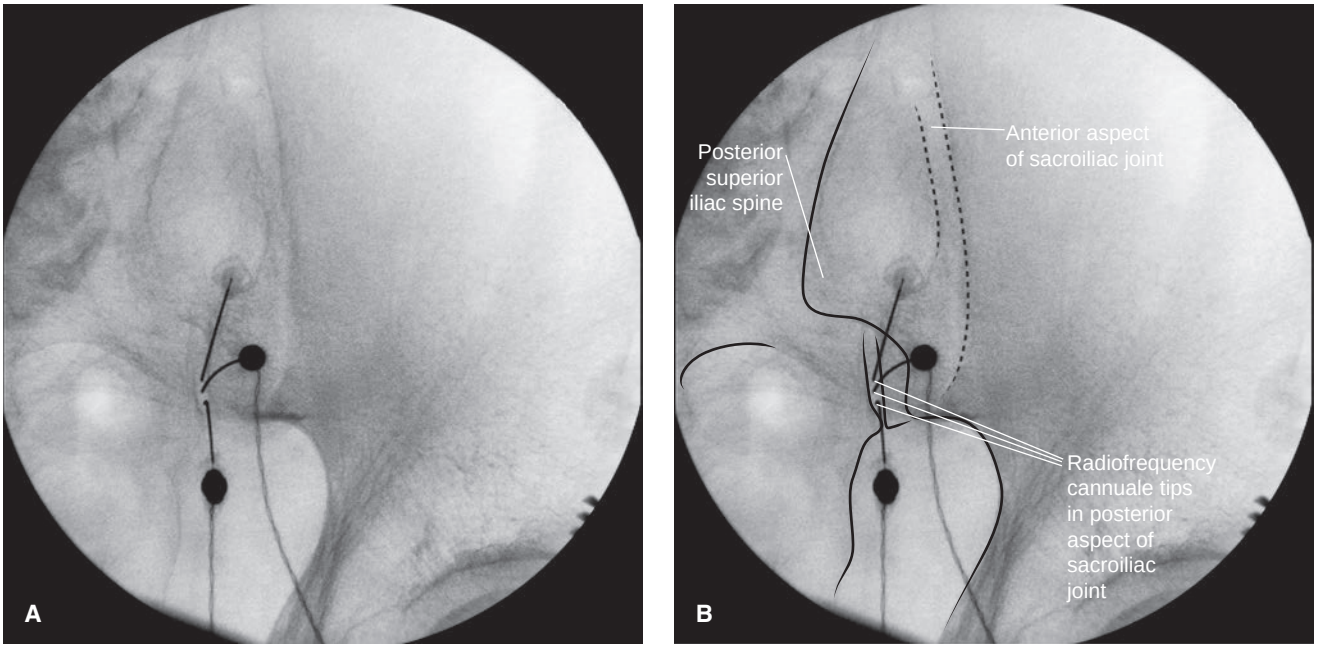


Figure 8-10.
Anterior-posterior radiograph of the SI joint during bipolar radiofrequency treatment of the SI joint. **A:** Three separate 22-gauge, 10-cm SMK cannulae with 5-mm active tips are in position over the posterior-inferior aspect of the right SI joint. One of the cannulae is attached to the active electrode output from the radiofrequency generator, and the other is attached to the ground (reference electrode) port. Lesions are created at 90°C for 90 to 120 seconds. While the first lesion is being produced, a third cannula is placed within 6 mm cephalad to the second cannula. A second lesion is then created between the second and the third cannulae, and additional cannulae are inserted just cephalad to the previous cannula along the entire posterior aspect of the SI joint. In this way, a series of connected lesions are created. The superior limit of the treatment is limited by access to the SI joint, which is blocked by the overlying posterior-superior iliac spine. **B:** Labeled image.

tips lie nearly parallel to one another. The depth of placement should be to the surface of the SI joint capsule where an increase in resistance to needle advancement is first felt. Because there are no major sensory or motor nerves in the region, there is no need or use for sensory or motor testing during this procedure. After placing 0.5 mL of 2% lidocaine through each cannula, a bipolar lesion is created by treating at 90°C for 120 seconds. While the first lesion is being produced, a third cannula can be placed 5 to 6 mm cephalad to the second cannula, and local anesthetic instilled (see Fig. 8-9). After the first lesion is complete, the second lesion can be started immediately. In this way, sequential lesions are created one above the other along the entire posterior and inferior aspect of the joint that is accessible. This usually results in a total of six to eight sequential lesions between the inferior pole of the joint and the point where further cephalad lesion creation is blocked by the posterior-superior iliac spine.

Block Technique: Lateral Branch Lesioning Using Cooled Radiofrequency

Lesioning of the sacral lateral branch nerves requires use of a combination of conventional and cooled radiofrequency techniques. Conventional radiofrequency cannulae rely on large voltage fluctuations in the radiofrequency energy range to produce movement of ions within the tissue adjacent to the active tip of the cannulae. This results in a lesion of predictable size that is independent of the impedance of the tissue surrounding the tip of the cannula. However, the lesion created using conventional thermal radiofrequency treatment is nearly entirely along the shaft of the needle, with little of the lesion extending anterior to the tip of the needle (Figs. 7-20 and 8-11). Thus, if a conventional radiofrequency cannula is placed perpendicular to the course of the nerve to be treated, the absence of any lesion anterior to the needle's tip is likely to result in sparing of the nerve to be treated. Cooled radiofrequency treatment employs cannulae that have a chamber within the shaft of the treatment cannulae through which cool water is continuously circulated. This cooling allows delivery of significantly greater energy without the boiling and tissue charring that would occur using conventional treatment cannulae at these higher energies. The resultant lesion is larger in size and, of most significance, extends directly anterior to the tip of the treatment cannula (Fig. 8-11). Radiofrequency cannulae can easily be placed perpendicular to the posterior sacral surface for treatment of the lateral branch nerves at the S1, S2, and

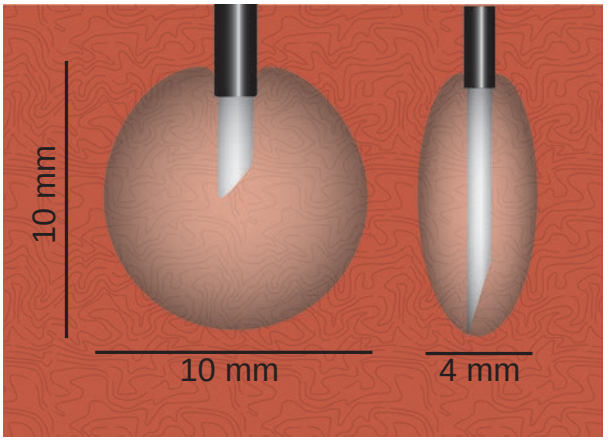


Figure 8-11.
Diagram demonstrating the difference in lesion size and shape between cooled (left) and conventional radiofrequency probes (right).

S3 levels, and use of cooled radiofrequency cannulae assures that there is ample lesion created anterior to the tip of the cannulae such that effective denervation is accomplished.

To perform this technique, conventional, thermal radiofrequency lesions are placed at the L4 and L5 levels and cooled radiofrequency lesions are placed around the lateral aspects of the S1, S2, and S3 foramina (Fig. 8-12). The skin and subcutaneous tissues overlying the transverse process of L5 and the sacral ala where the block is to be carried out are anesthetized with 1 to 2 mL of 1% lidocaine. Two 10-cm SMK cannulae with 5-mm active tips are placed and lesions created at these levels using a conventional technique as described for treatment of the medial branch nerves to the lumbar facets (see Chapter 7). Attention is then turned to treatment of the sacral lateral branch nerves. To assure proper and safe placement of the cooled radiofrequency lesions, the posterior sacral foramina at the S1, S2, and S3 levels must be identified. Many practitioners do this by placing a 25-gauge, 3.5-inch spinal needle through each of the sacral foramina and then leaving the spinal needle in place to guide position of the cooled radiofrequency lesions. Because there is great anatomic variation in the position of the lateral branch nerves from one individual to another, multiple lesions must be placed lateral to each foramen to assure adequate denervation. This is accomplished by placing a needle at the 2:30, 4:00, and 5:30 positions based on the face of a clock superimposed over each foramen (see Figs. 8-12, **Inset** and 8-13). Proper positioning of the cannulae can be facilitated by use of an epsilon-shaped radiographic marker over each foramen. Once each cannula has been positioned and 0.5 mL of 2% lidocaine has been instilled, a lesion is created using cooling-probe technology; the tissue temperature immediately adjacent to the cooled electrode is maintained at 60°C for 2.5 minutes at each level. Cooled radiofrequency lesions are created in a similar fashion sequentially surrounding each of the sacral foramina (see Figs. 8-12 and 8-13). Because there are no major motor nerves in the region, there is no need or use for motor testing during this procedure. This results in a total of eight sequential lesions surrounding the lateral aspects of the S1 through S3 foramina.

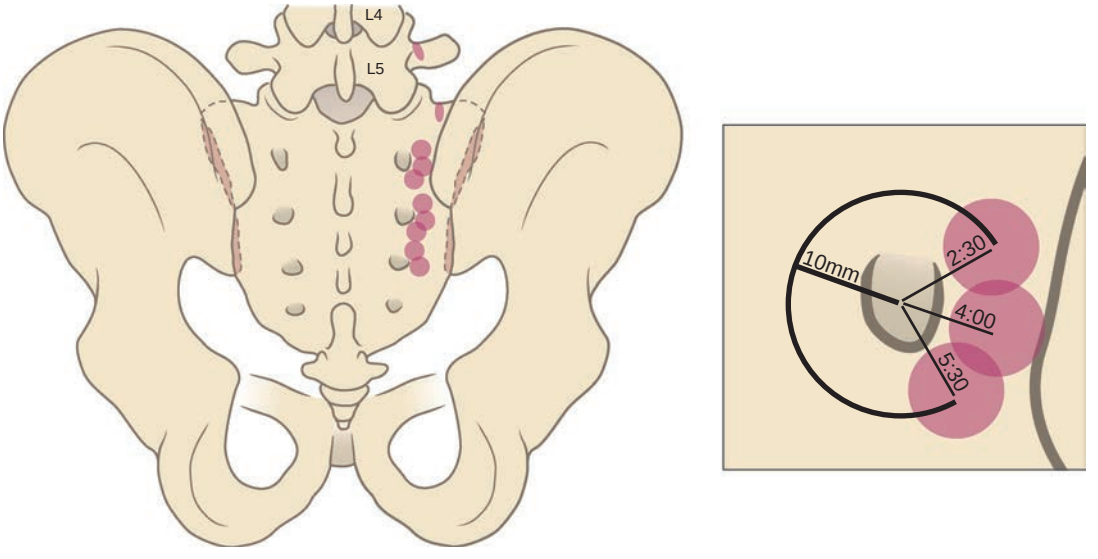
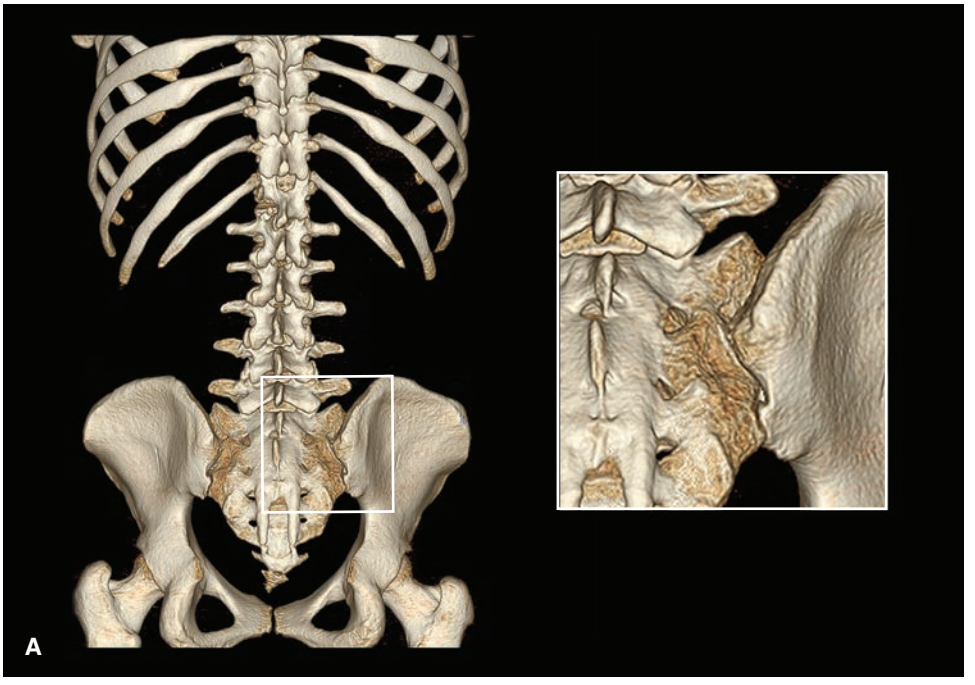
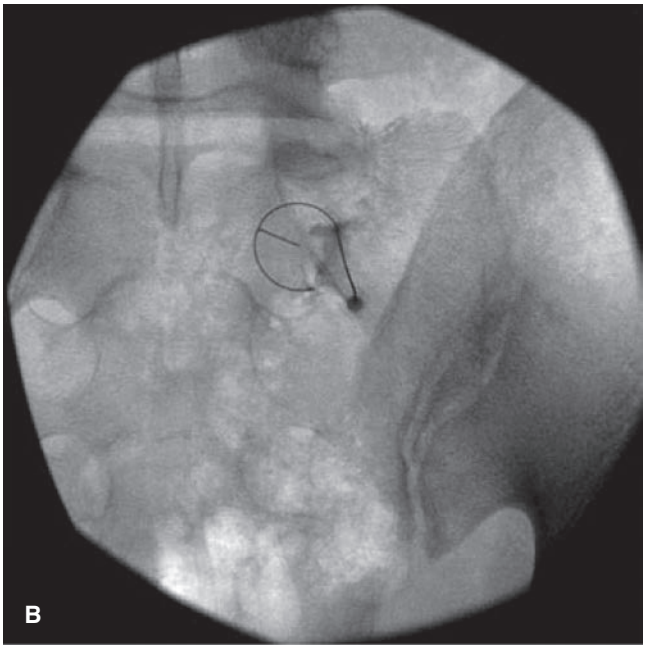


Figure 8-12.
Target points and the anticipated lesions for right-sided conventional (L4 and L5) and cooled (S1 to S3) radiofrequency denervation at the junction of the L5 superior articular and transverse processes (L4 primary dorsal ramus), the sacral ala (L5 primary dorsal ramus), and S1 to S3 foramina (lateral branches). Inset (right): Lesions should be placed at the 2:30, 4:00, and 5:30 positions relative to the face of a clock ~10 mm lateral to the center of each foramen.





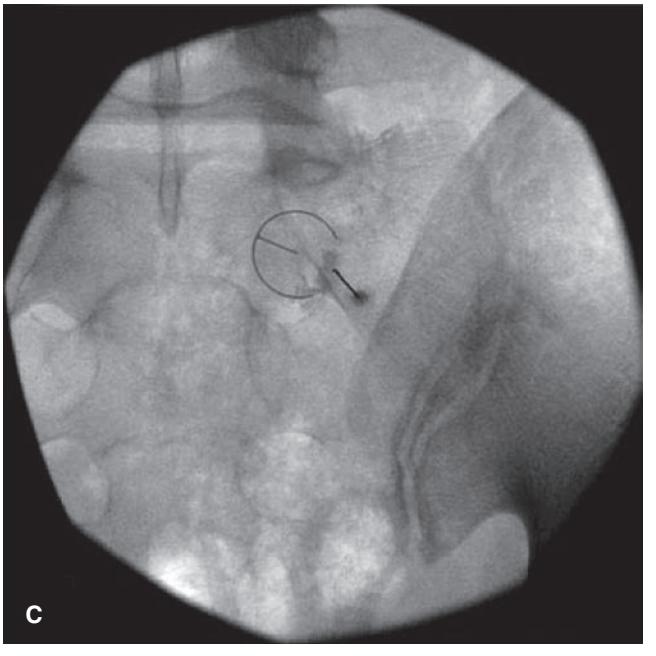


Figure 8-13.

A: Bony anatomy relevant to radiofrequency denervation of the SI joint using cooled radiofrequency technique for sacral lateral branch denervation. Three-dimensional reconstruction CT of the lumbar spine as viewed in the anterior-posterior projection used to perform SI denervation. **Inset** matches the anatomic area in the radiographs shown in **(B–E)**. **B:** Anterior-posterior radiograph of the SI joint during lateral branch block adjacent to the right S1 foramen. An epsilon-shaped radiographic marker is in place over the right S1 posterior sacral foramen, with the central arm of the marker at the medial aspect of the foramen. A 22-gauge spinal needle is in position seated on the posterior surface of the sacrum at the 2:30 position; 0.2 mL of radiographic contrast has been instilled. **C:** A 22-gauge spinal needle is in position seated on the posterior surface of the sacrum at the 4:00 position; 0.2 mL of radiographic contrast has been instilled. ***(Cont.)***

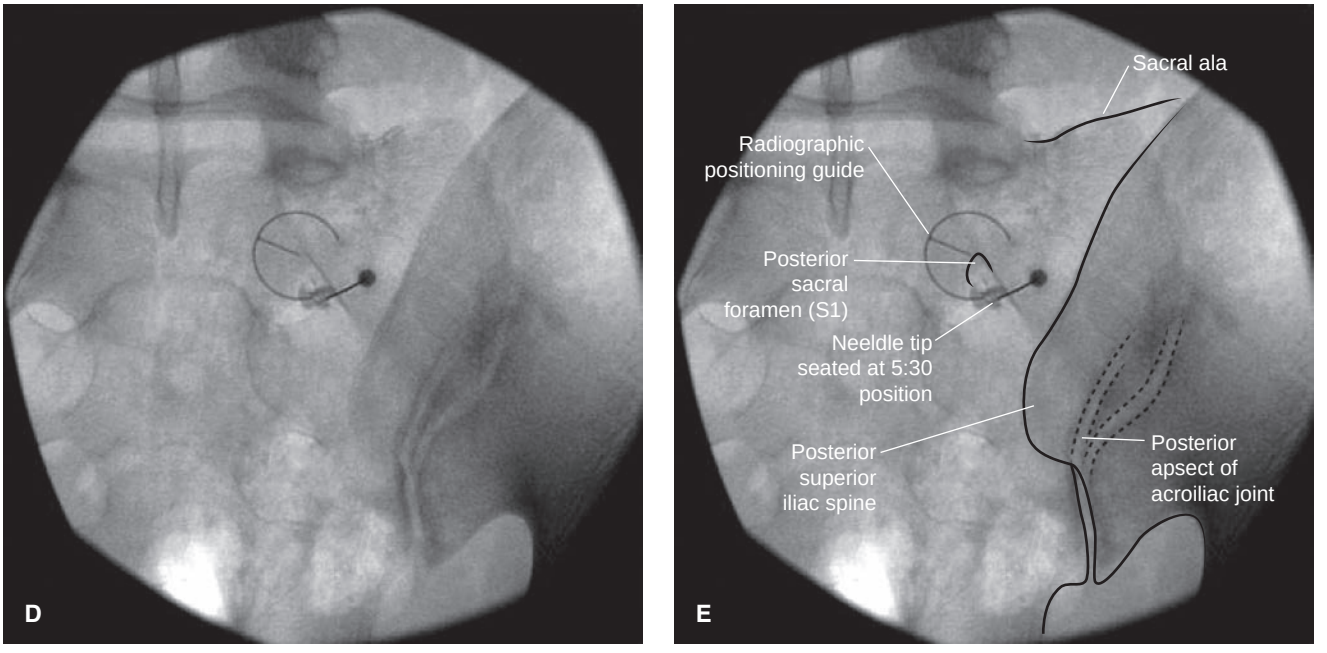


Figure 8-13. ***(Continued)***
D: A 22-gauge spinal needle is in position seated on the posterior surface of the sacrum at the 5:30 position; 0.2 mL of radiographic contrast has been instilled. **E:** Labeled image (**panel D**). (Radiographs in Fig. 8-13B–E are reproduced with permission from Dreyfuss P, Henning T, Malladi N, et al. The ability of multi-site, multi-depth sacral lateral branch blocks to anesthetize the sacroiliac joint complex. *Pain Med*. 2009;10:679–688.)

Complications of Radiofrequency Treatment of the Sacroiliac Joint

Patients should be warned of the typical postprocedural flare in pain symptoms that occurs after radiofrequency treatment of the SI joint. This results in an exacerbation of their typical pain lasting several days to a week. Major complications have not been reported with this radiofrequency procedure. Because there are no major nerves or blood vessels in the region, injury is unlikely. Similar to intra-articular injection, infection can also occur, leading to abscess within the presacral musculature; however, the incidence is exceedingly low. Some practitioners employ cannulae with 10-mm active tips for radiofrequency treatment of the SI joints. Great care should be taken to assure that the entire length of the active tip is well below the layer of the dermis before producing lesions. Direct thermal radiofrequency treatment within the dermis or epidermis can lead to open, fistulous tracts that are prone to secondary infection and must heal by secondary intention.

SUGGESTED READINGS

American Society of Anesthesiologists Task Force on Chronic Pain Management; American Society of Regional Anesthesia and Pain Medicine. Practice guidelines for chronic pain management: an updated report by the American Society of Anesthesiologists Task Force on Chronic Pain Management and the American Society of Regional Anesthesia and Pain Medicine. *Anesthesiology*. 2010;112:810–833.

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CHAPTER 9

Lumbar Discography and Intradiscal Treatment Techniques

OUTLINE

Overview

Discography is a diagnostic test in which radiographic contrast is injected into the nucleus pulposus of the intervertebral disc. Although originally developed for the study of disc herniation, discography is now used most commonly to identify symptomatic disc degeneration. There are two components of discography: (a) the anatomic appearance of contrast spread within the disc (using plain radiographs and/or computed tomography [CT]) and (b) the presence or absence of typical pain during contrast injection within the disc (pain provocation). The usefulness of discography remains controversial, and the last several years have seen an increase in the level of this controversy. Some clinicians continue to routinely use discography to identify symptomatic discs prior to surgical fusion, while others believe the test is of unproven benefit in identifying symptomatic discs. Discography remains the only test available that attempts to correlate pain response from the patient during provocation with abnormal discs discovered on imaging studies. Improved surgical outcomes following lumbar fusion have been reported when guided by the use of discography. However, a recent 10-year retrospective case-control study suggested that patients who underwent diagnostic discography had accelerated disc degeneration, disc herniation, loss of disc height and signal, and the development of reactive endplate changes compared to match-controls involving the control (normal) disc involved in the diagnostic discography procedure. Intradiscal electrothermal therapy (IDET) is a minimally invasive procedure that offers an alternative treatment to a subset of those patients with discogenic low back pain. Much like its use prior to fusion, discography is used to identify symptomatic intervertebral discs prior to IDET. During the past few years, close examination of the existing evidence has produced conflicting results, as the available controlled trials of IDET have produced conflicting results. The use of IDET in the treatment of symptomatic degenerative disc disease has declined dramatically in recent years. A description of IDET has been retained in this edition, as the technique remains available for clinical use. Several other intradiscal techniques have emerged, but the available evidence remains inconclusive. Among these techniques is plasma disc decompression (PDD), a technique that uses radiofrequency technology to reduce intradiscal pressure and treat patients with persistent radicular pain associated with small, contained disc herniations and disc bulges. One controlled trial is now available for this treatment technique and it is described in this chapter. Symptomatic degenerative disc disease remains common and the available treatments are unsatisfactory; undoubtedly, new intradiscal techniques will be developed in the near future.

Anatomy

The intervertebral discs are comprised of glucosaminoglycans with a relatively fluid inner nucleus pulposus surrounded by a stiff, lamellar outer annulus fibrosis. With aging, the hydration of the intervertebral discs declines, leading to loss of disc height and fissure formation in the annulus fibrosis. These fissures begin centrally near the border between the nucleus pulposus and the annulus fibrosis and can extend to the periphery of the disc space. This process of degradation is called internal disc disruption and is believed to be responsible for producing discogenic pain. These same radial fissures within the annulus represent paths through which nuclear material can pass and extrude as a herniation of nucleus pulposus. When this extruded material is adjacent to an exiting spinal nerve, it can lead to intense inflammation, spinal nerve compression, and radicular pain with or without radiculopathy (spinal nerve dysfunction in the form of numbness, weakness, and/or loss of deep tendon reflexes).

The lowest three lumbar intervertebral discs (L3/L4, L4/L5, and L5/S1) are most commonly associated with discogenic pain. The disc spaces at these levels can be entered safely using an oblique approach by placing a needle that passes near the junction of the transverse process and the superior articular process of the vertebra bordering the inferior aspect of the disc space to be studied. The needle then passes medially and inferior to the exiting spinal nerve to penetrate the posterolateral aspect of the annulus en route to the center of the disc space (Fig. 9-1). The L3/L4 disc space lies close to the axial plane, whereas the plane of the L4/L5 and L5/S1 discs follows the lumbar lordosis and is angled progressively in a cephalad-caudal direction. A clear grasp of the plane in which each disc is typically found and accurate alignment of the C-arm are essential to carrying out discography safely and successfully.

Patient Selection

The patient with low back or neck pain originating from the vertebral disc often presents with deep, aching, axial midline pain. Pain can be referred to the buttocks and posterior thigh from lumber discs but does not extend to the distal extremities. Patients with discogenic pain are often young and otherwise healthy; discogenic pain is common in those with jobs that require repetitive motion of the affected spine segment (e.g., package handlers) or that expose the spine to excessive vibration (e.g., long-distance truck drivers, helicopter pilots, jackhammer operators). Onset of symptoms is usually gradual. Pain is experienced with prolonged sitting (sitting intolerance), standing, and bending forward. The referred pain usually remains in the proximal part of the extremity. Results of physical examination are nonspecific, with limited range

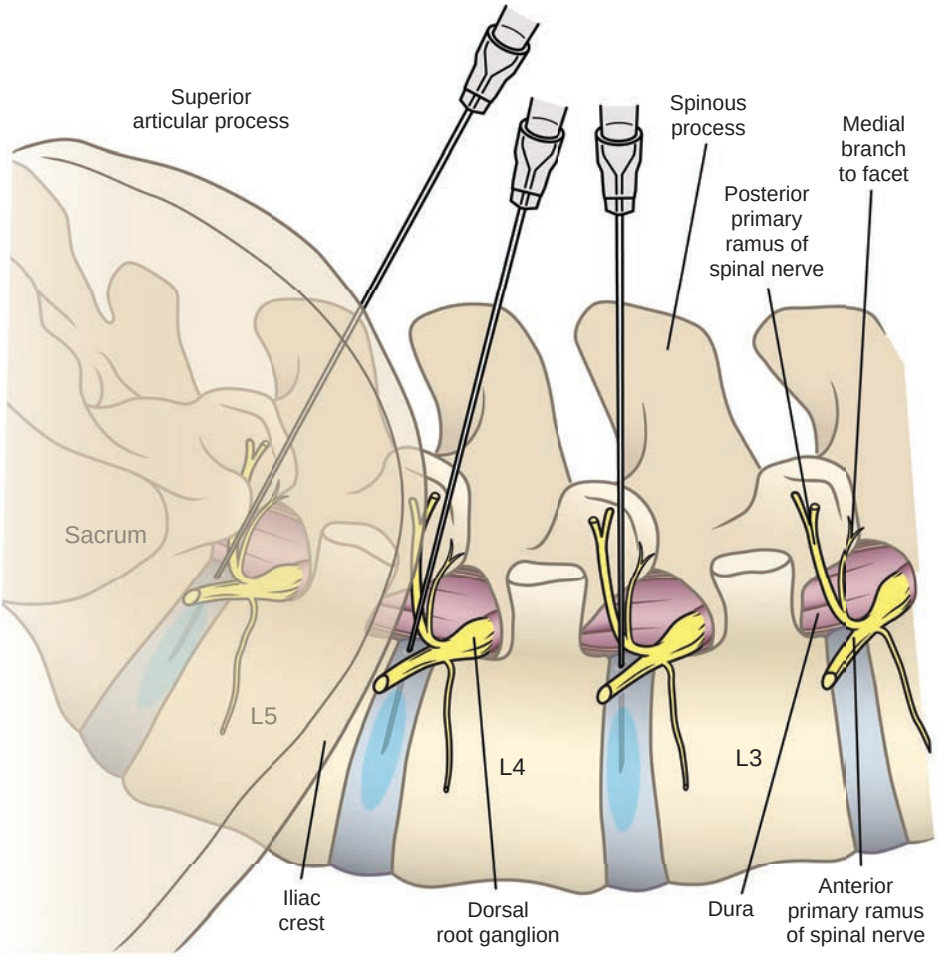


Figure 9-1.
Anatomy of the lumbar intervertebral discs (lateral view) during lumber discography. In general, the L3/L4 disc lies close to the axial plane, the L4/L5 disc is angled caudally 0 to 15 degrees, and the L5/S1 disc is angled caudally 25 to 35 degrees. Needles can be safely inserted into each disc through the posterolateral aspect of the annulus fibrosis, just caudal and medial to the spinal nerve, which traverses from just inferior to the pedicle within the intervertebral foramen in an anterior, lateral, and inferior direction.

of motion at the affected segment or pain with movement, particularly on flexion. Magnetic resonance imaging (MRI) and CT reveal only nonspecific findings, such as loss of disc height and/or hydration; these findings are often present without pain. The presence of a high-intensity zone on MRI at the posterior aspect of the disc indicates that a radial tear or fissure may be present in the annulus fibrosis, a nonspecific finding commonly found in those without back pain. Treatment for discogenic pain starts with conservative therapy, including physical therapy and oral nonsteroidal anti-inflammatory drugs (NSAIDs). In those with prolonged or disabling pain that is suspected to be of discogenic origin, provocative discography can help identify the affected level and guide targeted therapy. Patient selection for IDET and PDD is critical to assuring any benefit, as both procedures have shown modest benefits but only in highly selected patients. The selection criteria for these two intradiscal treatment techniques are discussed in the sections describing the techniques below.

Level of Evidence

Quality of Evidence and Grading of Recommendation			
Grade of Recommendation/Description	**Benefit vs. Risk and Burdens**	**Methodological Quality of Supporting Evidence**	**Implications**
RECOMMENDATION: *Diagnostic discography: Provocative discography may be considered for the evaluation of selected patients with suspected discogenic pain; it should not be used for routine evaluation of a patient with chronic nonspecific back pain.*			
2C/weak recommendation, low-quality or very low-quality evidence	Uncertainty in the estimates of benefits, risks, and burden; benefits, risk, and burden may be closely balanced	II-2: Observational studies or case series	Very weak recommendations; other alternatives may be equally reasonable
RECOMMENDATION: *Intradiscal Electothermal Therapy (IDET): IDET may be considered for young active patients with early single-level degenerative disc disease with well-maintained disc height.*			
2C/weak recommendation, low-quality or very low-quality evidence	Uncertainty in the estimates of benefits, risks, and burden; benefits, risk, and burden may be closely balanced	I: Randomized controlled trials (RCTs) with important limitations (inconsistent results, methodological flaws, indirect, or imprecise) and strong evidence from observational studies	Very weak recommendations; other alternatives may be equally reasonable
RECOMMENDATION: *Percutaneous Disc Decompression (PDD): PDD may be considered for patients with small (<3 mm) contained disc herniations and persistent radicular pain.*			
2B/weak recommendation, moderate-quality evidence	Benefits closely balanced with risks and burden balanced	I: Randomized controlled trials (RCTs) with important limitations (inconsistent results, methodological flaws, indirect, or imprecise) and strong evidence from observational studies	Weak recommendation, best action may differ depending on circumstances or patients' or societal values

The use of diagnostic discography has evolved rapidly in recent years. The addition of pressure monitoring during injection has become widespread and undergone careful scientific validation, and a number of more recent clinical trials have incorporated discography into patient selection criteria for treatment. Yet, the usefulness of this diagnostic test remains in question: advocates point to the fact that pain on provocation is highly suggestive as the disc as a source of pain and critics emphasize the subjective nature of the test and lack of a gold standard for validation. Emerging evidence from retrospective study suggests that there is accelerated disc degeneration within the disc that was previously normal (the control disc) over the decade following diagnostic discography. There are no definitive answers, but the controversy has led to a decline in the use of discography as a diagnostic test. Nonetheless, many practitioners and clinical investigators still rely on discography as the best available means to select patients with symptomatic degenerative disc disease for targeted treatment.

In no area of interventional pain is disagreement more apparent than when discussing expert recommendations regarding use of diagnostic discography. The American Pain Society (APS) Low Back Pain Guideline Panel published a report in 2009, concluding, "In patients with chronic non-radicular low back pain, provocative discography is not recommended as a procedure for diagnosing discogenic low back pain (strong recommendation, moderate-quality evidence)." Subsequently, the American Society of Anesthesiologists (ASA) Task Force on Chronic Pain Management published A 2010 Practice Guideline, offering the following recommendation: "Provocative discography may be considered for the evaluation of selected patients with suspected discogenic pain; it should not be used for routine evaluation

of a patient with chronic nonspecific back pain." Both guideline panels considered the same body of scientific evidence. The APS group cited the lack of any available gold standard against which to validate discography and the significant complications associated with the test, while the ASA group focused on the small number of uncontrolled trials suggesting that discography allows for improved patient selection for invasive treatments, including surgical lumbar fusion.

IDET has also been the subject of much debate. Two moderate-sized RCTs appeared during this decade, one demonstrating modest long-term reduction in back pain in a subset of patients and a second showing no benefit when compared to sham treatment; both trials were limited to patients with early degenerative disc disease at a single disc who reported concordant symptoms during discography. Several observational trials do suggest modest reduction in pain after treatment with IDET. The 2009 APS Low Back Pain Guideline Panel concluded, "IDET may be considered for young active patients with early single-level degenerative disc disease with well maintained disc height." The 2010 ASA Task Force on Chronic Pain Management made the following recommendation: "There is insufficient evidence to adequately evaluate benefits of … intradiscal electrothermal therapy (IDET) … for nonradicular low back pain." Despite the suggestive evidence that IDET may provide some pain reduction in young, active patients with early degenerative disc disease, many third party payers in the United States have eliminated reimbursement for this treatment and there has been a sharp decline in its use.

There are a number of emerging treatments for discogenic pain including the application of thermal energy to the annulus, injection of growth factors within the nucleus pulposus, or the injection of fibrin "glue" within the central disc: All await clinical validation. While no recommendations can be made about these treatments today, it seems more likely than not that some form of therapy requiring percutaneous access to the intervertebral discs will emerge from current scientific development efforts. Thus, the skills needed to place a needle within the intervertebral disc that are described in this chapter are likely to remain a core part of the skill set of interventional pain specialists.

Among intradiscal treatments that have undergone direct clinical validation, PDD is among the few, and thus it has been included in this discussion of intradiscal treatments. A single multicenter trial comparing the efficacy of PDD with transforaminal injection of steroids was conducted in patients with small, contained disc herniations and persistent radicular pain. The trial showed sustained reductions in leg pain and improvements in physical function during the 2-year follow-up period that were superior in those treated with PDD when compared to those receiving transforaminal steroid injections. It is important to emphasize that the group treated was highly selected: patients with small (<3 mm) disc protrusions and predominance of ongoing leg pain. Most patients with such small disc herniations are asymptomatic, and this group represents just 5% to 10% of patients with radicular symptoms. It is also important to emphasize that PDD is not meant to be used for the treatment of discogenic pain.

Diagnostic Lumbar Discography

Positioning

Lumbar discography is a painful procedure, even when performed by the most skilled practitioners. Intravenous sedation can facilitate the procedure; however, caution must be used to avoid oversedation, which could impede ongoing communication with the patient. The patient must be able to report paresthesiae before neural injury occurs. Discography also relies on the patient to report the location and severity of symptoms during provocation; thus, excessive sedation can make interpretation of the results difficult. The patient lies prone, with the head turned to one side (Fig. 9-2). A pillow is placed under the lower abdomen, above the iliac crest, in an effort to reduce the lumbar lordosis. Asking the patient to rotate the inferior aspect of the pelvis anteriorly toward the table will tip the iliac crests posteriorly and is often key to successfully performing discography at the L5/S1 level. The C-arm is rotated 25 to 35 degrees obliquely and centered on the disc space to be studied. The C-arm is then angled in a cephalad direction, the degree of which will vary from patient to patient, depending on the disc to be studied and each patient's degree of lumbar lordosis (see Fig. 9-2). In general, the L3/L4 disc lies close to the axial plane and requires no cephalad angulation to align the vertebral endplates (Fig. 9-3), the L4/L5 disc requires 0 to 15 degrees of cephalad angulation, and the L5/S1 disc requires 25 to 35 degrees of cephalad angulation (Fig. 9-4). Proper alignment of the C-arm is critical to the safety and success of discography.

Block Technique

The skin and subcutaneous tissues overlying the disc space where discography is to be carried out are anesthetized with 1 to 2 mL of 1% lidocaine, and additional local anesthetic is instilled liberally as the needle is advanced. A 22-gauge, 5-inch spinal needle is placed through the skin and advanced until it is seated in the tissues in a plane that is coaxial with the axis of the x-ray path (Figs. 9-3 to 9-5). A 7- or 8-inch spinal needle is often required in obese patients and is often needed at the L5/ S1 level due to the long and oblique trajectory to the disc space. Without careful use of a coaxial technique throughout the entire course of needle advancement, discography will require redirecting the needle multiple times, if it can be done successfully at all. The direction of the needle should be rechecked after every 1 to 1.5 cm of needle advancement and adjusted to remain coaxial. The position of the exiting spinal nerve beneath the pedicle should be kept in mind at all times, and efforts to

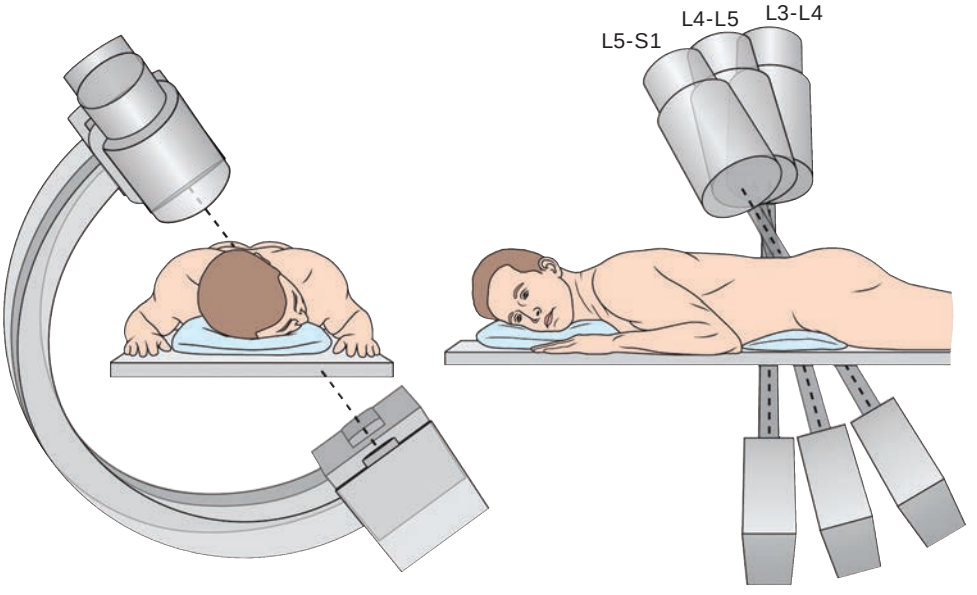


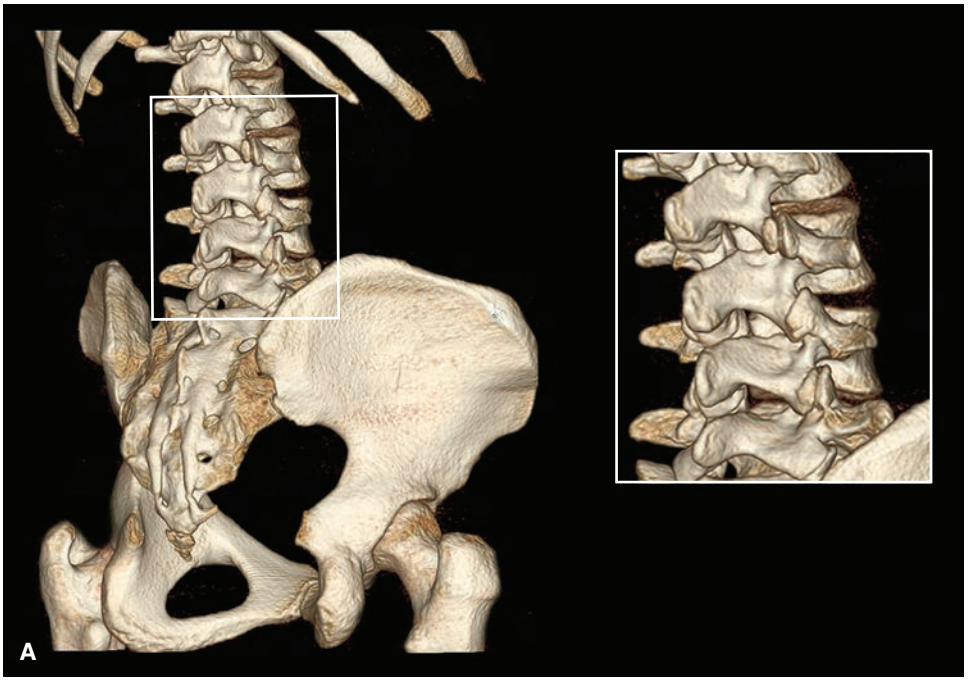
Figure 9-2.
Position for lumbar discography. The patient is placed prone with the head turned to one side. The C-arm is rotated 25 to 35 degrees obliquely and centered on the disc space to be studied. The C-arm is then angled in a cephalad direction that will vary from patient to patient, depending on the disc to be studied and each patient's degree of lumbar lordosis. In general, the L3/L4 disc lies close to the axial plane and requires no angulation to align the vertebral endplates, the L4/L5 disc requires 0 to 15 degrees of cephalad angulation, and the L5/S1 disc requires 25 to 35 degrees of cephalad angulation.

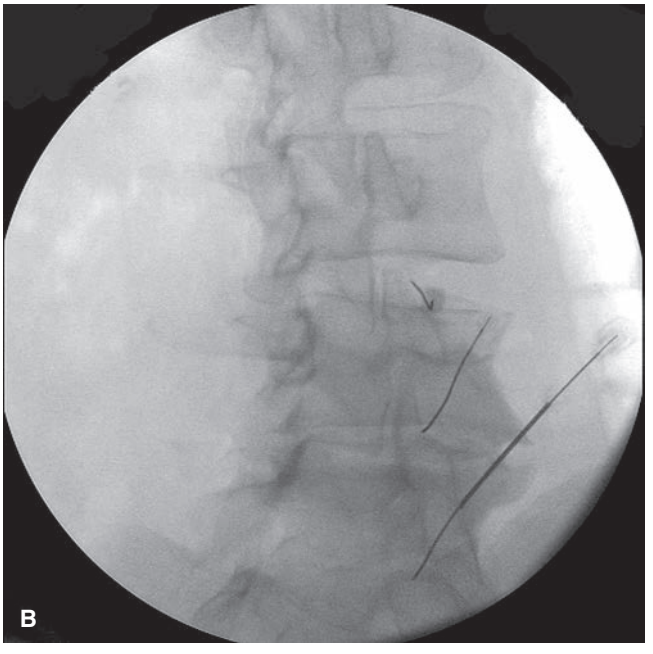
ensure the needle does not stray cephalad or lateral to the intended point over the middle of the disc will reduce the likelihood of striking the spinal nerve en route to the disc (Figs. 9-6 and 9-7). Once the needle is in contact with the surface of the disc, there will be a notable increase in resistance to needle placement. At this point, the C-arm should be rotated to a lateral position, and the needles should be advanced halfway from the anterior to the posterior margin of the disc (Fig. 9-8). Proper final placement is then checked in the anterior-posterior (AP) plane, where again the needle should be in the midportion of the disc space (Fig. 9-9). The nucleus pulposus occupies the central one-third of the disc space, and placement of the needle tip anywhere within the nucleus should suffice. The final needle path lies inferior to the exiting spinal nerve, and in many patients, it is difficult or impossible to position the needle exactly in the center of the disc (see Figs. 9-6 and 9-7).

Once the needles are in final position at all levels to be tested, provocative testing is conducted. A small volume of radiographic contrast containing antibiotic is placed at each level (<1.5 mL of iohexol 180 mg per mL containing 1 mg per mL of cefazolin). The contrast material is injected under live fluoroscopy to observe the pattern of contrast spread within the disc (Fig. 9-10). As the contrast is injected, the resistance to injection is noted and the patient is questioned about his or her symptoms. Some practitioners use an in-line pressure monitoring device to ensure excess pressure is not delivered during the provocative test. There is evidence that pain reproduction using small volumes without excessive pressure during injection correlates most closely with symptomatic discogenic pain; injection under high pressure or with large volumes may well produce pain even in normal discs. A concordant discogram result occurs when the patient reports his or her typical pattern of severe pain during injection at the level of suspected pathology and the same patient reports no pain on injection of an adjacent disc that is normal in appearance. After injection of all levels, final AP and lateral radiographs should be obtained to document the levels tested and the patterns of contrast spread during injection. Some practitioners advocate for subsequent CT to assess the patterns of disc disruption using axial imaging (Fig. 9-11), but the usefulness of CT-discography in planning subsequent therapy is unclear.

Complications of Lumbar Discography

The majority of patients will experience a marked exacerbation of their typical back pain in the days following discography. They should be warned to expect this and given a short course of oral analgesics for treatment of the exacerbation. Less commonly, injury to the exiting spinal nerve can occur. The position of the spinal nerve is in close proximity to the needle's path (see Fig. 9-1). Care must be taken to advance the needle slowly as it passes over the transverse process en route to the posterolateral margin of the disc. If the patient reports a paresthesia to the lower extremity, the needle should be withdrawn and redirected. Paresthesia will occur in a small proportion of patients, even with good technique. Persistent paresthesiae are uncommon and typically ensue only after repeated paresthesiae occur during the procedure. Infection can also occur,





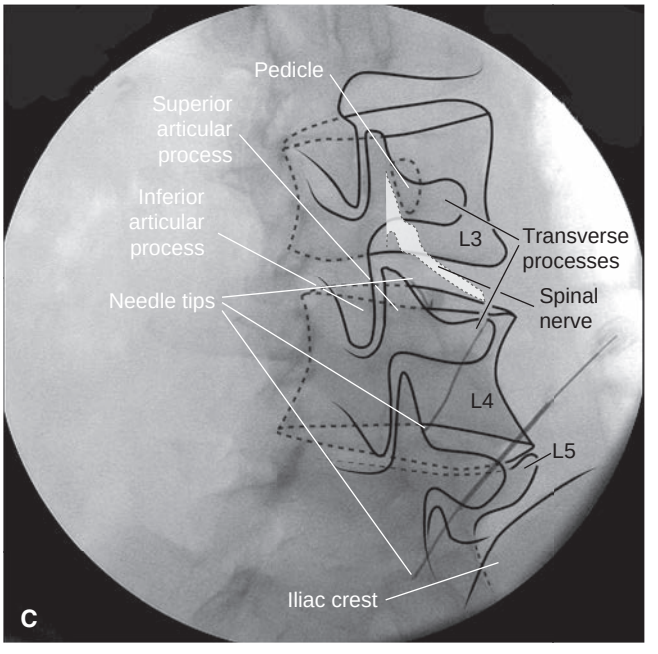


Figure 9-3.

A: Bony anatomy relevant to lumbar discography at the L3/L4 level. Three-dimensional reconstruction CT of the lumbar spine as viewed in the oblique projection used to perform lumbar discography at the L3/L4 level. **Inset** matches the anatomic area in the radiographs shown in **(B,C)**. **B:** Oblique radiograph during lumbar discography (L3/L4). The superior endplate of the L4 vertebral body is nearly aligned with the inferior endplate of the L3 vertebral body. The junction of the L4 transverse process with the superior articular process lies just caudal to the L3/L4 disc space. A needle is directed slightly superior and posterior toward the L3/L4 disc space. **C:** Labeled figure. The approximate location of the L3 spinal nerve is shown as it traverses inferior to the L3 pedicle and courses in an anterior, lateral, and inferior direction, well superolateral to the path of the needle as it enters the disc space.

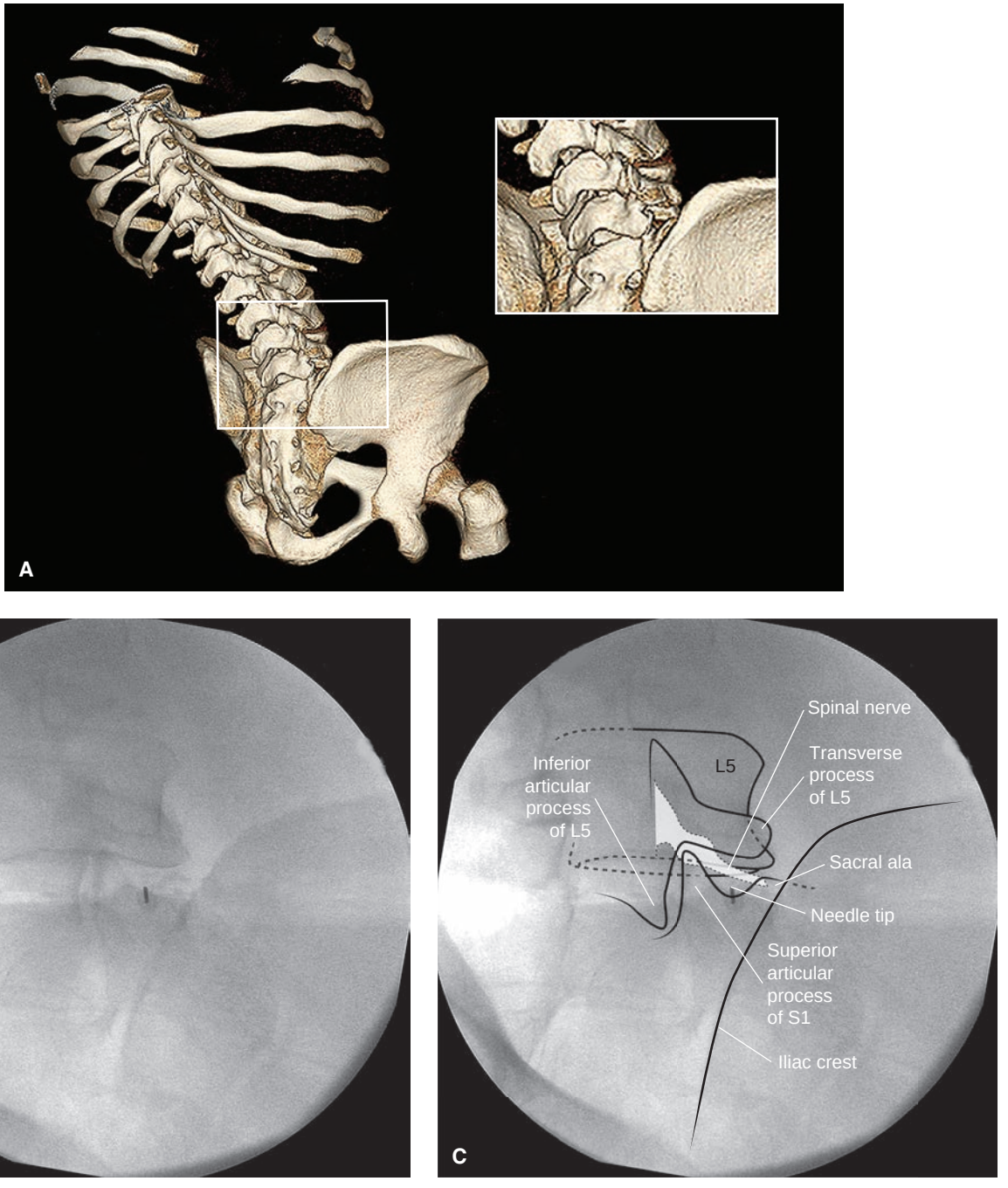


Figure 9-4.

A: Bony anatomy relevant to lumbar discography at the L5/S1 level. Three-dimensional reconstruction CT of the lumbar spine as viewed in the oblique projection with marked cranial angulation used to perform lumbar discography at the L5/S1 level. **Inset** matches the anatomic area in the radiographs shown in **(B,C)**. Oblique radiograph during lumbar discography (L5/S1). **B:** The superior end plate of the sacrum is aligned with the inferior end plate of the L5 vertebral body. The junction of the sacral ala with the superior articular process of the sacrum lies just caudal to the L5/S1 disc space. The iliac crest overlies the anterior portion of the L5/S1 disc space, and its position often makes placing a needle for L5/S1 discography difficult. A needle is directed slightly superior toward the L5/S1 disc space. **C:** Labeled figure. The approximate location of the L5 spinal nerve is shown as it traverses inferior to the L5 pedicle and courses in an anterior, lateral, and inferior direction, just superolateral to the path of the needle as it enters the disc space.

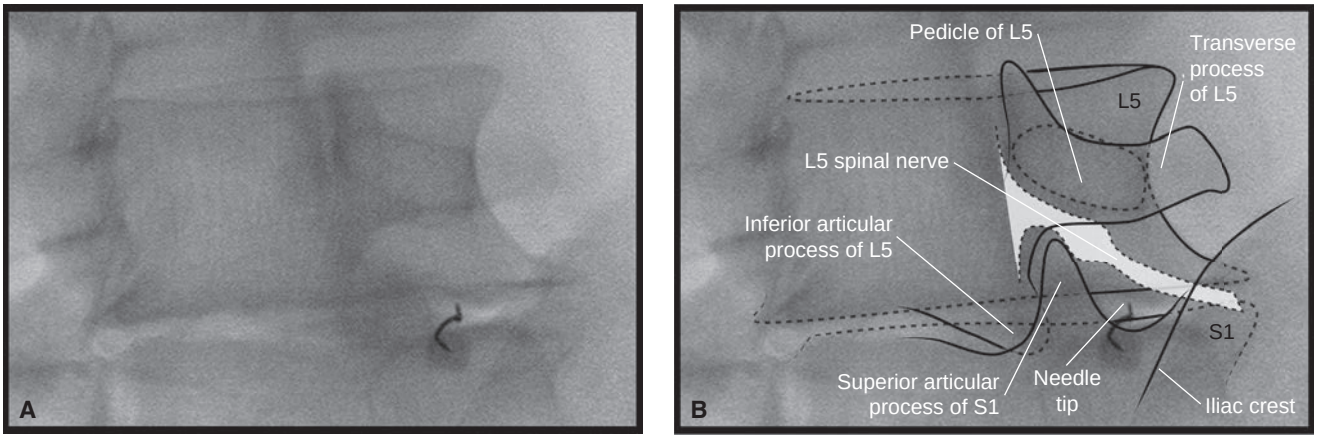


Figure 9-5.
Oblique radiograph during lumbar discography (L5/S1 in a patient with advanced disc degeneration and near complete loss of disc height). **A:** The superior end plate of the sacrum is aligned with the inferior end plate of the L5 vertebral body. Note the minimal remaining disc space. Discography can be difficult or impossible in those with markedly diminished disc height, and intradiscal treatments such as IDET should not be attempted unless disc height is well preserved. The junction of the sacral ala with the superior articular process of the sacrum lies just caudal to the L5/S1 disc space. The iliac crest overlies the anterior portion of the L5/S1 disc space, and its position often makes placing a needle for L5/S1 discography difficult. A needle is directed slightly superior toward the L5/S1 disc space. **B:** Labeled figure. The approximate location of the L5 spinal nerve is shown as it traverses inferior to the L5 pedicle and courses in an anterior, lateral, and inferior direction, just superolateral to the path of the needle as it enters the disc space.

leading to abscess within the presacral musculature, but the incidence is exceedingly low. Infection within the disc space (discitis) is the most feared complication of discography and occurs with an incidence of <1:1,000. Treatment of discitis may require long-term administration of intravenous antibiotics and/or the need for surgical removal of the infection. There have been no cases of discitis reported to date in patients who have received intradiscal antibiotics during discography. Bleeding complications have not been associated with discography. Recent data from a long-term, case-control retrospective study examined changes in normal discs used as controls during the years following discography suggest that modern discography techniques using small-gauge needle and limited pressurization resulted in accelerated disc degeneration, disc herniation, loss of disc height and signal, and the development of reactive endplate changes compared to matched controls. Careful consideration of the risks and benefits must be given when recommending procedures involving disc injection.

Intradiscal Electrothermal Therapy

In those patients who have early degenerative disc disease with preservation of near normal disc height (>75% of normal disc height remaining), but severe ongoing back pain that does not improve with conservative therapy, IDET (Smith & Nephew Orthopaedics, Memphis, TN) may lead to modest reduction in back pain in some patients. Spinal fusion is usually reserved for those patients with more advanced disc degeneration. Patients who are most suitable for IDET are those with concordant pain on discography at one spinal level and no pain during provocation of an adjacent control disc. IDET makes use of a navigable thermal resistance wire that is placed percutaneously and positioned along the posterior aspect of the annulus fibrosis (Fig. 9-12). Once in position, the disc is heated using a standardized protocol. Prospective studies have demonstrated significant pain reduction and improvement in physical function in 30% to 50% of patients who met these strict treatment criteria and who received IDET.

Positioning

Like discography, IDET is a painful procedure, even when performed by the most skilled practitioners. Intravenous sedation can facilitate the procedure, but a level of sedation that allows for ongoing communication with the patient is essential. The patient must be able to report paresthesiae or excess discomfort during the intradiscal treatment before neural injury occurs. Placement of the cannulae for IDET is identical to that for needle placement during discography. The patient lies prone, with the head turned to one side (see Fig. 9-2). A pillow is placed under the lower abdomen, above the iliac crest, in an effort to reduce the lumbar lordosis. The C-arm is rotated 25 to 35 degrees obliquely and centered on the disc space to be studied. The C-arm is then angled in a cephalad direction that will vary from patient to patient, depending on the disc to be studied and each patient's degree of lumbar lordosis (see Fig. 9-2). In general, the L3/L4 disc lies close to the axial plane and requires no cephalad angulation to align the vertebral endplates (see Fig. 9-3), the L4/L5 disc requires 0 to 15 degrees of cephalad angulation, and the

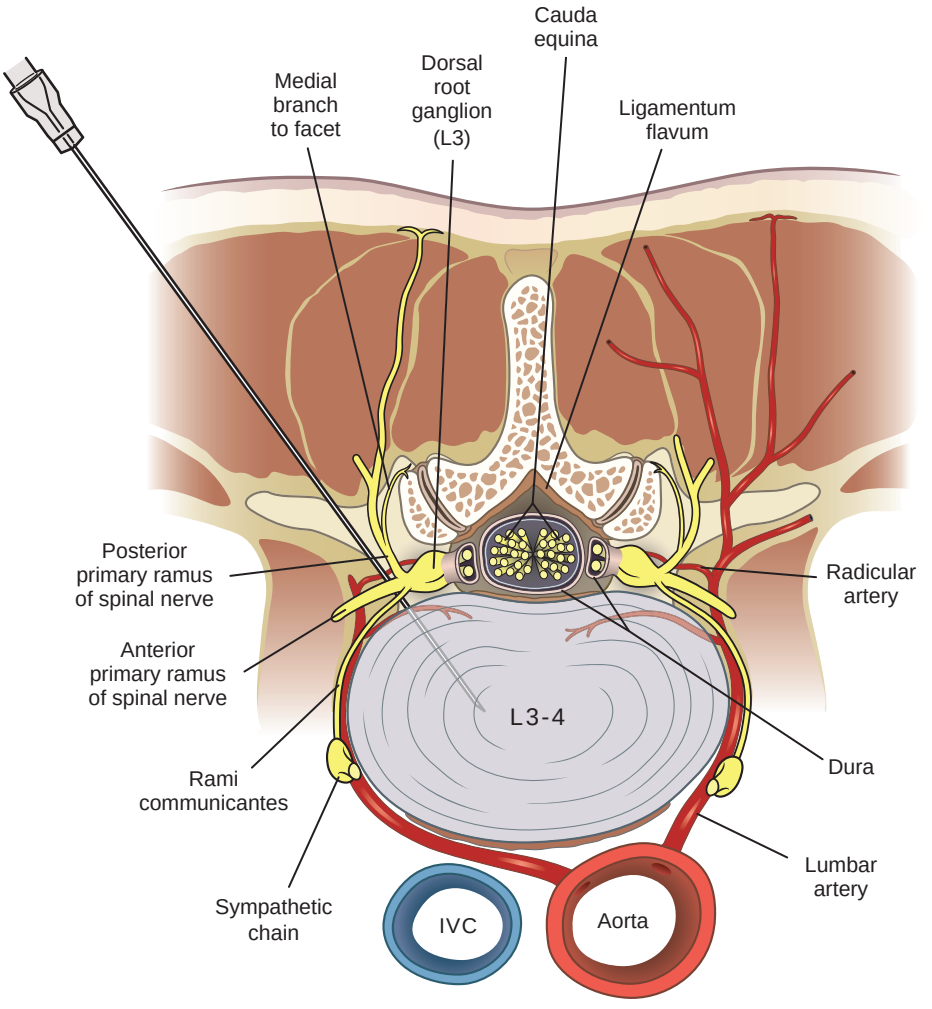


Figure 9-6.
Axial diagram of L3/L4 discography. The needle enters the posterolateral aspect of the intervertebral disc, just inferomedial to the exiting L3 spinal nerve.

L5/S1 disc requires 25 to 35 degrees of cephalad angulation (see Fig. 9-4). Proper alignment of the C-arm is critical to the safety and success of IDET.

Block Technique

The technique for placing the introducer cannulae through which the IDET catheter is introduced into the disc is similar to that for needle placement for discography. However, the final position of the introducer is best placed in the anterolateral aspect of the nucleus, rather than in the central portion of the nucleus. This allows for a more gradual angle as the IDET catheter exits the introducer and curves around the inner aspect of the annulus (see Fig. 9-12). The skin and subcutaneous tissues overlying the disc space where IDET is to be carried out are anesthetized with 1 to 2 mL of 1% lidocaine, and additional local anesthetic is instilled liberally as the cannulae are advanced. A 17-gauge introducer supplied by the manufacturer is placed through the skin and advanced until it is seated in the tissues in a plane that is coaxial with the axis of the x-ray path (Fig. 9-13). The IDET introducer is stiff and easy to redirect as it is advanced. The direction of the cannula should be rechecked after ever 1 to 1.5 cm of needle advancement and adjusted to remain coaxial. The position of the spinal nerve beneath the pedicle should be kept in mind at all times, and efforts to ensure the cannula does not stray cephalad or lateral to the intended point over the middle of the disc will reduce the likelihood of striking the spinal nerve en route to the disc (see Figs. 9-6 and 9-7). Once the cannula is in contact with the surface of the disc, there will be a notable increase in resistance to needle placement. At this point, the C-arm should be rotated to a lateral position, and the cannula advanced halfway from the anterior to the posterior margin of the disc (Fig. 9-14A). Proper final placement is then checked in the AP plane, where again the cannula's tip should be in the midportion of the disc space (Fig. 9-14B).

Once the IDET introducer is in a satisfactory position, the navigable thermal resistance catheter (SpineCATH, Smith & Nephew Orthopaedics, Memphis, TN) is introduced. The tip of the catheter slides along the medial circumference of the annulus and can be guided by gently

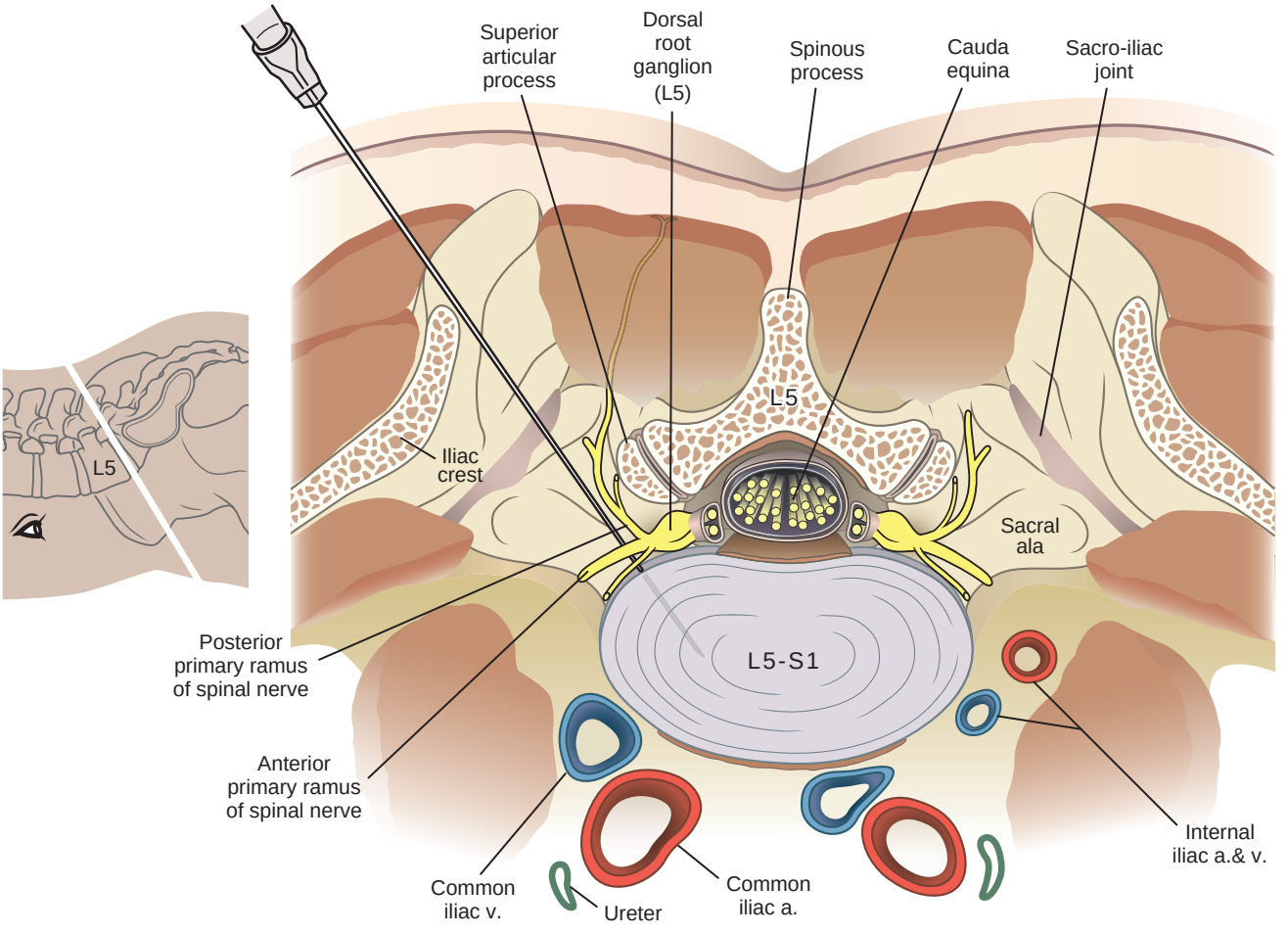


Figure 9-7.
Axial diagram of L5/S1 discography. The needle enters the posterolateral aspect of the intervertebral disc, just inferomedial to the exiting L5 spinal nerve. Note the position of the overlying iliac crest that often obscures direct needle placement. The **inset** indicates the approximate plane of the L5/S1 disc and needle.

rotating the proximal end of the catheter. The catheter is first advanced beyond the tip of the introducer and into the disc space using lateral radiography (see Fig. 9-14A). When the tip of the catheter passes to the posterior aspect of the annulus and begins to traverse along the posterior annulus, the C-arm is then rotated to the AP view, and the catheter is advanced into final position across the entire posterior annulus (see Fig. 9-14B). The catheter has two radiopaque guides that indicate the active treatment portion of the catheter, and these markers should be positioned to either side of the disc to indicate that the entire posterior annulus will be treated (see Fig. 9-14B). This brief description is overly simplistic. In actuality, guiding the IDET catheter into final position can be quite challenging and requires delicate manipulation of the catheter to keep the tip from advancing into radial tears within the annulus. Overly aggressive handling of the catheter will cause it to kink, and once kinked, it will be difficult or impossible to steer.

Once the catheter is in final position, heat is introduced using a specific protocol designed to gradually raise the temperature within the disc to 80°C to 90°C and maintain that temperature for a minimum treatment period, typically 14 to 16 minutes. It is important that the patient is not overly sedated during the actual heat treatment so he or she can report discomfort due to excess heat, before neural injury occurs.

Complications of IDET

Patients should be warned of the typical postprocedural flare in pain symptoms that occurs after IDET. This results in an exacerbation of their typical axial back pain, often lasting several days to weeks. Less commonly, injury to the spinal nerve can occur. The position of the spinal nerves is in close proximity to the needle's path (see Fig. 9-1). Care must be taken to advance the needle slowly as it passes over the transverse process en route to the posterolateral margin of the disc. If the patient reports a paresthesia to the lower extremity, the needle should be withdrawn and redirected. Paresthesia will occur in a small proportion of patients, even with good technique. Persistent paresthesiae are uncommon and typically ensue only after repeated paresthesiae occur during the procedure.

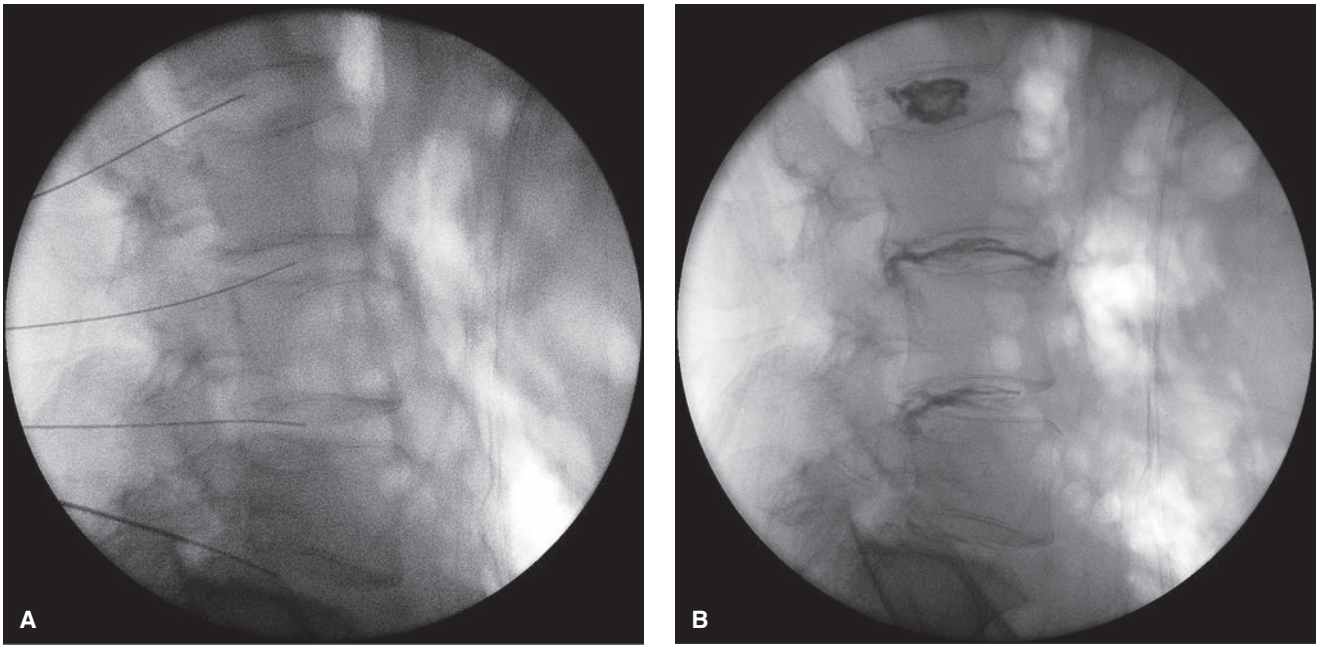


Figure 9-8.
A: Lateral radiograph of the lumbar spine with needles in final position for lumbar discography at the L2/L3, L3/L4, L4/L5, and L5/S1 levels. All needles are positioned within the central 1/3 of the intervertebral disc. **B:** Lateral radiograph of the lumbar spine following lumbar discography at the L2/L3, L3/L4, L4/L5, and L5/S1 levels. Disc height is normal at the L2/L3 level and minimally reduced at the L3/L4, L4/L5, and L5/S1 levels. Discogenic pain was suspected based on persistence of low back pain and loss of T2-weighted signal on MRI within the central disc at the L3/L4 and L4/L5 levels (not shown). The L2/L3 discogram has the characteristic bilobed appearance of normal contrast spread within the nucleus pulposus, without any contrast extension into the annulus fibrosus. The L3/L4 and L4/L5 discograms have diffuse linear spread of the dye to the limits of the annulus fibrosus. There is greater anterior extension of the contrast at the L3/L4 level and the L4/L5 level with contrast extending all the way to the limits of the annulus posteriorly at both levels. The L5/S1 discogram also appears normal. The axis of the L5/S1 disc is tilted in a cephalad-to-caudad direction relative to the x-ray path. Note that the call for discography at four adjacent levels is extremely uncommon. In this case, provocation produced symptoms at the L3/L4 and L4/L5 levels and the L5/S1 level were asymptomatic. The L2/L3 disc was then tested as an adjacent control above the symptomatic levels and produced no pain on provocation. Thus the symptomatic levels based on provocative discography were L3/L4 and L4/L5 alone.

The key to successful outcome following IDET is strict adherence to a structured rehabilitation program that guides the patient through gradual increases in physical activity over a 6-week to 3-month time period. The rehabilitation following IDET is similar to the programs used following lumbar fusion. Thermal injury to the cauda equina has been reported following IDET with severe neuropathic pain in the lower extremities, as well as bowel and bladder dysfunction. Injury to the cauda equina is more likely to occur when there is an insufficient posterior annulus and the thermal catheter lies in close proximity to the thecal sac. The catheter can also exit the disc space to enter the epidural space; however, this should be evident before treatment on lateral radiographs. Ensuring the patient is awake enough to report excessive discomfort during the IDET treatment should reduce the chances of significant neural injury.

Finally, overly aggressive handling of the IDET catheter leads to kinking of the catheter near the point where it exits the tip of the introducer within the intervertebral disc. Repeated attempts to reposition the catheter once it is kinked can lead to shearing of the catheter tip.

Plasma Disc Decompression

In those patients who have early degenerative disc disease with preservation of near normal disc height (>50% of normal disc height remaining) and a broad-based disc bulge or small disc protrusion (<3 mm in maximum dimension extending beyond the normal contour of the adjacent outer annulus fibrosis) and severe ongoing radicular pain that does not improve with conservative therapy, PDD (Nucleoplasty, ArthroCare Corporation, Austin, TX) has appeared as a promising new treatment. Broad-based disc bulges and small disc protrusions can cause persistent spinal nerve irritation and ongoing leg pain in some individuals. Surgical discectomy is a poor treatment option, as there is no disc herniation that can be removed without further disruption

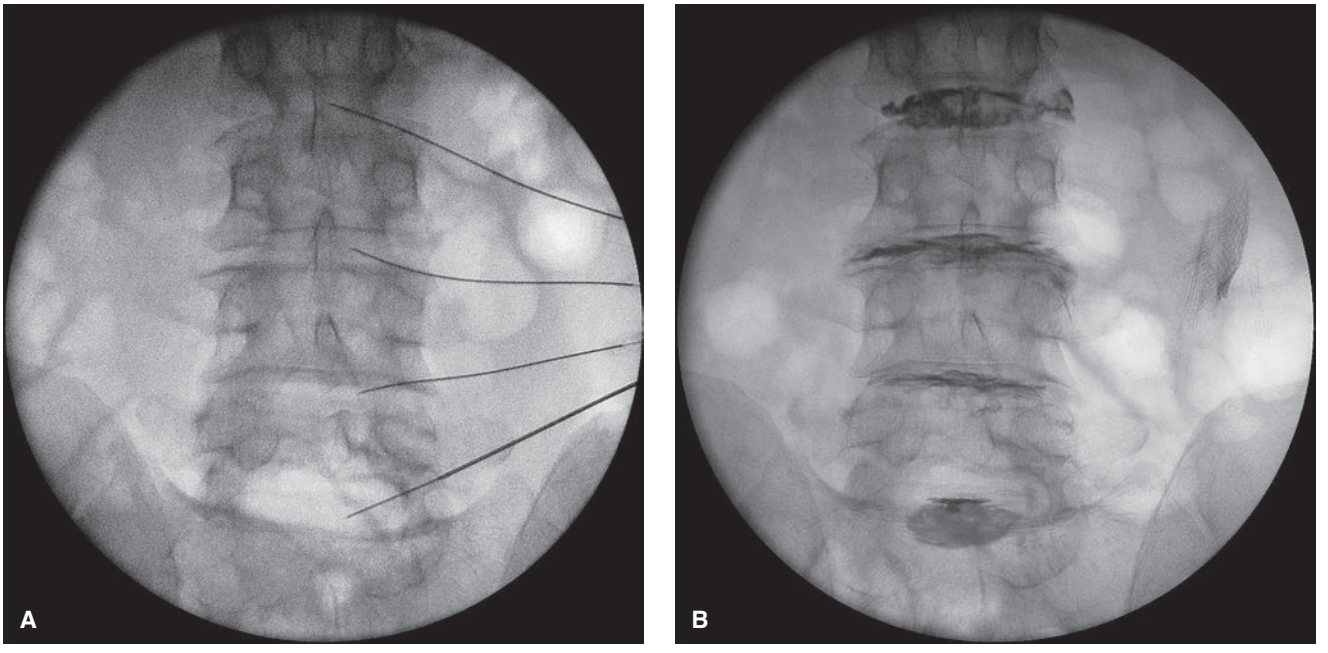


Figure 9-9.

A. AP radiograph of the lumbar spine with needles in final position for lumbar discography at the L2/L3, L3/L4, L4/L5, and L5/S1 levels. All needles are positioned within the central 1/3 of the intervertebral disc. **B.** AP radiograph of the lumbar spine following lumbar discography at the L2/L3, L3/L4, L4/L5, and L5/S1 levels. Disc height is normal at the L2/L3 level and minimally reduced at the L3/L4, L4/L5, and L5/S1 levels. Discogenic pain was suspected based on persistence of low back pain and loss of T2-weighted signal on MRI within the central disc at the L3/L4 and L4/L5 levels (not shown). The L2/L3 discogram has the characteristic bilobed appearance of normal contrast spread within the nucleus pulposus, with a small volume of contrast extending into the annulus fibrosus on the right. The L3/L4 and L4/L5 discograms have diffuse linear spread of the dye to the limits of the annulus fibrosus on both left and right sides. The L5/S1 discogram also appears normal. The circular appearance of the contrast is caused by the normal lumbar lordosis. The axis of the L5/S1 disc is tilted in a cephalad-to-caudad direction relative to the x-ray path. Note that the call for discography at four adjacent levels is extremely uncommon. In this case, provocation produced symptoms at the L3/L4 and L4/L5 levels and the L5/S1 level were asymptomatic. The L2/L3 disc was then tested as an adjacent control above the symptomatic levels and produced no pain on provocation. Thus the symptomatic levels based on provocative discography were L3/L4 and L4/L5 alone.

of the outer annulus, which potentially increases the risk for recurrent disc herniation. Thus this small, but important group of patients has often gone untreated. Patients with evidence of extruded or sequestered disc herniation should not be considered for PDD. PDD makes use of a variant of radiofrequency technology that delivers a focused energy field between closely spaced electrodes at the tip of a rigid treatment probe (SpineWand, ArthroCare Corporation, Austin, TX) (Fig. 9-15). The PDD devices use radiofrequency energy to excite electrolytes in a conductive medium, such as saline solution, creating a focused plasma. The energized particles in the plasma have sufficient energy to break molecular bonds, excising or dissolving soft tissue at temperatures typically ranging between 40°C and 70°C. When applied within the central nucleus pulposus, PDD creates a series of channels within the disc, thereby reducing intradiscal pressure and reducing the size of the disc protrusion. Once the device is in position, the disc is treated using a standardized protocol. In study patients who had radicular pain associated with a contained lumbar disc herniation, those patients treated with PDD had significantly reduced pain and better quality of life scores than those treated using repeated transformational epidural steroid injections, with sustained improvement extending to 2 years beyond treatment.

Positioning

Like discography, PDD is a painful procedure, even when performed by the most skilled practitioners. Intravenous sedation can facilitate the procedure, but a level of sedation that allows for ongoing communication with the patient is essential. The patient must be able to report paresthesiae or excess discomfort during the intradiscal treatment before neural injury occurs. Placement of the cannulae for PDD is identical to that for needle placement during discography. The patient lies prone, with the head turned to one side (see Fig. 9-2). A pillow is placed under the lower abdomen, above the iliac crest, in an effort to reduce the lumbar

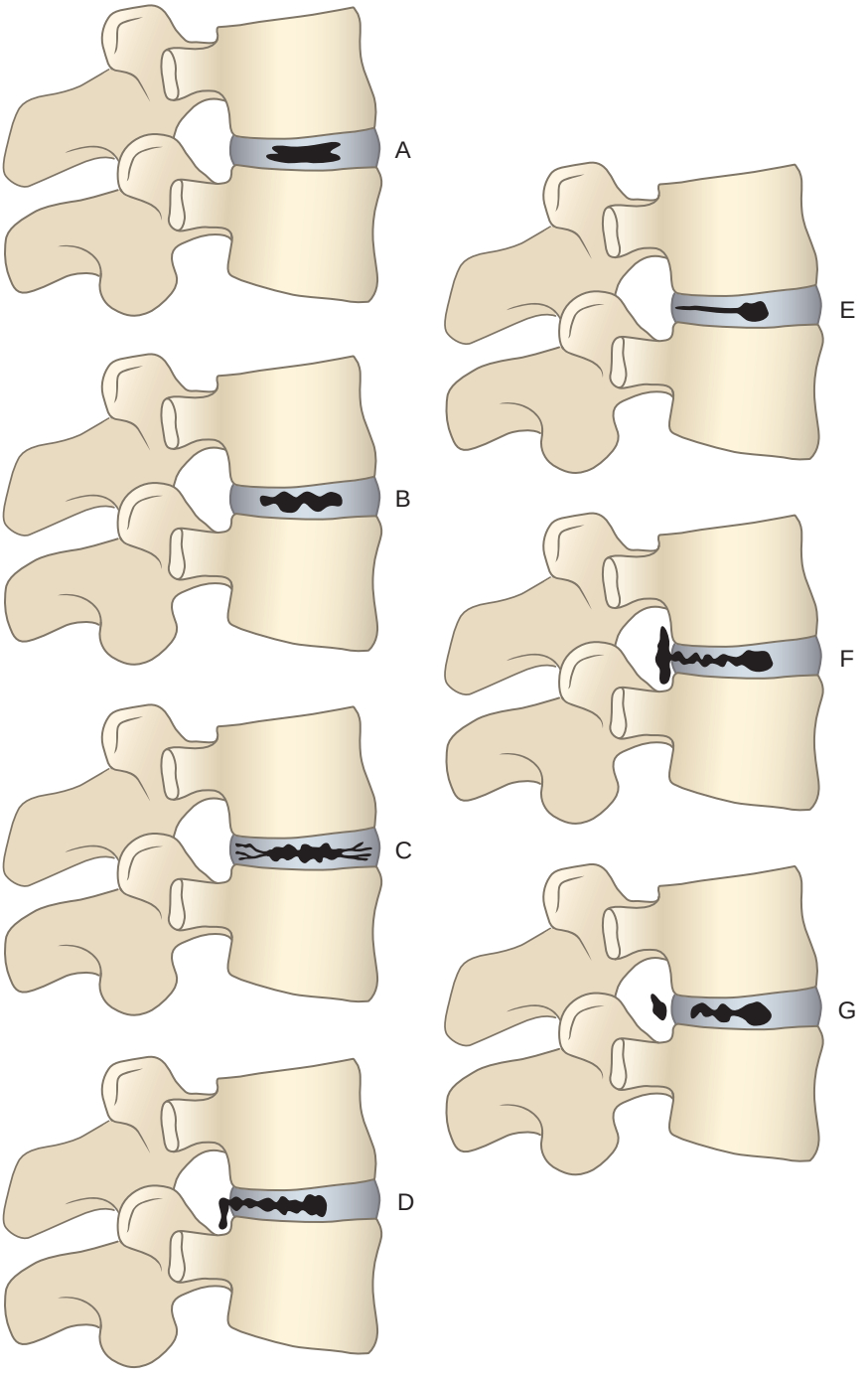


Figure 9-10.
Discogram morphology in the lateral projection. **A:** Normal. **B:** Degenerated disc. **C:** Degenerated disc with an annular tear. **D:** Extruded disc (candle drip). **E:** Radial tear. **F:** Radial tear with protruded disc. **G:** Extruded disc with a sequestered disc fragment.

lordosis. The C-arm is rotated 25 to 35 degrees obliquely and centered on the disc space to be studied. The C-arm is then angled in a cephalad direction that will vary from patient to patient, depending on the disc to be studied and each patient's degree of lumbar lordosis (see Fig. 9-2). In general, the L3/L4 disc lies close to the axial plane and requires no cephalad angulation to align the vertebral endplates (see Fig. 9-3), the L4/L5 disc requires 0 to 15 degrees of cephalad angulation, and the L5/S1 disc requires 25 to 35 degrees of cephalad angulation (see Fig. 9-4). Proper alignment of the C-arm is critical to the safety and success of PDD.

Block Technique

The technique for placing the cannulae through which the PDD treatment device is introduced into the disc is similar to

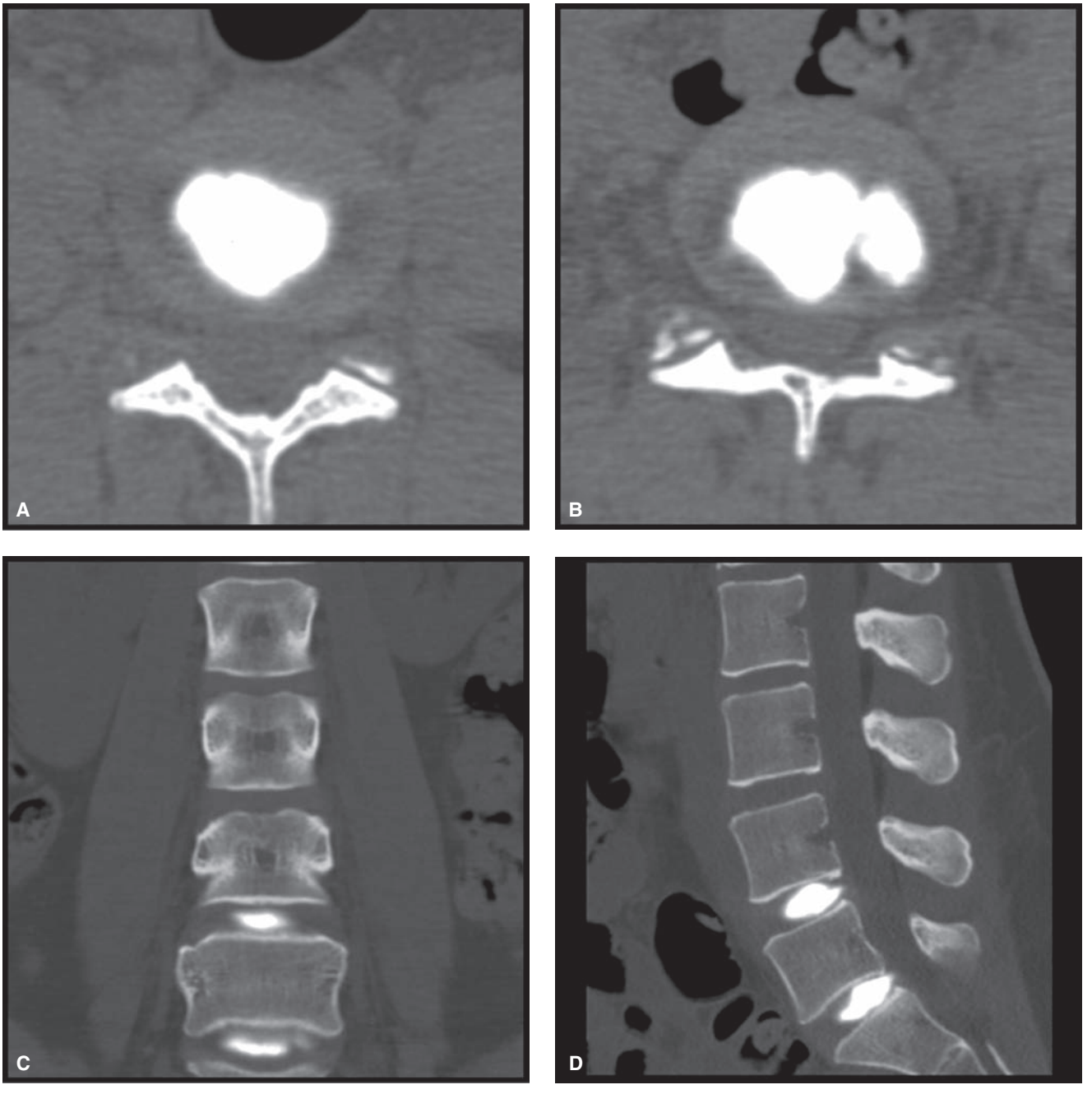


Figure 9-11.

CT following discography (CT discogram) at the L4/L5 and L5/S1 levels demonstrating the use of multiplanar and three-dimensional reconstruction in defining the anatomy of the anatomic abnormality within the discs. **A:** Axial CT image of a normal L4/L5 intervertebral disc following discography. Contrast is seen within the nucleus pulposus, without extension into the annulus fibrosus. **B:** Axial CT image of an abnormal L5/S1 intervertebral disc following discography. Contrast is seen within the nucleus pulposus and extends into the annulus fibrosus in a localized concentric tear to the left lateral annulus fibrosus. **C:** Coronal CT image at the midpoint of the intervertebral disc in the AP direction. Both the L4/L5 and L5/S1 discs appear normal, with a faint hint of contrast lateral to the nucleus on the left at the L5/S1 level. **D:** Sagittal CT image at midline of the intervertebral disc. The L4/L5 disc appears normal; the L5/S1 disc has contrast that extends more posterior than is typical, but without any discrete abnormality on this midline image. *(Cont.)*

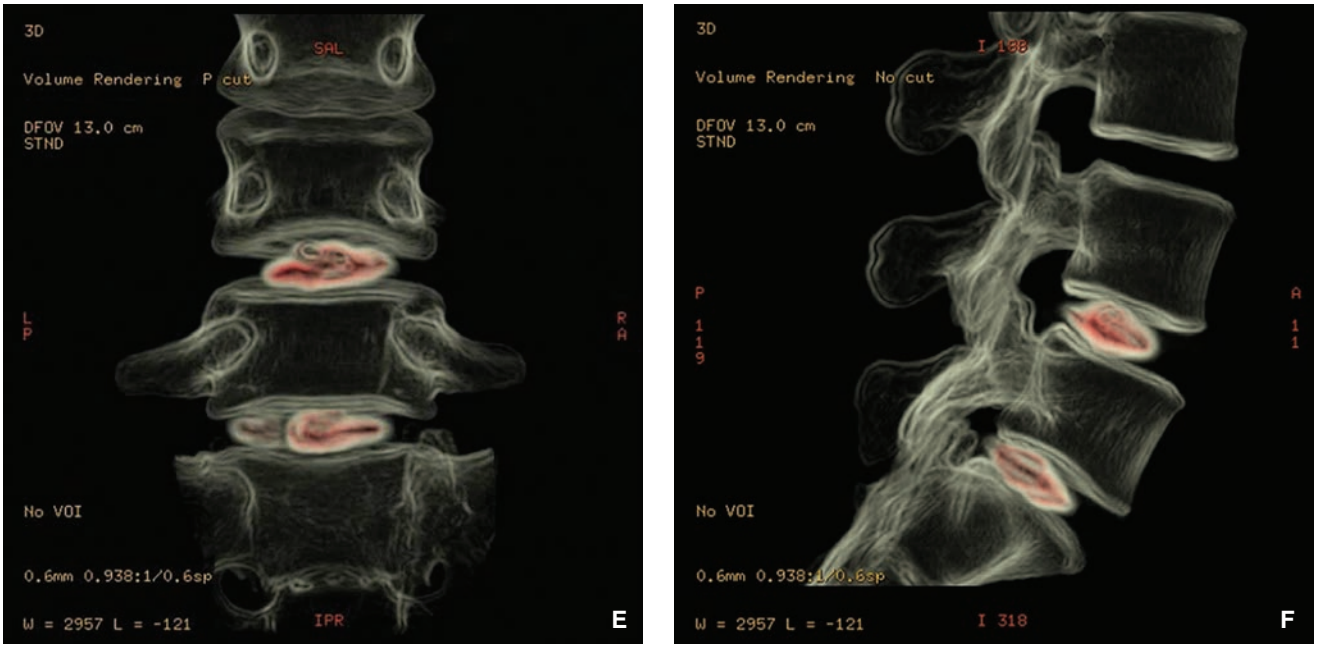


Figure 9-11. *(Continued)*

E: Three-dimensional CT reconstruction in the AP view using surface contours. The bony elements are outlined in white and the contrast within the disc is highlighted in *red*. Using 3D reconstruction, the extent of the left lateral concentric tear at the L5/S1 level can be seen readily. **F:** Three-dimensional CT reconstruction in the lateral view using surface contours. The bony elements are outlined in white and the contrast within the disc is highlighted in red. Using 3D reconstruction, the extent of the posterior insufficiency of the annulus fibrosus can be seen readily.

that for needle placement for discography. However, the final position of the introducer is best placed in the posterolateral aspect of the nucleus, rather than in the central portion of the nucleus. This allows for creation of channels within the nucleus pulposus that extend across the greatest distance from the posterolateral aspect of the nucleus on one side of the disc to the anterolateral aspect on the opposite side of the disc (see Fig. 9-15). The skin and subcutaneous tissues overlying the disc space where PDD is to be carried out are anesthetized with 1 to 2 mL of 1% lidocaine, and additional local anesthetic is instilled liberally as the cannulae are advanced. A 17-gauge introducer supplied by the manufacturer is placed through the skin and advanced until it is seated in the tissues in a plane that is coaxial with the axis of the x-ray path (Fig. 9-16). The PDD introducer is stiff and easy to redirect as it is advanced. The direction of the cannula should be rechecked after ever 1 to 1.5 cm of needle advancement and adjusted to remain coaxial. The position of the spinal nerve beneath the pedicle should be kept in mind at all times, and efforts to ensure the needle does not stray cephalad or lateral to the intended point over the middle of the disc will reduce the likelihood of striking the spinal nerve en route to the disc (see Figs. 9-6 and 9-7). Once the needle is in contact with the surface of the disc, there will be a notable increase in resistance to needle placement. At this point, the C-arm should be rotated to a lateral position, and the introducer advanced one-third of the distance from the posterior to the anterior margin of the disc (Fig. 9-16D). Proper final placement is then checked in the AP plane, where again the introducer should be one-third of the distance from the ipsilateral lateral disc margin to the contralateral lateral disc margin (Fig. 9-16E). The C-arm is again rotated to a lateral position, and the treatment probe (SpineWand, ArthroCare Corporation, Austin, TX) is advanced through the introducer and into the disc without application of any energy; the probe is advanced until increase in resistance of the anterior inner margin of the annulus is felt and a lateral radiograph is taken to assure

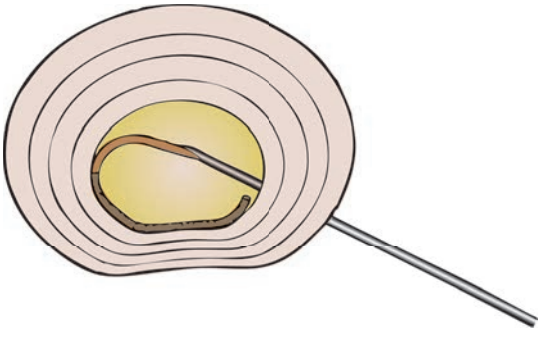
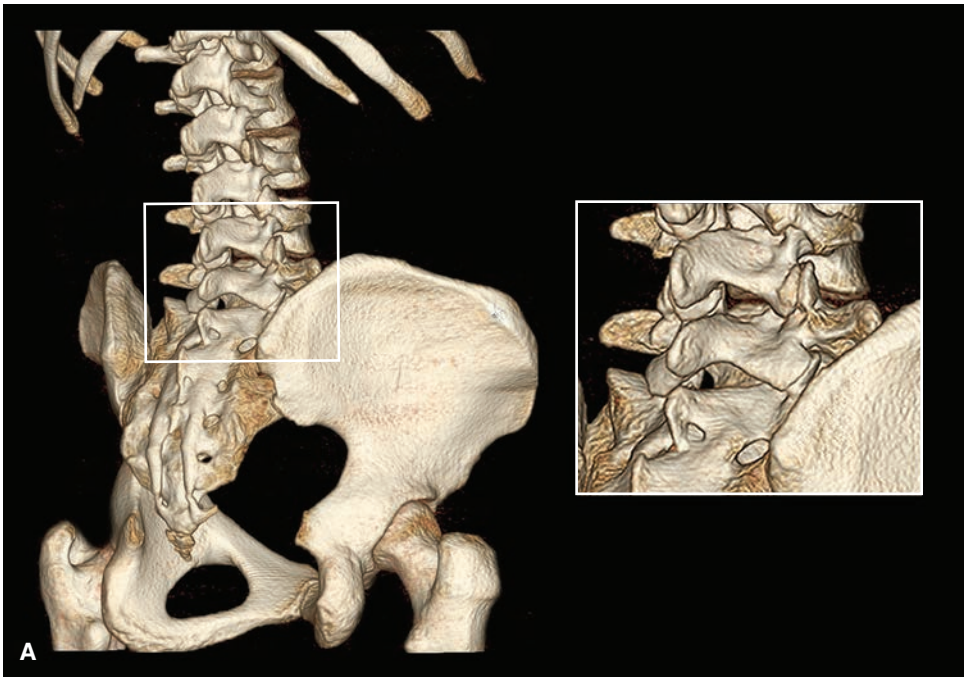
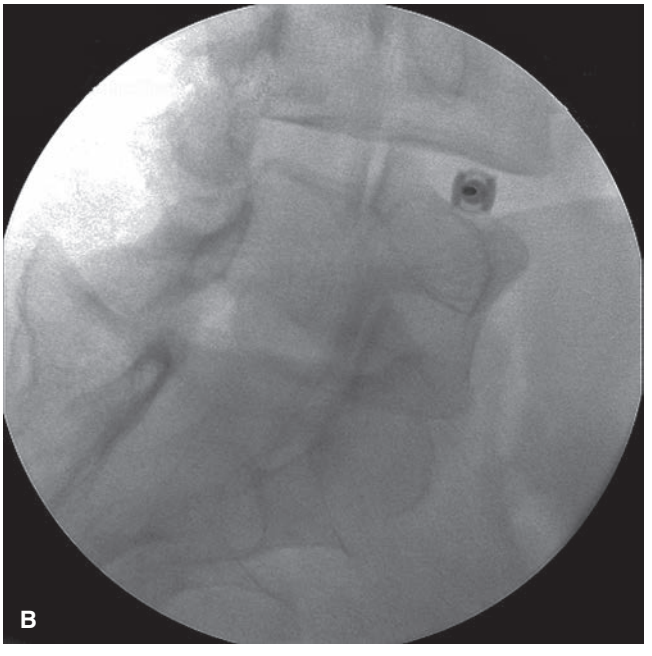


Figure 9-12.

Axial diagram of IDET introducer and catheter in proper position for treatment. The introducer is placed in the anterolateral portion of the nucleus pulposus. The catheter is then threaded through the introducer and steered along the inner circumference of the annulus fibrosis until the catheter is in place along the entire posterior annular wall.





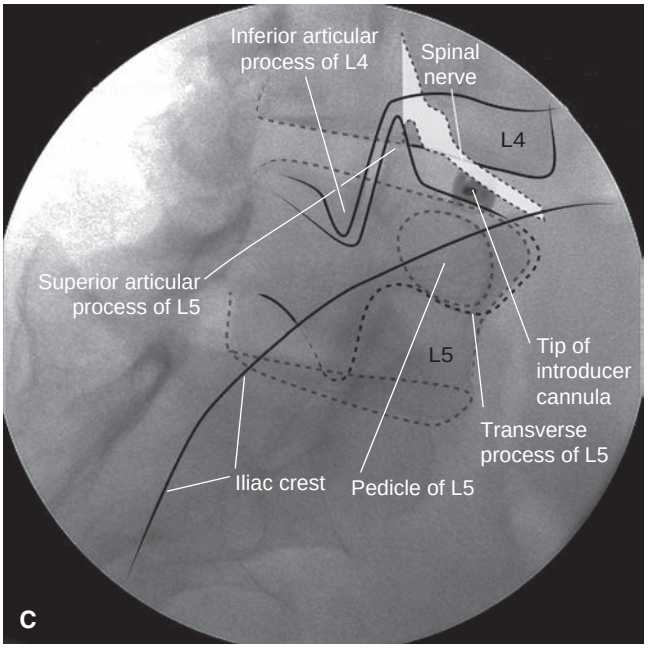


Figure 9-13.

A: Bony anatomy relevant to IDET at the L4/L5 level. Three-dimensional reconstruction CT of the lumbar spine as viewed in the oblique projection used to perform IDET at the L4/L5 level. **Inset** matches the anatomic area in the radiographs shown in **(B,C)**. **B:** Oblique radiograph of the lumbar spine demonstrating coaxial placement of the introducer cannula for IDET. The cannula is directed toward the anterolateral aspect of the L4/L5 intervertebral disc space. **C:** Labeled image. The approximate location of the L4 spinal nerve is shown as it traverses inferior to the L4 pedicle and courses in an anterior, lateral, and inferior direction, just superolateral to the path of the cannula as it enters the disc space.

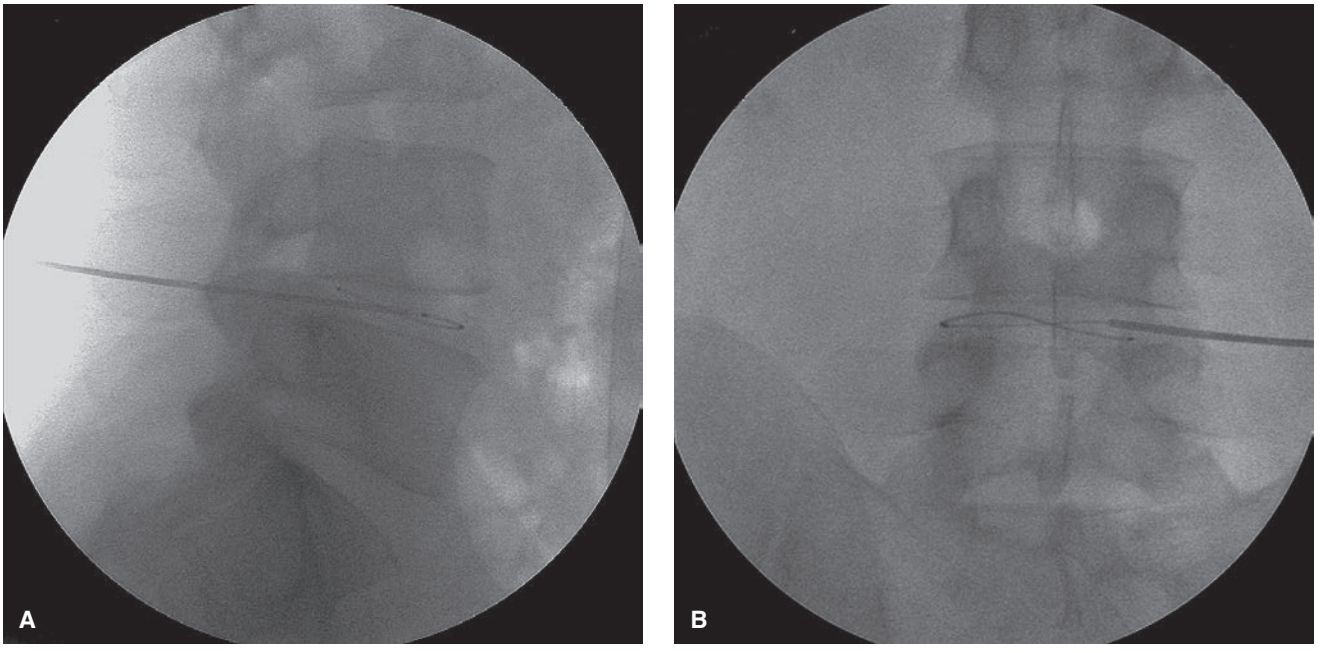


Figure 9-14.

A: Lateral radiograph of the lumbar spine during initial placement of the catheter for IDET. After the introducer is in position, the IDET catheter is threaded initially using radiographic guidance in the lateral view. In this plane, the IDET catheter can be followed as it hugs the contralateral inner annular wall and travels toward the posterior annular wall. When the tip of the cannula reaches the posterior annular wall, it should turn toward the ipsilateral side and hug the posterior annular wall. Great care should be taken to observe the position of the catheter along the posterior annular wall because, in the presence of a significant posterior annular tear, the catheter can easily exit the disc space and enter the epidural space. **B:** AP radiograph of the lumbar spine during final placement of the catheter for IDET. When the IDET catheter tip reaches the posterior annular wall in the lateral radiograph, the view is changed to the AP plane before the catheter is advanced further. The catheter is then guided across the posterior annular wall until the radiographic markers extend across the entire posterior annulus.

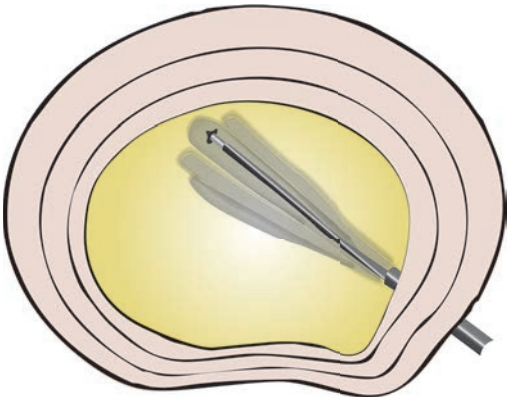
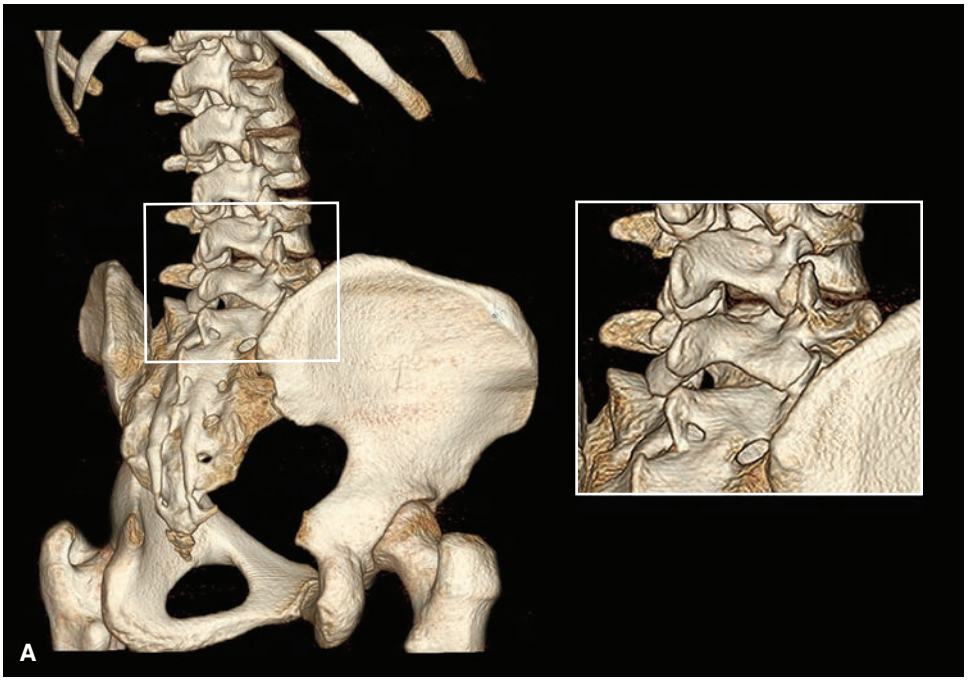


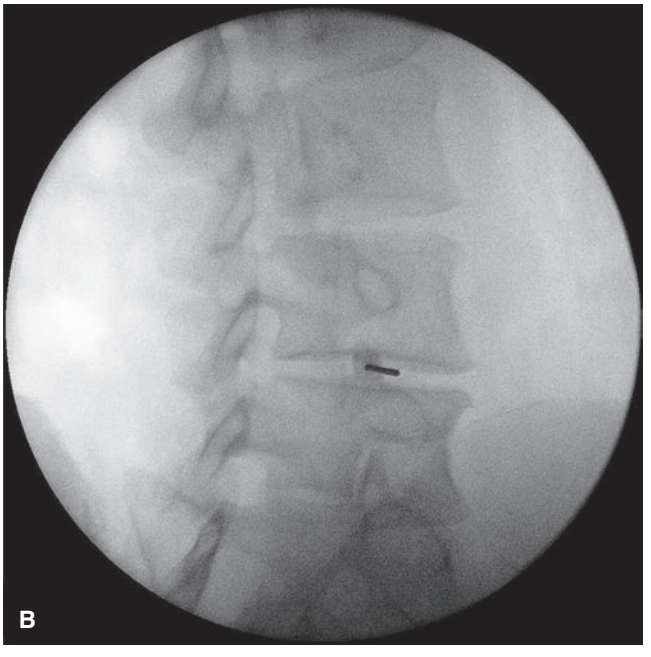
Figure 9-15.

Axial diagram of the introducer and treatment device used to perform PDD. The introducer is placed in the posterolateral portion of the disc at the inner border of the annulus fibrosus. The treatment device has a discrete area located at the distal portion of the probe where the energy is delivered. The device has a slight angulation so that a series of channels can be created within the disc by advancing the device through the nucleus pulposus as energy is delivered and rotating the device after each channel is created to create a new channel in a different plane. In this way, a discrete volume of nucleus pulposus is removed, lowering pressure within the nucleolus and reducing the size of the bulging disc or contained disc herniation.

that the probe remains within the limits of the disc space (Fig. 9-16F). A spring loaded marker is moved down the shaft of the needle to mark this anterior most extension and used to guide the probe advancement during all subsequent treatment passes.

Once the PDD introducer is in a satisfactory position and the anterior extent of advancement of the treatment probe has been marked, treatment can begin. The treatment probe is withdrawn until just the active tip remains within the nucleus, just beyond the tip of the introducer cannulae; this position is marked by a shaded area along the shaft of the treatment probe. The treatment probe is then slowly advanced while energy is applied until the previously determined depth is reached and then withdrawn. After each pass, the probe is rotated 60 degrees and another treatment pass is performed until a total of six treatment passes have been applied (see Fig. 9-15). This brief description is overly simplistic and meant only to describe the critical aspects of positioning the introducer cannula and assuring that the treatment probe remains within the disc during treatment. The specific treatment protocol is straight forward but requires an understanding of each element of this new technology. Treatment takes ~10 minutes, once the device has been positioned. It is important that the patient is not





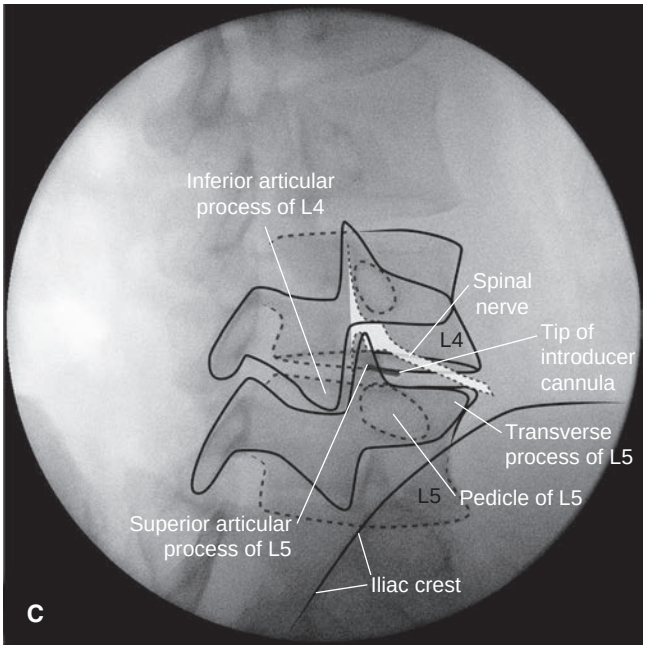
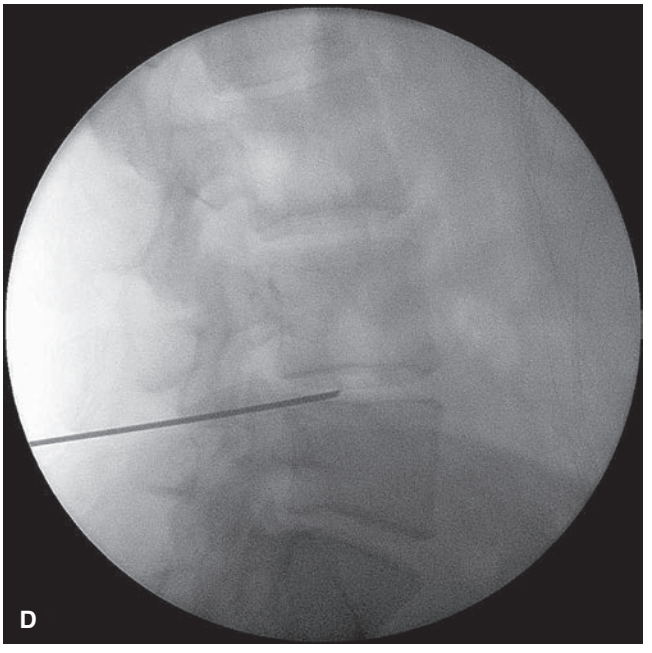
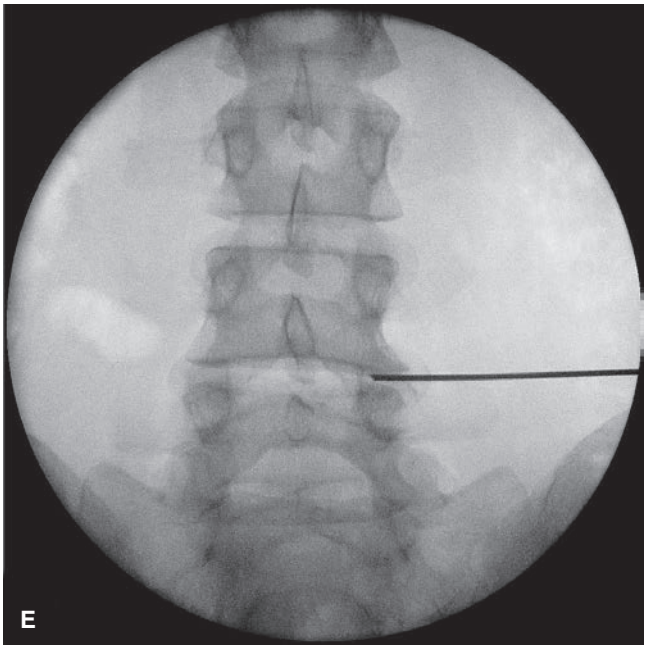


Figure 9-16.

A: Bony anatomy relevant to PDD at the L4/L5 level. Three-dimensional reconstruction CT of the lumbar spine as viewed in the oblique projection used to perform PDD at the L4/L5 level. **Inset** matches the anatomic area in the radiographs shown in **(B,C)**. **B:** Oblique radiograph of the lumbar spine demonstrating coaxial placement of the introducer cannula for PDD at the L4/L5 level. The cannula is directed toward the posterolateral aspect of the L4/L5 intervertebral disc space. **C:** Labeled image. The approximate location of the L4 spinal nerve is shown as it traverses inferior to the L4 pedicle and courses in an anterior, lateral, and inferior direction, well superolateral to the path of the cannula as it enters the disc space. ***(Cont.)***





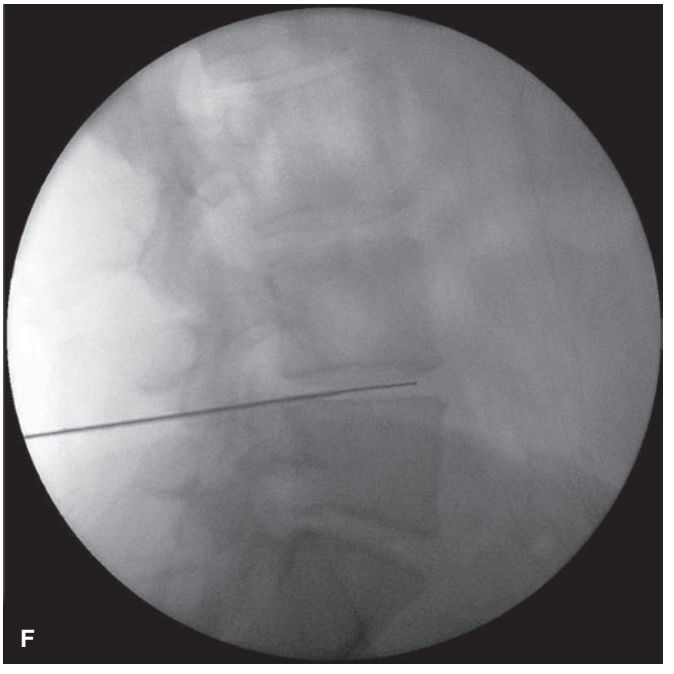


Figure 9-16. ***(Continued)***

D: Lateral radiograph of the lumbar spine demonstrating placement of the introducer cannula for PDD at the L4/L5 level. The cannula tip is in position in the posterior aspect of the disc, approximately one-third of the distance from the posterior to the anterior margin of the disc, corresponding to the central margin of the annulus fibrosus. **E:** AP radiograph of the lumbar spine demonstrating placement of the introducer cannula for PDD at the L4/L5 level. The cannula tip is in position in the lateral aspect of the disc, approximately one-third of the distance from the right to the left lateral margin of the disc, corresponding to the central margin of the annulus fibrosus. **F:** Lateral radiograph of the lumbar spine demonstrating the anterior most deployment of the plasma decompression device. Once the introducer cannula has been positioned, the PDD treatment device is advanced to the anterior margin of the nucleus pulposus where resistance is felt. The device is first advanced without delivering any energy and a lateral radiograph is taken to assure that the device has not extended too far anteriorly beyond the disc space. A marking device is then positioned along the shaft of the treatment device to mark this anterior-most extension (the point at which advancement of the device should stop during the treatment period). The treatment device is withdrawn until the active tip is positioned just beyond the tip of the introducer cannula and treatment is begun (see text for a more detailed description).

overly sedated during the actual heat treatment so he or she can report discomfort due to excess heat, before neural injury occurs.

Complications of PDD

Patients should be warned of the typical postprocedural flare in pain symptoms that occurs after PDD. This results in an exacerbation of axial back pain, often lasting several days to weeks. Less commonly, injury to the spinal nerve can occur. The position of the spinal nerve is in close proximity to the needle's path (see Fig. 9-1). Care must be taken to advance the introducer cannula slowly as it passes over the transverse process en route to the posterolateral margin of the disc. If the patient reports a paresthesia to the lower extremity, the cannula should be withdrawn and redirected. Paresthesia will occur in a small proportion of patients, even with good technique. Persistent paresthesiae are uncommon and typically ensue only after repeated paresthesiae occur during the procedure.

SUGGESTED READINGS

American Society of Anesthesiologists Task Force on Chronic Pain Management; American Society of Regional Anesthesia and Pain Medicine. Practice guidelines for chronic pain management: an updated report by the American Society of Anesthesiologists Task Force on Chronic Pain Management and the American Society of Regional Anesthesia and Pain Medicine. *Anesthesiology*. 2010;112:810–833.

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SECTION III

SYMPATHETIC AND PERIPHERAL NERVE BLOCKS

CHAPTER 10

Stellate Ganglion Block

OUTLINE

Overview

The sympathetic nervous system is involved in the pathophysiology that leads to a number of different chronic pain conditions, including complex regional pain syndrome (CRPS) and ischemic pain. These chronic pain states are often referred to as *sympathetically maintained pain* because they share the characteristic of pain relief that follows blockade of the regional sympathetic ganglia. Stellate ganglion block is an established method for the diagnosis and treatment of sympathetically maintained pain of the head, neck, and upper extremity.

Anatomy

Sympathetic fibers to and from the head, neck, and upper extremities pass through the stellate ganglion. In many individuals, the stellate ganglion is formed by fusion of the inferior cervical and first thoracic sympathetic ganglia. The ganglion is commonly found just lateral to the lateral border of the longus colli muscle, and anterior to the neck of the first rib and the transverse process of the seventh cervical vertebra (Figs. 10-1 and 10-2). In this position, the ganglion lies posterior to the superior border of the first part of the subclavian artery and the origin of the vertebral artery and posterior to the cupola of the lung. Although several approaches to stellate ganglion block have been described, the most common is the anterior paratracheal approach at C6 using surface landmarks. Performing the block at C6 reduces the likelihood of pneumothorax, which is more likely when the block is carried out close to the cupola of the lung at C7. The anterior tubercle of the transverse process of C6 (Chassaignac's tubercle) is readily palpable in most individuals. To perform the block without radiographic guidance, the operator palpates the cricoid cartilage and then slides a finger laterally into the groove between the trachea and the sternocleidomastoid muscle, retracting the muscle and adjacent carotid and jugular vessels laterally. Chassaignac's tubercle is typically palpable in this groove at the C6 level. Once the tubercle has been identified, a needle is advanced through the skin and seated on the tubercle, where local anesthetic is injected. The local anesthetic spreads along the prevertebral fascia in a caudal direction to anesthetize the stellate ganglion, which lies just inferior to the point of injection in the same plane. In practice, there is marked variation in the size and shape of Chassaignac's tubercle that reduces the rate of successful block. The adjacent vertebral artery and C6 spinal nerve must be avoided to safely conduct this block (Figs. 10-1 to 10-3). A simple modification of technique in which the needle is directed medially toward the base of the transverse process using radiographic guidance is a safe and simple means of improving the reliability of stellate ganglion block and is described in the following sections. The use of ultrasound to guide needle placement has revolutionized the conduct of regional anesthesia for surgical anesthesia, but its use in pain treatment has been more limited. The majority of pain treatment techniques are now carried out with radiographic guidance and the bony elements of the spine prevent effective visualization of many structures within the spinal canal. However, stellate ganglion block is a notable exception to this rule. The critical soft tissue and vascular structures relevant to safely perform stellate ganglion block cannot be seen with fluoroscopy but are readily visualized with ultrasound (Fig. 10-4). Description of ultrasound-guided stellate ganglion block is beyond the scope of this text, but this technique may well supplant the use of radiographic guidance as more practitioners gain expertise with ultrasound.

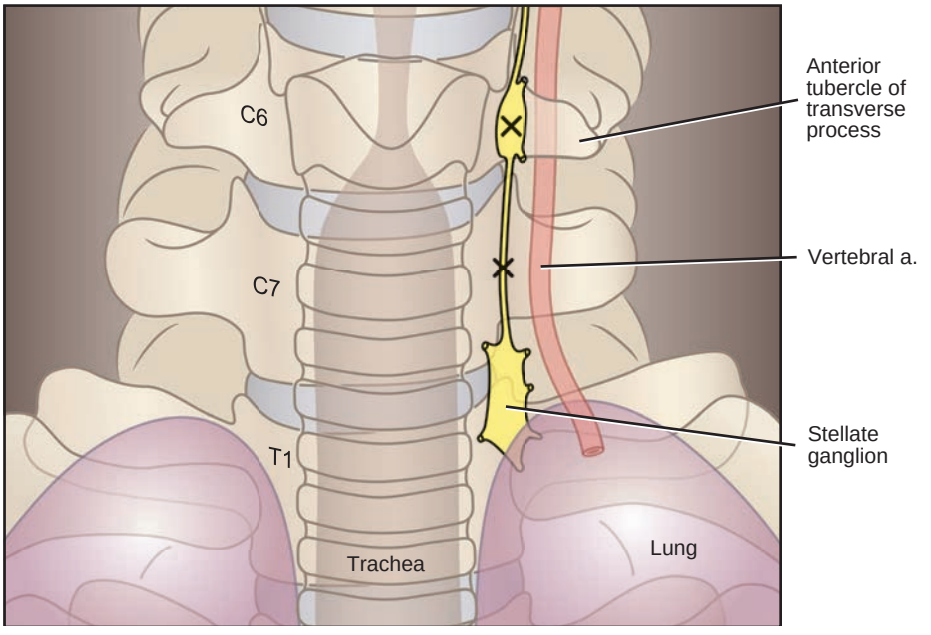

Figure 10-1.
Anatomy of the stellate ganglion. The stellate ganglion conveys sympathetic fibers to and from the upper extremities and the head and neck. The ganglion is comprised of the fused superior thoracic ganglion and the inferior cervical ganglion and is named for its fusiform shape (in many individuals, the two ganglia remain separate). The stellate ganglia lie over the head of the first rib at the junction of the transverse process and uncinate process of T1. The ganglion is just posteromedial to the cupola of the lung and medial to the vertebral artery. Stellate ganglion block is typically carried out at the C6 or C7 level to avoid pneumothorax, and a volume of solution that will spread along the prevertebral fascia inferiorly to the stellate ganglion is employed (usually 10 mL). When radiographic guidance is not used, the operator palpates the anterior tubercle of the transverse process of C6 (Chassaignac's tubercle), and a needle is seated in this location. With radiographic guidance, it is simpler and safer to place a needle over the vertebral body just inferior to the uncinate process of C6 or C7. Particular care should be taken when performing the block at the C7 level to ensure the needle does not stray lateral to the uncinate process because the vertebral artery courses anterior to the transverse process at this level and is often not protected within a bony foramen transversarium. The Xs mark the target for needle placement when performing stellate ganglion block at either the C6 or the C7 level.

Patient Selection

Stellate ganglion block has long been the standard approach to diagnosis and treatment of sympathetically maintained pain syndromes involving the upper extremity, such as CRPS. Other neuropathic pain syndromes, including ischemic neuropathies, herpes zoster (shingles), early postherpetic neuralgia, and postradiation neuritis, may respond to stellate ganglion block. Blockade of the stellate ganglion has also proven successful in reducing pain and improving blood flow in vascular insufficiency conditions such as intractable angina pectoris, Raynaud's disease, frostbite, vasospasm, and occlusive and embolic vascular disease. Finally, the sympathetic fibers control sweating; thus, stellate ganglion block can be quite effective in controlling hyperhidrosis (recurrent and uncontrollable sweating of the hands).

Causalgia (CRPS, type 2) was first described during the American Civil War. Soon thereafter, it was recognized that blockade of the sympathetic chain with local anesthetic could produce significant pain relief in patients with causalgia. Patients with CRPS have a history of trauma to the affected area: Those with a major nerve trunk injury, such as a gunshot wound to the brachial plexus, are classified as CRPS, type 2 (causalgia), and those with no major nerve trunk injury are classified as CRPS, type 1 (reflex sympathetic dystrophy). Both types of CRPS share the same signs and symptoms. Patients with CRPS report pain that has characteristics of neuropathic pain, including spontaneous burning pain and allodynia (pain produced by stimulation that usually does not cause pain, such as light touch). Patients with CRPS also report symptoms or have signs on physical examination of sympathetic dysfunction. These include temperature and color asymmetries between the affected and unaffected limbs, edema, and asymmetries in sweating of the limbs. Dystrophic changes may appear late in the course of CRPS, including thinning of the skin, hair loss, and pitting of the nail beds.

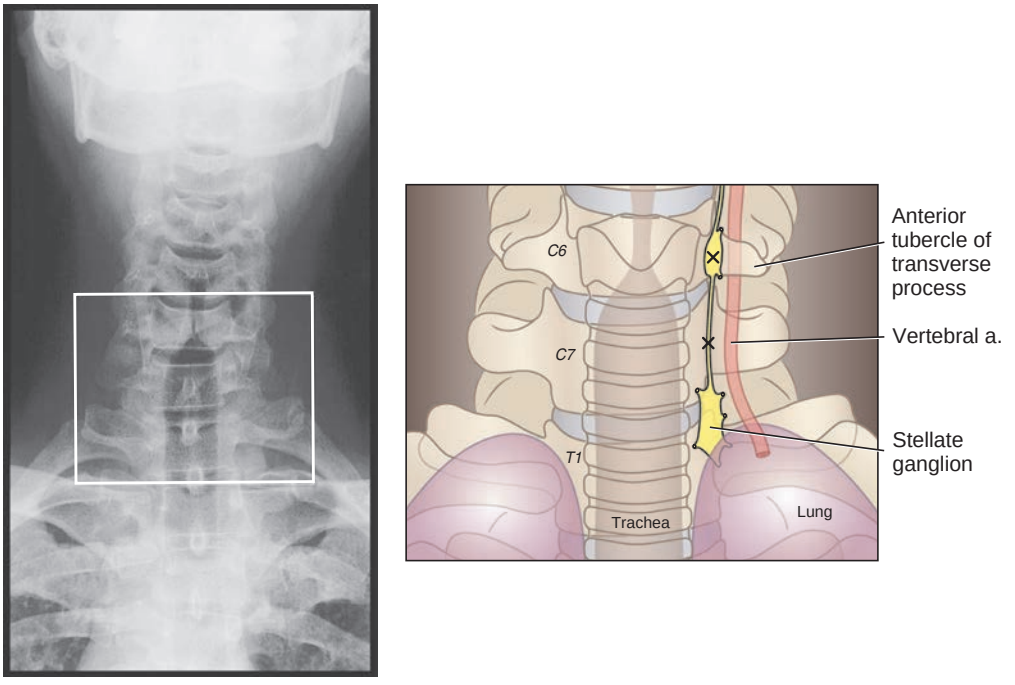

Figure 10-2.
Correlation between position of the stellate ganglion, the vertebral artery, and the inferior cervical vertebrae. The relative positions of the C6, C7, and T1 vertebral bodies; Chassaignac's tubercle (anterior tubercle of C6 transverse process); and the vertebral artery are illustrated. The vertebral artery traverses within the bony foramen transversarium at the C6 level, but the presence of a bony foramen at C7 is variable, and here the artery often courses unprotected anterior to the C7 transverse process.

Patients with signs and symptoms of CRPS may gain significant pain relief from stellate ganglion block. Unfortunately, the duration and magnitude of the pain relief are unpredictable. This led to the use of repeated sympathetic blocks, sometimes as often as daily or weekly blocks over an extended period of time in an attempt to improve the duration of pain relief. Experts widely agree that repeated sympathetic blocks alone rarely eliminate the pain and disability associated with CRPS. A coordinated, multidisciplinary rehabilitation plan is essential for effective treatment of patients with CRPS. This treatment plan typically includes physical therapy, oral neuropathic pain medications, and supportive psychotherapy. Neuroablation has been used to destroy the sympathetic chain in those patients who attain excellent pain relief of temporary duration with local anesthetic blocks. There are few data available to evaluate the success of sympathetic ablation, and expert opinion is varied regarding the usefulness of this approach in the long-term treatment of CRPS.

Level of Evidence

Quality of Evidence and Grading of Recommendation			
Grade of Recommendation/ Description	**Benefit vs. Risk and Burdens**	**Methodological Quality of Supporting Evidence**	**Implications**
RECOMMENDATION: *Sympathetic blocks, including stellate ganglion block. The use of sympathetic blocks may be considered to support the diagnosis of sympathetically maintained pain. They should not be used to predict the outcome of surgical, chemical, or radiofrequency sympathectomy. Lumbar sympathetic blocks or stellate ganglion blocks may be used as components of the multimodal treatment of CRPS if used in the presence of consistent improvement and increasing duration of pain relief. Sympathetic nerve blocks should not be used for long-term treatment of non-CRPS neuropathic pain.*			
2C/weak recommendation, low-quality or very low-quality evidence	Uncertainty in the estimates of benefits, risks, and burden; benefits, risk, and burden may be closely balanced	II-2: Observational studies or case series	Very weak recommendations; other alternatives may be equally reasonable

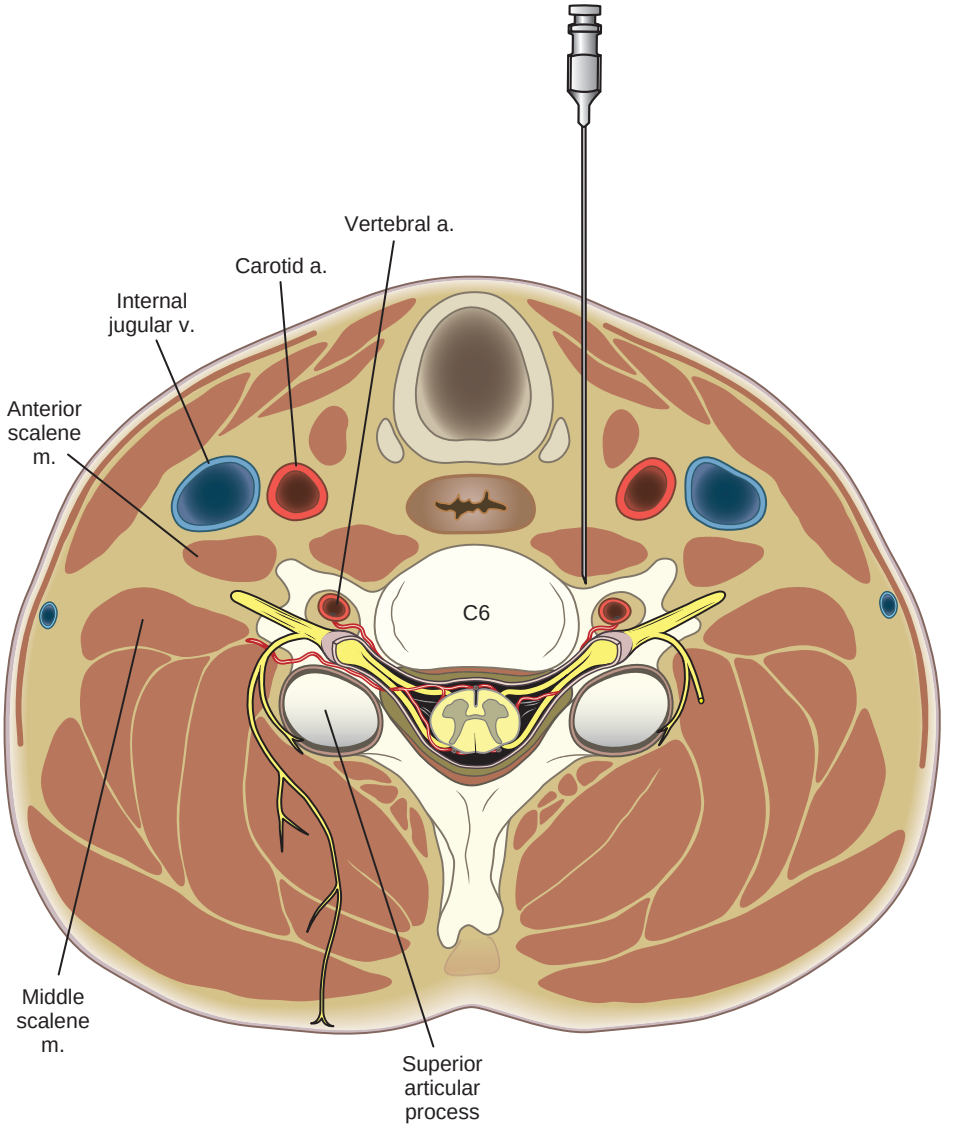

Figure 10-3.
Axial diagram of stellate ganglion block. The needle is positioned in the vertebral gutter, a shallow depression where the transverse process joins with the vertebral body. Note the position of the vertebral artery within the foramen transversarium, the exiting nerve root, and the carotid artery.

The use of sympathetic blocks in the diagnosis and management of a number of chronic pain conditions, including CRPS, has been common for decades despite the lack of scientific validation for this approach. Indeed, the very origins of the field of pain medicine grew from the anesthesiologists' use of regional anesthesia including regional blockade of the sympathetic chain. Yet, the usefulness of sympathetic blocks in either the diagnostic evaluation or the long-term management of pain syndromes remains in question.

The American Society of Anesthesiologists (ASA) Task Force on Chronic Pain Management published a 2010 Practice Guideline, offering the following recommendation regarding use of sympathetic blocks for the diagnosis of pain: "The use of sympathetic blocks may be considered to support the diagnosis of sympathetically maintained pain. They should not be used to predict the outcome of surgical, chemical, or radiofrequency sympathectomy." The ASA Guideline made the following recommendations regarding use of sympathetic blocks as a component of pain treatment: "Lumbar sympathetic blocks or stellate ganglion blocks may be used as components of the multimodal treatment of CRPS if used in the presence of consistent improvement and increasing duration of pain relief. Sympathetic nerve blocks should not be used for long-term treatment of non-CRPS neuropathic pain."

CRPS is uncommon and conducting randomized trials in this heterogeneous group of patients with neuropathic pain has been limited to a small number of small studies. Clear benefits have not been reported with sympathetic blocks based on the limited available data, yet the use of

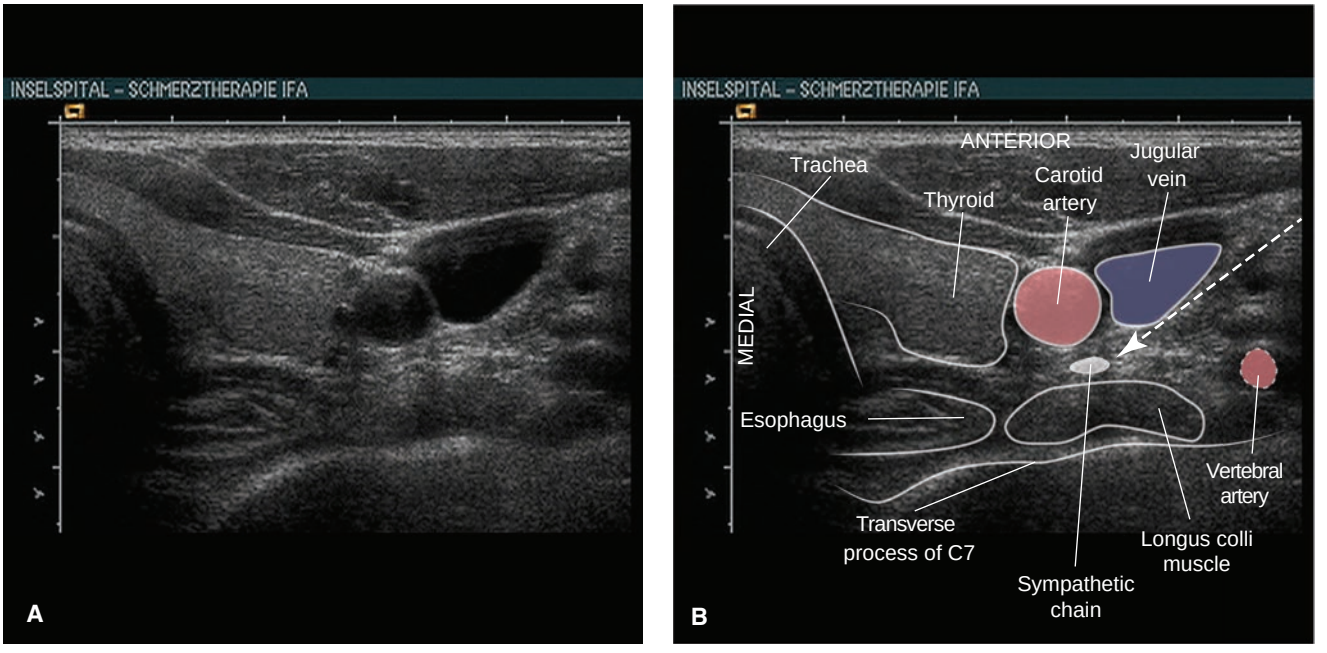

Figure 10-4.

Anatomy relevant to stellate ganglion block as seen on ultrasound. **A:** Transverse (short-axis) ultrasound view at the level of the transverse process of C7. **B:** Labeled image. Note that the vertebral artery can be seen anterior to the echogenic transverse process at the level of C7. The vertebral artery cannot be seen clearly at the C6 level on ultrasound, as it lies posterior to the echogenic transverse process within the foramen transversarium. At the level of C7, the superior margin of the thyroid is seen just lateral to the trachea. The *dashed arrow* indicates the optimal trajectory for placing a needle using an in-plane approach, for example, placing the needle in a lateral to medial direction with the shaft in the transverse plane of the ultrasound image. (Ultrasound image courtesy of Urs Eichenberger MD, PhD, University Department of Anesthesiology and Pain Therapy, University Hospital of Bern, Bern, Switzerland, 2011.)

sympathetic blocks remains a component of the treatment algorithms put forth by contemporary experts. If the use of sympathetic blocks produces pain relief of sufficient magnitude and duration in an individual patient such that efforts to restore normal function are improved, then they should be incorporated into the treatment algorithm. If they produce pain relief of limited magnitude and duration for an individual patient, then the risks involved in using sympathetic blocks outweigh the benefits and their use for that patient should be abandoned.

Positioning

The patient lies supine, facing directly forward with a pillow under the upper back and lower neck to hold the neck in slight extension (Fig. 10-5). The C-arm is centered over the lower cervical spine without angulation. The position of the vertebral bodies and transverse processes of C6 and C7 are identified (see Fig. 10-2).

Block Technique

The skin and subcutaneous tissues overlying the base of the transverse process of C6 or C7 on the affected side are anesthetized with 1 to 2 mL of 1% lidocaine. The transverse processes are often difficult to distinguish from the underlying facet columns, but the transverse process joins the vertebral body just inferior to the uncinate process of the vertebral body, a structure that is easily discernible on the posterior-anterior (PA) radiograph (Fig. 10-6). The block can be carried out at either the C6 or the C7 level when using radiographic guidance. However, it is important to realize that the vertebral artery overlies the base of the transverse process at C7, and many individuals lack a bony foramen transversarium at this level (see Figs. 10-1 and 10-2). Thus, at C7, care must be taken to keep the needle tip in line or medial to a line connecting the uncinate process of C7 and T1. Straying more lateral will risk penetration of the vertebral artery. The overlying carotid artery must be retracted laterally to perform the classic technique for stellate ganglion block over the C6 transverse process, but this is unnecessary when the needle is directed toward the base of the transverse process (see Fig. 10-3). A 25-gauge, 3.5-inch needle is placed through the skin and advanced until it is seated in the tissues in a plane that is coaxial with the axis of the x-ray path. The needle may not remain seated easily without advancing the needle further than is safe before checking the needle's direction with

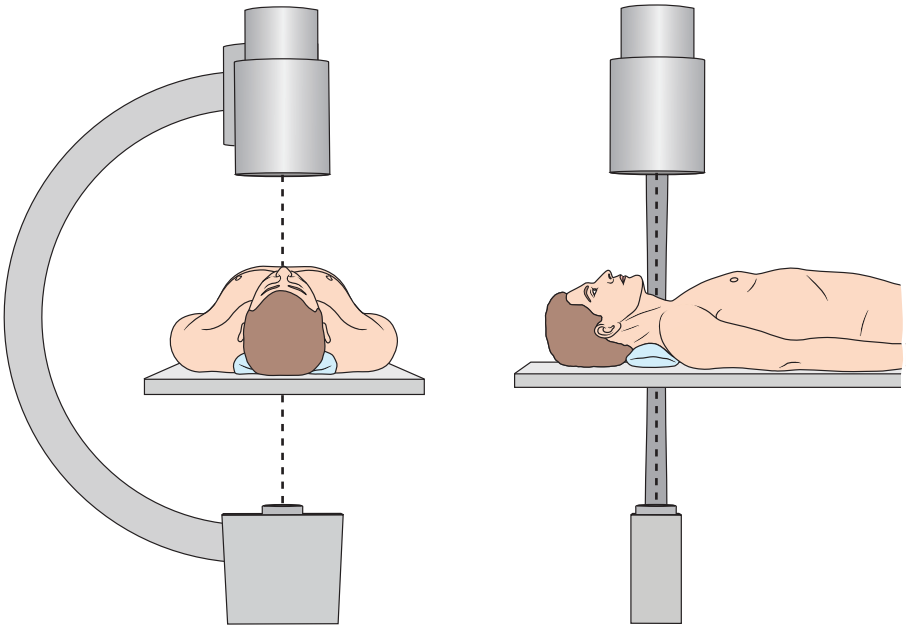

Figure 10-5.
Position for stellate ganglion block. The patient lies supine with a pillow beneath the upper back and lower neck to place the neck in slight extension. The C-arm is positioned over the cervicothoracic junction without angulation.

fluoroscopy. The needle can be held in a coaxial plane using a small clamp or hemostat and directed toward the target in this manner. The needle is adjusted to remain coaxial as it is directed toward the base of the transverse process, just inferior to the uncinate process using repeat PA images after every 2 to 4 mm of needle advancement. Once the surface of the vertebral body is contacted, the needle is in final position. Intravascular placement is ruled out and proper position is ensured by injecting 1 to 1.5 mL of radiographic contrast (iohexol 180 mg per mL or the equivalent). The contrast should spread along the anterolateral margin of the vertebral bodies in both PA and lateral radiographs (Figs. 10-6 to 10-8). Thereafter, 10 mL of local anesthetic (0.25% bupivacaine) is injected incrementally. Repeat radiographs following local anesthetic injection should show dilution of the contrast and spread of the solution inferior to the T1 level where the stellate ganglion lies. Sympathetic block should ensue within 20 minutes following injection and is ensured by seeing a 1°C or greater rise in temperature of the ipsilateral hand. Signs of successful stellate ganglion block are listed in Table 10-1.

Complications

There are many structures within the immediate vicinity of the needle's tip once it is properly positioned for stellate ganglion block (see Figs. 10-1 and 10-3). Commonly, diffusion of local anesthetic blocks the adjacent recurrent laryngeal nerve. This often leads to hoarseness, a feeling of having a lump in the throat, and a subjective feeling of shortness of breath and difficulty swallowing. Bilateral stellate ganglion block should not be performed because bilateral recurrent laryngeal nerve blocks may well lead to loss of laryngeal reflexes and respiratory compromise. The phrenic nerve is also commonly blocked by direct spread of local anesthetic and will lead to unilateral diaphragmatic paresis. Diffusion of local anesthetic, as well as direct placement of local anesthetic adjacent to the posterior tubercle, will result in somatic block of the upper extremity. This may take the form of a small area of sensory loss due to diffusion of local anesthetic or a complete brachial plexus block when the local anesthetic is placed within the nerve sheath. Patients with significant somatic block to the upper extremity should be sent home with a sling in place and counseled to guard their limb, just as one would instruct a patient who had received a brachial plexus block.

Major complications associated with stellate ganglion block include neuraxial block (spinal or epidural) and seizures. Extreme medial angulation of the needle from a relatively lateral skin entry point may lead to needle placement into the spinal canal through the anterolaterally oriented intervertebral foramen. In this manner, local anesthetic can be deposited in the epidural space or, if the needle is advanced far enough, it may penetrate the dural cuff surrounding the spinal nerve and lie within the intrathecal space. More likely is placement of the needle tip on the posterior tubercle of the transverse process and spread of local anesthetic proximally along the nerve to enter the epidural space. In this case, partial or profound neuraxial block, including high spinal or epidural block with loss of consciousness and apnea, may ensue. Airway protection, ventilation, and intravenous sedation should be promptly administered and continued until the patient regains airway reflexes and consciousness. Because the maximal effects

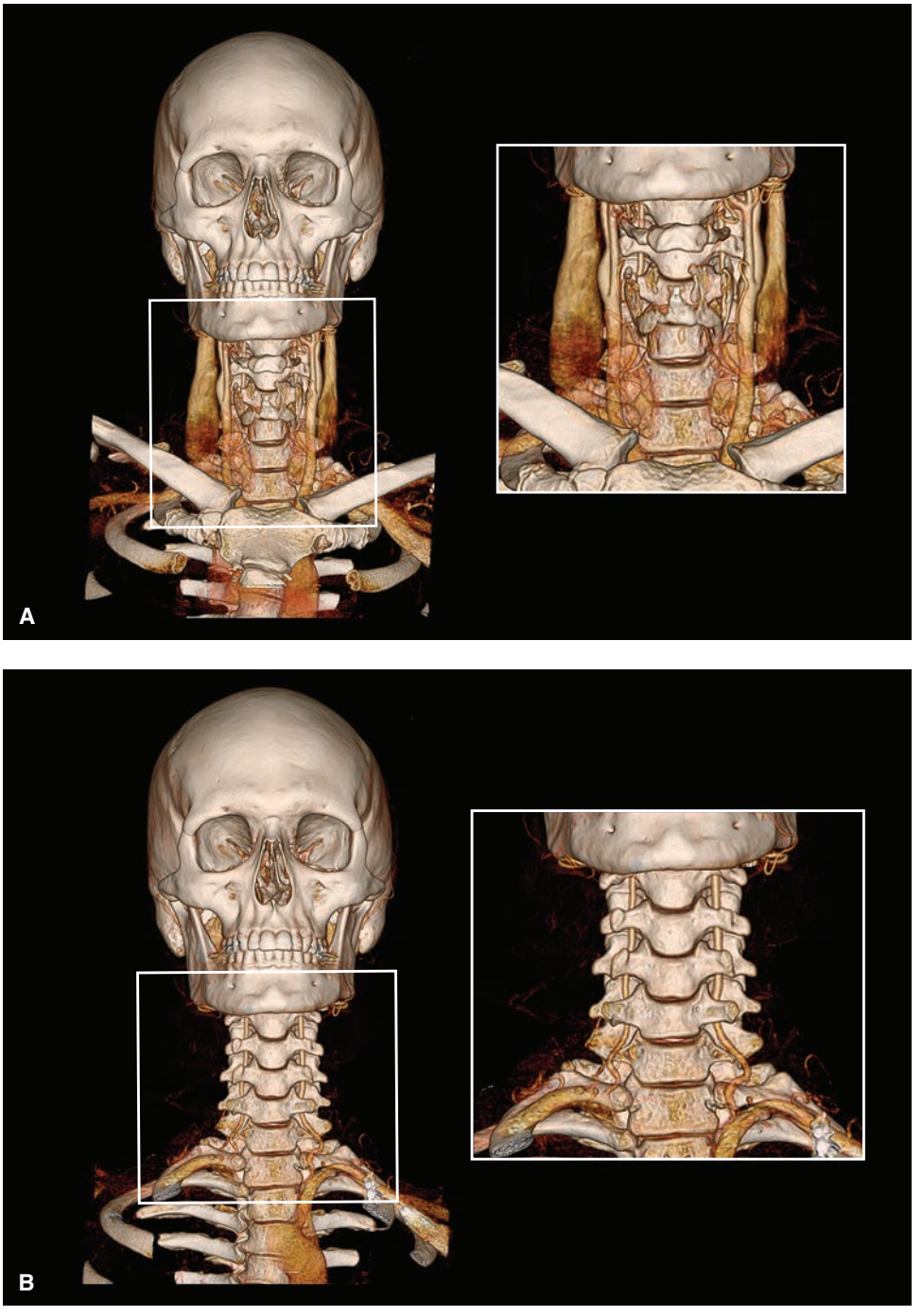

Figure 10-6.

A: Bony and vascular anatomy relevant to stellate ganglion block using an anterior paratracheal approach. Three-dimensional reconstruction computed tomography angiogram of the head and neck including the carotid artery as viewed in the anterior-posterior projection used to perform stellate ganglion block. **Inset** matches the anatomic area in the radiographs shown in **(C,D)**. **B:** Bony and vascular anatomy relevant to stellate ganglion block using an anterior, paratracheal approach. Three-dimensional reconstruction computed tomography angiogram of the head and neck with the carotid artery and sternocleidomastoid muscle removed to demonstrate the course of the vertebral artery as viewed in the anterior-posterior projection used to perform stellate ganglion block. **Inset** matches the anatomic area in the radiographs shown in **(C,D)**. *(Cont.)*

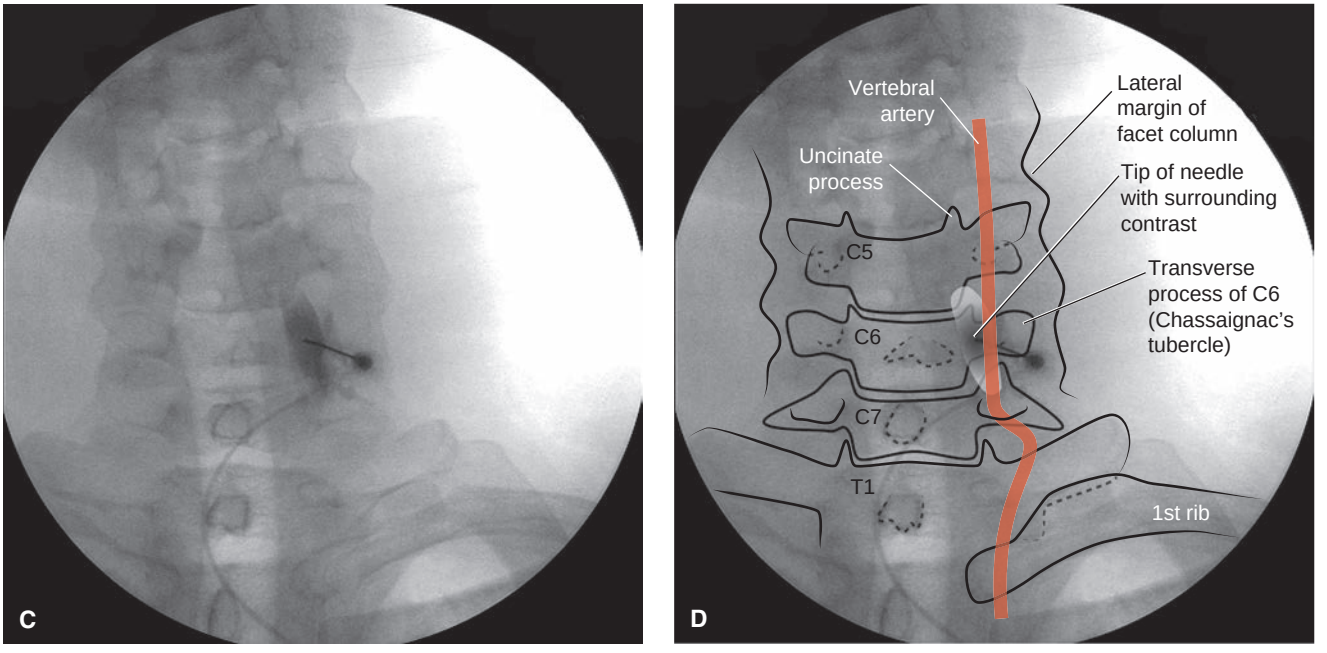

Figure 10-6. *(Continued)*

C: PA radiograph of the cervical spine during stellate ganglion block at C6. The needle is in position at the junction of the C6 transverse process and the vertebral body, just inferior to the uncinate process of C6. Radiographic contrast (1.5 mL of iohexol 180 mg per mL) has been injected and spreads along the anterolateral surface of C6 to reach the adjacent vertebra. Typically, 5 to 10 mL of volume is necessary to see spread to the level of the stellate ganglion at T1. **D:** Labeled image. The approximate location of the vertebral artery is shown.

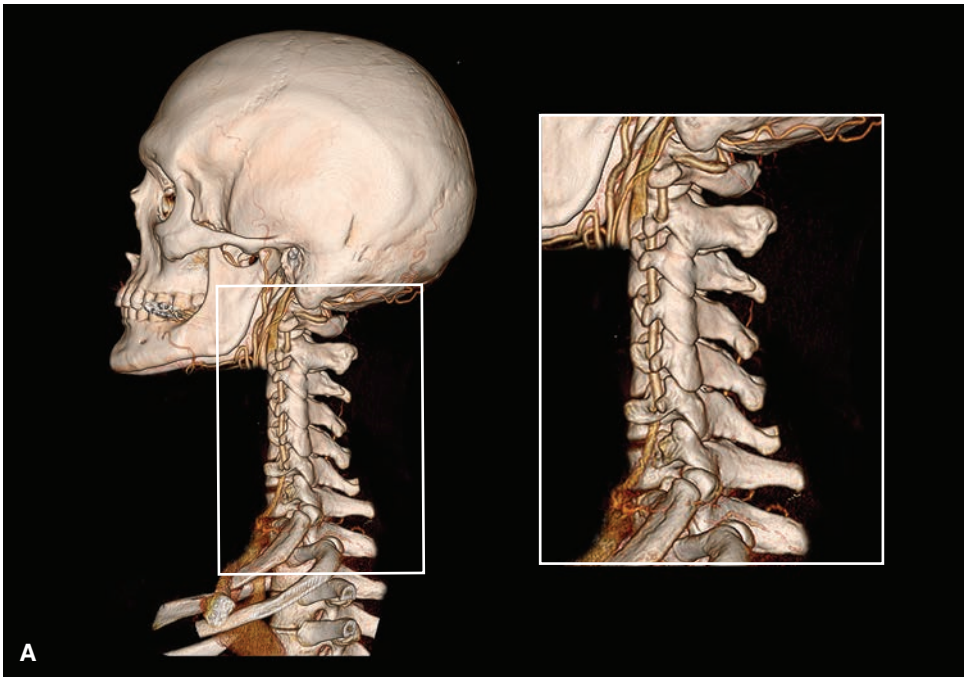

Figure 10-7.

A: Bony and vascular anatomy relevant to stellate ganglion block using an anterior, paratracheal approach. Three-dimensional reconstruction computed tomography angiogram of the head and neck with the carotid artery and sternocleidomastoid muscle removed to demonstrate the course of the vertebral artery as viewed in the lateral. **Inset** matches the anatomic area in the radiographs shown in **(B,C)**. *(Cont.)*

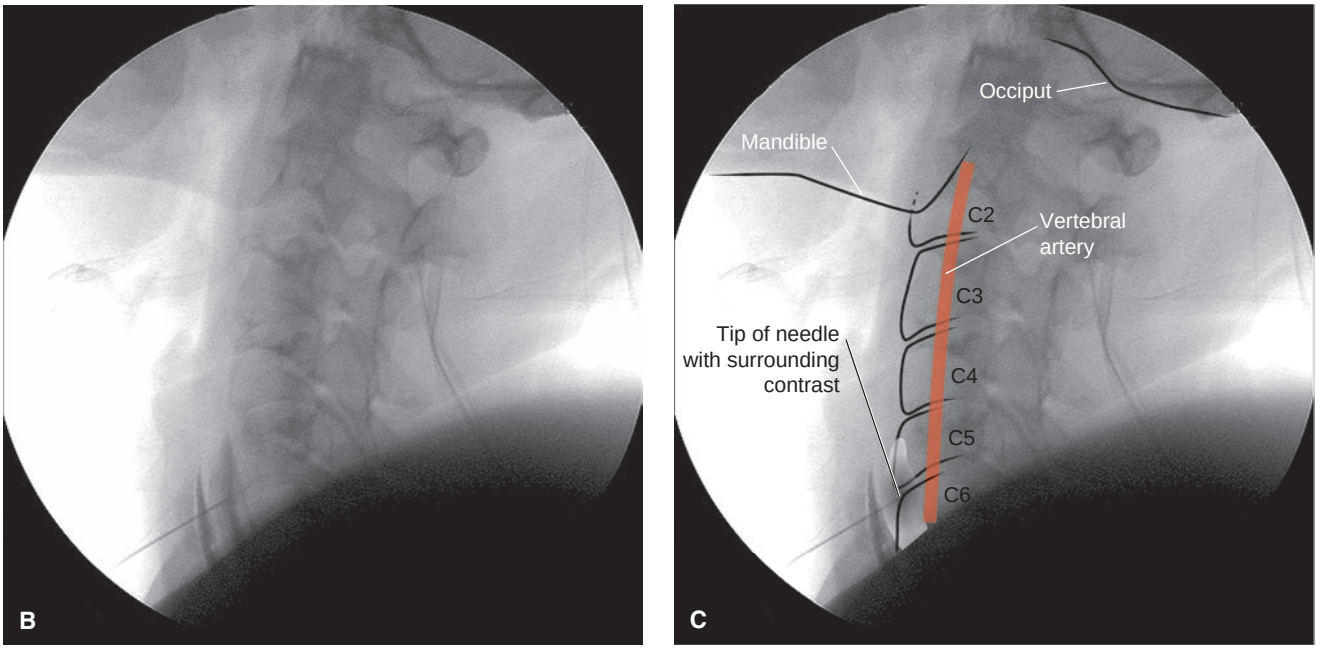

Figure 10-7. *(Continued)*

B: Lateral radiograph of the cervical spine during stellate ganglion block at C6. The needle is seated against the anterior surface of C6. Radiographic contrast (1.5 mL of iohexol 180 mg per mL) has been injected and spreads along the anterolateral surface of C6 to reach the adjacent vertebra. A small amount of contrast is seen in a more superficial plane and was placed before the needle was firmly seated against the vertebral body. **C:** Labeled image. The approximate location of the vertebral artery is shown.

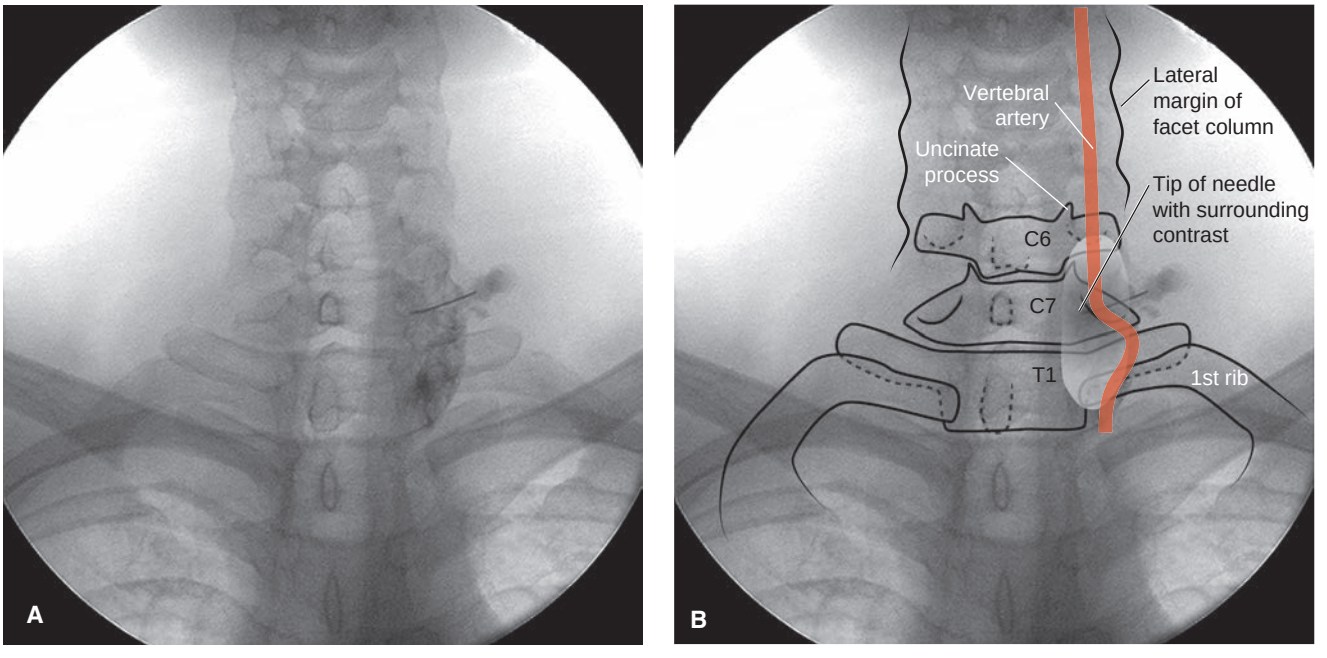

Figure 10-8.

A: PA radiograph of the cervical spine during stellate ganglion block at C7. The needle is in position at the junction of the C7 transverse process and the vertebral body, just inferior to the uncinate process of C7. Particular care must be taken when performing stellate ganglion block at the C7 level. The needle tip must remain aligned below the uncinate process or more medial to avoid the vertebral artery, which courses unprotected over the anterior surface of the C7 transverse process in many individuals. Radiographic contrast (1.5 mL of iohexol 180 mg per mL) has been injected, followed by 10 mL of 0.25% bupivacaine, and spreads along the anterolateral surface of C6 to T2. **B:** Labeled image. The approximate location of the vertebral artery is shown.

Table 10–1

Signs of Successful Stellate Ganglion Block

- Horner's syndrome
  - Miosis (pupillary constriction)
  - Ptosis (drooping of the upper eyelid)
  - Enophthalmos (recession of the globe within the orbit)
- Anhidrosis (lack of sweating)
- Nasal congestion
- Venodilation in the hand and forearm
- Increase in temperature of the blocked limb by at least 1°C

of epidural local anesthetic may require 15 to 20 minutes to develop when using longer acting local anesthetics, it is imperative that patients are monitored for at least 30 minutes after stellate ganglion block.

Intravascular injection during stellate ganglion block will likely result in immediate onset of generalized seizures. The carotid artery lies just anteromedial to Chassaignac's tubercle, whereas the vertebral artery lies within the bony transverse foramen just posteromedial to the tubercle. If injection occurs into either structure, the local anesthetic injected enters the arterial supply traveling directly to the brain, and generalized seizures typically begin rapidly and after only small amounts of local anesthetic (as little as 0.2 mL of 0.25% bupivacaine have led to seizure). However, because the local anesthetic rapidly redistributes, the seizures are typically brief and do not require treatment. In the event of seizure, halt the injection, remove the needle, and begin supportive care (see Chapter 4 for more detail regarding local anesthetic toxicity).

SUGGESTED READINGS

American Society of Anesthesiologists Task Force on Chronic Pain Management; American Society of Regional Anesthesia and Pain Medicine. Practice guidelines for chronic pain management: an updated report by the American Society of Anesthesiologists Task Force on Chronic Pain Management and the American Society of Regional Anesthesia and Pain Medicine. *Anesthesiology*. 2010;112:810–833.

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CHAPTER 11

Celiac Plexus Block and Neurolysis

OUTLINE

Overview

Neurolytic celiac plexus block (NCPB) is among the most widely applicable of all neurolytic blocks. NCPB has a long-lasting benefit for 70% to 90% of patients with pancreatic and other intra-abdominal malignancies. Several techniques have been described for localizing the celiac plexus. The classic technique employs a percutaneous posterior approach, using surface and bony landmarks to position needles in the vicinity of the plexus. Numerous reports have described new approaches for celiac plexus block (CPB), using guidance from plain radiographs, fluoroscopy, computed tomography (CT), or ultrasound. No single methodology has proven clearly superior in either its safety or its success rate. In more recent years, it has been generally agreed that radiographic guidance is necessary to perform CPB. Many practitioners have turned to routine use of CT, taking advantage of the ability to visualize adjacent structures when performing this technique.

Anatomy

The celiac plexus is comprised of a diffuse network of nerve fibers and individual ganglia that lie over the anterolateral surface of the aorta at the T12/L1 vertebral level. Sympathetic innervation to the abdominal viscera arises from the anterolateral horn of the spinal cord between the T5 and T12 levels. Nociceptive information from the abdominal viscera is carried by afferents that accompany the sympathetic nerves. Presynaptic sympathetic fibers travel from the thoracic sympathetic chain toward the ganglion, traversing over the anterolateral aspect of the inferior thoracic vertebrae as the greater (T5 to T9), lesser (T10 to T11), and least (T12) splanchnic nerves (Fig. 11-1). Presynaptic fibers traveling via the splanchnic nerves synapse within the celiac ganglia over the anterolateral surface of the aorta surrounding the origin of the celiac and superior mesenteric arteries at approximately the L1 vertebral level. Postsynaptic fibers from the celiac ganglia innervate all the abdominal viscera, with the exception of the descending colon, sigmoid colon, rectum, and pelvic viscera.

CPB using a transcrural approach places the local anesthetic or neurolytic solution directly on the celiac ganglion anterolateral to the aorta (see Fig. 11-1). The needles pass directly through the crura of the diaphragm en route to the celiac plexus. Spread of the solution toward the posterior surface of the aorta may thus be limited, perhaps reducing the chance of spinal nerve or spinal segmental artery involvement. In contrast, splanchnic nerve block (see Fig. 11-1) avoids the risk of penetrating the aorta and uses smaller volumes of solution, and the success is unlikely to be affected by anatomic distortion caused by extensive adenopathy or tumor within the pancreas. Because the needles remain posterior to the diaphragmatic crura in close apposition to the T12 vertebral body, this has been termed the retrocrural technique. Splanchnic nerve block is a minor modification of the classic retrocrural CPB; the only difference being that for splanchnic block, the needles are placed over the midportion of the T12 vertebral body rather than over the cephalad portion of L1. Retrocrural CPB at the superior aspect of the L1 vertebral body and splanchnic nerve block at the mid T12 vertebral body have both been described, and they are essentially the same technique, relying on cephalad spread of solution to block the splanchnic nerves in a retrocrural location.

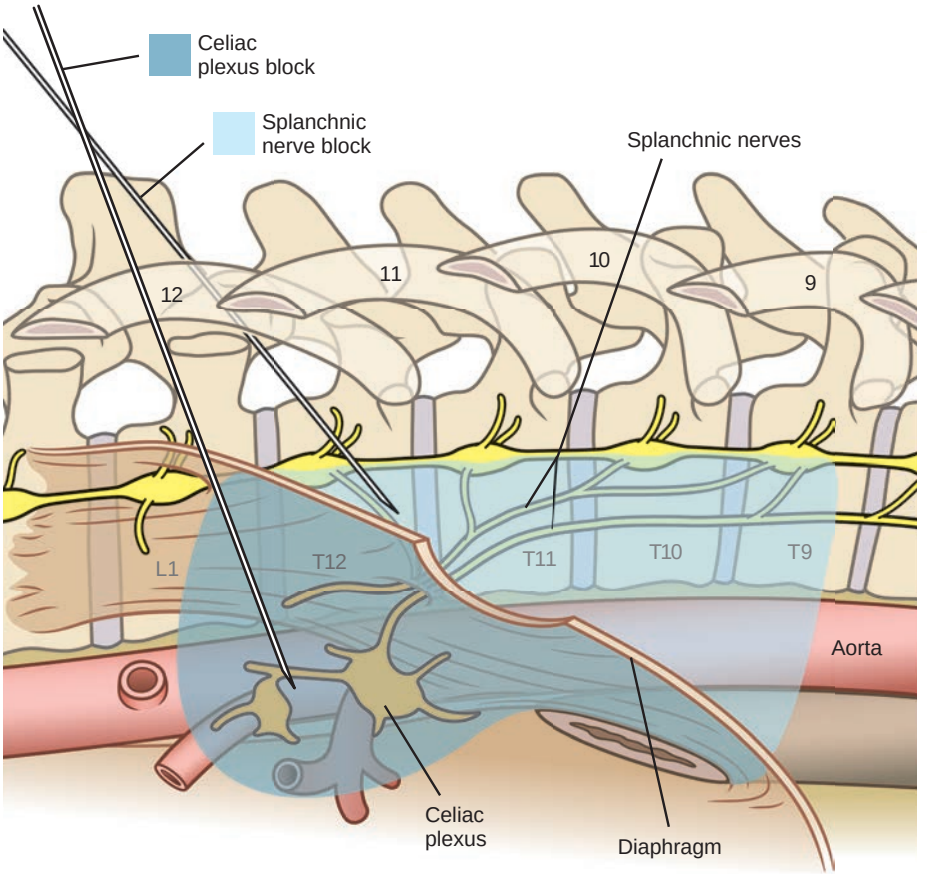


Figure 11-1.
Anatomy of the celiac plexus and splanchnic nerves. The celiac plexus is comprised of a diffuse network of nerve fibers and individual ganglia that lie over the anterolateral surface of the aorta at the T12/L1 vertebral level. Presynaptic sympathetic fibers travel from the thoracic sympathetic chain toward the ganglion, traversing over the anterolateral aspect of the inferior thoracic vertebrae as the greater (T5 to T9), lesser (T10 to T11), and least (T12) splanchnic nerves. CPB using a transcrural approach places the local anesthetic or neurolytic solution directly on the celiac ganglion anterolateral to the aorta. The needles pass directly through the crura of the diaphragm en route to the celiac plexus. In contrast, for splanchnic nerve blocks, the needles remain posterior to the diaphragmatic crura in close apposition to the T12 vertebral body. Shading indicates the pattern of solution spread for each technique.

In most cases, celiac plexus (transcrural or retrocrural) and splanchnic nerve block can be used interchangeably to affect the same results. Although there are those who strongly advocate one approach over the other, there is no evidence that either results in superior clinical outcomes.

Patient Selection

Celiac plexus and splanchnic nerve block are used to control pain arising from intra-abdominal structures. These structures include the pancreas, liver, gall bladder, omentum, mesentery, and alimentary tract from the stomach to the transverse colon. The most common application of NCPB is to treat pain associated with intra-abdominal malignancy, particularly pain associated with pancreatic cancer. Neurolysis of the splanchnic nerves or celiac plexus can produce dramatic pain relief, reduce or eliminate the need for supplemental analgesics, and improve quality of life in patients with pancreatic cancer and other intra-abdominal malignancies. The long-term benefit of NCPB in patients with chronic nonmalignant pain, particularly those with chronic pancreatitis, is debatable.

Level of Evidence

Quality of Evidence and Grading of Recommendation			
Grade of Recommendation/Description	**Benefit vs. Risk and Burdens**	**Methodological Quality of Supporting Evidence**	**Implications**
RECOMMENDATION: *Celiac plexus block (CPB) for pain secondary to pancreatic cancer. Neurolytic CPB should be used for reduction of abdominal pain and reducing opioid-related side effects in patients with pain associated with pancreatic cancer. Treatment may be more effective in those with early malignancy and those with tumor located in the head of the pancreas when compared with the body of tail of the gland.*			
1A/strong recommendation, high-quality evidence	Benefits clearly outweigh risk and burdens, or vice versa	I: Randomized controlled trials (RCTs) without important limitations or overwhelming evidence from observational studies	Strong recommendation, can apply to most patients in most circumstances without reservation
RECOMMENDATION: *Celiac plexus block (CPB) for pain secondary to chronic pancreatitis. CPBs using local anesthetics may be used for the treatment of pain secondary to chronic pancreatitis.*			
2C/weak recommendation, low-quality or very low-quality evidence	Uncertainty in the estimates of benefits, risks, and burden; benefits, risk, and burden may be closely balanced	II-2: Observational studies or case series	Very weak recommendations; other alternatives may be equally reasonable

The use of NCPB using alcohol or phenol to treat abdominal pain associated with intra-abdominal malignancy, particularly pain associated with pancreatic cancer, has shown considerable benefit in controlled trials. The use of CPB using local anesthetic solutions with or without corticosteroids for treating pain secondary to chronic pancreatitis is less well studied, but observational trials suggest intermediate-term pain reduction in some patients.

A 2011 Cochrane Library Review examined the available evidence for use of CPB for pancreatic cancer pain in adults and concluded, "Although statistical evidence is minimal for the superiority of pain relief over analgesic therapy, the fact that CPB causes fewer adverse effects than opioids is important for patients." The American Society of Anesthesiologists (ASA) Task Force on Chronic Pain Management published a 2010 Practice Guideline, offering the following recommendation regarding the use of CPBs for the treatment of pain associated with chronic pancreatitis: "Studies with observational findings report that celiac plexus blocks can provide pain relief for 25–50% of patients with pancreatitis for assessment periods ranging from 1 to 6 months."

While there is strong support from controlled trials for the use of NCPB for treating pain due to pancreatic cancer, significant questions remain. There are numerous methods for performing this block, including the fluoroscopic and CT-guided techniques described here as well an endoscopic, transgastric, ultrasound-guided technique performed primarily by gastroenterologists. There is little information to guide choice among the various approaches. Likewise, the use of both alcohol and phenol as neurolytic agents remains common, and there is no evidence that one agent is superior to the other. Finally, the use of local anesthetic alone and anesthetic and steroid combinations has been reported in the treatment of pain associated with chronic pancreatitis, and there is little scientific study to guide choice between the two. However, the use of particulate steroid in this region should be untaken with great caution, as the arterial supply to the spinal cord lies in close proximity to the site of injection and placement of particulate steroid into a critical reinforcing artery to the spinal cord is likely to lead to catastrophic spinal cord infarction.

Positioning

The patient lies prone with the head turned to one side (Fig. 11-2). The C-arm is centered over the thoracolumbar junction. The final needle position for CPB is over the anterolateral surface of the aorta, just anterior to the T12/L1 junction. The C-arm is rotated obliquely 20 to 30 degrees, until the tip of the transverse process of L1 overlies the anterolateral margin of the L1 vertebral body (Fig. 11-3). The final needle position for splanchnic nerve block is anterolateral to the T12 vertebral body; thus, cephalad angulation of the C-arm is also needed to bring the inferior margin of the 12th rib cephalad to the T12 vertebral body (see Fig. 11-2).

Block Technique

Celiac Plexus Block (Transcrural Technique)

Once the C-arm is aligned, the skin and subcutaneous tissues overlying the superior margin of the L1 vertebral body are anesthetized with 1 to 2 mL of 1% lidocaine. The aorta lies to the left of midline over the vertebral bodies.

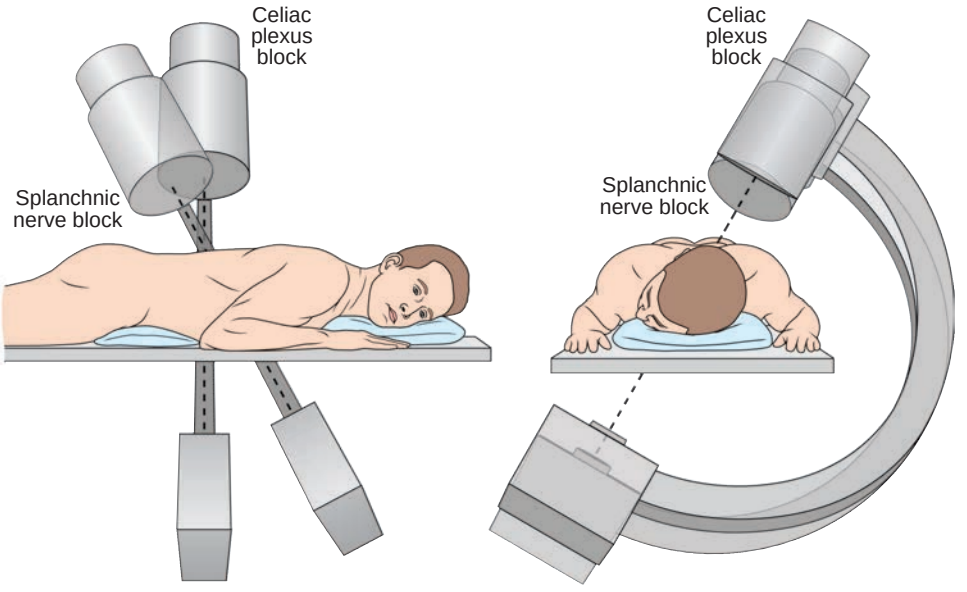


Figure 11-2.
Position for CPB and splanchnic nerve block. The patient is placed prone with the head turned to one side. The C-arm is rotated obliquely 20 to 30 degrees until the tip of the transverse process of L1 overlies the anterolateral margin of the L1 vertebral body (Fig. 11-3). For splanchnic nerve block, the C-arm is then angled 20 to 30 degrees cephalad to bring the inferior margin of the 12th rib cephalad to the T12 vertebral body.

By routinely placing the left-sided needle first, a single needle can often be used for the block (see Fig. 11-3). If the aorta is penetrated en route, a transaortic technique is employed. A 22-gauge, 5-inch spinal needle (8 inch for the obese patient) is advanced just caudal to the margin of the 12th rib and cephalad to the transverse process of L1 toward the anterolateral surface of the L1 vertebral body. The needle is advanced, using repeat images every 1 to 2 cm of advancement to ensure the needle remains coaxial until the needle contacts the anterolateral margin of L1. The

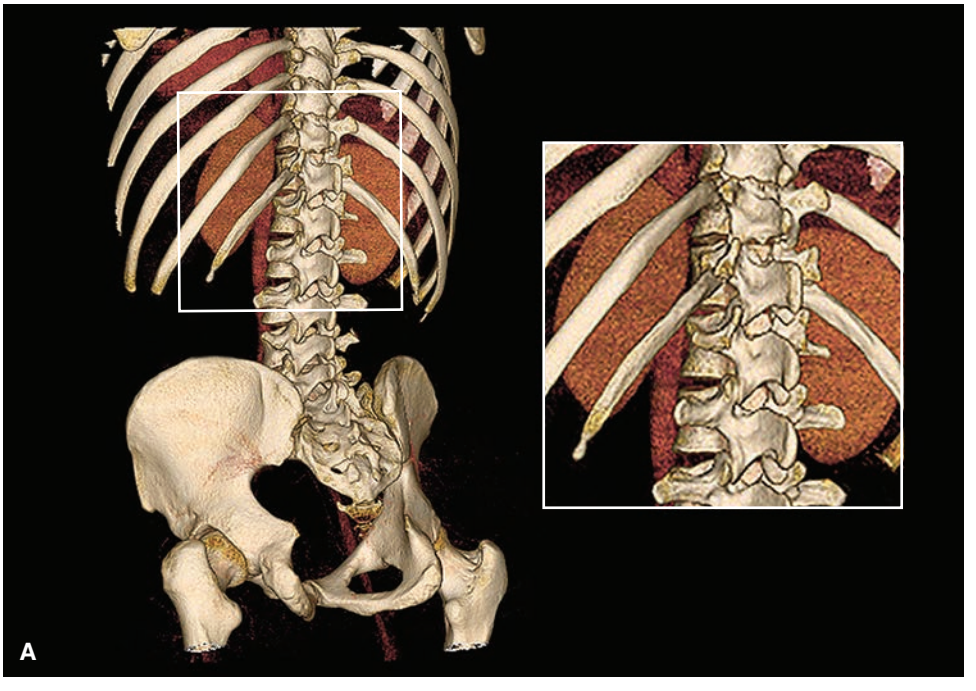


Figure 11-3.
A: Bony and vascular anatomy relevant to CPB using posterolateral approach. Three-dimensional reconstruction CT angiogram of the abdomen including the aorta and kidneys as viewed in the posterior oblique projection used to perform CPB. **Inset** matches the anatomic area in the radiographs shown in **(B,C).** ***(Cont.)***

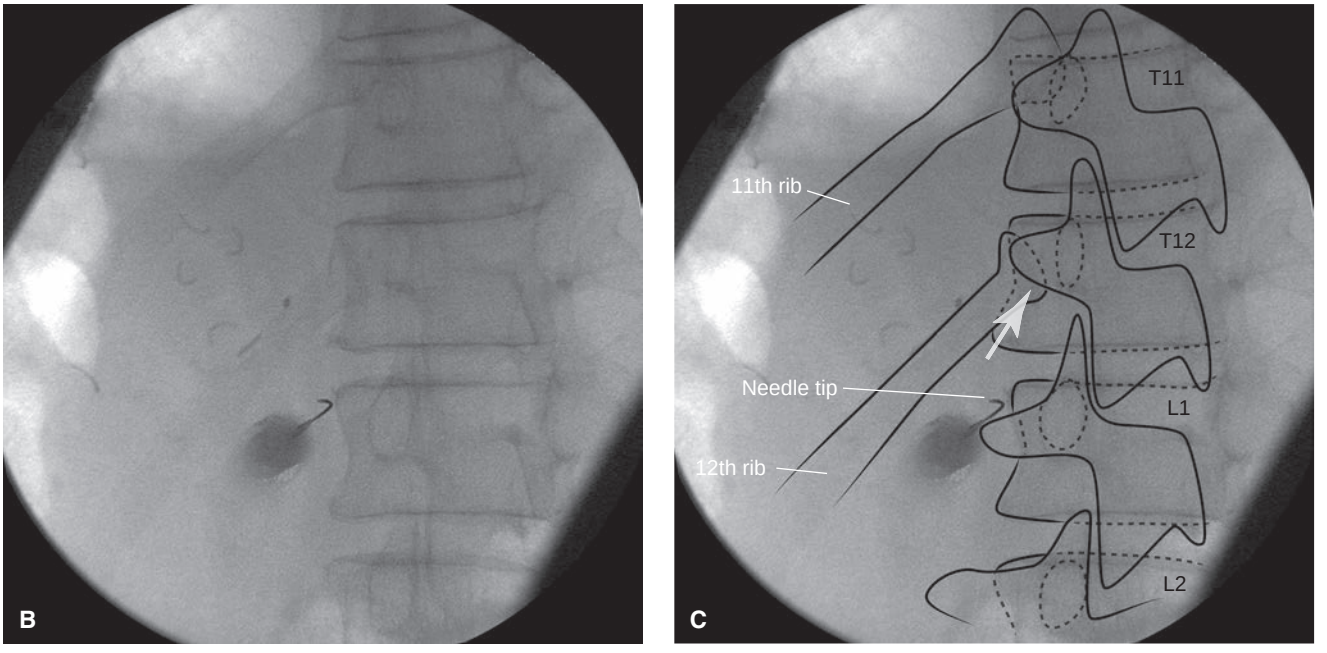


Figure 11-3. *(Continued)*
B: Oblique radiograph of the spine during CPB. A needle passes from left oblique angle to lie over the anterolateral surface of the superior aspect of the L1 vertebral body. It passes superior to the transverse process of L1 and inferomedial to the 12th rib. **C:** Labeled image. The *white arrow* indicates the final needle position for splanchnic nerve block.

C-arm is then rotated to a lateral projection, and the needle is advanced to lie 2 to 3 cm anterior to the anterior margin of L1 in the lateral view (Fig. 11-4). Continuous aspiration should be applied as the needle is advanced anterior to the anterior border of L1. If blood appears, the needle has penetrated the aorta and should be advanced through the anterior wall of the aorta, until blood can no longer be aspirated. The needle tip should be medial to the lateral border

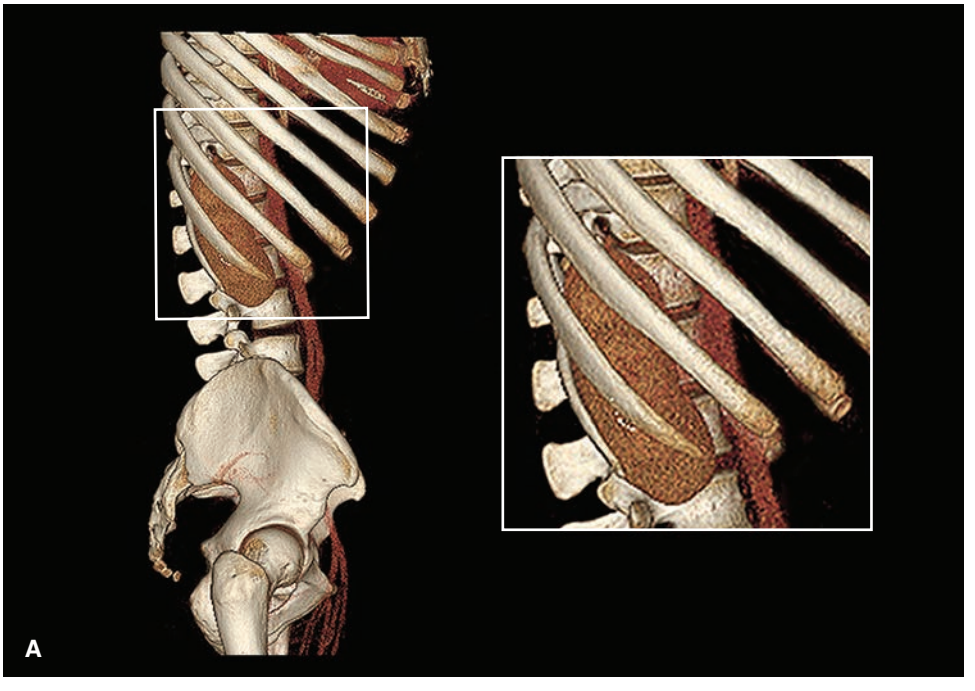


Figure 11-4.
A: Bony and vascular anatomy relevant to CPB. Three-dimensional reconstruction CT angiogram of the abdomen including the aorta and kidneys as viewed in the lateral projection. **Inset** matches the anatomic area in the radiographs shown in **(B,C).** *(Cont.)*

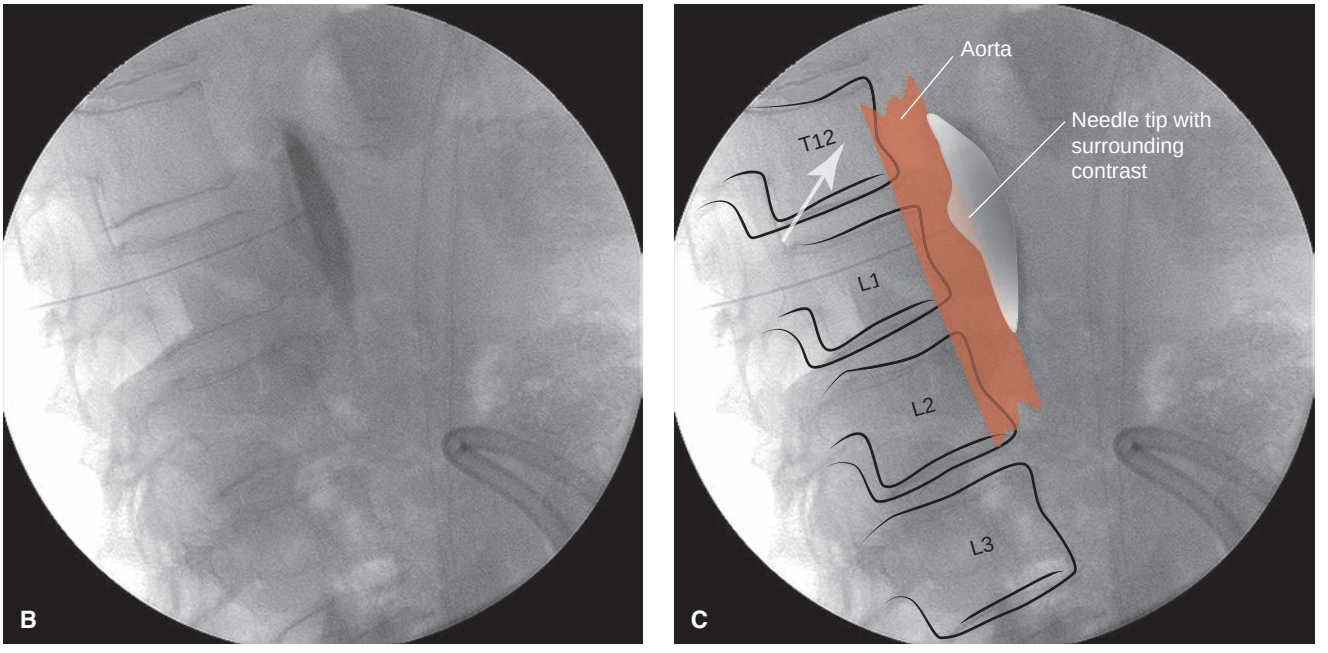


Figure 11-4. *(Continued)*

B: Lateral radiograph of the spine during CPB. A single needle is in final position over the anterolateral surface of the aorta, ~2 cm anterior to the vertebral body of L1. Radiographic contrast (2 mL of iohexol 180 mg per mL) has been injected. The contrast layers over the anterior surface of the aorta, and during live fluoroscopy, pulsation of the aorta can be seen. Note the slight rotation of the vertebral bodies such that the left and right intervertebral foramina are not aligned. **C:** Labeled image. The *white arrow* indicates the final needle position for splanchnic nerve block.

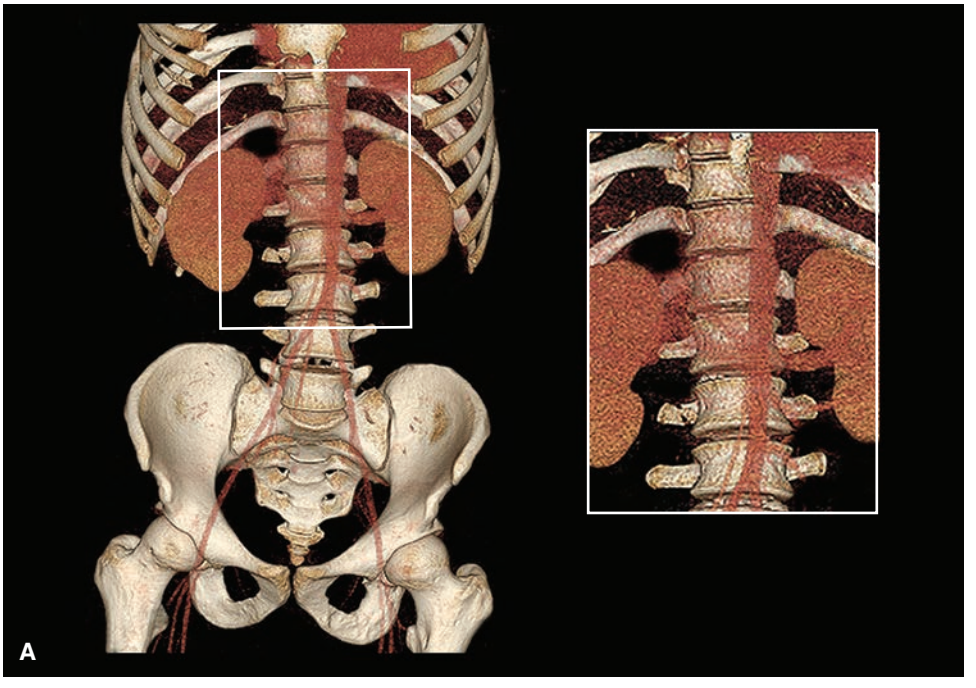
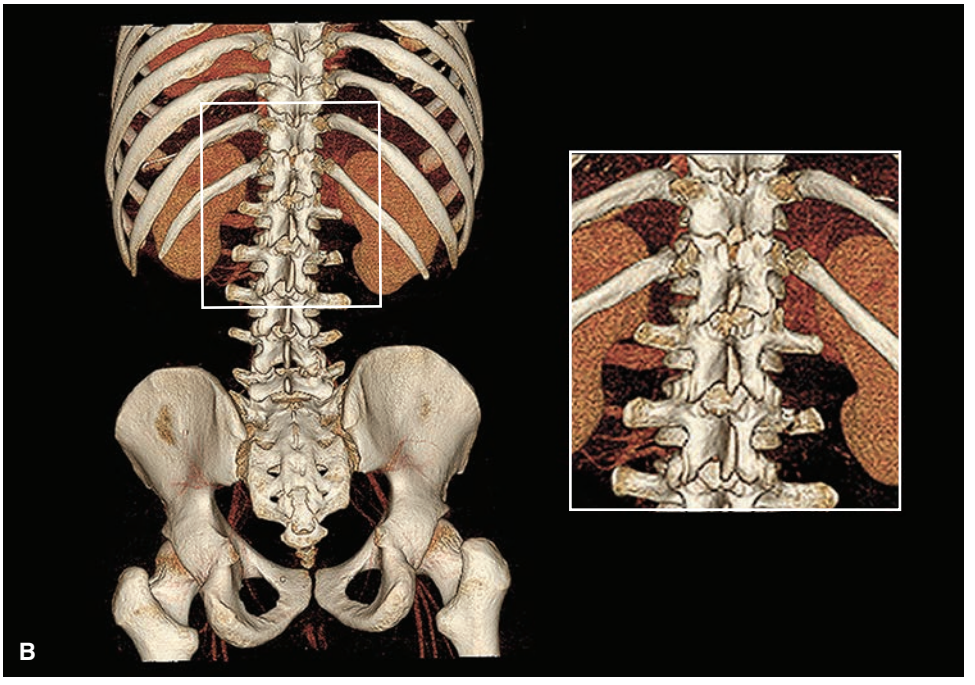


Figure 11-5.

A: Bony and vascular anatomy relevant to CPB. Three-dimensional reconstruction CT angiogram of the abdomen including the aorta and kidneys as viewed in the AP projection (anterior view is used here to best demonstrate the position of the aorta and kidneys relevant to the vertebrae). **Inset** matches the anatomic area in the radiographs shown in **(C,D).** *(Cont.)*



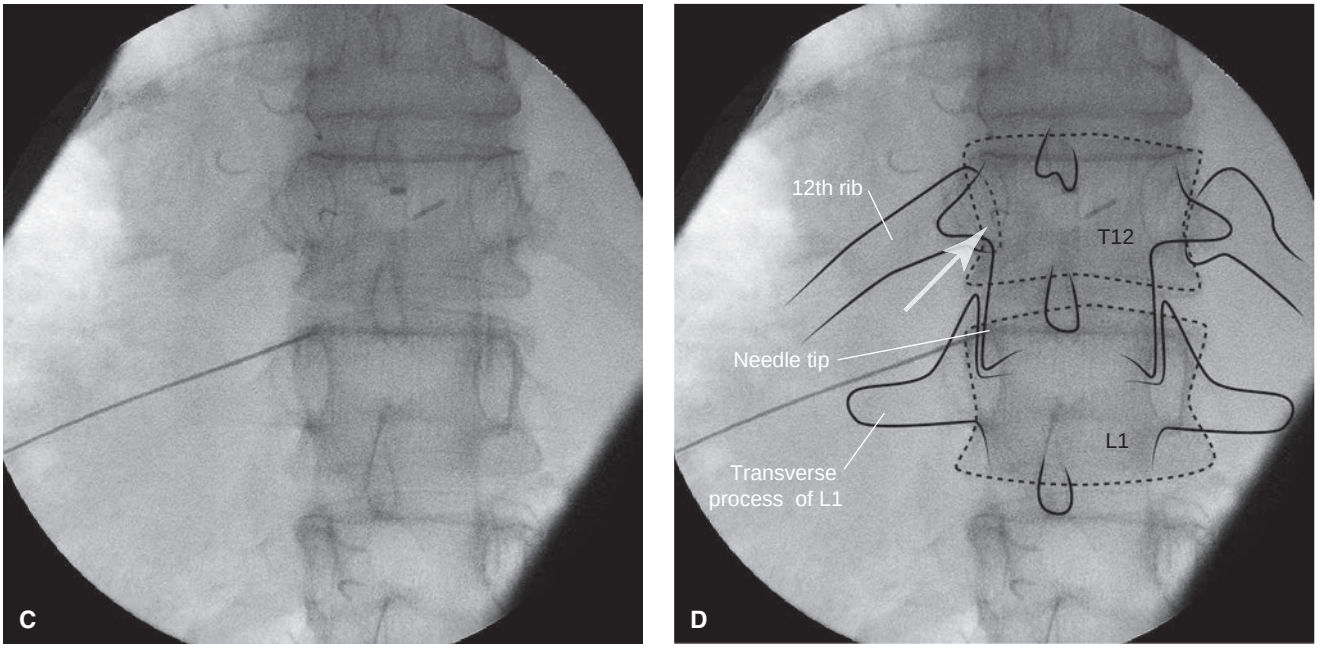


Figure 11-5. *(Continued)*

B: Bony and vascular anatomy relevant to CPB. Three-dimensional reconstruction CT angiogram of the abdomen including the aorta and kidneys as viewed in the AP projection (posterior view is used here to best demonstrate the anatomy of the bony posterior elements of the spine). **Inset** matches the anatomic area in the radiographs shown in **(C,D). C:** AP radiograph of the spine during CPB. A single needle has been inserted from a left oblique approach and is in final position over the anterolateral surface of the aorta. **D:** Labeled image. The *white arrows* indicate the final needle position for splanchnic nerve block.

of the L1 vertebral body in the anterior-posterior (AP) view (Fig. 11-5). Final needle position is confirmed by injecting 1 to 2 mL of radiographic contrast (iohexol 180 mg per mL) under live fluoroscopy. The contrast should layer over the anterior surface of the aorta (see Fig. 11-4) and appear pulsatile. If the contrast spreads to both sides of midline over the anterior surface of the aorta (Fig. 11-6), then only a single needle is necessary for the block. If the contrast remains to the left of midline over the anterolateral surface of the aorta, a second needle is placed from the contralateral side using the same technique described for the left-sided block. Diagnostic imaging is almost universally available prior to

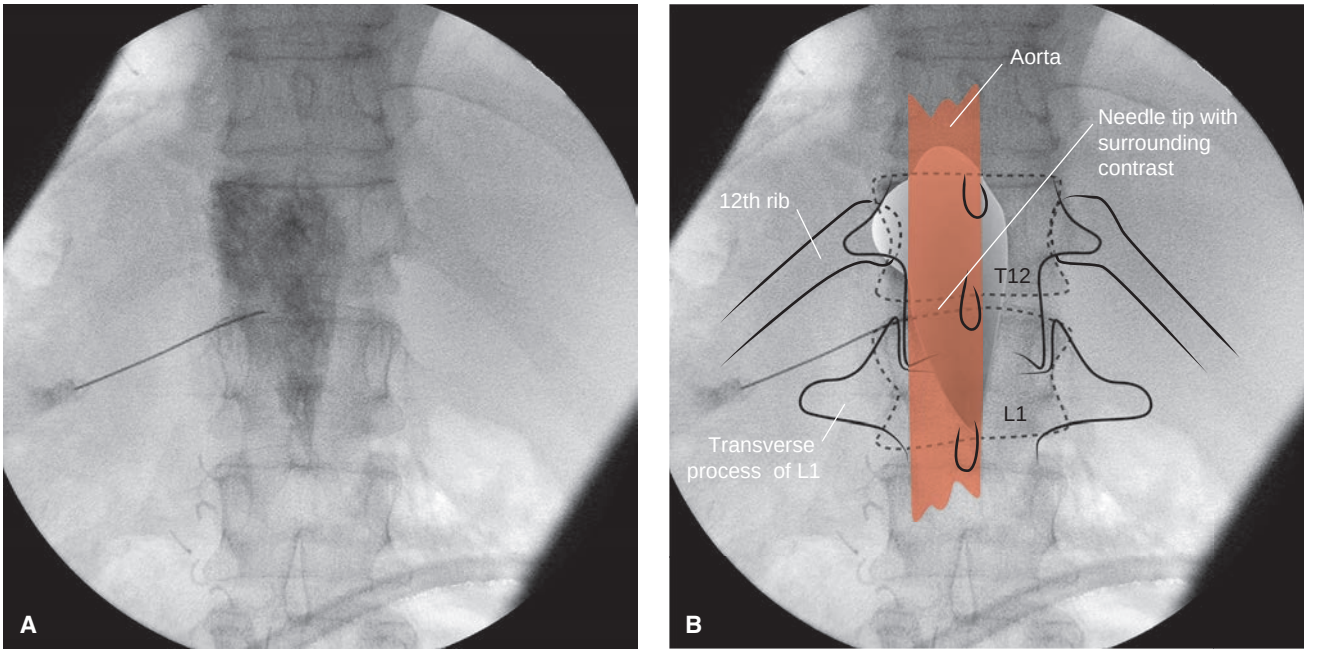


Figure 11-6.
A: AP radiograph of the spine during CPB. A single needle has been inserted from a left oblique approach and is in final position over the anterolateral surface of the aorta. Radiographic contrast (2 mL of iohexol 180 mg per mL) has been injected followed by 20 mL of 0.25% bupivacaine. The local anesthetic has diluted the contrast and extended the spread. A portion of the contrast spreads along the inferior border of the left hemidiaphragm. **B:** Labeled image. The approximate position of the aorta is shown.

performing CPB, and these diagnostic images can be used to plan the safest approach to needle placement and to perform precise measurements to guide the position of needle entry and the final depth of needle advancement (Fig. 11-7). The final needle location for CPB and the adjacent structures are illustrated in Figure 11-8. Diagnostic CPB prior to neurolysis is carried out using 20 to 30 mL of 0.25% bupivacaine (10 to 15 mL per side). The dose should be given in increments of 5 mL, aspirating periodically to ensure the needle has not moved to an intravascular location.

Splanchnic Nerve Block (Retrocrural Technique)

Once the C-arm is aligned, the skin and subcutaneous tissues overlying the anterolateral margin of the midportion of the T12 vertebral body are anesthetized with 1 to 2 mL of 1% lidocaine. For splanchnic nerve block and neurolysis, needles must be placed on both sides. A 22-gauge, 5-inch spinal needle (8 inch for the obese patient) is advanced just caudal to the margin of the 12th rib and cephalad to the transverse process of L1 toward the anterolateral surface of the T12 vertebral body. This requires 20 to 30 degrees of cephalad angulation of the C-arm (see Figs. 11-1 and 11-2). The needle is advanced, using repeat images every 1 to 2 cm of advancement to ensure the needle remains coaxial until the needle contacts the anterolateral margin of T12. The C-arm is then rotated to a lateral projection, and the needle is advanced 1 to 2 cm to align with the anterior one-third of the T12 vertebral body in the lateral view (see Fig. 11-4). The needle tip should be just medial to the lateral border of the T12 vertebral body in the AP view (see Fig. 11-5). Final needle position is confirmed by injecting 1 to 2 mL of radiographic contrast (iohexol 180 mg per mL) under live fluoroscopy. The contrast should layer over the anterolateral surface of the T12 vertebral body. A second needle is placed from the contralateral side, using the same technique described for the left-sided block. The final needle location for splanchnic nerve block and the adjacent structures are illustrated in Figure 11-9. Diagnostic splanchnic nerve block prior to neurolysis is carried out using 10 to 15 mL of 0.25% bupivacaine (5 to 8 mL per side). The dose should be given in increments of 5 mL or less, aspirating periodically to ensure the needle has not moved to an intravascular location.

Celiac Plexus and Splanchnic Neurolysis

The technique for needle placement is identical for diagnostic local anesthetic block of the celiac plexus or splanchnic nerves and for neurolysis. The two commonly used neurolytic solutions are ethyl alcohol and phenol. The pharmacology of these agents is discussed in detail in Chapter 4. A 10% to 12% solution of phenol can be prepared in radiographic contrast (iohexol 180 mg per mL). This allows the spread of the neurolytic solution to be monitored

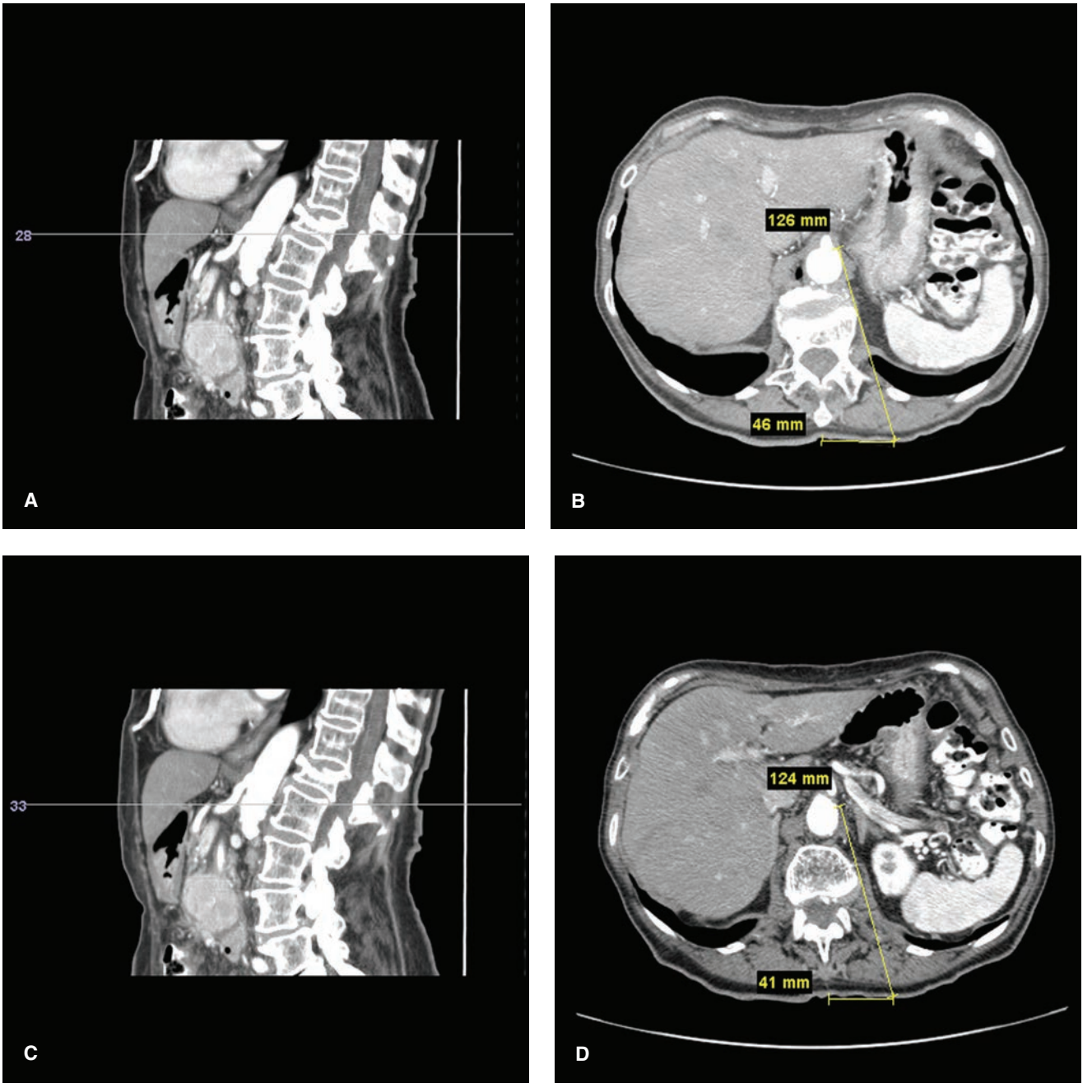


Figure 11-7.

Use of a diagnostic CT angiography study of the abdomen to plan position and depth of needle placement in a patient referred for CPB. The diagnostic CT angiogram can be used to determine the safest position to place needles and plan the final depth on needle insertion; these measurements can then be used to carry out the block with either fluoroscopy or CT guidance. **A:** Sagittal image through the celiac artery. The celiac artery arises from the aorta at the junction between the L1 and L2 vertebrae. This patient has a vertebral compression fracture of the L1 vertebral body. The *line* through this image corresponds with the axial image in **(B). B:** Axial image through the origin of the celiac artery from the anterior aorta, the typical site for CPB. Modern CT imaging software can be used to measure the distance from the anterolateral surface of the aorta to the skin surface (126 mm) and from the spinous process to the point of needle entry (46 mm). This patient has significant flattening of the diaphragms from chronic obstructive pulmonary disease. Performing the CPB at the level of L1 as shown will result in the needle traversing the pleura en route to the anterolateral surface of the aorta and is likely to result in a pneumothorax. **C:** Sagittal image 1 cm inferior to the origin of the celiac artery. The *line* through this image corresponds with the axial image in **(D). D:** Axial image 1 cm inferior to the origin of the celiac artery from the anterior aorta, below the inferior reflections of the pleura. The distance from the anterolateral surface of the aorta to the skin surface (124 mm) and from the spinous process to the point of needle entry (41 mm); similar measurements can be made for placement of the needle on the right side. Performing the CPB somewhat inferior to the celiac artery in this patient was carried out successfully: The needles were well below the pleura at this level.

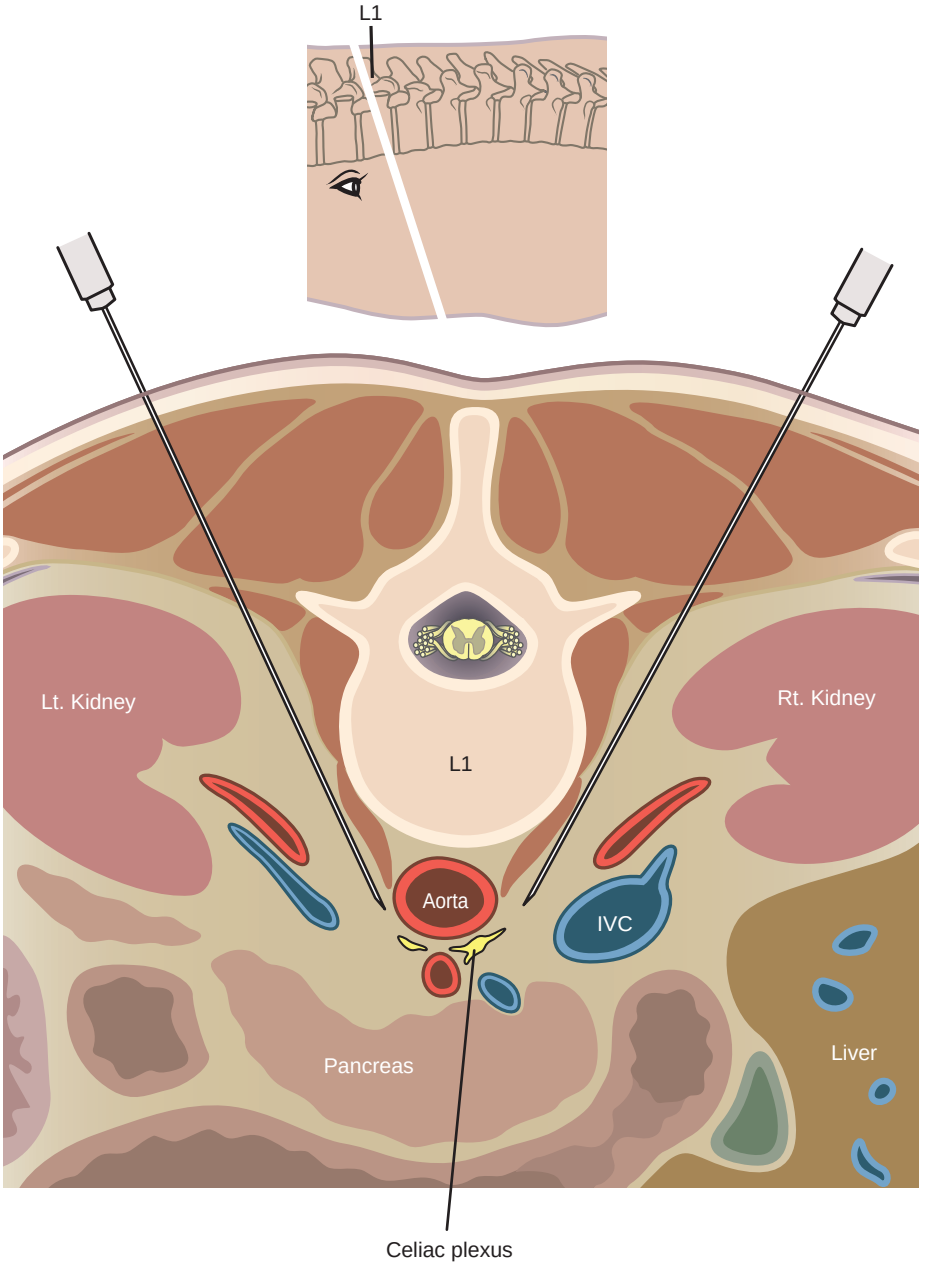


Figure 11-8.
Axial diagram of CPB. Two needles pass through the crura of the diaphragm adjacent to the L1 vertebral body and are in final position over the anterolateral surface of the aorta. The **inset** indicates the approximate plane of the needles.

radiographically as it is injected. For celiac plexus neurolysis, 20 to 30 mL (10 to 15 mL per side) is injected. If the neurolytic solution spreads to both sides of midline over the anterior surface of the aorta (see Fig. 11-6), then only a single needle is necessary for the block. If the neurolytic solution begins to spread posteriorly toward the intervertebral foramen, the injection should be halted to avoid nerve root injury. During splanchnic neurolysis, the contrast should layer over the anterolateral surface of the T12 vertebral body. A second needle is placed from the contralateral side using the same technique described for the left-sided block. For splanchnic neurolysis, 10 to 15 mL (5 to 8 mL per side) is injected. The needles should be flushed with saline or local anesthetic before they are removed to avoid depositing the neurolytic solution along the needle track. Neurolysis can also be carried out using 50% to 100% ethyl alcohol in similar volumes. Phenol has a direct local anesthetic effect and is associated with minimal pain on injection. Ethyl alcohol produces intense burning pain on injection and is best diluted with local anesthetic prior to injection or injected after placing a small volume of local anesthetic.

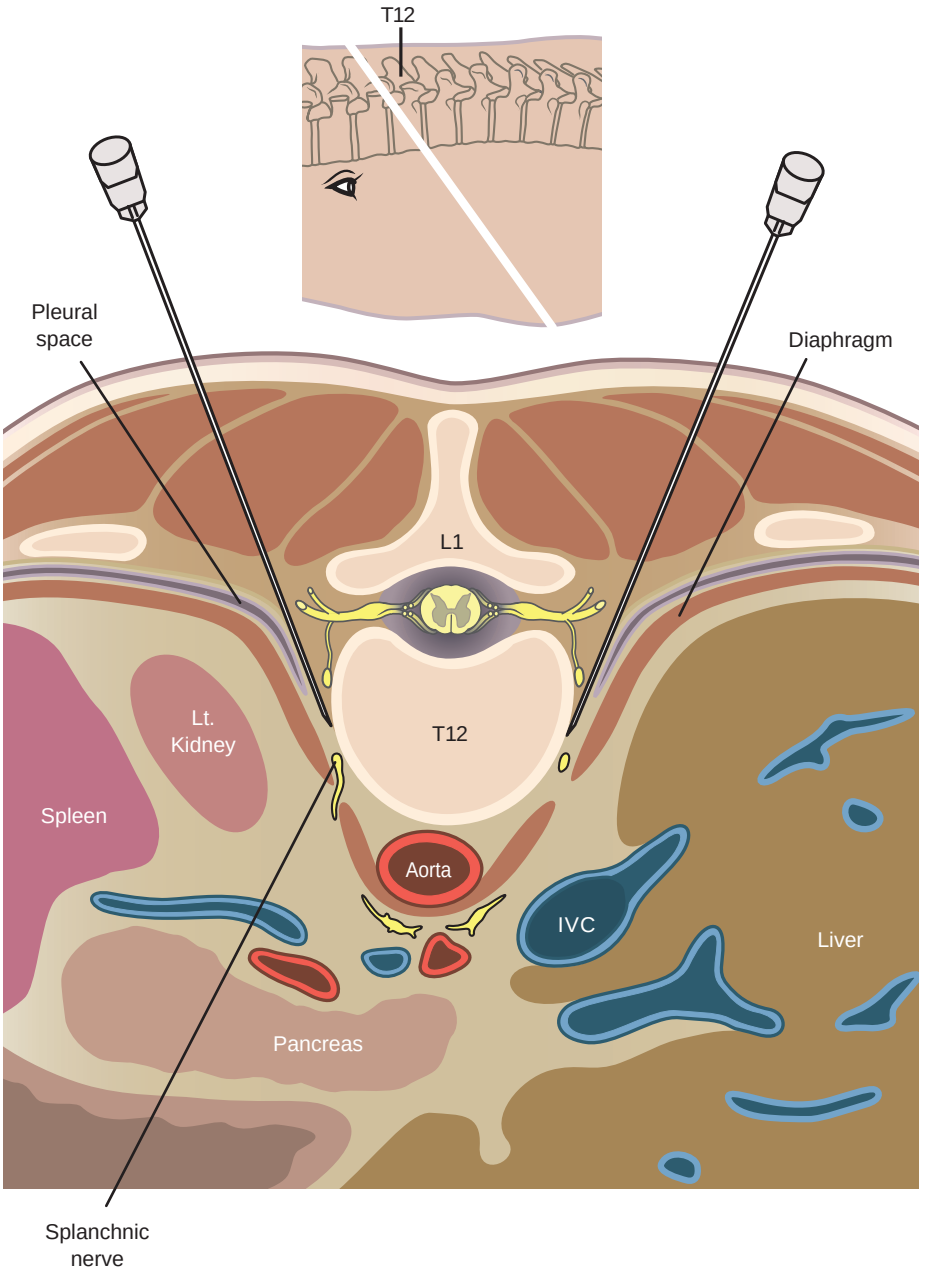


Figure 11-9.
Axial diagram of splanchnic nerve block. Two needles remain posterior to the crura of the diaphragm and are in final position over the anterolateral surface of the T12 vertebral body. The **inset** indicates the approximate plane of the needles.

Computed Tomography–guided Celiac Plexus Block

Although the majority of cases can be carried out using fluoroscopic guidance alone, CT allows excellent visualization of the anatomic structures that lie in close proximity to the target site during NCPB. To directly ablate the celiac plexus, the needles must be advanced through the diaphragm until they lie adjacent to the anterolateral surface of the aorta. This can be accomplished by advancing two separate needles adjacent to the anterolateral surface of the aorta (Fig. 11-10) or using a single needle advanced through the aorta (Fig. 11-11). CT allows visualization of the structures that lie adjacent to the celiac ganglion.

CT-guided CPB is carried out with the patient positioned prone in the CT scanner gantry with the head turned to one side (Fig. 11-12). A radiographic marker is placed on the skin surface 1 cm inferior to the inferior margin of

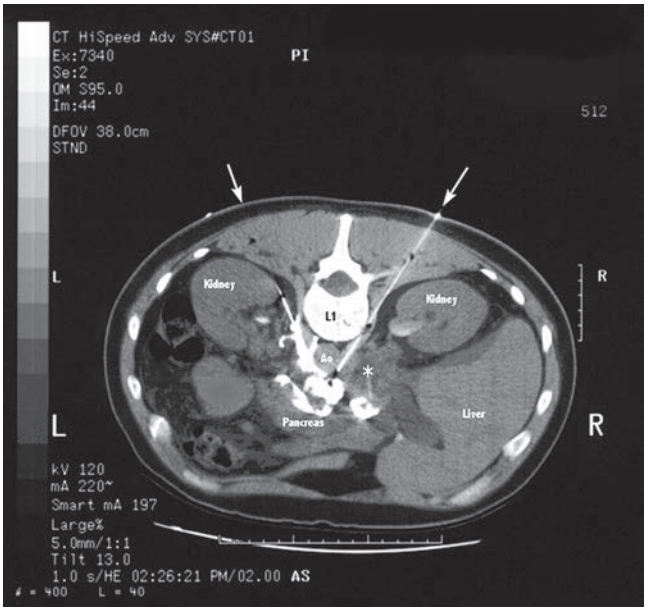


Figure 11-10.
CT after placement of two transcrural needles for NCPB. Neurolytic solution (10% phenol in iohexol 100 mg per mL) has been injected through both needles (10 mL on each side). The *arrows* indicate the approximate needle trajectory on each side. Contrast extends over the left anterolateral surface of the aorta and anteriorly along the posterior surface of the pancreas. There is a large soft-tissue mass adjacent to the right-sided needle (*asterisk*) consistent with adenopathy or metastatic tumor. (Reprinted from Rathmell JP, Gallant JM, Brown DL. Computed tomography and the anatomy of celiac plexus block. *Reg Anesth Pain Med*. 2000;25:412, with permission.)

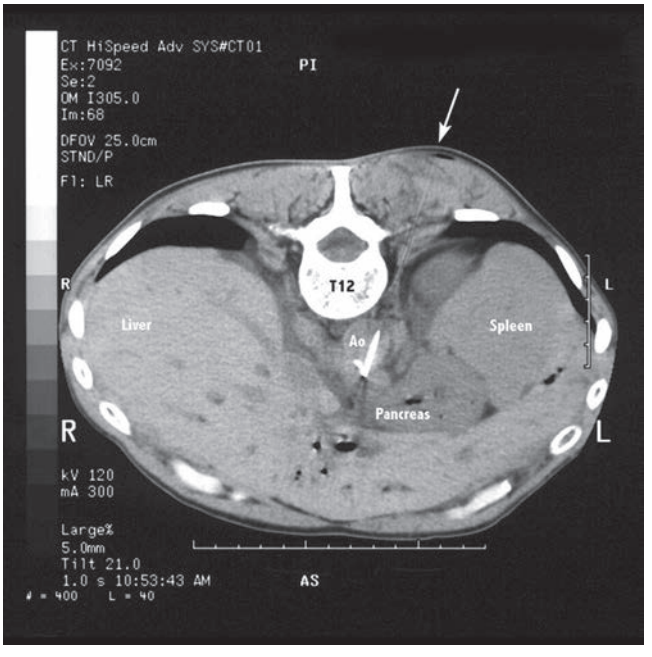


Figure 11-11.
CT after placement of a single transaortic needle. The *arrow* indicates the approximate trajectory of the needle. The medial pleural reflection can be seen passing within 2 mm of the needle's path. (Reprinted from Rathmell JP, Gallant JM, Brown DL. Computed tomography and the anatomy of celiac plexus block. *Reg Anesth Pain Med*. 2000;25:414, with permission.)

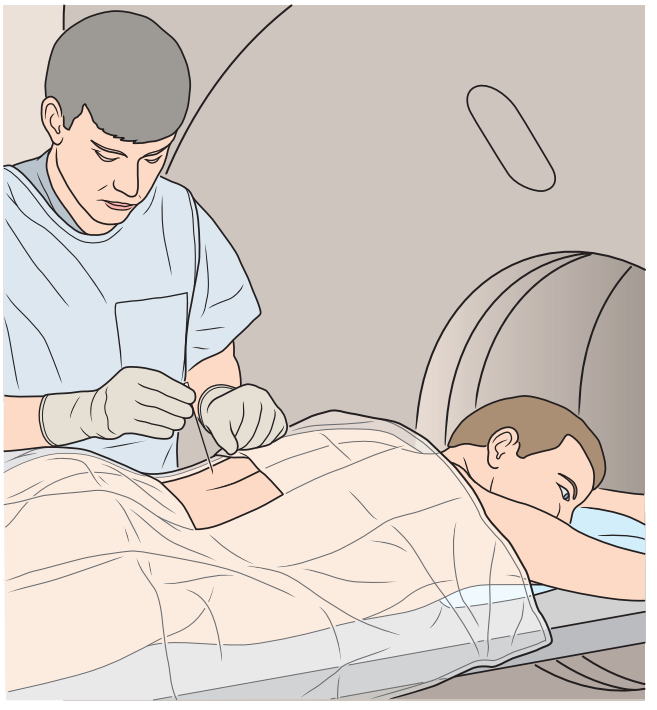


Figure 11-12. Patient position for CT-guided CPB. The patient is placed prone in the CT scanner gantry with the arms overhead and the head turned to one side. The operator stands to one side and advances the needle using a position and trajectory determined via the CT axial images (see Fig. 11-13).

the 12th rib and 7 cm from midline, and axial CT images extending from T12 through L1 are taken in 3-mm intervals. In this way, the position of the needle entry site on the skin's surface can be adjusted to form a direct path to the anterolateral surface of the aorta, without passing through adjacent structures (see Fig. 11-10). The skin is anesthetized with 1 to 2 mL of 1% lidocaine, and a 22-gauge, 5-inch spinal needle is then seated in a plane that corresponds to the axis seen on CT (the exact angle can be calculated using software available within the CT scanner). With the needle seated in the subcutaneous tissue, but still superficial, a repeat CT image is obtained through the tip of the needle (Fig. 11-13A), and the angle of the needle is then redirected toward the anterolateral surface of the aorta (Fig. 11-13B). The needle is advanced and repeat CT images are obtained after every 1 to 2 cm of needle advancement (Fig. 11-13C). Once the needle is in position, a small volume of radiographic contrast is injected to confirm needle position (0.5 mL of iohexol 100 mg per mL is sufficient, Fig. 11-13D). A 10% to 12% solution of phenol in radiographic contrast (iohexol 100 mg per mL) allows the spread of the neurolytic solution to be monitored radiographically as it is injected (Fig. 11-13E). A repeat CT image is obtained after every 5 mL of injection. For celiac plexus neurolysis, 20 to 30 mL (10 to 15 mL per side) is injected. If the neurolytic solution spreads to both sides of midline over the anterior surface of the aorta, then only a single needle is necessary for the block.

Complications

There are several physiologic side effects that are expected following CPB. These include diarrhea and orthostatic hypotension. Blockade of the sympathetic innervation to the abdominal viscera results in unopposed parasympathetic innervation of the alimentary tract and may produce abdominal cramping and sudden diarrhea. Likewise, the vasodilation that ensues often results in orthostatic hypotension. These effects are invariably transient but may persist for several days after neurolytic block. The hypotension seldom requires treatment other than intravenous hydration.

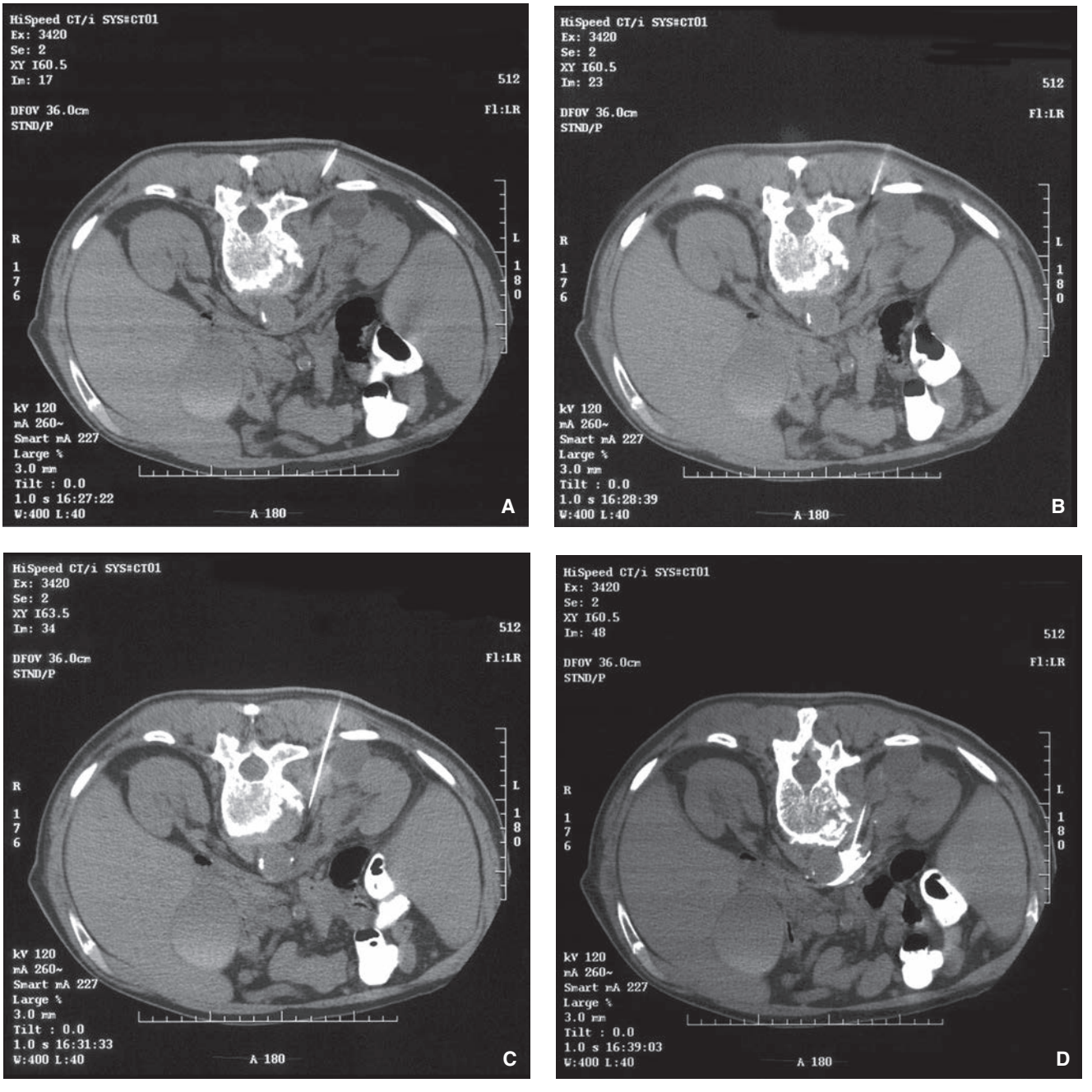


Figure 11-13.

Sequential axial images during CT-guided CPB. **A:** Axial image at the L1 vertebral level with the needle seated just beneath the skin. Note the needle is aimed directly at the transverse process. **B:** The needle direction has been corrected to pass lateral to the transverse process and toward the anterolateral surface of the aorta. **C:** Repeat axial images are obtained after every 1 to 2 cm of needle advancement and here shows the needle passing lateral to the L1 vertebral body. **D:** Axial image with the needle in final position over the anterolateral surface of the aorta and showing good spread of contrast over the anterior surface of the aorta (1 mL of iohexol 100 mg per mL). ***(Cont.)***

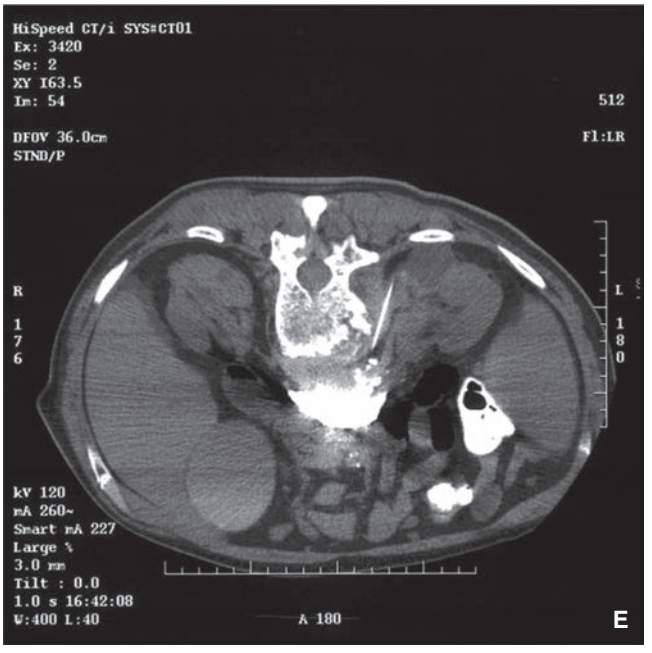


Figure 11-13. ***(Continued)***

E: Final axial image after placement of 15 mL of 10% phenol in iohexol 100 mg per mL. The contrast spreads over the entire anterior surface of the aorta without extending to the posterior surface of the aorta or the intervertebral foramina. Placement of a second needle on the contralateral side is not necessary.

Complications of celiac plexus and splanchnic nerve block include hematuria, intravascular injection, and pneumothorax. CT allows visualization of the structures that lie adjacent to the celiac ganglion as the block is being performed (see Figs. 11-10 and 11-11). The kidneys extend between T12 and L3, with the left kidney slightly more cephalad than the right. The aorta lies over the left anterolateral border of the vertebral column. The celiac arterial trunk arises from the anterior surface of the aorta at the T12 level and divides into the hepatic, left gastric, and splenic arteries. Using the transaortic technique, caution must be used to avoid needle placement directly through the axis of the celiac trunk as it exits anteriorly. The inferior vena cava lies just to the right of the aorta over the anterolateral surface of the vertebral column. The medial pleural reflection extends inferomedially as low as the T12 to L1 level.

NCPB carries small but significant additional risk. Intravascular injection of 30 mL of 100% ethanol will result in a blood ethanol level well above the legal limit for intoxication but below danger of severe alcohol toxicity. Intravascular injection of phenol is associated with clinical manifestations similar to that of local anesthetic toxicity—central nervous system excitation, followed by seizures, and, in extreme toxicity, cardiovascular collapse. The most devastating complication associated with NCPB using either alcohol or phenol is paraplegia. The theoretical mechanism is spread of the neurolytic solution toward the posterior surface of the aorta to surround the spinal segmental arteries. At the level of T12 or L1, it is common to have a single, dominant spinal segmental artery, the artery of Adamkiewicz. In some individuals, this artery is the dominant arterial supply to the anterior two-thirds of the spinal cord in the low thoracic region. Neurolytic solution may cause spasm or even necrosis and occlusion of the artery of Adamkiewicz leading to paralysis. The actual incidence of this complication is unknown, but it appears to be <1:1,000.

SUGGESTED READINGS

American Society of Anesthesiologists Task Force on Chronic Pain Management; American Society of Regional Anesthesia and Pain Medicine. Practice guidelines for chronic pain management: an updated report by the American Society of Anesthesiologists Task Force on Chronic Pain Management and the American Society of Regional Anesthesia and Pain Medicine. *Anesthesiology*. 2010;112:810–833.

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CHAPTER 12

Lumbar Sympathetic Block and Neurolysis

OUTLINE

Overview

The sympathetic nervous system is involved in the pathophysiology that leads to a number of different chronic pain conditions, including complex regional pain syndrome (CRPS) and ischemic pain. These chronic pain states are often referred to as *sympathetically maintained pain* because they share the characteristic of pain relief following blockade of the regional sympathetic ganglia. Lumbar sympathetic block is an established method for the diagnosis and treatment of sympathetically maintained pain of the lower extremities.

Anatomy

The lumbar sympathetic chain consists of four to five paired ganglia that lie over the anterolateral surface of the second through fourth lumbar vertebrae (Figs. 12-1 and 12-2). The cell bodies of the neurons that travel to the lumbar sympathetic ganglia lie in the anterolateral region of the spinal cord from T11 to L2, with variable contributions from T10 and L3. The preganglionic fibers leave the spinal canal with the corresponding spinal nerve, join the sympathetic chain as white communicating rami, and then synapse within the appropriate ganglion. Postganglionic fibers exit the chain to join the diffuse perivascular plexus around the iliac and femoral arteries, or via the gray communicating rami to join the spinal nerves that form the lumbar and lumbosacral plexuses. Sympathetic fibers accompany all the major nerves to the lower extremities. The majority of the sympathetic innervation to the lower extremities passes through the second and third lumbar sympathetic ganglia, and blockade of these ganglia results in near complete sympathetic denervation of the lower extremities.

Patient Selection

Lumbar sympathetic blockade has been used extensively in the treatment of sympathetically maintained pain syndromes involving the lower extremities. The most common of these are CRPS, type 1 (reflex sympathetic dystrophy) and type 2 (causalgia) (see Chapter 10 for an overview of CRPS). The local anesthetic block can produce marked pain relief of long duration, and this block is used as part of a comprehensive treatment plan to provide analgesia and facilitate functional restoration.

Patients with peripheral vascular insufficiency due to small vessel occlusion may also be treated effectively with lumbar sympathetic blockade. Proximal fixed lesions are best treated with surgical intervention using bypass grafting or intra-arterial stent placement to restore blood flow. In those patients with diffuse, small vessel occlusion, lumbar sympathetic block can improve microvascular circulation and reduce ischemic pain. If local anesthetic block improves blood flow and reduces pain, these patients will often benefit from surgical or chemical sympathectomy.

Other patients with neuropathic pain involving the lower extremities have shown variable response to lumbar sympathetic block. In those with acute herpes zoster and early postherpetic neuralgia, sympathetic block may reduce pain. However, once postherpetic neuralgia is well established (beyond 3 to 6 months from onset), sympathetic blockade is rarely helpful. Likewise, deafferentation syndromes such as phantom limb pain and neuropathic lower extremity pain following spinal cord injury have shown variable and largely disappointing responses to sympathetic blockade.

Level of Evidence

Quality of Evidence and Grading of Recommendation			
Grade of Recommendation/ Description	**Benefit vs. Risk and Burdens**	**Methodological Quality of Supporting Evidence**	**Implications**
RECOMMENDATION: *Sympathetic blocks, including lumbar sympathetic block. The use of sympathetic blocks may be considered to support the diagnosis of sympathetically maintained pain. They should not be used to predict the outcome of surgical, chemical, or radiofrequency sympathectomy. Lumbar sympathetic blocks or stellate ganglion blocks may be used as components of the multimodal treatment of CRPS if used in the presence of consistent improvement and increasing duration of pain relief. Sympathetic nerve blocks should not be used for long-term treatment of non-CRPS neuropathic pain.*			
2C/weak recommendation, low-quality or very low-quality evidence	Uncertainty in the estimates of benefits, risks, and burden; benefits, risk, and burden may be closely balanced	II-2: Observational studies or case series	Very weak recommendations; other alternatives may be equally reasonable

The use of sympathetic blocks in the diagnosis and management of a number of chronic pain conditions, including CRPS, has been common for decades despite the lack of scientific validation for this approach. Indeed, the very origins of the field of pain medicine grew from the anesthesiologists' use of regional anesthesia including regional blockade of the sympathetic chain. Yet, the usefulness of sympathetic blocks in either the diagnostic evaluation or the long-term management of pain syndromes remains in question.

The American Society of Anesthesiologists (ASA) Task Force on Chronic Pain Management published a 2010 Practice

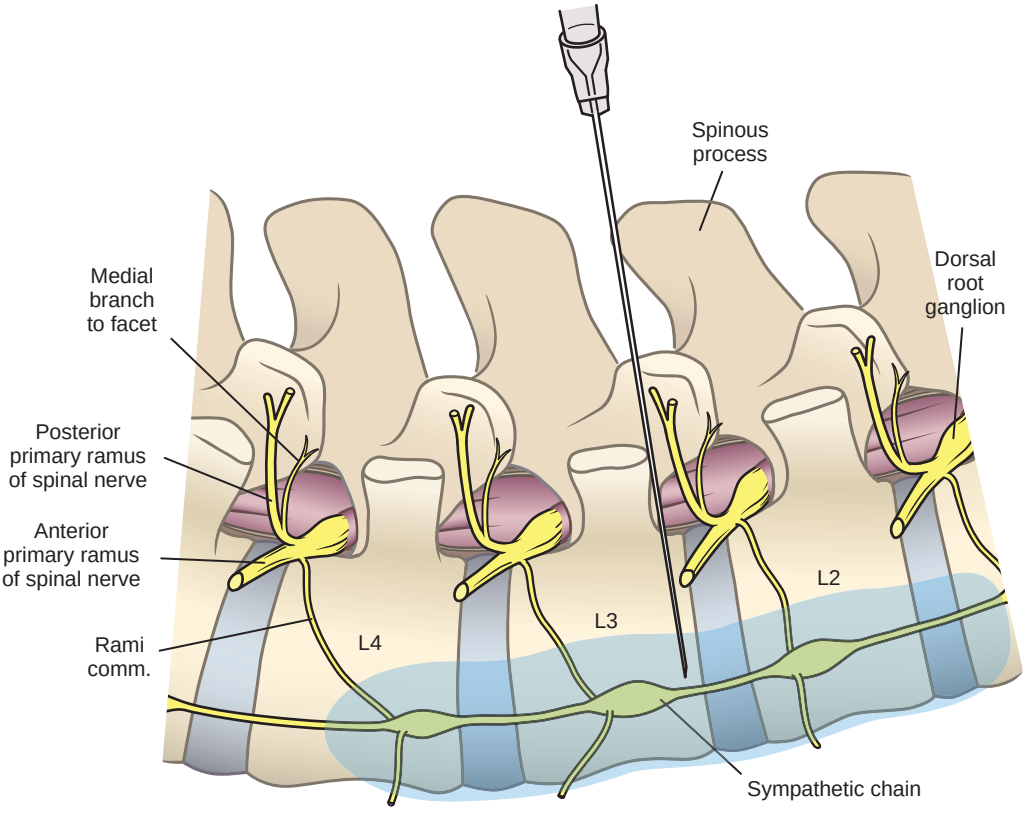


Figure 12-1.
Anatomy of the lumbar sympathetic chain. The lumbar sympathetic ganglia are variable in number and location from one individual to another. Most commonly, the ganglia lie over the anteromedial surface of the vertebral bodies between L2 and L4. Temporary lumbar sympathetic block using local anesthetic is best performed by advancing a single needle cephalad to the transverse process of L3 to avoid the spinal nerve. The needle tip is placed adjacent to the superior portion of the anteromedial surface of the L3 vertebral body. Use of 15 to 20 mL of local anesthetic solution will spread to cover multiple vertebral levels (*shaded region*).

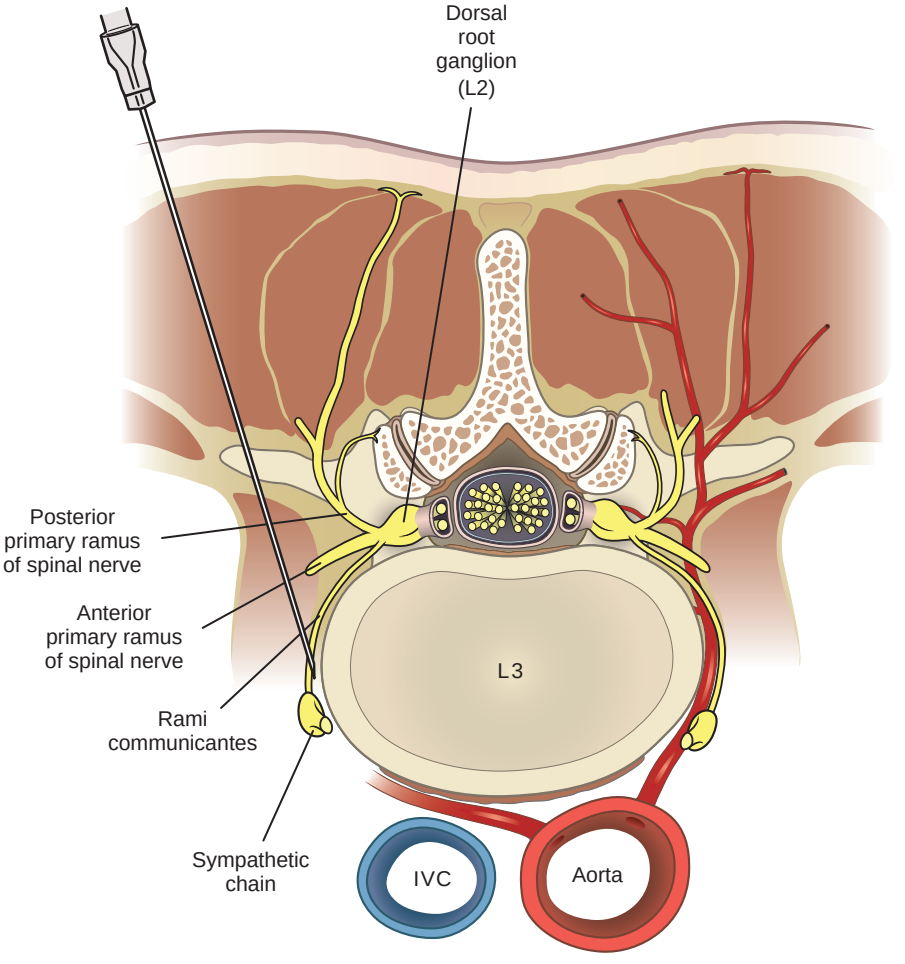


Figure 12-2.
Axial diagram of lumbar sympathetic block. A single needle passes over the transverse process, and the tip is in position adjacent to the lumbar sympathetic ganglia over the anteromedial surface of the L3 vertebral body.

Guideline, offering the following recommendation regarding the use of sympathetic blocks for the diagnosis of pain: "The use of sympathetic blocks may be considered to support the diagnosis of sympathetically maintained pain. They should not be used to predict the outcome of surgical, chemical, or radiofrequency sympathectomy." The ASA Guideline made the following recommendations regarding the use of sympathetic blocks as a component of pain treatment: "Lumbar sympathetic blocks or stellate ganglion blocks may be used as components of the multimodal treatment of CRPS if used in the presence of consistent improvement and increasing duration of pain relief. Sympathetic nerve blocks should not be used for long-term treatment of non-CRPS neuropathic pain."

CRPS is uncommon and conducting randomized trials in this heterogeneous group of patients with neuropathic pain has been limited to a small number of small studies. Clear benefits have not been reported with sympathetic blocks based on the limited available data, yet the use of sympathetic blocks remains a component of the treatment algorithms put forth by contemporary experts. If the use of sympathetic blocks produces pain relief of sufficient magnitude and duration in an individual patient such that efforts to restore normal function are improved, then they should be incorporated into the treatment algorithm. If they produce pain relief of limited magnitude and duration for an individual patient, then the risks involved in using sympathetic blocks outweigh the benefits and their use for that patient should be abandoned.

Positioning

The patient lies prone with the head turned to one side (Fig. 12-3). The C-arm is centered over the midlumbar region. The final needle position for lumbar sympathetic block is over the anterolateral surface of the lumbar vertebral body (see Fig. 12-2). The C-arm is rotated obliquely 20 to 30 degrees, until the tip of the transverse process of L3 overlies the anterolateral margin of the L3 vertebral body (Fig. 12-4).

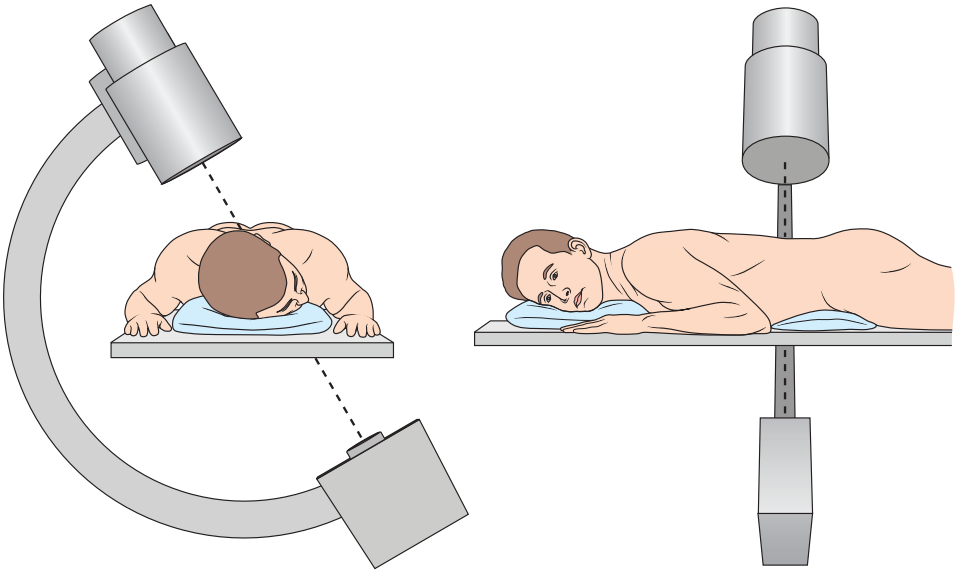


Figure 12-3.
Patient position for lumbar sympathetic block. The patient lies prone with the head turned to one side. The C-arm is positioned over the midlumbar spine with 20 to 30 degrees of oblique angulation.

Block Technique

Lumbar sympathetic block is typically carried out using a single needle technique and a large volume of local anesthetic to spread cephalad and caudad to bathe adjacent ganglia. The ganglia of the lumbar sympathetic chain are variable in number and location from one individual to another. The ganglia lie between L2 and L4, and in most humans, the ganglia lie over the inferior portion of L2 and the superior portion of L3. Thus, the optimal location to

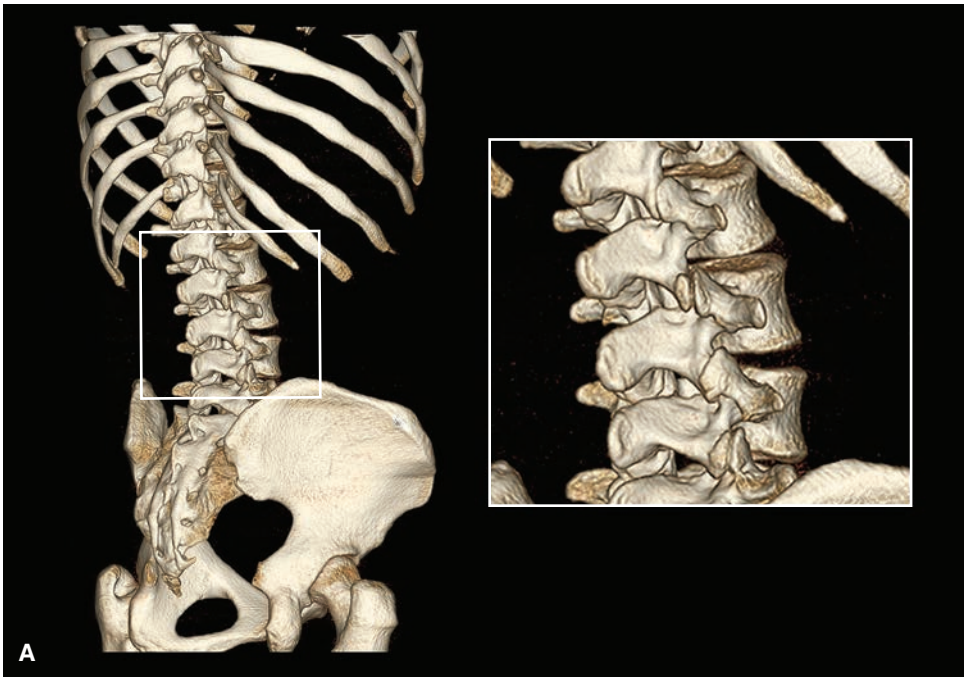


Figure 12-4.
A: Bony anatomy relevant to lumbar sympathetic block. Three-dimensional reconstruction computed tomography of the lumbar spine as viewed in the oblique projection used to perform lumbar sympathetic block. **Inset** matches the anatomic area in the radiographs shown in **(B,C).** *(Cont.)*

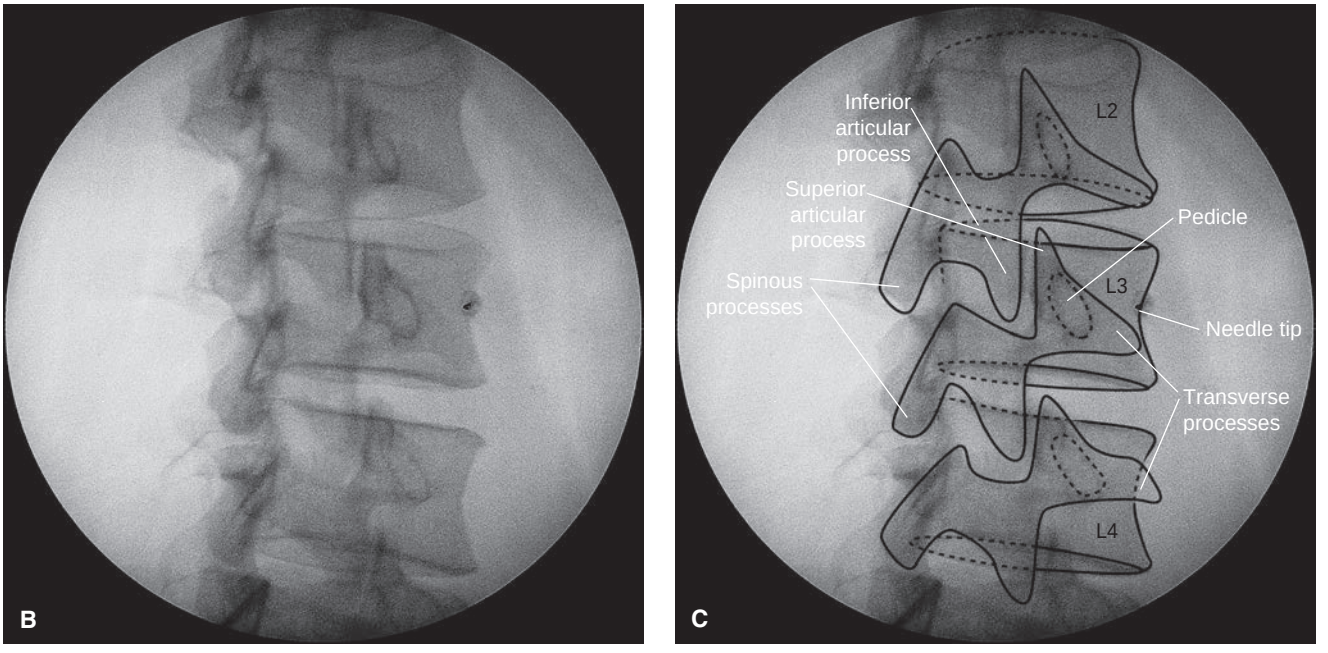


Figure 12-4. *(Continued)*
B: Oblique radiograph of the lumbar spine during lumbar sympathetic block. A needle passes cephalad to the transverse process of L3 to lie anterolateral to the middle aspect of the L3 vertebral body. **C:** Labeled image.

place a single needle is over the anterolateral margin of the inferior portion of L2, the L2/L3 interspace, or the superior margin of L3.

The patient is placed in the prone position with a pillow under the lower abdomen and iliac crest to reduce the lumbar lordosis (see Fig. 12-3). The skin and subcutaneous tissues are anesthetized with 1 to 2 mL of 1% lidocaine. A 22-gauge, 5-inch spinal needle (7 to 8 inch for obese patients) is advanced using a coaxial technique toward the anterolateral surface of the L3 vertebral body (see Fig. 12-4). The direction of the needle is assessed and redirected by obtaining repeat images after every 1 to 1.5 cm of needle advancement. The needle tip should be kept over the lateral margin of the vertebral body until the needle gently contacts bone. An additional 1 to 1.5 mL of 1% lidocaine is placed on the vertebral body, and the needle is then walked laterally off the bony margin. The C-arm is rotated to a lateral projection, and the needle is advanced until the tip lies over the anterior one-third of the vertebral body (Fig. 12-5). Proper needle position is verified in the anterior-posterior (AP) projection, where the needle tip should lie medial to the lateral margin of the vertebral body (Fig. 12-6).

Once the needle is in position, aspiration to detect intravascular needle placement is carried out, followed by the incremental injection of local anesthetic (15 to 20 mL of 0.25% bupivacaine). Signs of successful sympathetic blockade in the lower extremities include venodilation and temperature rise. The skin temperature should also be monitored in the contralateral foot to assess for changes unrelated to the block. A rise in temperature of at least 1°C without a rise in the temperature of the contralateral limb should occur with successful sympathetic block.

Lumbar Sympathetic Neurolysis

Neurolytic lumbar sympathetic block has been used in efforts to provide long-term sympathetic blockade in those who receive only short-term pain relief with local anesthetic blocks. Lumbar sympathetic neurolysis can be accomplished using either injection of a neurolytic solution or radiofrequency lesioning. Because the locations of the lumbar sympathetic ganglia are variable, injection of neurolytic solution that spreads to encompass an area beyond the needle tip may produce more reliable neurolysis than radiofrequency treatment. Nonetheless, when the needle tips are positioned accurately, the discrete lesions resulting from radiofrequency treatment can produce effective neurolysis. Although the techniques are well described, there are few data available to guide the choice among chemical neurolysis, radiofrequency neurolysis, and open surgical sympathectomy.

Chemical Neurolysis

Chemical neurolysis of the lumbar sympathetic chain is carried out by placing three separate needles at the L2, L3, and L4 levels as described previously for local anesthetic block

(Figs. 12-7 and 12-8). The needles should be directed to the mid- or inferior aspect of L2, as well as the superior aspects of L3 and L4, to correlate with the most frequent anatomic locations of the lumbar sympathetic ganglia. Three needles are placed so that the smallest volume of neurolytic solution can be injected to treat the ganglia at each level. Once proper needle position has been confirmed in the AP and lateral projections, a small volume of radiographic contrast (1 mL of iohexol 180 mg per mL) is placed through each needle to ensure the needles are not intravascular and the injectate

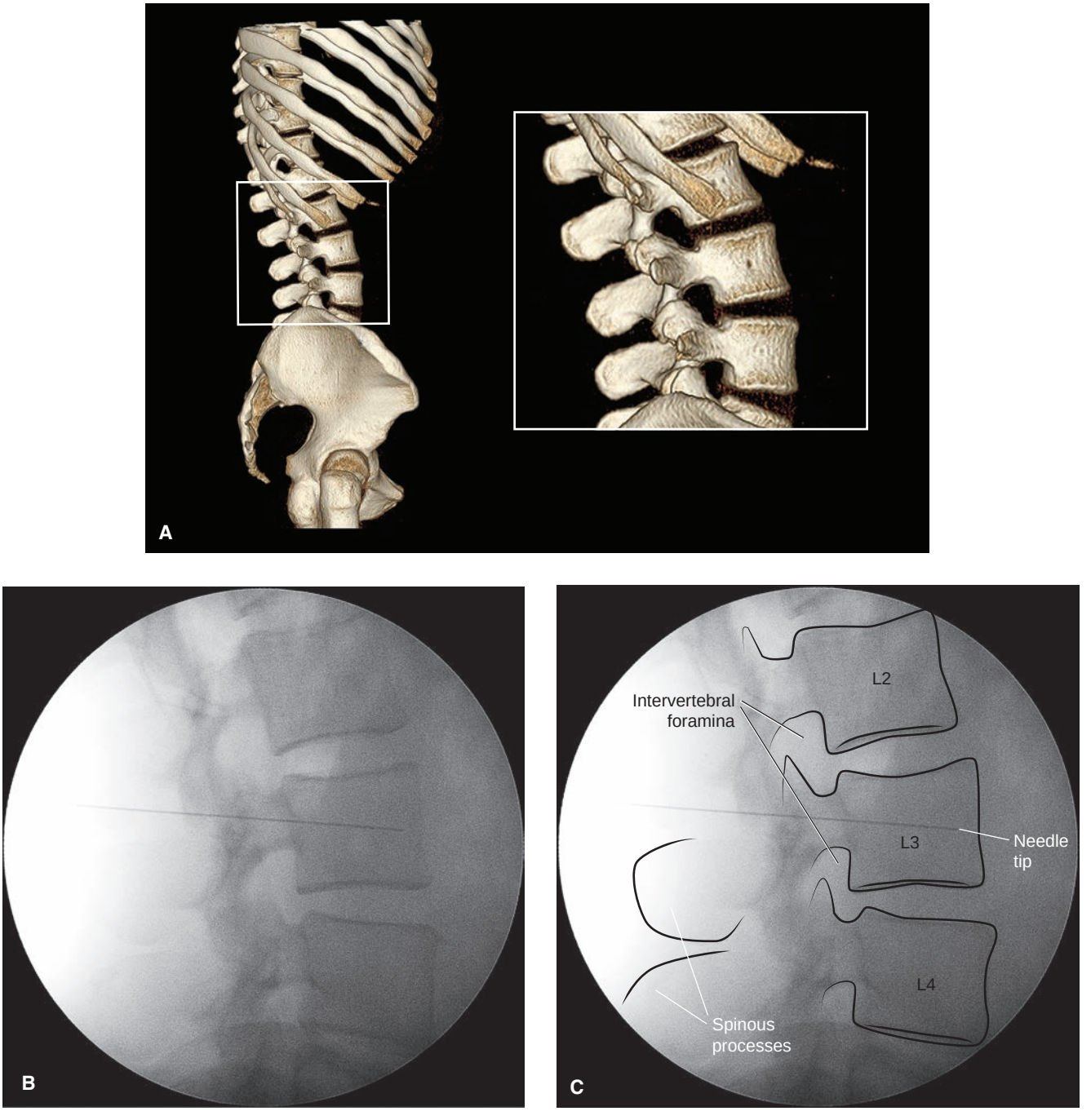


Figure 12-5.

A: Bony anatomy relevant to lumbar sympathetic block. Three-dimensional reconstruction computed tomography of the lumbar spine as viewed in the lateral projection. **Inset** matches the anatomic area in the radiographs shown in **(B,C). B:** Lateral radiograph of the lumbar spine during lumbar sympathetic block. A needle is in position over the anterolateral surface of L3. The tip should be positioned over the anterior one-third of the vertebral body in the lateral projection. Note that the foramen and thus the spinal nerve are distant from the path of the needle. **C:** Labeled image. ***(Cont.)***

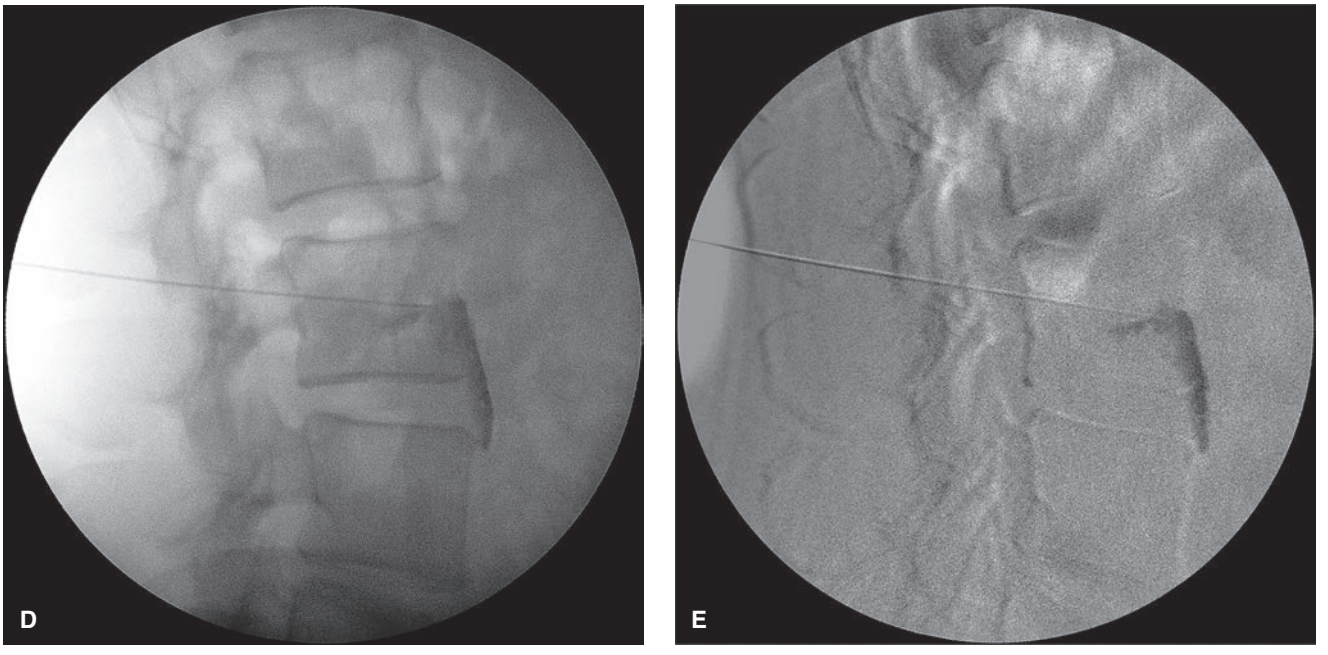


Figure 12-5. *(Continued)*
D: Lateral radiograph of the lumbar spine during lumbar sympathetic block after placement of radiographic contrast. A needle is in position over the anterolateral surface of L3 and the radiographic contrast spreads over the surface of the vertebral body. **E:** Lateral radiograph of the lumbar spine during lumbar sympathetic block after placement of radiographic contrast: digital subtraction image showing precise pattern of contrast spread.

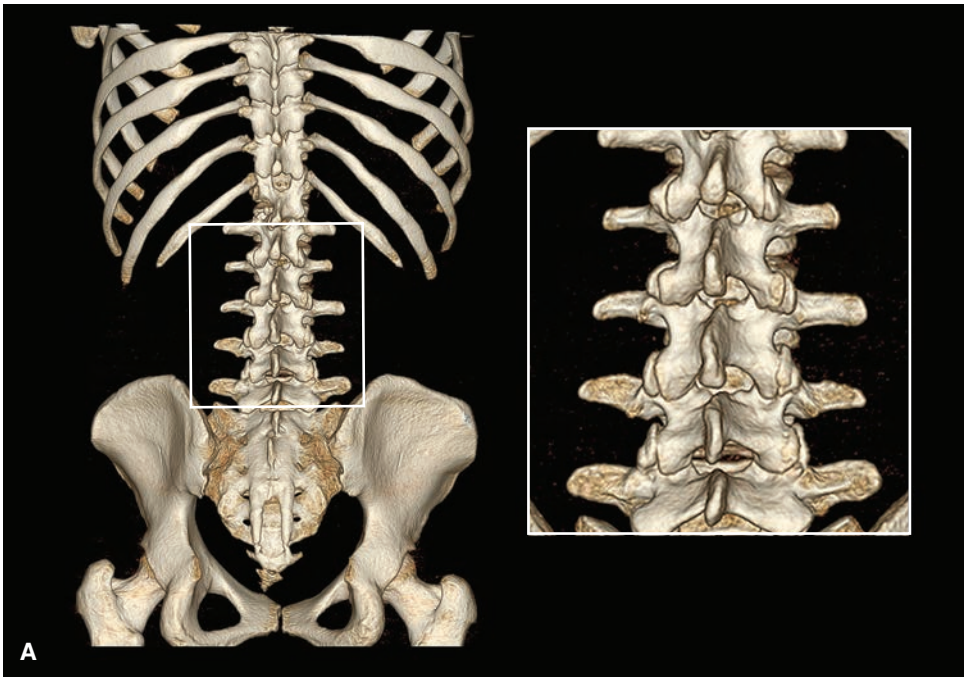
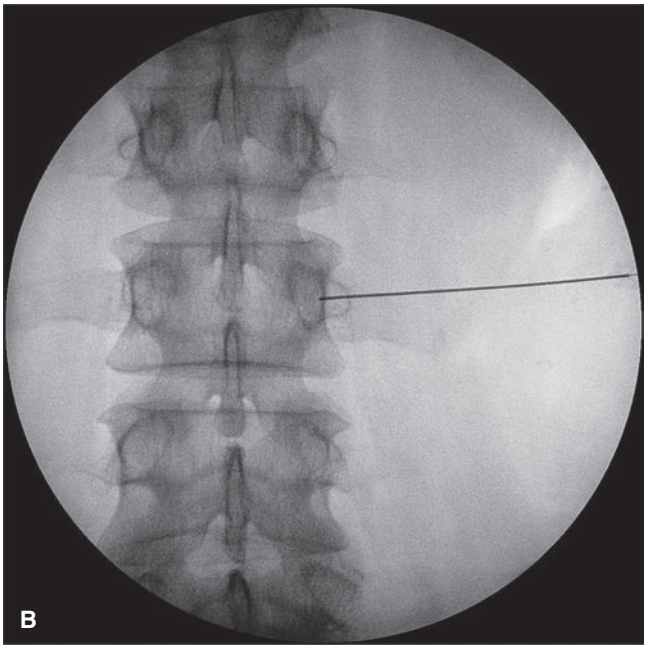
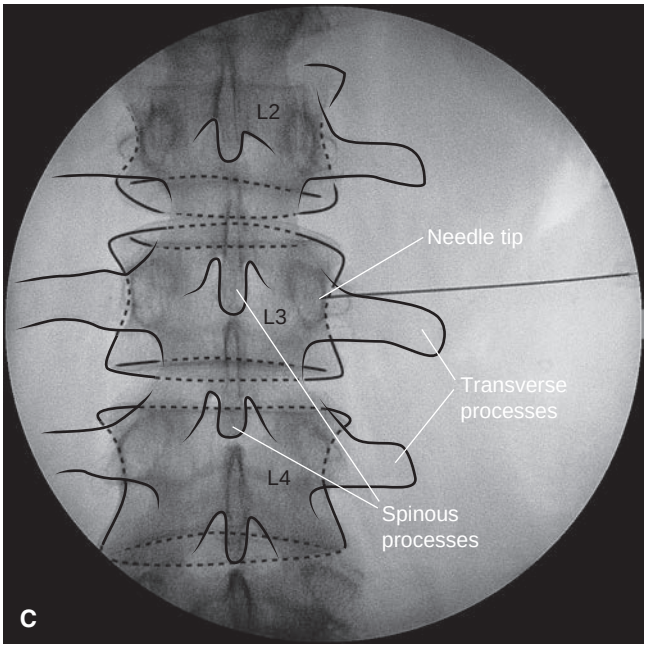


Figure 12-6.
A: Bony anatomy relevant to lumbar sympathetic block. Three-dimensional reconstruction computed tomography of the lumbar spine as viewed in the AP projection. **Inset** matches the anatomic area in the radiographs shown in **(B,C).** *(Cont.)*





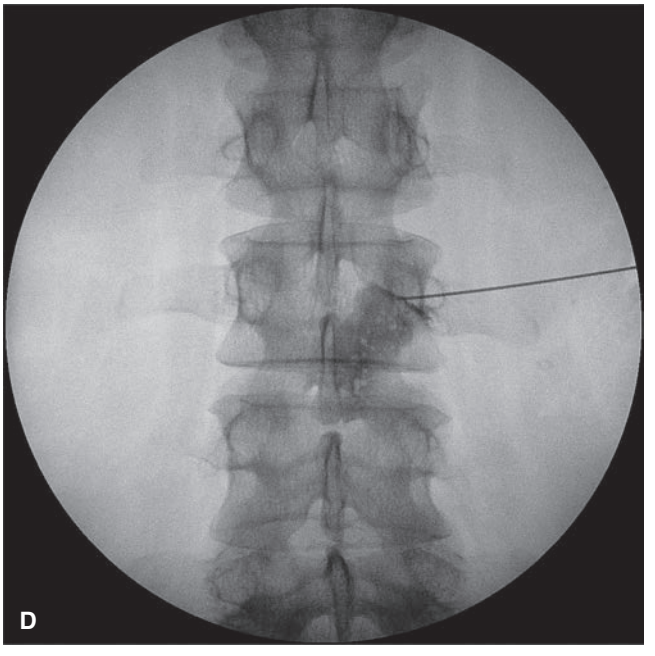
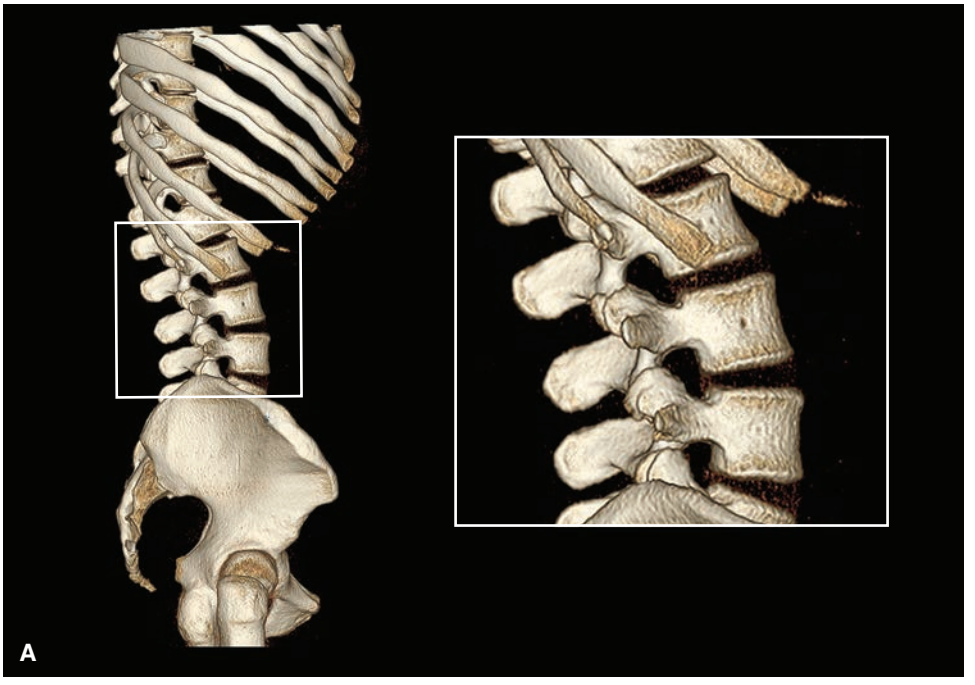


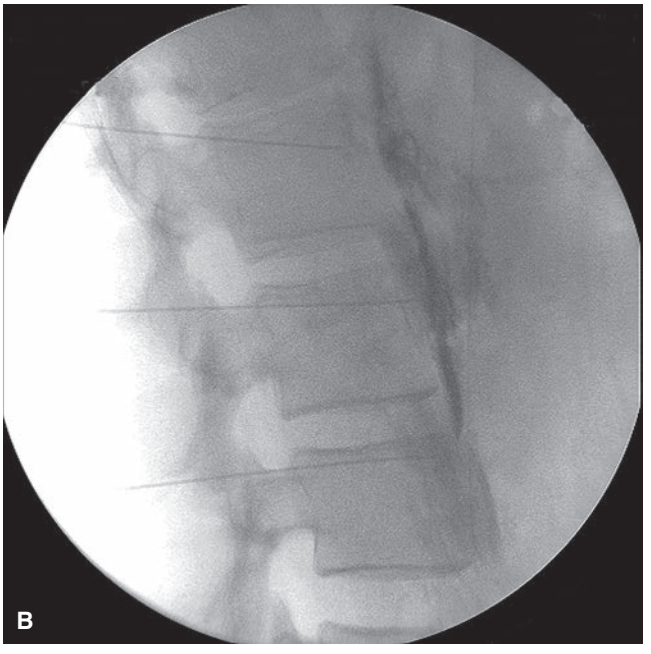
Figure 12-6. ***(Continued)***
B: AP radiograph of the lumbar spine during lumbar sympathetic block. A needle passes cephalad to the transverse process of L3, and the tip lies over the anterolateral surface of L3. When positioned correctly, the needle tip should lie medial to the lateral margin of the vertebral body in the AP projection. This indicates that the tip of the needle is in close apposition to the anterolateral surface of the vertebral body. **C:** Labeled image. **D:** AP radiograph of the lumbar spine during lumbar sympathetic block after placement of radiographic contrast. A needle is in position over the anterolateral surface of L3 and the radiographic contrast spreads over the surface of the vertebral body.

will layer in close apposition to the anterolateral margin of the vertebral bodies (see Figs. 12-7 and 12-8). Thereafter, 2 to 3 mL of neurolytic solution (10% phenol in iohexol 180 mg per mL or 50% to 100% ethyl alcohol) is placed through each needle.

Radiofrequency Neurolysis

Similar to chemical neurolysis, radiofrequency neurolysis of the lumbar sympathetic chain is carried out by placing three separate 15-cm radiofrequency cannulae with





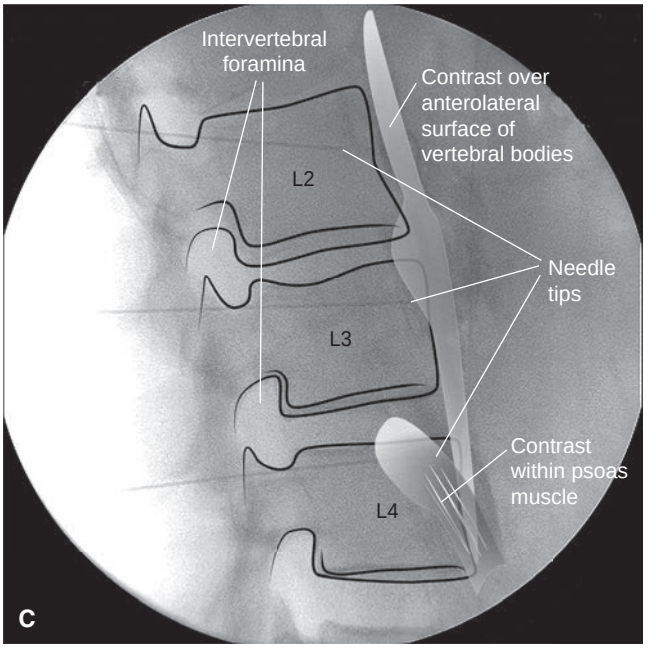


Figure 12-7.

A: Bony anatomy relevant to lumbar sympathetic block. Three-dimensional reconstruction computed tomography of the lumbar spine as viewed in the lateral projection. **Inset** matches the anatomic area in the radiographs shown in **(B,C). B:** Lateral radiograph of the lumbar spine during neurolytic lumbar sympathetic block. Three needles are in position with their tips over the anterolateral surface of L2, L3, and L4. One milliliter of radiographic contrast (iohexol 180 mg per mL) has been placed through each needle. Contrast has spread tightly adjacent to the anterolateral surface of the vertebral bodies through the needles at L2 and L3. The contrast adjacent to the needle at L4 has spread more diffusely in an anterior and inferior direction, indicating injection within the psoas muscle (see also Fig. 12-8). This needle must be repositioned before neurolysis in a more anterior and medial direction. Neurolysis is carried out by placing 2 to 3 mL of neurolytic solution (10% phenol in iohexol 180 mg per mL or 50% to 100% ethyl alcohol) through each needle. The needle position for radiofrequency neurolysis is identical. **C:** Labeled image.

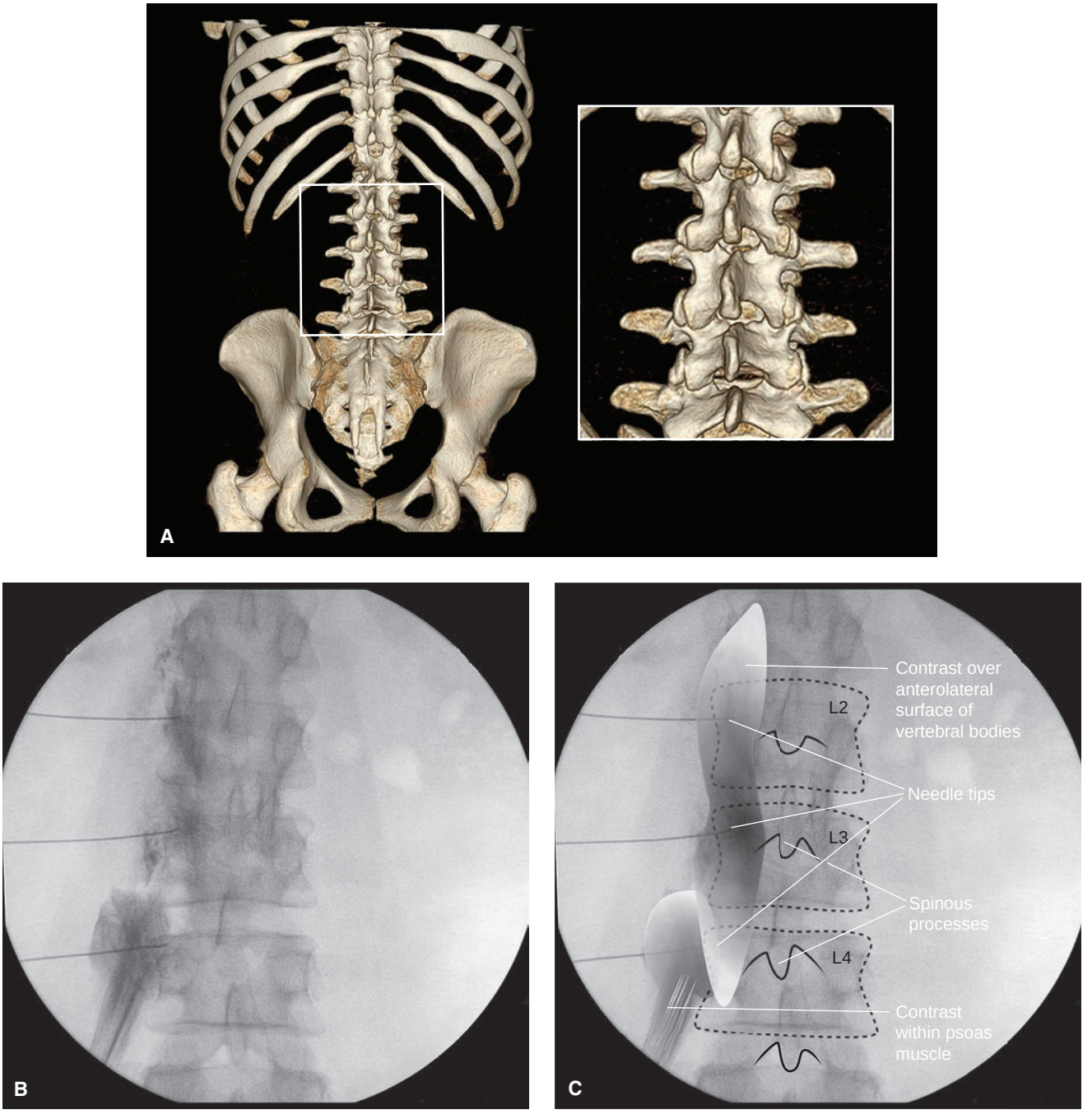


Figure 12-8.

A: Bony anatomy relevant to lumbar sympathetic block. Three-dimensional reconstruction computed tomography of the lumbar spine as viewed in the AP projection. **Inset** matches the anatomic area in the radiographs shown in **(B,C). B:** AP radiograph of the lumbar spine during neurolytic lumbar sympathetic block. Three needles are in position with their tips over the anterolateral surface of L2, L3, and L4. One milliliter of radiographic contrast (iohexol 180 mg per mL) has been placed through each needle. Contrast has spread tightly adjacent to the anterolateral surface of the vertebral bodies through the needles at L2 and L3. The contrast adjacent to the needle at L4 has spread more diffusely in a lateral and inferior direction, indicating injection within the psoas muscle (see also Fig. 12-7). This needle must be repositioned before neurolysis in a more anterior and medial direction. Neurolysis is carried out by placing 2 to 3 mL of neurolytic solution (10% phenol in iohexol 180 mg per mL or 50% to 100% ethyl alcohol) through each needle. The needle position for radiofrequency neurolysis is identical. **C:** Labeled image.

10-mm active tips over the anterolateral surface of the L2, L3, and L4 vertebral bodies (see Figs. 12-7 and 12-8). Once proper needle position has been confirmed, sensory and motor stimulation are conducted. When the cannulae are in proper position over the sympathetic ganglia, the patient will typically report vague back or abdominal discomfort with <1 V of output with sensory stimulation at 50 Hz. However, the report of any sensation during sensory testing is more variable than during sensory testing before radiofrequency treatment of the facets. Motor stimulation is then carried out to ensure the cannulae do not lie along the course of the anterior primary ramus of one of the spinal nerves. There should be no muscle movement in the lower extremities during stimulation at 2 Hz at an output of at least 3 V. Our practice has been to place the lesions if the cannulae appear to be in the proper anatomic position, even if there is no report of pain or discomfort during sensory stimulation. Lesions are created after instilling 0.5 mL of 2% lidocaine at 80°C for 90 seconds.

Complications

Significant and potentially toxic levels of local anesthetic can result from direct needle placement into a blood vessel and intravascular injection during lumbar sympathetic block. Hematuria can follow direct needle placement through the kidney and is usually self-limited. Spinal nerve, epidural, or intrathecal injection can arise when the needle is advanced through the intervertebral foramen and is usually avoided entirely with proper use of radiographic guidance. Following neurolytic lumbar sympathetic block, significant postsympathectomy pain arises in the L1 and L2 nerve root distribution over the anterior thigh in as many as 10% of treated patients. This observation stems from the results following open surgical sympathectomy, but such postsympathectomy neuralgia has also been reported after both chemical and radiofrequency sympathectomy. Postsympathectomy neuralgic pain in the anterior thigh has been postulated to result from partial neurolysis of adjacent sensory fibers, most often the genitofemoral nerve.

SUGGESTED READINGS

American Society of Anesthesiologists Task Force on Chronic Pain Management; American Society of Regional Anesthesia and Pain Medicine. Practice guidelines for chronic pain management: an updated report by the American Society of Anesthesiologists Task Force on Chronic Pain Management and the American Society of Regional Anesthesia and Pain Medicine. *Anesthesiology*. 2010;112:810–833.

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CHAPTER 13

Superior Hypogastric Block and Neurolysis

OUTLINE

Overview

The sympathetic nervous system is involved in the pathophysiology that leads to a number of different chronic pain conditions, including pain arising from the bladder, uterus, rectum, vagina, and prostate. The relevant anatomy and technique for superior hypogastric block has been well described, but only limited observational data point to the usefulness of this technique for treating chronic pain arising from the pelvic viscera.

Anatomy

The superior hypogastric plexus is composed of a flattened band of intercommunicating nerve fibers that descend over the aortic bifurcation. The plexus carries sympathetic afferents and postganglionic efferent fibers from the lumbar sympathetic chain, as well as parasympathetic fibers that arise from S2 to S4. The plexus is retroperitoneal in location and lies over the anterior surface of the fourth and fifth lumbar and the first sacral vertebrae (Figs. 13-1 and 13-2). Sympathetic nerves passing through the plexus innervate the pelvic viscera, including the bladder, uterus, rectum, vagina, and prostate.

Patient Selection

Superior hypogastric plexus block is used in the treatment of pain arising from the pelvic viscera. In patients with pain of nonmalignant origin, temporary block may be useful in better defining the source of the pain. More often, superior hypogastric neurolysis is used to treat intractable pelvic visceral pain associated with malignancy. Patients with locally invasive cancer involving the proximal vagina, uterus, ovaries, prostate, and rectum that are associated with pelvic pain may gain significant pain relief from this approach.

Level of Evidence

Quality of Evidence and Grading of Recommendation			
Grade of Recommendation/ Description	**Benefit vs. Risk and Burdens**	**Methodological Quality of Supporting Evidence**	**Implications**
RECOMMENDATION: *Superior hypogastric plexus block for pain secondary to pelvic cancer. Neurolytic superior hypogastric plexus block may be used for reduction of abdominal pain and reducing opioid-related side effects in patients with pain associated with pelvic cancer.*			
2C/weak recommendation, low-quality or very low-quality evidence	Uncertainty in the estimates of benefits, risks, and burden; benefits, risk, and burden may be closely balanced	II-3: Observational studies or case series	Very weak recommendations; other alternatives may be equally reasonable

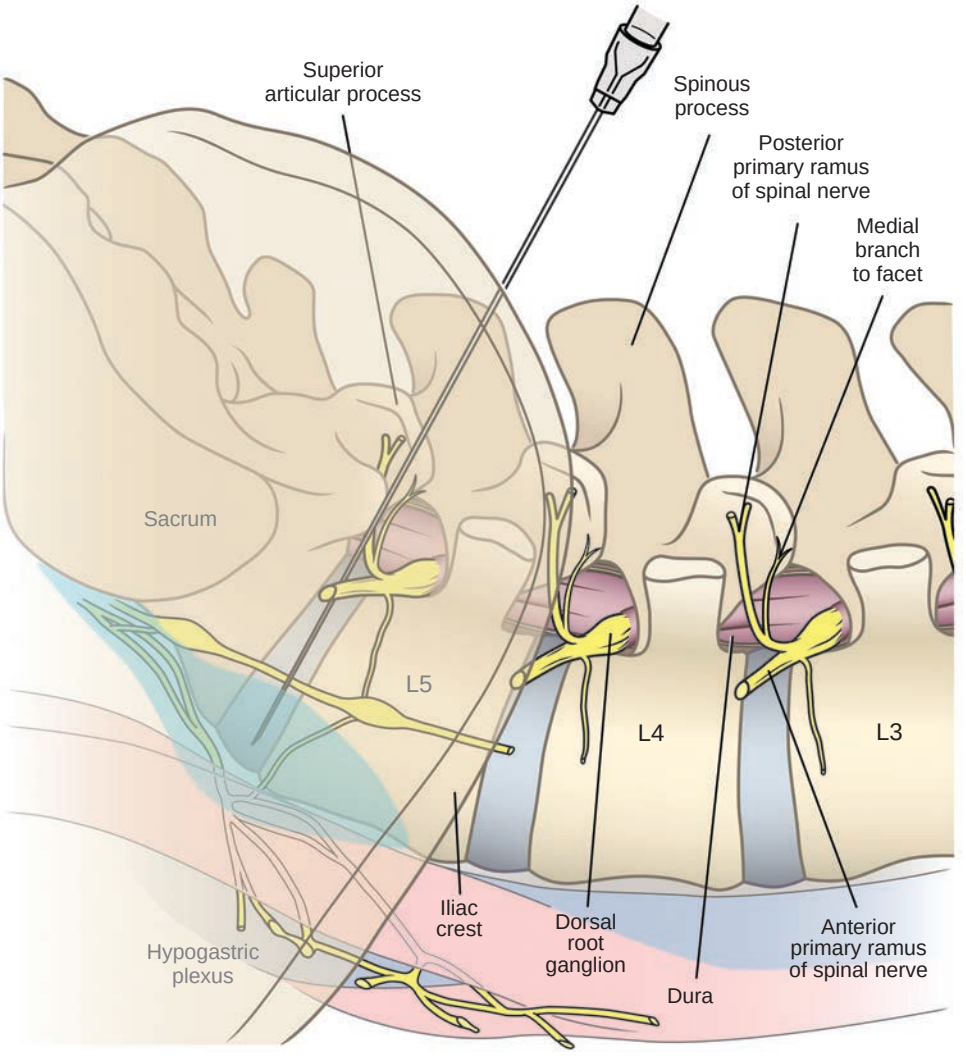


Figure 13-1.
Anatomy of the superior hypogastric plexus. The superior hypogastric plexus is comprised of a loose, web-like group of interlacing nerve fibers that lie over the anterolateral surface of the L5 vertebral body and extend inferiorly over the sacrum. Needles are positioned over the anterolateral surface of the L5/S1 intervertebral disc or the inferior aspect of the L5 vertebral bodies to block the superior hypogastric plexus. The use of 8 to 10 mL of local anesthetic solution will spread along the anterior surface of the L5 vertebral body and the sacrum (*shaded area*).

The use of sympathetic blocks in the diagnosis and management of a number of chronic pain conditions, including complex regional pain syndrome (CRPS), has been common for decades despite the lack of scientific validation for this approach. Yet, the usefulness of sympathetic blocks in either the diagnostic evaluation or the long-term management of pain syndromes remains in question. Superior hypogastric block was first popularized by Plancarte and colleagues in the late 1980s for treating pain associated with pelvic malignancies. Like other sympathetic blocks, there has been no rigorous testing of the safety and efficacy of this treatment approach and we can rely only on small, uncontrolled observational trials for hints at usefulness.

The American Society of Anesthesiologists (ASA) Task Force on Chronic Pain Management published a 2010 Practice Guideline offering the following recommendation regarding the use of sympathetic blocks for the diagnosis of pain: "The use of sympathetic blocks may be considered to support the diagnosis of sympathetically maintained pain. They should not be used to predict the outcome of surgical, chemical, or radiofrequency sympathectomy." The ASA Guideline made the following recommendations regarding the use of sympathetic blocks as a component of pain treatment: "Lumbar sympathetic blocks or stellate ganglion blocks may be used as components of the multimodal treatment of CRPS if used in the presence of consistent improvement and increasing duration of pain relief. Sympathetic nerve blocks should not be used for long-term treatment of non-CRPS neuropathic pain." Because of the dearth of available scientific evidence regarding superior hypogastric block, there is no current practice guideline that makes specific recommendations regarding the use of this block.

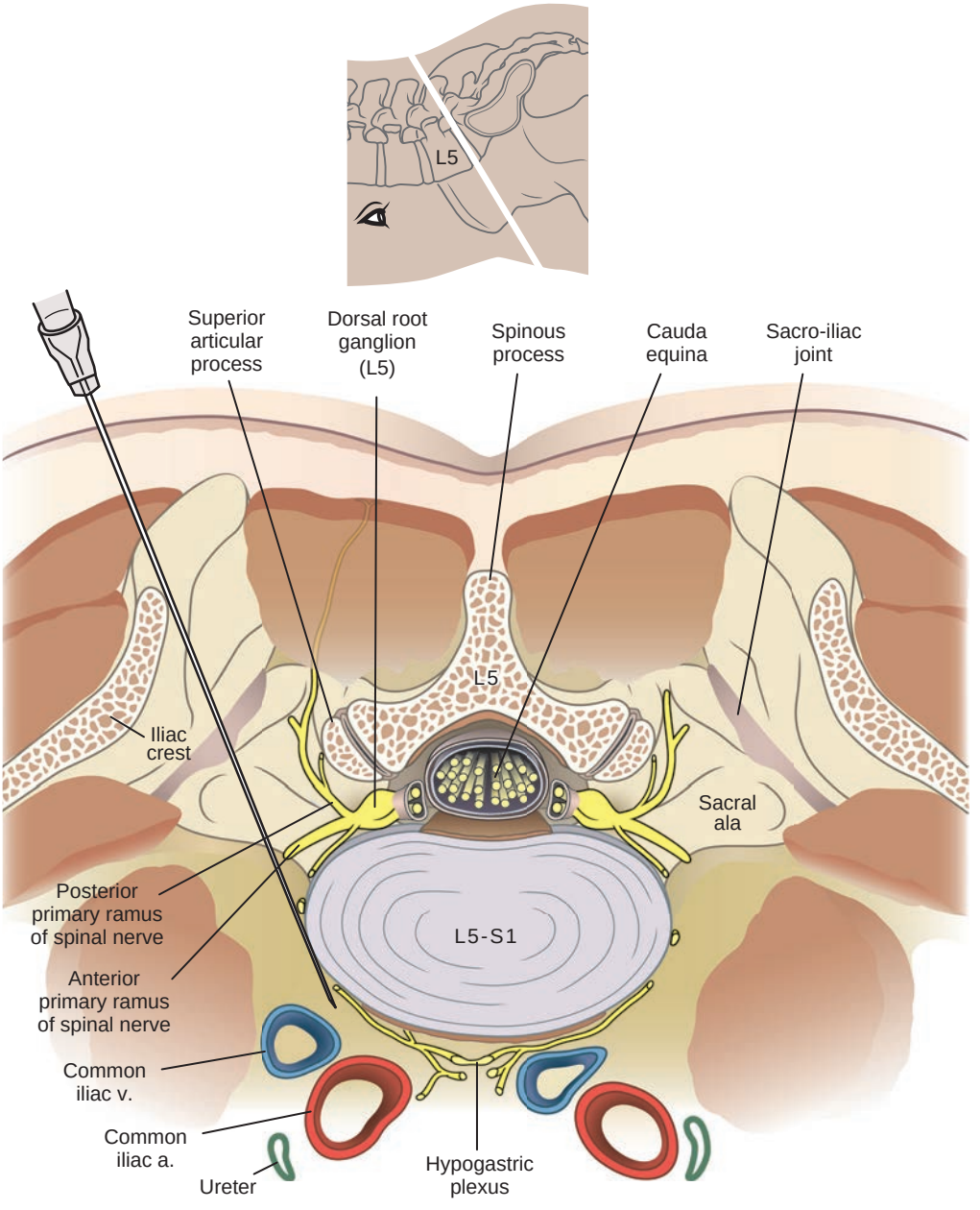


Figure 13-2.
Axial diagram of superior hypogastric plexus block. Needles are advanced from either side over the junction between the sacral ala and the superior articular process of S1 to position the needle tips over the anterolateral surface of the L5/S1 disc space. Positioning of the needles can be simplified by advancing them through the anterolateral aspect of the L5/S1 intervertebral disc to place the needle tips in the same final position (transdiscal approach). Note the close proximity of the iliac vessels. The **inset** shows the plane and orientation of the axial diagram.

Numerous, small observational studies point toward significant reduction in pain and opioid use in the early weeks following neurolytic superior hypogastric block for treating pain associated with pelvic cancer. A few observational studies have described the use of this technique for treating chronic pelvic pain that was not related to cancer. Most recent reports have focused on variations in the technical aspects of conducting this block, with transdiscal, computed tomography–assisted and ultrasound-guided techniques appearing. New and better-designed studies are needed to confirm the effectiveness of hypogastric plexus block in relieving pelvic pain. These studies need to incorporate stricter inclusion criteria, longer follow-up, and evaluation of symptoms other than pain after the procedure. Superior hypogastric plexus block should be considered experimental and not used as first-line therapy until additional evidence about the risks and benefits of this technique is available.

Positioning

The patient and C-arm positioning for superior hypogastric block are similar to those used for discography at the L5/S1 level (Fig. 13-3). The target for needle placement lies over the anterolateral surface of the L5/S1 junction (see Fig. 13-2). The patient lies prone, with the head turned to one side. A pillow is placed under the lower abdomen, above the iliac crest, in an effort to reduce the lumbar lordosis. Asking the patient to rotate the inferior aspect of the pelvis anteriorly toward the table will tip the iliac crests posteriorly and is often key to successfully performing this block. The C-arm is rotated 25 to 35 degrees obliquely and centered on the lumbosacral junction. The C-arm is then angled with 25 to 35 degrees of cephalad angulation, and the L5/S1 disc is brought into view.

Block Technique

With the C-arm properly aligned, there is a small triangular window through which the needle must pass to reach the anterolateral margin of the lumbosacral junction. The triangle is bounded superiorly by the transverse process of L5, laterally by the iliac crest, and medially by the L5/S1 facet joint, structures that are readily identified using fluoroscopy (Fig. 13-4). A skin entry point is made over the lowest point of this triangle and typically overlies the iliac crest, 5 to 7 cm from midline at the level of the L5 spinous process. A 22-gauge, 5-inch needle (8 inch for obese patients) is advanced using fluoroscopic guidance to lie anterolateral to the L5/S1 intervertebral disc or the inferior margin of the L5 vertebral body (Figs. 13-5 and 13-6). The trajectory for needle placement is similar to that used for discography at the L5/S1 level. Indeed, several investigators have described a transdiscal technique in which the needle is placed through the anterolateral portion of the intervertebral disc to reach the anterolateral surface of the vertebral column at the L5/S1 level. Either the transdiscal or the paravertebral techniques can be used; the transdiscal technique simplifies needle placement significantly. A small volume (2 to 3 mL) of radiographic contrast material will spread along the anterior surface of the lumbosacral junction, confirming correct needle position (Figs. 13-7 and 13-8). The same procedure is then carried out on the contralateral side. Temporary block is performed with 8 to 10 mL of local anesthetic (0.25% bupivacaine).

Superior Hypogastric Neurolysis

In those patients who are candidates for neurolysis who report 50% or more pain reduction with local anesthetic block, neurolysis can be carried out using a technique identical to that used for local anesthetic block, but injecting 5 to 8 mL of 10% phenol or alcohol on each side. Similar to neurolytic celiac plexus block, the phenol can be dissolved in radiographic contrast (iohexol 180 mg per mL or the equivalent), and the spread can then be monitored during injection to ensure intravascular injection and spread toward the intervertebral foramina are avoided.

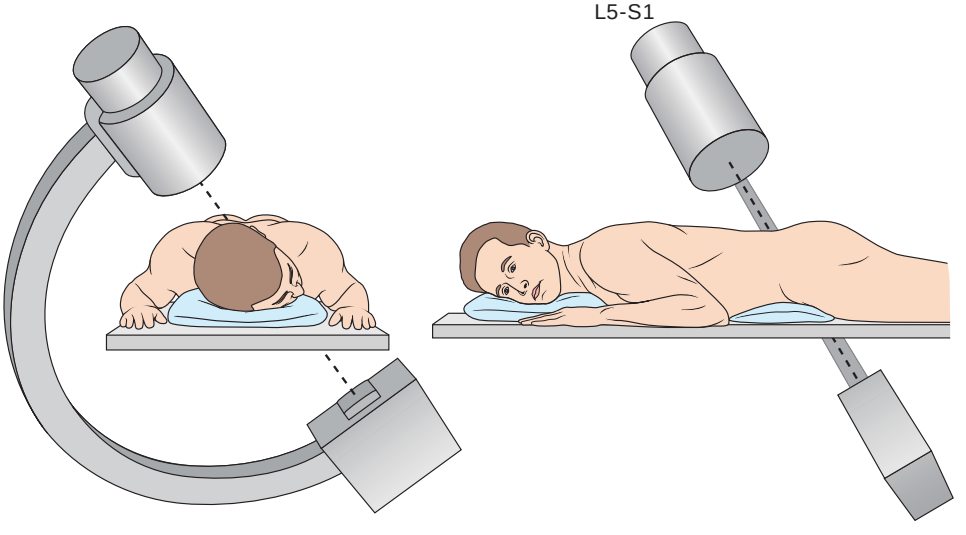


Figure 13-3.
Patient position for superior hypogastric plexus block. The patient lies prone, with the head turned to one side. A pillow is placed under the lower abdomen, above the iliac crest, in an effort to reduce the lumbar lordosis. Asking the patient to rotate the inferior aspect of the pelvis anteriorly toward the table will tip the iliac crests posteriorly and is often key to successfully performing this block. The C-arm is rotated 25 to 35 degrees obliquely and centered on the lumbosacral junction. The C-arm is then angled in a cephalad direction, and the L5/S1 disc is brought into view with 25 to 35 degrees of angulation.

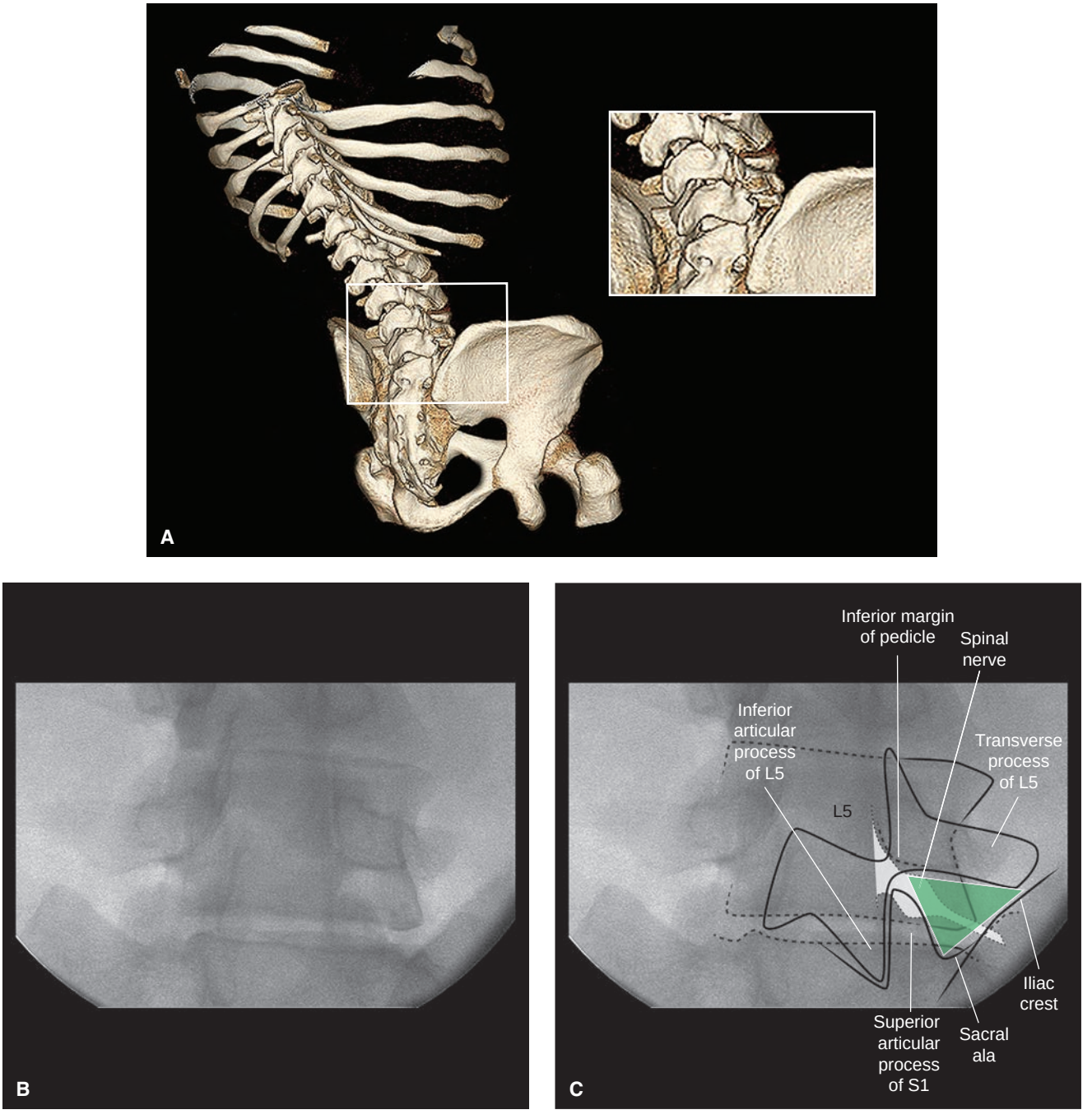
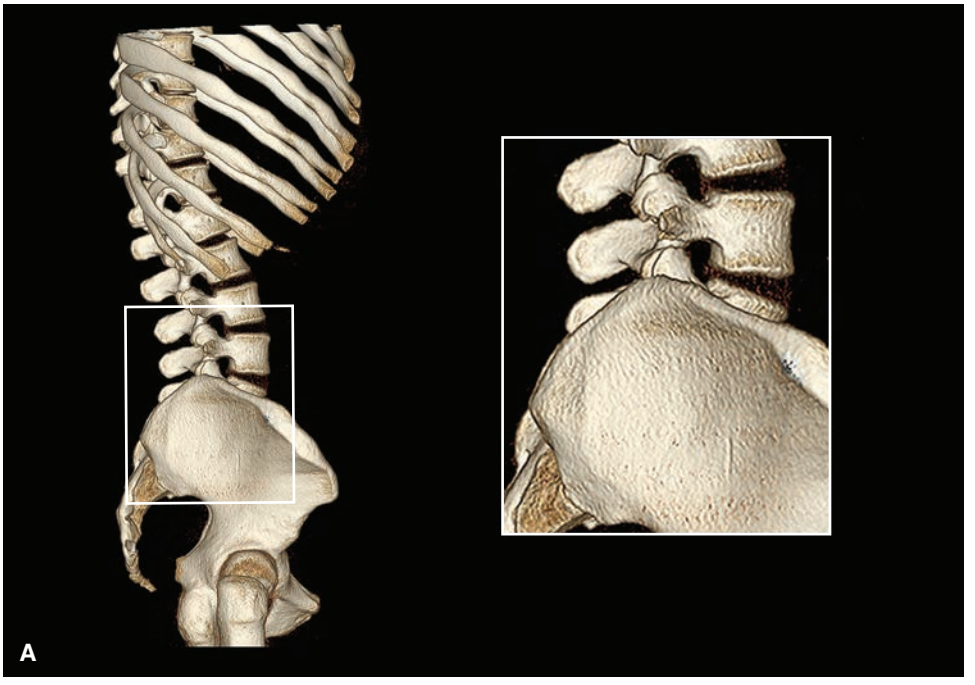
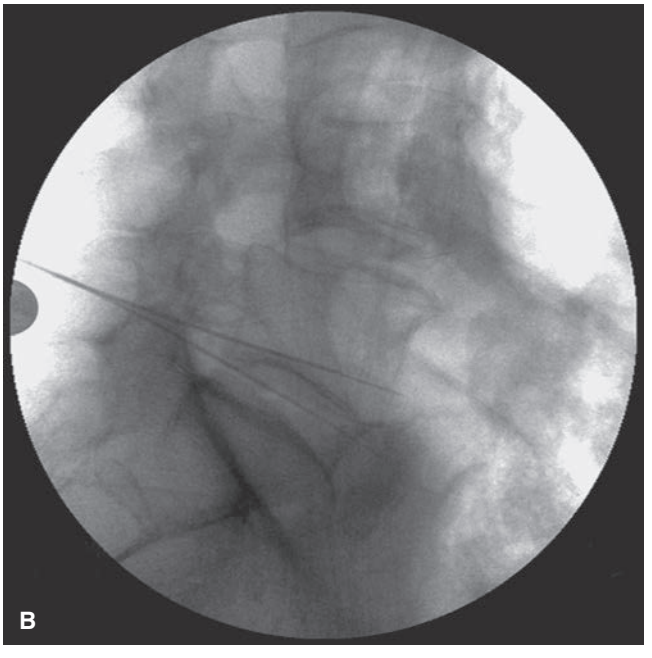


Figure 13-4.

A: Bony anatomy relevant to superior hypogastric plexus block at the L5/S1 level. Three-dimensional reconstruction computed tomography of the lumbar spine as viewed in the oblique projection with marked cranial angulation used to perform superior hypogastric plexus block at the L5/S1 level. **Inset** matches the anatomic area in the radiographs shown in **(B)** and **(C)**. **B:** Oblique radiograph during superior hypogastric plexus block (L5/S1). Oblique radiograph of the lumbosacral junction illustrating the triangular window through which the needle passes for superior hypogastric plexus block. There is a small triangular window through which the needle must pass to reach the anterolateral margin of the lumbosacral junction. **C:** Labeled image. The triangle (*shaded in green*) is bounded superiorly by the transverse process of L5, laterally by the iliac crest, and medially by the L5/S1 facet joint—structures that are readily identified using fluoroscopy. The approximate position of the L5 spinal is shown; the use of the transdiscal approach reduces the likelihood of contact with the spinal nerve as the needle is advanced.





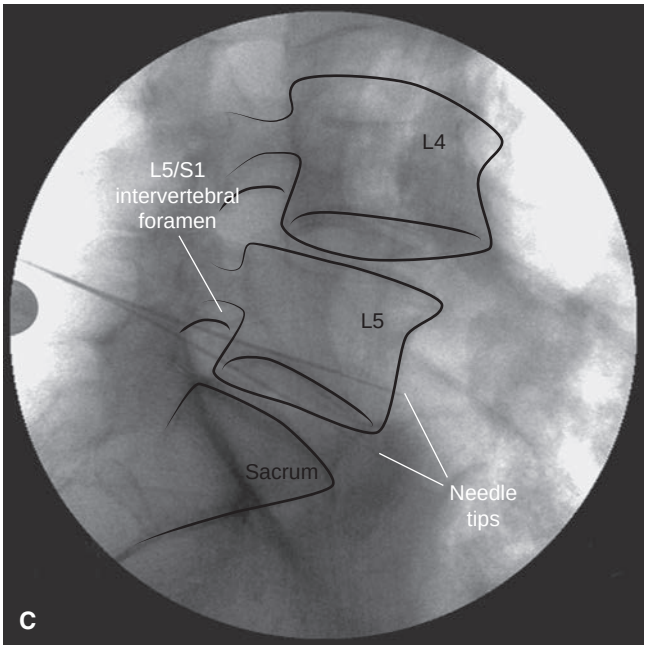


Figure 13-5.

A: Bony anatomy relevant to superior hypogastric plexus block. Three-dimensional reconstruction computed tomography of the lumbar spine as viewed in the lateral projection. **Inset** matches the anatomic area in the radiographs shown in **(B)** and **(C)**. **B:** Lateral radiograph of the lumbosacral spine during superior hypogastric plexus block. Two needles are in position over the anterolateral surface of the lumbosacral junction. The needle tips are aligned with the anterior vertebral margin in the lateral projection. **C:** Labeled image. The slight cephalad angulation of the x-ray axis causes the needles to appear high in the intervertebral foramina. The path of the needles passes just inferior to the spinal nerves anterolateral to the intervertebral foramina.

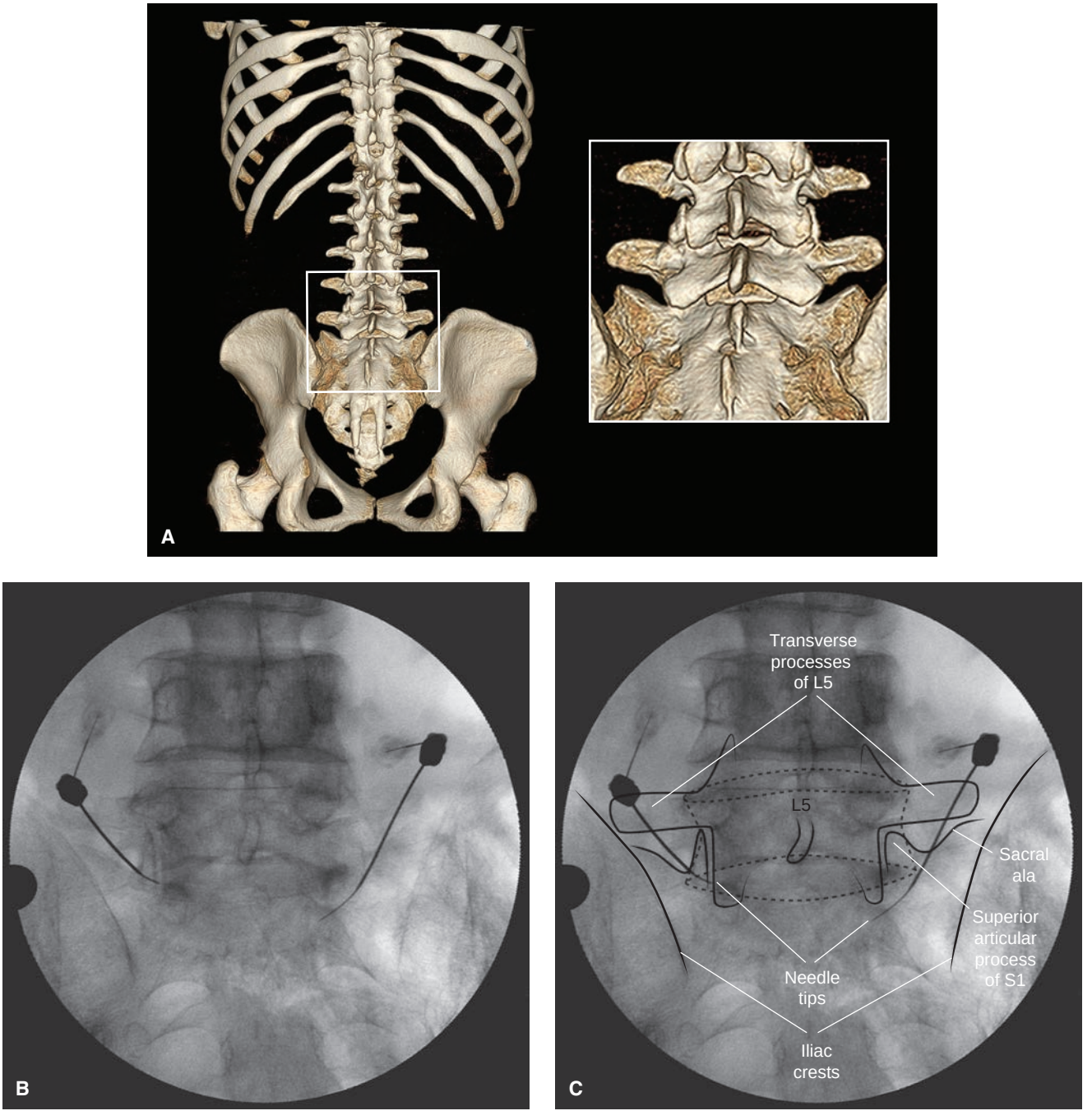


Figure 13-6.

A:Bony anatomy relevant to superior hypogastric plexus block. Three-dimensional reconstruction computed tomography of the lumbar spine as viewed in the anterior-posterior projection. **Inset** matches the anatomic area in the radiographs shown in **(B)** and **(C)**. **B:** Anterior-posterior radiograph of the lumbosacral spine during superior hypogastric plexus block. Two needles pass obliquely over the sacral ala, where they join with the superior articular processes of S1. The needle tips are in position over the anterolateral surface of the L5/S1 intervertebral disc. **C:** Labeled image.

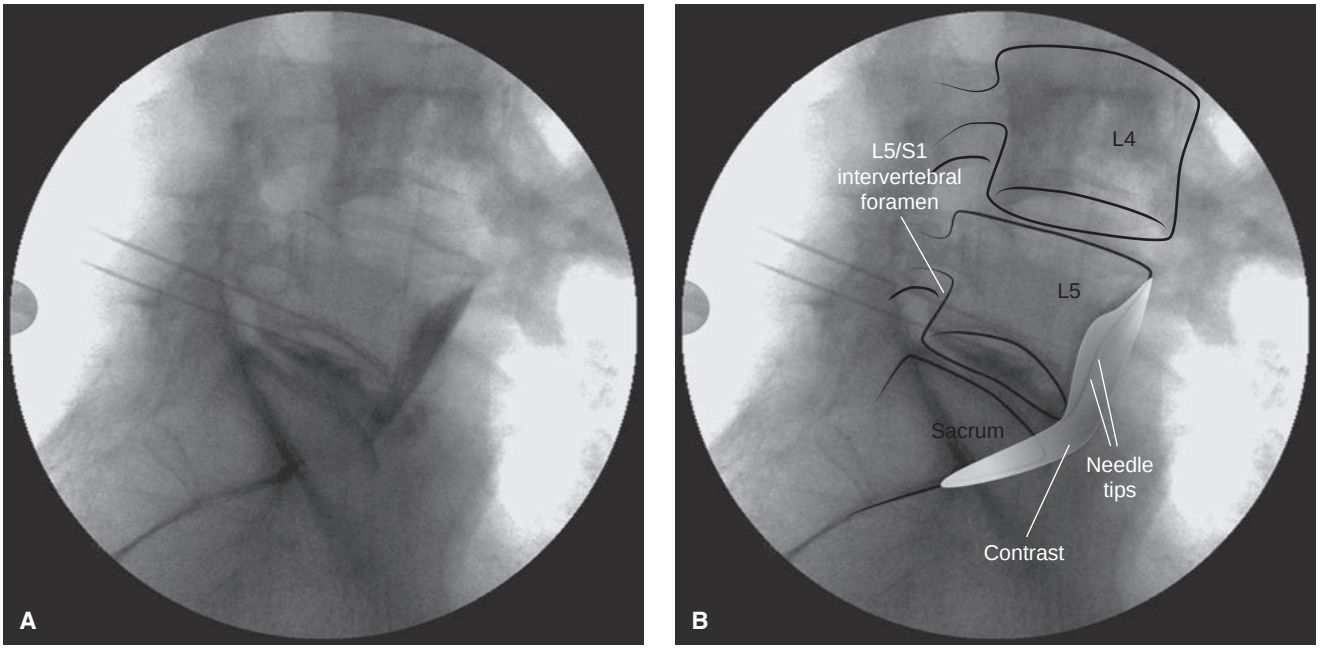


Figure 13-7.

A: Lateral radiograph of the lumbosacral spine during superior hypogastric plexus block following contrast injection. Two needles are in position over the anterolateral surface of the lumbosacral junction. The needle tips are aligned with the anterior vertebral margin in the lateral projection. **B:** Labeled image. Note the slight cephalad angulation of the x-ray axis allows the pedicles on each side of midline to be visible. Contrast spreads in a linear fashion over the anterior surface of the L5 vertebral body and the superior portion of the sacrum (*shaded area*).

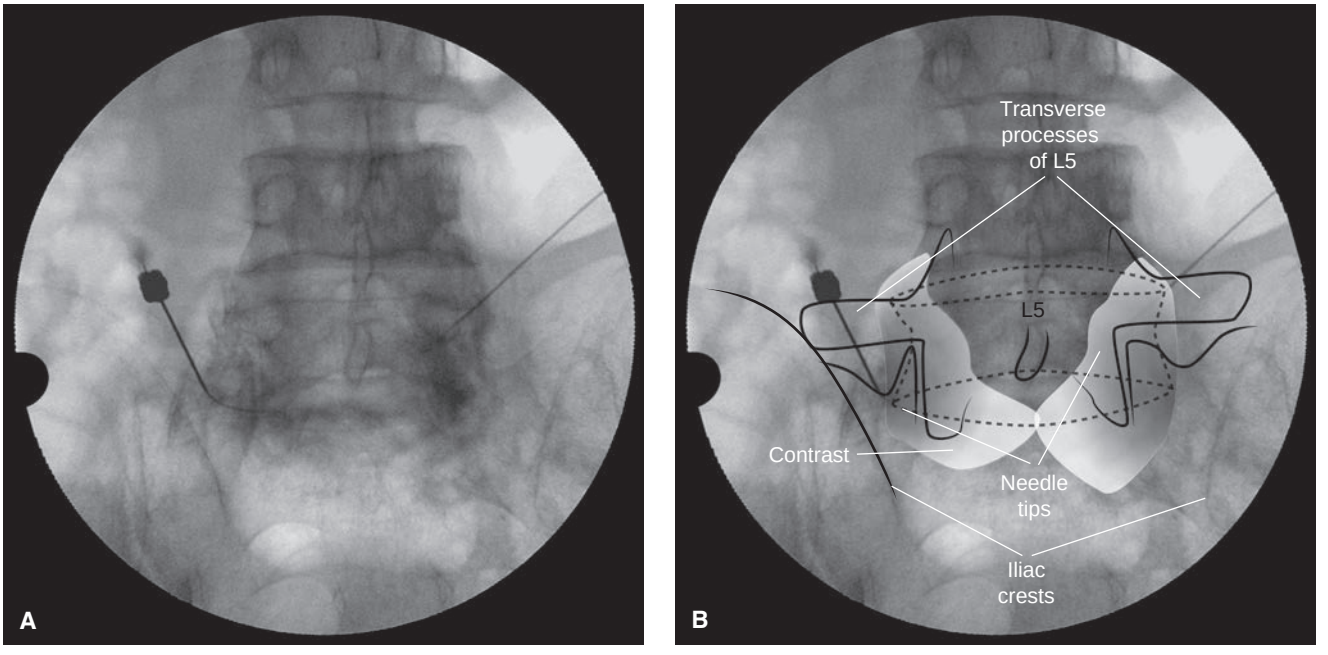


Figure 13-8.

Anterior-posterior radiograph of the lumbosacral spine during superior hypogastric plexus block following contrast injection. **A:** Two needles pass obliquely over the sacral ala, where they join with the superior articular processes of S1. The needle tips are in position over the anterolateral surface of the L5/S1 intervertebral disc. **B:** Labeled image. Contrast extends along the anterolateral surface of the L5 vertebral body and the superior portion of the sacrum (*shaded areas*).

Complications

There are only a limited number of reports detailing the use of superior hypogastric plexus block, and none have reported complications with this procedure. Due to the close proximity of the iliac vessels, intravascular injection can easily occur.

ACKNOWLEDGMENT

The radiographs used in Figs. 13-5 to 13-8 were generously provided by Paul Kreis, MD, Professor of Anesthesiology, Division of Pain Medicine, University of California, Davis, Sacramento, CA.

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CHAPTER 14

Intercostal Nerve Block and Neurolysis

OUTLINE

Overview

The intercostal nerves supply sensation to the thorax and abdomen. Prior to the widespread adoption of the thoracic epidural approach to provide analgesia following major thoracic and abdominal surgery, multiple intercostal nerve blocks were frequently used to provide postoperative pain control for common abdominal operations such as open cholecystectomy. In the postoperative setting, intercostal nerve block is rarely conducted with radiographic guidance. This is a simple technique that can be performed safely and effectively at the bedside using surface landmarks to guide placement. In contrast, neurolysis of the intercostal nerves has been used to provide long-lasting pain relief for patients with painful metastases involving the chest wall. Use of image-guided injection for neurolysis of the intercostal nerves can ensure that the neurolytic solution is injected at the level of the metastases and in close proximity to the intercostal nerves.

Anatomy

The intercostal nerves arise from the anterior primary rami of the first through 12th thoracic spinal nerves. The thoracic spinal nerves traverse through the intervertebral foramina to enter the paravertebral space (Fig. 14-1). The paravertebral space is bound by the pleura anteromedially, the vertebral body medially, and the transverse spinous processes and paravertebral musculature posteriorly. The ribs traverse this space and form two articulations with the vertebral bodies: the costotransverse articulation, where the rib contacts the transverse process, and the costovertebral articulation, where the head of the rib meets the vertebral body. The thoracic spinal nerve root traverses through the intervertebral foramen and ramifies into anterior and posterior branches; the anterior branch forms the intercostal nerve. The intercostal nerve traverses laterally to lie in the subcostal groove, a shallow notch along the inferior margin of each rib. Within this groove, the intercostal vein and artery lie in close proximity, just superior to the nerve (Fig. 14-2). This accounts for the high plasma levels of local anesthetic produced with intercostal nerve blocks. The costal groove becomes shallow and disappears altogether some 5 to 8 cm lateral to the posterior midline. The intercostal nerve may lie immediately below the rib margin or closer to the midpoint between ribs as it traverses laterally. The lateral branch of the intercostal nerve rises over the posterolateral chest wall anterior to the posterior axillary line (an imaginary line extending directly inferior from the posterior axillary fold). This is an important factor to understand because intercostal nerve blocks performed anterior to the posterior axillary line may not anesthetize this branch and may produce incomplete truncal anesthesia. The nerves continue anteriorly around the chest wall, ending in the anterior branches. These terminal branches supply sensation to the anterior chest wall. The critical soft tissue and vascular structures relevant to safely perform intercostal nerve block cannot be seen with fluoroscopy but are readily visualized with ultrasound (Fig. 14-3). Time-motion mode (M-mode) ultrasound also provides a sensitive and simple technique for detecting even the smallest pneumothoraces (see Fig. 14-3C). Description of ultrasound-guided intercostal nerve block is beyond the scope of this text, but this technique may well supplant the use of radiographic guidance as more practitioners gain expertise with ultrasound.

Patient Selection

Multiple intercostal nerve blocks were frequently used to provide postoperative pain control for common abdominal operations such as open cholecystectomy, but thoracic

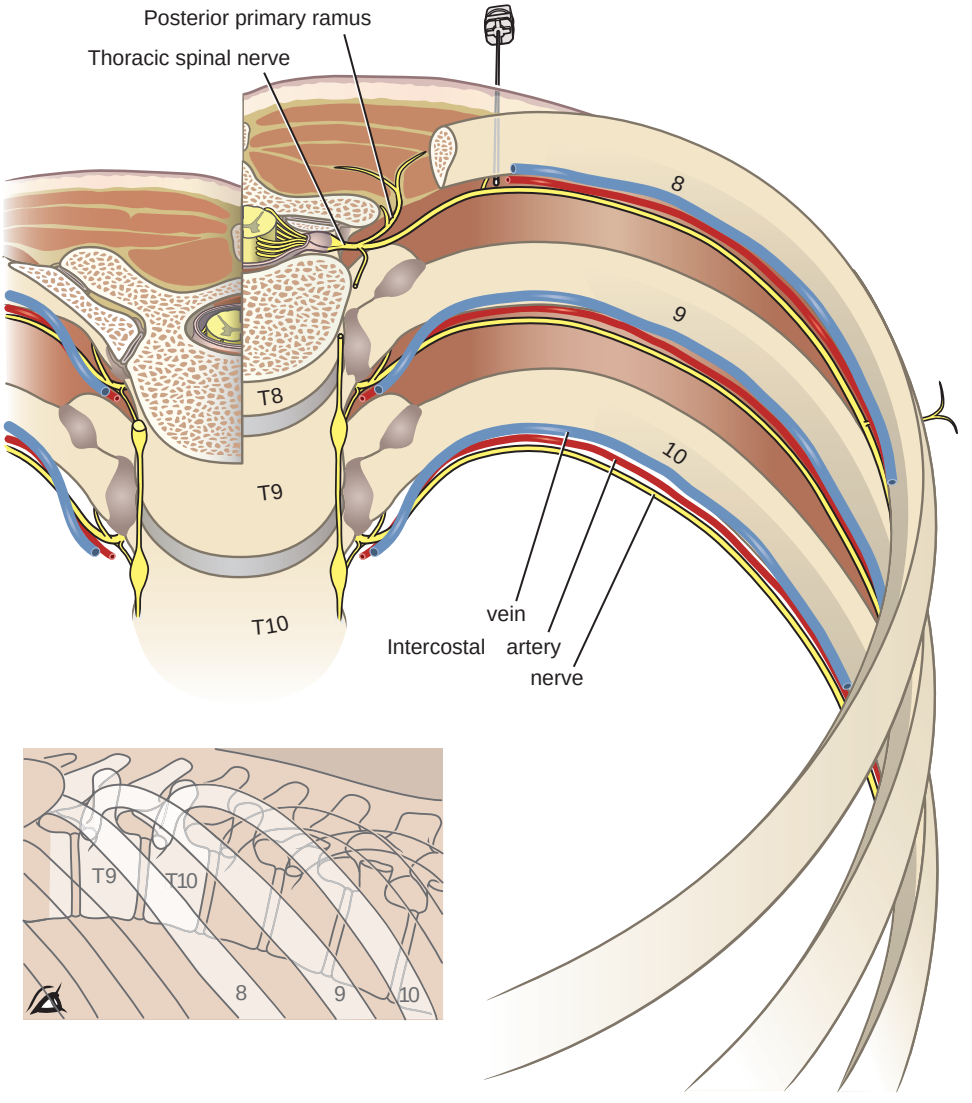

Figure 14-1.
Anatomy of the intercostal nerves. The thoracic spinal nerves traverse the spinal canal through the intervertebral foramina and divide into anterior and posterior primary rami. The anterior rami course laterally to enter a groove beneath the inferior margin of each rib, where they traverse laterally inferior to the intercostal vein and artery. The posterior cutaneous branch rises in a variable location along the course of the intercostal nerve but always anterior to the posterior axillary line (a line that extends directly inferior from the posterior fold of the axilla). Thus, intercostal nerve block should be carried out medial to the posterior axillary line to ensure the entire sensory distribution of the nerve is blocked. The **inset** shows the orientation of the diagram.

epidural infusion is simpler and provides effective continuous analgesia. The use of intercostal blocks has also been described for repair of small umbilical hernias, extracorporeal shock wave lithotripsy, and pacemaker insertion. The use of one- or two-level blocks remains an excellent means of providing anesthesia for chest tube insertion. Intercostal nerve block is a simple and effective means for relieving the pain of rib fractures, albeit limited to the duration of local anesthetic effect. Intercostal nerve blocks for treating pain in acute settings are usually carried out without radiographic guidance, using surface landmarks to guide block placement. Intercostal neurolytic blocks using phenol or alcohol have proven effective for treating painful, isolated metastatic lesions involving the ribs, and the use of radiographic guidance facilitates safe and effective intercostal neurolysis.

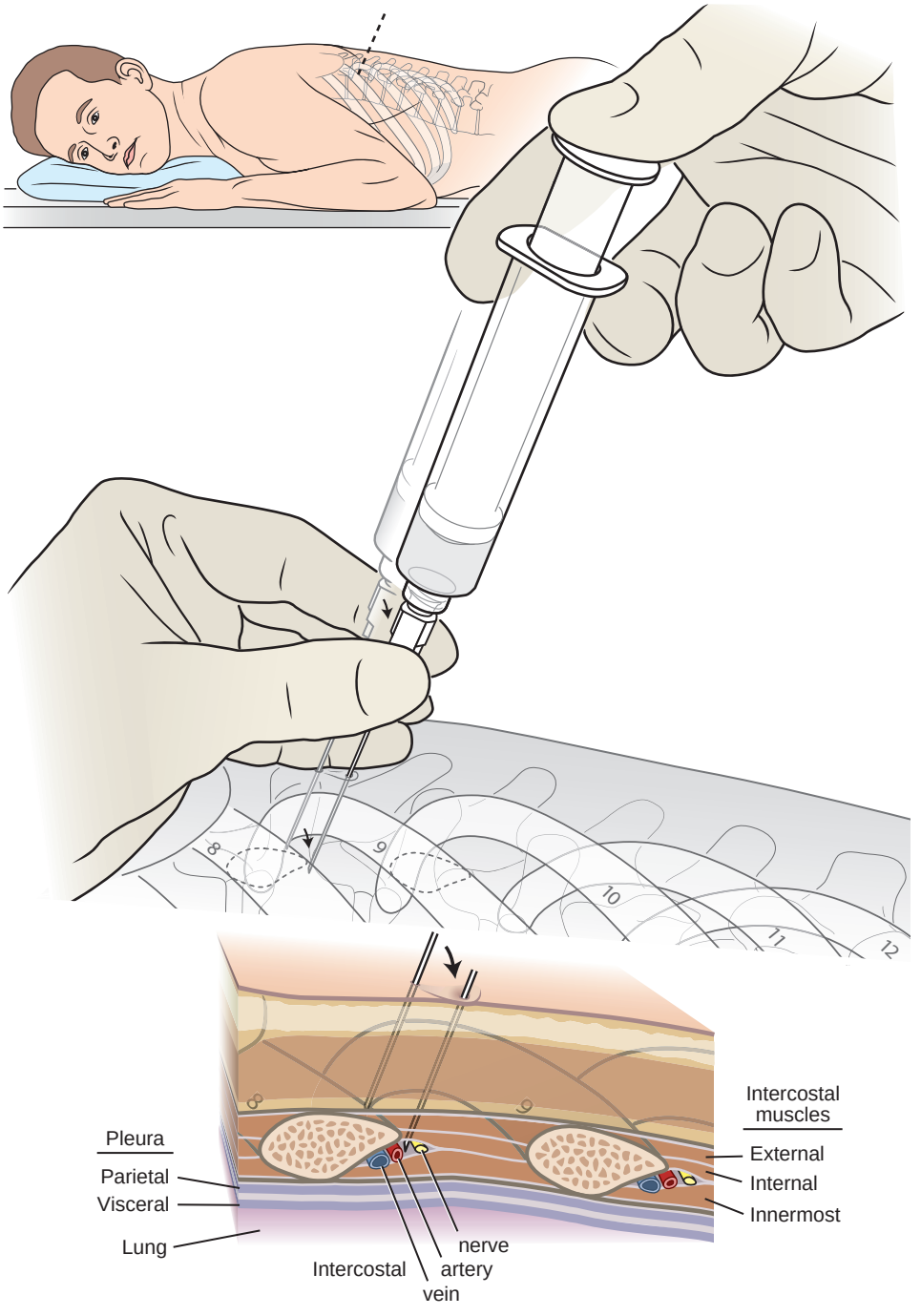

Figure 14-2.
Technique for intercostal nerve block. The needle is advanced with 15 to 20 degrees of cephalad angulation and is first seated on the inferior margin of the rib. The needle is then walked off the inferior rib margin while maintaining the same cephalad angulation of the needle and advanced 2 to 3 mm to lie adjacent to the intercostal nerve. The intercostal nerve lies inferior to the intercostal vein and artery, between the internal and the innermost intercostal muscles.

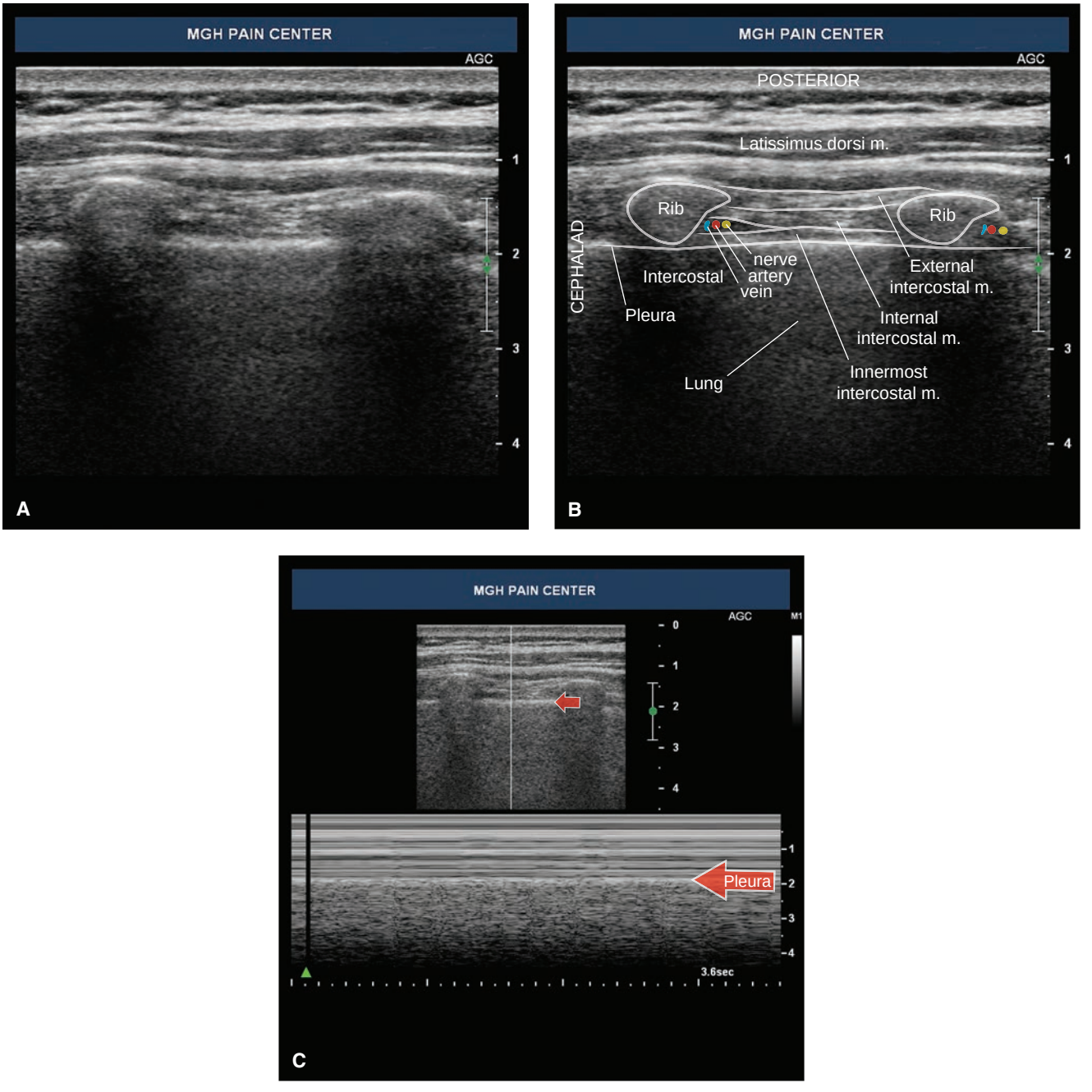

Figure 14-3.

Anatomy relevant to intercostal nerve block as seen on ultrasound. **A:** Ultrasound view in the sagittal plane near the mid-scapular line over the posterolateral chest wall at the level of eighth and ninth ribs. The anatomic region and orientation of this ultrasound image are the same as those shown in the **inset** of Figure 14-2. **B:** Labeled image. Note the clear delineation of adjacent muscular layers between adjacent ribs, the echogenic anterior surface of the two adjacent ribs, and the pleura. The neurovascular bundle lies just inferior to the inferior margin of each rib. **C:** M-mode (time-motion mode) ultrasound through the same region depicted in **(A)** and **(B)**. There is stark contrast in the ultrasound patterns seen using M-mode between the muscular layers and the pleura (*red arrow*). The appearance of the muscular layers on M-mode is a series of continuous parallel lines; in contrast, the lung has a speckled pattern owing to the constant movement of the alveoli during respiration. The pleural interface is easy to identify using M-mode and provides a simple tool for use in early detection of even the smallest pneumothoraces.

Level of Evidence

Quality of Evidence and Grading of Recommendation			
Grade of Recommendation/ Description	**Benefit vs. Risk and Burdens**	**Methodological Quality of Supporting Evidence**	**Implications**
RECOMMENDATION: *Neurolytic intercostal nerve block(s). Neurolytic intercostal nerve block(s) may be used for reduction of chest wall pain in patients with locally invasive or metastatic cancer causing localized pain of the chest wall.*			
2C/weak recommendation, low-quality or very low-quality evidence	Uncertainty in the estimates of benefits, risks, and burden; benefits, risk, and burden may be closely balanced	II-3: Observational studies or case series	Very weak recommendations; other alternatives may be equally reasonable

The use of neurolytic intercostal nerve blocks and neurolysis of other peripheral nerves in regions where locally invasive or metastatic cancer is producing pain associated with localized tissue injury is well described in case reports and small case series. These techniques are used infrequently because of the certainty of producing neurologic deficit. The intercostal nerves are accessible to treatment and there are few consequences to loss of the motor function when a limited number of intercostal nerves are destroyed. Nonetheless, the potential for partial neurolysis and significantly worsened pain is very real. Like the sympathetic blocks, there has been no rigorous testing of the safety and efficacy of this treatment approach and we can rely only on small, uncontrolled observational trials for hints at usefulness. The use of intercostal nerve blocks using local anesthetic with or without corticosteroid for treatment of chronic chest wall pain unrelated to cancer, for example, intercostal neuralgia following thoracotomy, is of limited value and is unlikely to produce any long-term benefit. The use of neurolytic intercostal nerve blocks for treating noncancer pain is uncertain and the risk-benefit ratio must be carefully considered in this group, as permanent worsening of pain has been described with this technique. Because of the dearth of available scientific evidence regarding intercostal neurolysis, there is no current practice guideline that makes specific recommendations regarding use of this block.

Positioning

The patient lies prone, with the head turned to one side (Fig. 14-4). The C-arm is centered over the hemithorax on the side to be treated with 15 to 20 degrees of caudal angulation. The intercostal nerves course in a groove beneath the rib, and the caudal angulation ensures the needle will traverse cephalad beneath the rib margin toward the nerve.

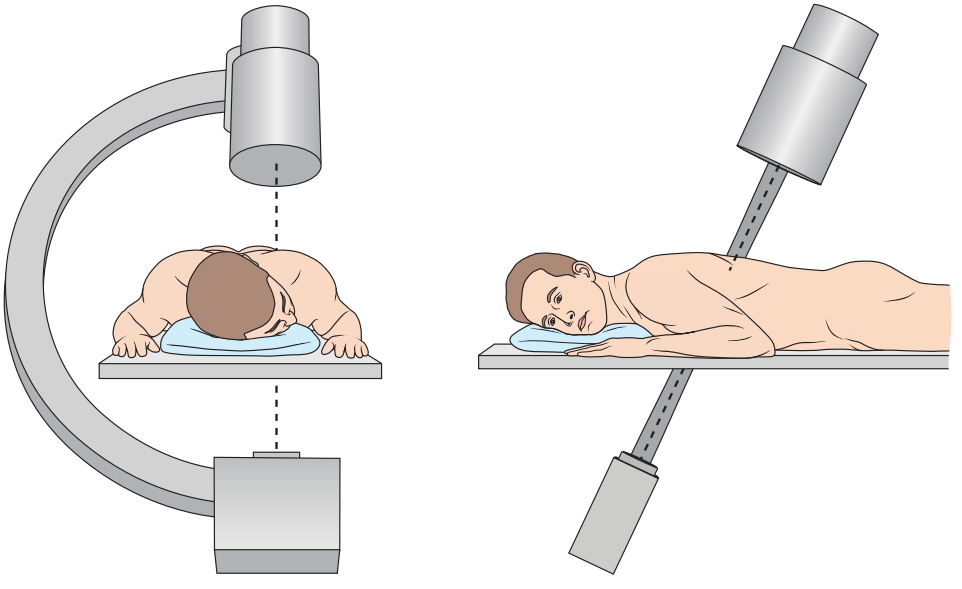

Figure 14-4.
Patient position for intercostal nerve block. The patient lies prone, with the head turned to one side. The C-arm is centered over the hemithorax to be treated with 15 to 20 degrees of caudal angulation to ensure the needle passes in a caudal-to-cephalad direction beneath the inferior margin of the rib.

Block Technique

The intercostal nerves can be blocked anywhere along their course from the paravertebral region to the anterior chest wall. To obtain complete anesthesia along the trunk within the distribution of a given intercostal nerve, the nerve must be blocked before the posterior cutaneous branch arises (posterior to the posterior axillary line, see Fig. 14-1). Access to the intercostal nerves is blocked by the overlying scapula above the level of T6 over the posterior chest wall; thus, the block must be carried out medial to the medial scapular border at these levels. Although intercostal blocks can be performed with the patient in nearly any position, the simplest way to perform multiple intercostal blocks is with the patient fully prone. The shoulder can be easily abducted, placing the forearm over the head to swing the scapula laterally and gain access to the upper ribs. The flat portion of each rib is easily palpated several centimeters from midline, and the inferior margin of each rib is marked. The levels to be blocked should be chosen based on the pattern of pain and the location of any chest wall metastases. In the presence of large metastatic lesions, block of the intercostal nerves one level above and below the affected rib may be necessary for effective pain relief.

The block is then carried out sequentially at each level. The inferior margin of each rib to be blocked is identified on fluoroscopy, and a skin wheal of local anesthetic is placed to provide anesthesia of the skin and subcutaneous tissues. A 22-gauge, 1.5-inch needle is inserted just beneath the skin in a plane coaxial with the x-ray path. The rib lies just 1 to 2 cm beneath the skin in the patient of average build, so care must be taken not to advance the needle too far before confirming its trajectory using fluoroscopy. The direction of the needle is then adjusted to direct the tip toward the inferior margin of the rib and advanced to contact the rib margin. The use of small-gauge needles is advocated by some experts, but because they bend easily, detecting contact with bone is more difficult. Once the needle is in contact with the inferior margin of the rib, the slight cephalad angle of the needle is maintained, and the needle is walked off the inferior margin of the rib and advanced 2 to 3 mm further (see Fig. 14-2). A small volume of radiographic contrast is then injected to ensure that the needle is in good position and there is no intravascular injection. If the needle is too superficial, the contrast will layer within a muscle layer and appear striated (Fig. 14-5). When the needle is adjacent to the intercostal nerve, the contrast typically extends along the inferior margin of the rib, outlining the neurovascular bundle (Fig. 14-6). For temporary or diagnostic intercostal nerve block, 2 to 4 mL of local anesthetic is placed at each level (0.25% or 0.5% bupivacaine). With injection of local anesthetic, the contrast is diluted and spreads along the course of the intercostal nerve (Fig. 14-7). The same procedure is carried out for adjacent levels. The small distance between the rib's inferior margin and the pleura must be emphasized;

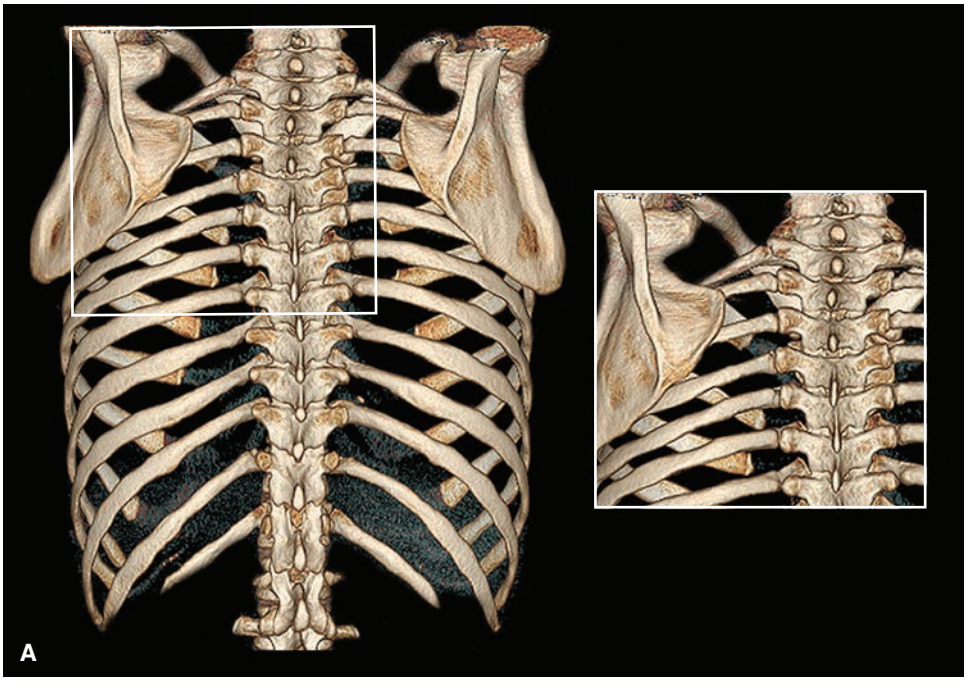

Figure 14-5.

A: Bony anatomy relevant to intercostal nerve block. Three-dimensional reconstruction computed tomography of the thorax as viewed in the anterior-posterior projection. **Inset** matches the anatomic area in the radiographs shown in **(B)** and **(C)**. Anterior-posterior radiograph of the chest during intercostal nerve block demonstrating intramuscular injection. ***(Cont.)***

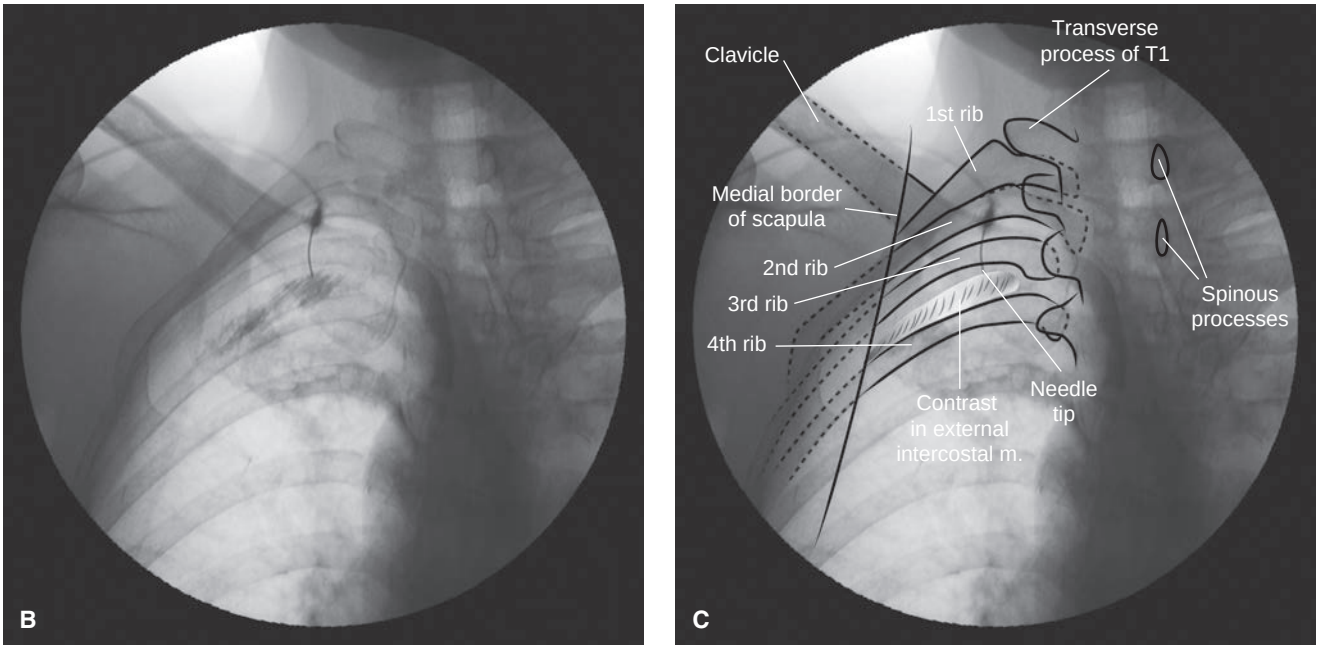

Figure 14-5. *(Continued)*

B: Anterior-posterior radiograph of the chest during intercostal nerve block demonstrating intramuscular injection. A needle is in position just inferior to the inferior margin of the third rib, ~5 cm from midline. One milliliter of radiographic contrast has been injected (iohexol 180 mg per mL) and spans the space between the third and the fourth ribs with a striated pattern extending in an inferior and lateral direction indicating superficial placement within the external intercostal muscle. The needle should be advanced 2 to 3 mm, and the injection repeated. **C:** Labeled image.

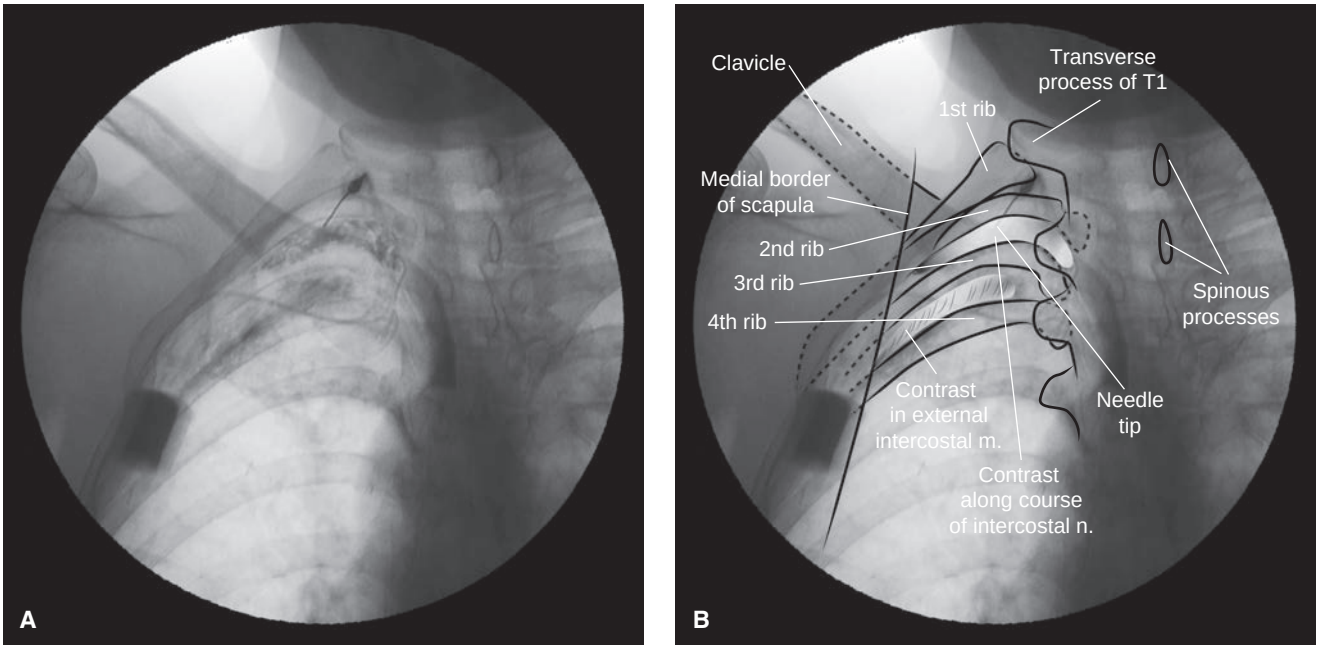

Figure 14-6.

A: Anterior-posterior radiograph of the chest during the second intercostal neurolysis. A needle is in position just inferior to the inferior margin of the second rib, ~5 cm from midline. Three milliliters of radiographic contrast containing phenol have been injected (10% phenol in iohexol 180 mg per mL). The neurolytic solution has spread along the course of the intercostal nerve, extending medially to the paravertebral space and several centimeters lateral from the point of injection. **B:** Labeled image. Note the residual intramuscular contrast from the first injection (see Fig. 14-5).

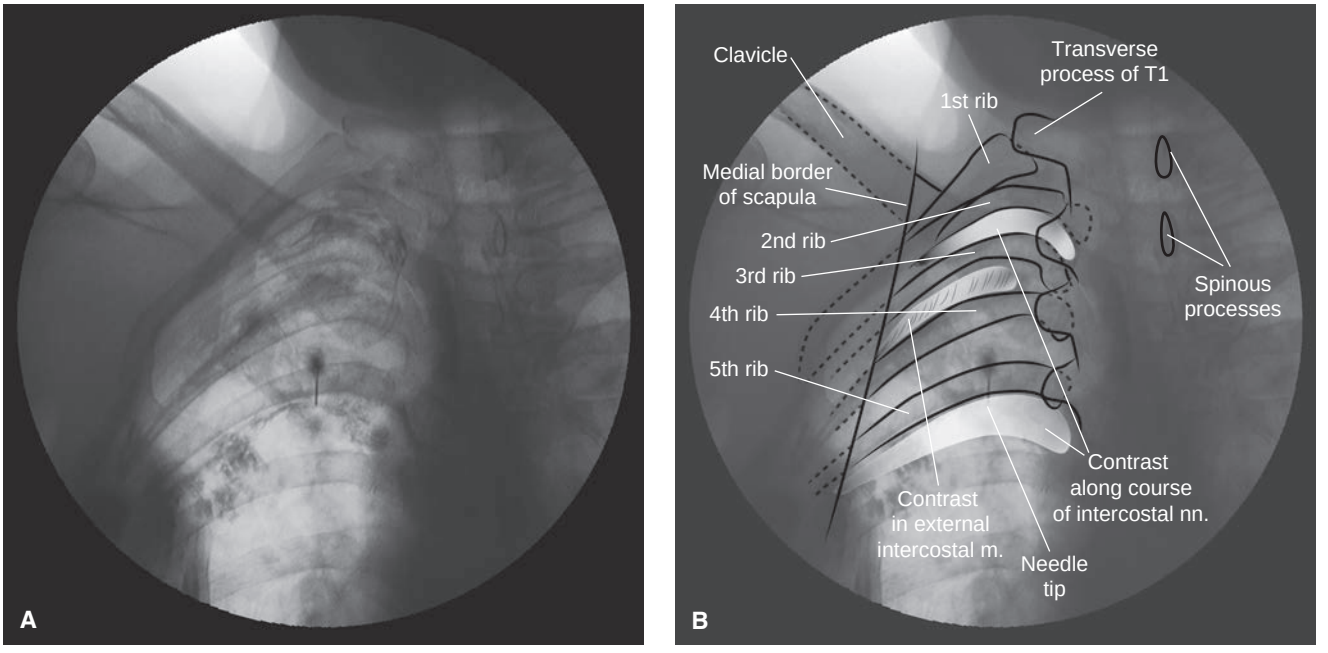

Figure 14-7.
Anterior-posterior radiograph of the chest during the fifth intercostal neurolysis. **A:** A needle is in position just inferior to the inferior margin of the fourth rib, ~5 cm from midline. Three milliliters of radiographic contrast containing phenol have been injected (10% phenol in iohexol 180 mg per mL). The neurolytic solution has spread along the course of the intercostal nerve, extending several centimeters medial and lateral from the point of injection. **B:** Labeled image. Note the residual contrast from the first two injections (see Figs. 14-5 and 14-6).

advancing the needle more than a few millimeters beyond the bony margin may result in pneumothorax (see Figs. 14-2 and 14-3).

Intercostal Neurolysis

Neurolysis of the intercostal nerves is carried out in the same manner described for intercostal nerve blocks using local anesthetic. Once the needle position has been confirmed with the injection of a small amount of radiographic contrast, the neurolytic solution is placed. The use of 10% phenol in radiographic contrast (e.g., iohexol 180 mg per mL) allows the spread of the injectate to be monitored (see Figs. 14-6 and 14-7). Injection of 2 to 4 mL of neurolytic solution is usually sufficient to produce spread along a 5- to 8-cm segment of the nerve. When intercostal neurolysis is carried out close to the proximal portion of the rib, the contrast will often extend to the paravertebral space and extend through the intervertebral foramen to the lateral epidural space. Epidural neurolysis is well described. In fact, extension of the contrast into the epidural space is unlikely to cause adverse effects and may well improve the results of neurolysis.

Complications

Because of the close proximity of vascular structures to the intercostal nerves, there is a significant risk of direct intravascular injection and vascular uptake during each block. Intercostal nerve blocks result in plasma concentrations of local anesthetic greater than any other peripheral nerve block, and care must be taken not to exceed total doses that may lead to systemic toxicity (see Table 4-3). Thus, close attention must be paid to the total local anesthetic dose delivered and to adequate monitoring, intravenous access, and ready availability of resuscitation equipment and drugs.

Pneumothorax can occur, but the incidence is low. Centers with extensive experience using intercostal nerve blocks for postoperative analgesia have reported significant pneumothorax in 0.1% of cases. The incidence is clinically insignificant, but radiographically demonstrable pneumothorax is somewhat higher (0.42%). Time-motion mode (M-mode) ultrasound provides a sensitive and simple technique for detecting even the smallest pneumothoraces (see Fig. 14-3C). Treatment of most pneumothoraces should be conservative, with observation and administration of oxygen, which will also aid reabsorption. Needle aspiration or chest tube drainage is rarely necessary and should be reserved only for patients with symptomatic pneumothorax.

Worsening of pain can arise during intercostal neurolysis and is likely the result of incomplete neurolysis of the treated intercostal nerve. Such patients typically report worsened pain in the distribution of the treated intercostal nerve and may develop signs and symptoms of neuropathic

pain, including burning or lancinating pain and allodynia in the affected region. Although this exacerbation of pain following intercostal neurolysis is usually self-limited, repeat neurolysis may be necessary to reduce or eliminate the pain, and pain may persist even after repeat neurolysis. There is at least one case report of spinal cord injury following intercostal neurolysis, but the mechanism of injury is not clear.

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SECTION IV

IMPLANTABLE DEVICES

CHAPTER 15

Implantable Spinal Drug Delivery System Placement

OUTLINE

Overview

Intrathecal morphine and other opioids are now widely used as useful adjuncts in the treatment of acute and chronic pain, and a number of agents show promise as analgesic agents with spinal selectivity. Continuous delivery of analgesic agents at the spinal level can be carried out using percutaneous epidural or intrathecal catheters, but vulnerability to infection and the cost of external systems typically limit them to short-term use (<6 weeks). Reliable implanted drug delivery systems are now available that make long-term delivery of medications to the intrathecal space feasible. These systems are comprised of a drug reservoir/pump implanted within the subcutaneous tissue of the abdominal wall, which is refilled periodically through an access port. The pump may be a fixed-rate, constant flow device or a variable-rate pump that can be programmed using a wireless radiofrequency transmitter similar to those used for implanted cardiac pacemakers.

Anatomy

The intrathecal catheter is placed directly within the cerebrospinal fluid (CSF) of the lumbar cistern by advancing a needle between vertebral laminae at the L2/L3 level or below. Direct delivery of the opioid at the spinal level corresponding to the dermatome(s) in which the patient is experiencing pain may improve analgesia, particularly when local anesthetics or lipophilic opioids (e.g., fentanyl or sufentanil) are used. Thus, some practitioners have advocated threading the catheter cephalad to the appropriate dermatome. In more recent years, reports of inflammatory mass formation surrounding the catheter tip of some chronic indwelling intrathecal catheters have appeared. These inflammatory masses often presented with gradual neurologic deterioration caused by spinal cord compression. Some experts recommend that implanted intrathecal catheters be placed only within the lumbar cistern below the conus medullaris (approximately below L2), where the appearance of an inflammatory mass is less likely to directly impinge on the spinal cord.

Patient Selection

Patient selection for intraspinal pain therapy is empiric and remains the subject of debate. In general, intrathecal drug delivery is reserved for patients with severe pain that does not respond to conservative treatment. In patients with cancer-related pain, most will have ongoing pain despite appropriate oral opioid therapy, or they may have developed intolerable side effects related to these medications. A randomized controlled trial (RCT) comparing maximal medical therapy with intrathecal drug delivery for cancer-related pain demonstrated improved pain control and reduction in opioid-related side effects in those who received intrathecal pain therapy. Intrathecal drug delivery has also been widely used for noncancer pain, particularly for the treatment of chronic low back pain. The use of this therapy in noncancer pain has not been subject to controlled trials. Recommendations from a 2010 consensus panel regarding key considerations for selection and implantation of patients with noncancer pain for intrathecal therapy are shown in Table 15-1.

Once a patient is selected for intrathecal therapy, a trial is carried out. Most physicians now conduct trials by placing a temporary, percutaneous intrathecal catheter and infusing the analgesic agent over several days to judge the effectiveness of this therapy *before* a permanent system is implanted. Some carry out the trial of intrathecal therapy using a single dose or by using a continuous epidural infusion. The most common analgesic agent used for spinal delivery is morphine; this remains the only opioid approved by the U.S. Food and Drug Administration for intrathecal use.

Level of Evidence

Quality of Evidence and Grading of Recommendation			
Grade of Recommendation/ Description	**Benefit vs. Risk and Burdens**	**Methodological Quality of Supporting Evidence**	**Implications**
RECOMMENDATION: *Intrathecal drug delivery. Intrathecal infusion of opioid, opioid and adjuvant analgesic combinations, or ziconotide may be used in selected patients with persistent, cancer-related pain unresponsive to more conservative treatments. Shared decision making regarding intrathecal infusion should include a specific discussion of potential complications. Neuraxial opioid trials should be performed before considering permanent implantation of intrathecal drug delivery systems.*			
2B/weak recommendation, moderate-quality evidence	Benefits closely balanced with risks and burden	II-1: RCTs with important limitations (inconsistent results, methodologic flaws, indirect, or imprecise) or exceptionally strong evidence from observational studies	Weak recommendation, best action may differ depending on circumstances or patients' or societal values
RECOMMENDATION: *Intrathecal drug delivery. Intrathecal infusion of opioid, opioid and adjuvant analgesic combinations, or ziconotide may be used in selected patients with persistent, noncancer pain unresponsive to more conservative treatments. Shared decision making regarding intrathecal infusion should include a specific discussion of potential complications. Neuraxial opioid trials should be performed before considering permanent implantation of intrathecal drug delivery systems.*			
2C/weak recommendation, low-quality or very low-quality evidence	Uncertainty in the estimates of benefits, risks, and burden; benefits, risk, and burden may be closely balanced	II-2: Observational studies or case series	Very weak recommendations; other alternatives may be equally reasonable

The use of intrathecal drug infusions of opioids, opioids in combination with other agents (commonly bupivacaine or clonidine), and ziconotide have all undergone extensive testing, most of which is observational and unblinded in nature. The use of intrathecal morphine has been compared with maximum medical therapy in the treatment of patients with advanced cancer and shown to provide comparable pain relief with significantly fewer opioid-related adverse effects, including sedation and fatigue. Intrathecal ziconotide has been compared with placebo in the treatment of patients with advanced illness and shown to provide marginally superior pain reduction with almost universal appearance of adverse effects, most common among them are vertigo and other central nervous system symptoms. The use of implanted drug delivery systems carries significant risk, including pump malfunction, device-related infection, and catheter-tip granuloma formation. In addition, recent population studies point to an increased risk of death in those receiving intrathecal infusions; errors in programming and misplacement of the drug into the subcutaneous pocket during refill have been proposed as possible causative factors. The risks of therapy must be closely weighed against the benefits when considering the use of long-term intrathecal drug delivery, and attempts to use more conservative means of treatment should be exhausted before using this approach.

Expert recommendations regarding the use of intrathecal drug delivery are mixed. The American Pain Society Low Back Pain Guideline Panel published a report in 2009, concluding, "There is insufficient evidence to adequately evaluate benefits of…intrathecal therapy with opioids or other medications for nonradicular low back pain." The American Society of Anesthesiologists Task Force on Chronic Pain Management published a 2010 Practice Guideline, offering the following recommendations: "Ziconotide infusion may be used in the treatment of a select subset of patients with refractory chronic pain." and "Intrathecal opioid injection or infusion may be used for patients with neuropathic pain. Shared decision making regarding intrathecal opioid injection or infusion should include a specific discussion of potential complications. Neuraxial opioid trials should be performed before considering permanent implantation of intrathecal drug delivery systems." Neither group considered the use of this therapy for cancer-related pain.

Two recent guidelines were prepared by a multidisciplinary panel of experts in the use of intrathecal drug delivery; one of the guidelines reviews the evidence regarding the use of intrathecal drug delivery for patients with cancer pain (Deer, 2011) and the other for patients with noncancer pain (Deer, 2010). The final panel recommendations were similar for both patient groups: "The consensus panel unanimously agrees that appropriate patient selection is vital to achieving successful outcomes with chronic IT analgesic therapy; however, specific patient selection indications for implantation with an IT drug delivery system are not supported by rigorous, literature-based scientific data. The ultimate determination to proceed with IT therapy requires resolution of two

Table 15–1

Key Considerations for Selection and Implantation of Patients with Noncancer Pain for Intrathecal Therapy

Contraindications for Immediate Trial/Implant	Indications to Proceed with Trial/Implant
• Immunocompromised patients at high risk for infection or patients presenting with an active infection • Patients presenting with severe psychological conditions, including untreated significant addiction; active psychosis with delusional/hallucinatory components; major uncontrolled depression/anxiety; active suicidal or homicidal behavior; serious cognitive deficits; or severe sleep disturbances • Current or anticipated lack of insurance coverage or means to pay out of pocket for both surgical implantation and ongoing medication refills/reprogramming • Inability to comply with medication refill schedule due to geographic limitations	• An appropriate diagnosis of the patients' pain has been established • Chronic pain results in significant interference with activities of daily living, including ability to work, and overall quality of life • Preexisting medical comorbidities are well controlled and appropriate disease-specific guidelines are followed pre- and postimplantation • Patients presenting without any severe or uncontrolled psychological conditions • Patients have tried and failed to achieve sufficient analgesia with less invasive therapies • Patients in whom oral opioid therapy is contraindicated, for example, a patient who has difficulties managing his or her medications, an individual with certain comorbid conditions in which oral opioids have the potential for severe adverse effects

Reproduced with permission from Deer TR, Smith HS, Cousins M, et al. Consensus guidelines for the selection and implantation of patients with noncancer pain for intrathecal drug delivery. *Pain Physician*. 2010;13:E175–E213.

principal overlapping decisions—who to implant and when to implant the patient with an internalized device. Although it is challenging to ascertain optimal timing for the initiation of IT therapy, various indicators may signal that a patient is 'ready' for this aggressive form of treatment. To optimize clinical practice in the absence of evidence-based guidance or validated tools for chronic IT analgesic therapy patient selection, the panel has assembled a set of arbitrary, multidisciplinary issues that merit consideration during individualized risk-versus-benefit evaluations." The list issues proposed by this consensus panel are shown in Table 15-1. While this is directed at selecting appropriate patients with noncancer pain for treatment with intrathecal drug delivery, the considerations are similar in those with cancer-related pain.

Intrathecal drug delivery is an invasive and expensive treatment modality that carries significant risk. The available evidence for long-term efficacy is modest and the risks associated with treatment are significant. The available expert opinion from different consensus groups offers imprecise guidance, highlighting the empiric nature of patient selection. The final recommendations put forth in the table above represents a composite of the available recommendations discussed in this section.

Positioning

Before the procedure, discuss with the patient the location of the pocket for the intrathecal pump. Most devices are large, and the only region suitable for placement is the left or right lower quadrants of the abdomen. Once the site is determined, mark the proposed skin incision with a permanent marker while the patient is in the sitting position. The position of the pocket on the abdominal wall is deceptively difficult to determine once the patient is lying on his or her side. If the location is not marked, the pocket is often placed too far lateral within the abdominal wall.

Implantation of an intrathecal drug delivery system is a minor surgical procedure that is carried out in the operating room using aseptic precautions, including skin preparation, sterile draping, and the use of full surgical attire (Fig. 15-1). The procedure can be conducted under either local anesthesia or general anesthesia using dedicated anesthesia personnel. Performing the initial spinal catheter placement under general anesthesia carries concerns about neural injury that are similar to performing any neuraxial technique under general anesthesia.

The patient is positioned on a radiolucent table in the lateral decubitus position with the patient's side for the pump pocket nondependent (see Fig. 15-1). The arms are extended at the shoulders and secured in position so they are well away from the surgical field. The skin is prepared, and sterile drapes are applied. The radiographic C-arm is then positioned across the lumbar region to provide a cross-table anterior-posterior (AP) view of the lumbar spine. Care must be taken to ensure that the x-ray view is not rotated by observing that the spinous processes are in the midline, halfway between the vertebral pedicles (Fig. 15-2).

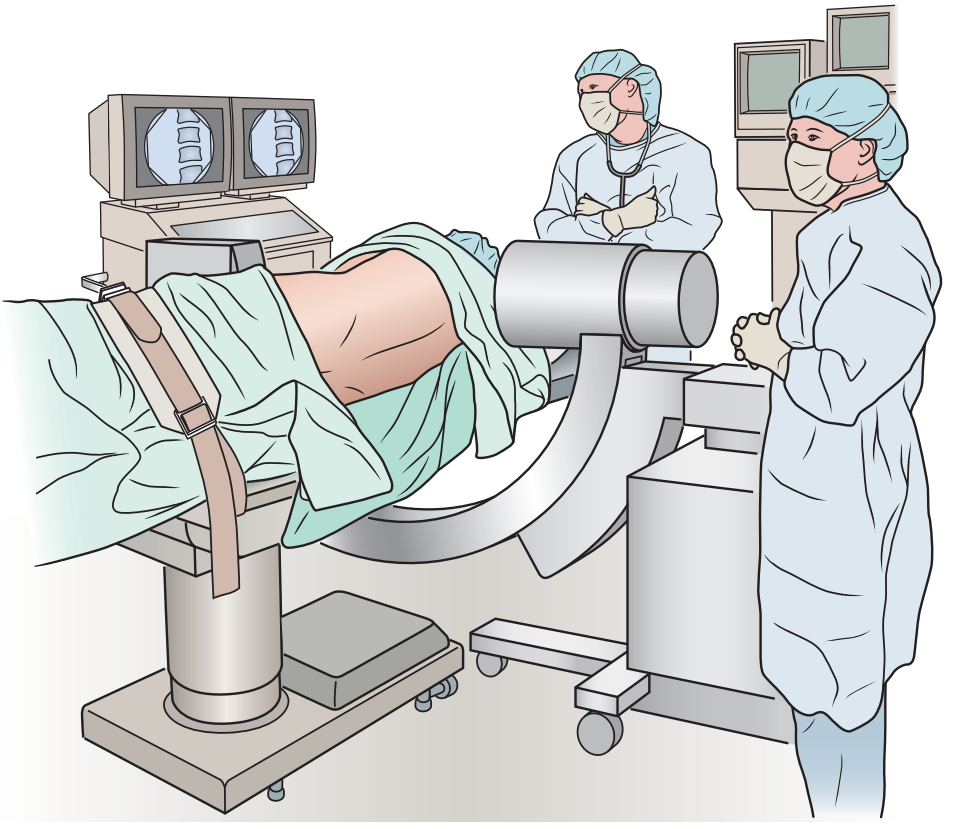

Figure 15-1.
View of typical operating room arrangement during intrathecal implantation. The patient is placed in the lateral position with the C-arm in place for a cross-table AP view of the lumbar spine.

Surgical Technique

The L3/L4, L4/L5, or L5/S1 interspace is identified using fluoroscopy. The spinal needle supplied by the intrathecal device manufacturer must be used to ensure that the catheter will advance through the needle without damage. The needle is advanced using a paramedian approach starting 1 to 1.5 cm lateral to the spinous processes and just inferior to the superior margin of the lamina that forms the inferior border of the interspace you plan to enter (see Fig. 15-2). The needle is directed to enter the spinal space in the midline; after dural penetration, the stylette is removed to ensure adequate flow of CSF (Fig. 15-3). Using fluoroscopic guidance, the spinal catheter is advanced through the needle until the tip is well into the spinal space but below L2 within the lumbar cistern (Fig. 15-4). Position of the catheter tip is verified using fluoroscopy in the AP and lateral planes (Figs. 15-5 and 15-6). The final catheter position can vary and there is no firm connection between the final position of the catheter within the thecal sac and the overall efficacy of intrathecal drug delivery (Fig. 15-7). The needle is then withdrawn slightly (~1 to 2 cm) but left in place around the catheter within the subcutaneous tissues to protect the catheter during the subsequent dissection (Fig. 15-8). The catheter is secured to the surgical field using a small clamp to ensure it does not fall outside the sterile field (see Fig. 15-8).

A 5- to 8-cm incision parallel to the axis of the spine is extended from just cephalad to just caudad to the needle, extending directly through the needle's skin entry point (Fig. 15-9). The subcutaneous tissues are divided using blunt dissection until the lumbar paraspinous fascia is visible surrounding the needle shaft. A purse-string suture is created within the fascia surrounding the needle shaft (Fig. 15-10). This suture is used to tighten the fascia around the catheter and prevent backflow of CSF that may lead to a chronic subcutaneous CSF collection. The needle and stylette are removed simultaneously, using care not to dislodge the spinal catheter (Fig. 15-11). Free flow of CSF from the catheter should be evident after the stylette is removed; if there is no CSF flowing from the catheter, a blunt needle can be inserted within the end of the catheter and gentle aspiration used to ensure the catheter remains within the thecal sac. If CSF cannot be aspirated from the catheter, it should be removed and replaced. The catheter is then secured to the paraspinous fascia using a specific anchoring device supplied by the manufacturer (Fig. 15-12).

Attention is now turned to creating the pocket within the patient's abdominal wall. A 10- to 12-cm transverse

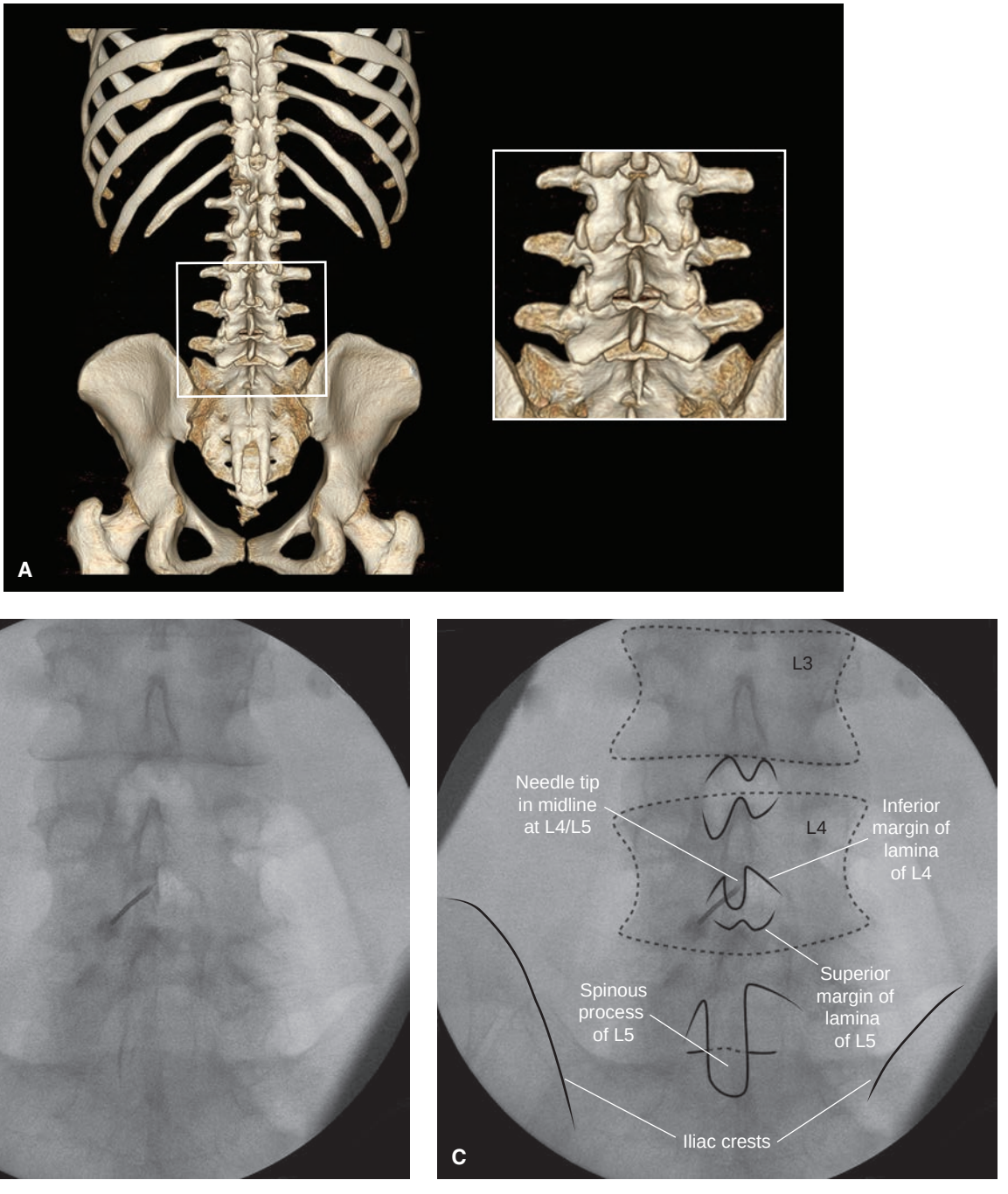

Figure 15-2.

A: Bony anatomy relevant to intrathecal catheter placement. Three-dimensional reconstruction computed tomography of the lumbar spine as viewed in the AP projection used to place a spinal catheter. **Inset** matches the anatomic area in the radiographs shown in **(B)** and **(C)**. **B:** Initial spinal needle placement via the L4/L5 interspace using a left paramedian approach. **C:** Labeled image.

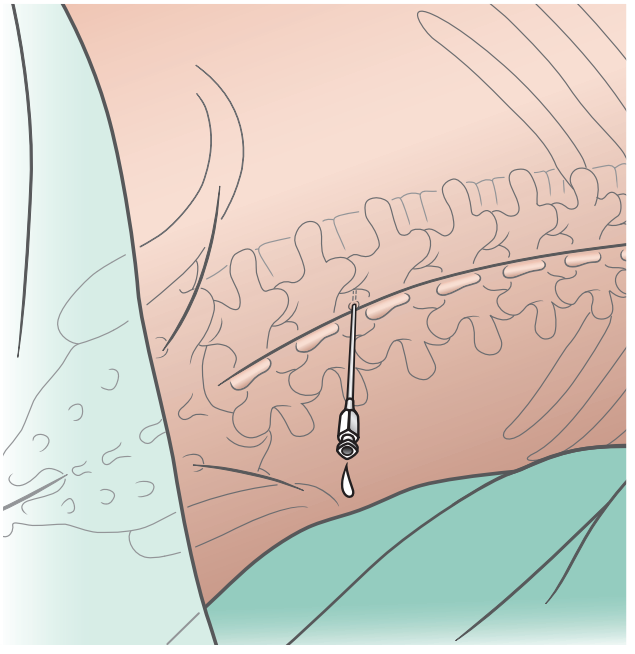

Figure 15-3.
Free flow of CSF indicates intrathecal location.

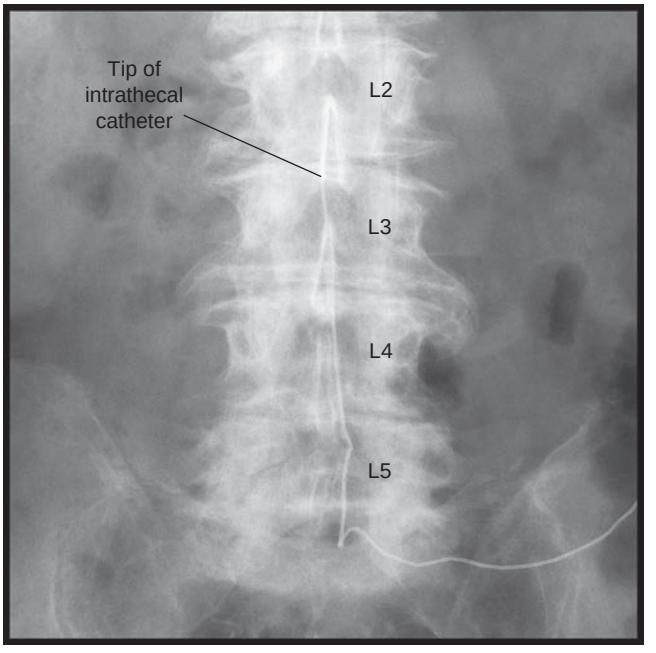

Figure 15-5.
AP radiograph of the intrathecal catheter in the final position with the tip adjacent to the L2/L3 intervertebral disc.

incision is made along the previously marked line, and a subcutaneous pocket is created using blunt dissection (Fig. 15-13). The pocket should always be created caudad to the incision. If the pocket is placed cephalad to the incision, the weight of the device on the suture line is likely to cause wound dehiscence. In many patients, the blunt dissection can be accomplished using gentle but firm pressure with the fingers. It is simpler and less traumatic to use a small pair of surgical scissors to perform the blunt dissection using repeated opening (*not closing or cutting*) motions

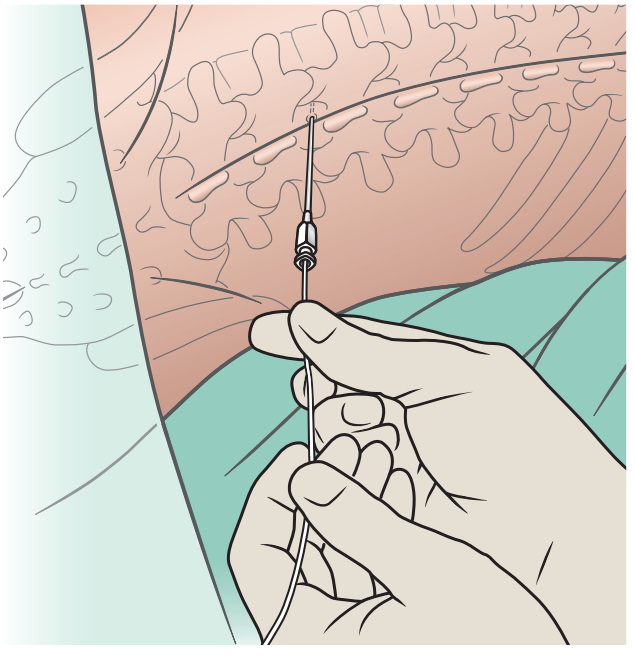

Figure 15-4.
Intrathecal catheter placement through the spinal needle under fluoroscopic guidance.

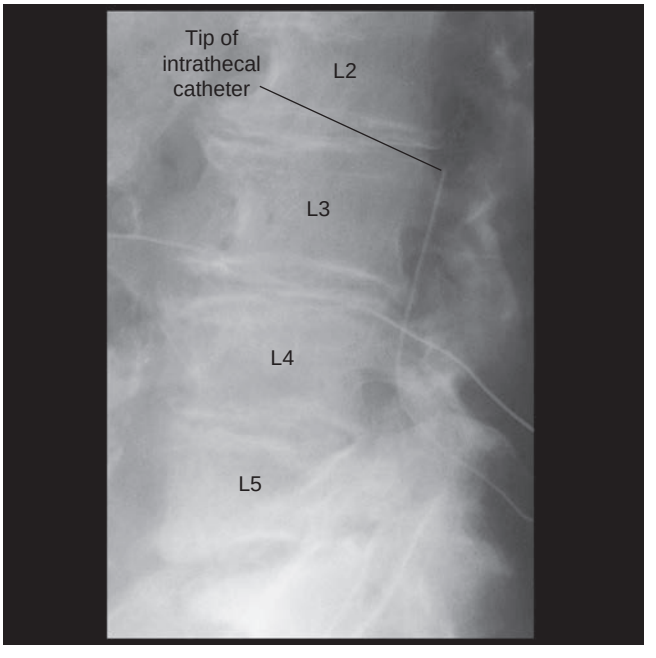

Figure 15-6.
AP radiograph of the intrathecal catheter in the final position with the tip adjacent to the L2/L3 intervertebral disc.

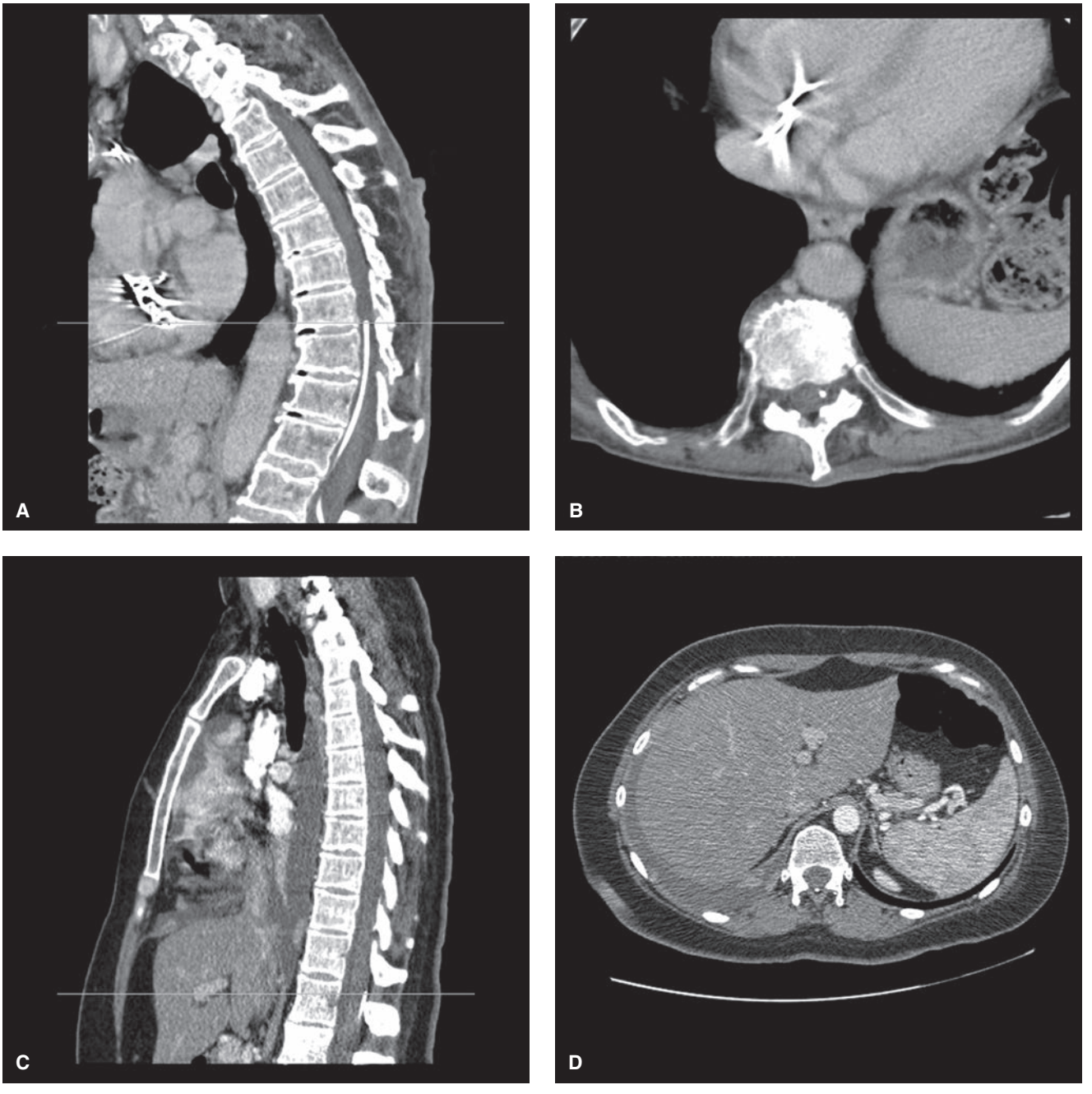

Figure 15-7.
Sagittal **(A)** and axial **(B)** computed tomography of the thorax in a patient with an intrathecal drug delivery system that has been in place for more than 10 years and providing ongoing pain relief for a patient with chronic axial low back pain. The catheter tip can be seen in the left anterolateral aspect of the thecal sac at the T6/T7 level. Sagittal **(C)** and axial **(D)** computed tomography of the thorax in a patient with an intrathecal drug delivery system placed and providing pain relief for a patient with chest wall pain associated with metastatic lung cancer. The catheter tip can be seen in the midline in the posterior aspect of the thecal sac at the T9/T10 level. Reference line on the sagittal images corresponds with the level of the axial images shown. Note that both of the imaging studies shown here were obtained for diagnostic purposes related to each patient's primary illness. They are shown here to demonstrate the variation in intrathecal catheter position that is commonly seen in practice.

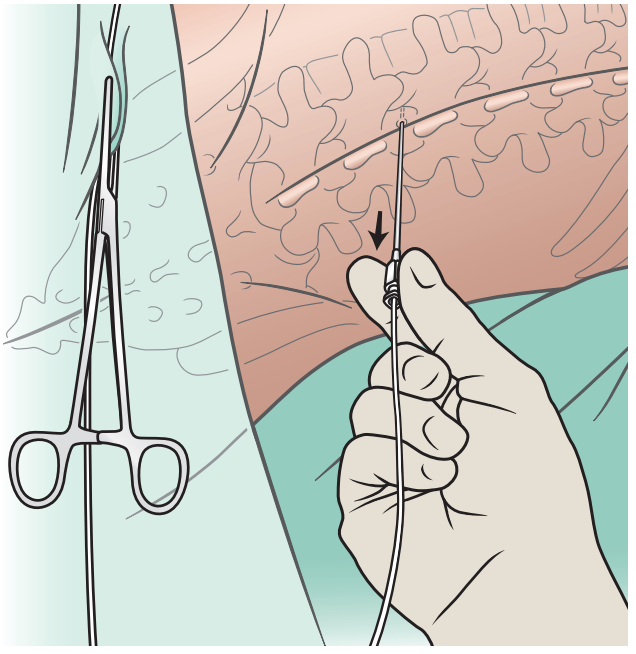

Figure 15-8.
After confirming the final position of the catheter tip, the spinal needle is withdrawn about 1 cm to lie in the subcutaneous tissue, and the proximal portion of the catheter is fastened to the surgical field. Leaving the needle in place protects the catheter during subsequent dissection.

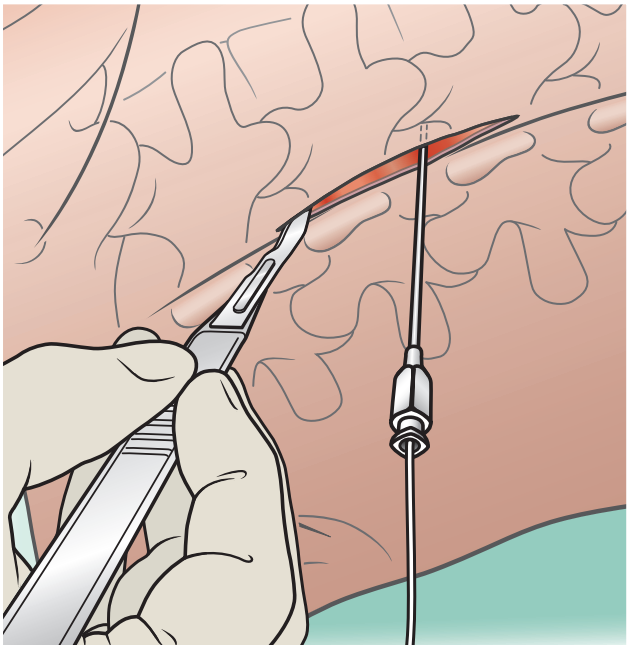

Figure 15-9.
A cephalad-caudad incision is made through the skin and subcutaneous tissues; the incision extends above and below the needle entry point. Using blunt dissection, the skin and subcutaneous tissues are further divided until the lumbar paravertebral fascia is exposed.

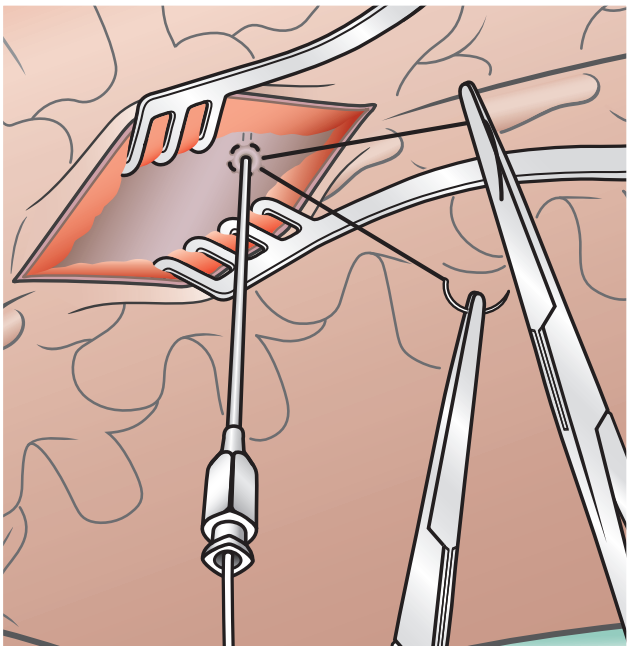

Figure 15-10.
A purse-string suture is placed around the base of the needle within the paravertebral fascia. This suture reduces the likelihood that CSF will track back along the catheter and result in a subcutaneous CSF collection.

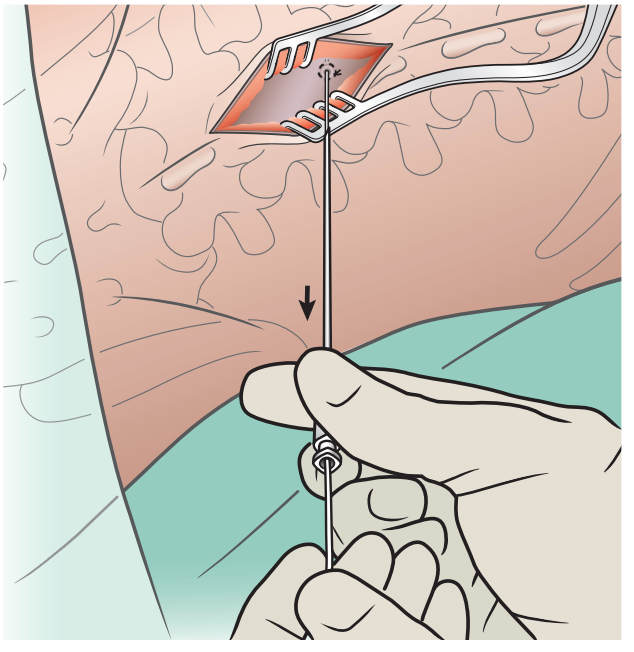

Figure 15-11.
The needle and stylette are removed together while holding the catheter firmly in position.

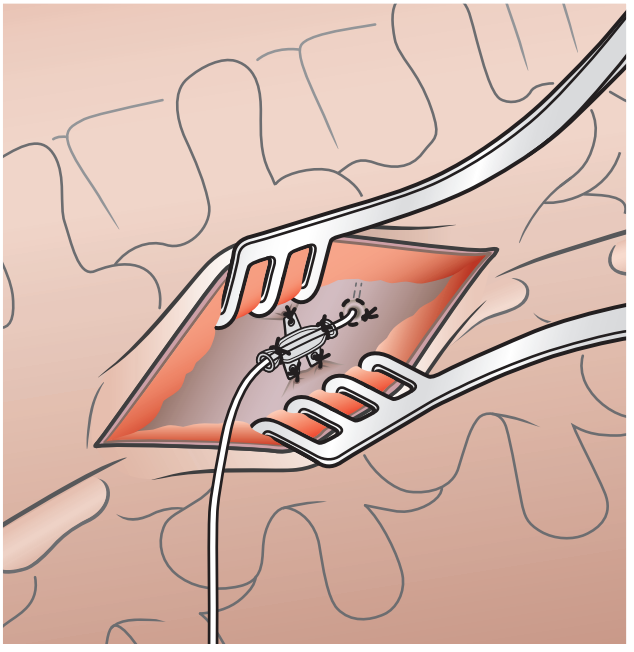

Figure 15-12.
The catheter is secured to the paravertebral fascia using an anchoring device supplied by the manufacturer. An older style anchor is shown in this illustration. Newer anchors that secure the catheter directly without the need for the circumferential sutures around the anchor and catheter have been developed.

or gentle use of electrocautery in the cutting mode. After creating the pocket, the pump is placed in the pocket to ensure the pocket is large enough. The pump should fit completely within the pocket without any part of the device extending beneath the incision. With the device in place, the wound margins must fall into close apposition. There should be no tension on the sutures during closure of the incision or the wound is likely to dehisce.

After pocket creation is completed, a tunneling device is extended within the subcutaneous tissues between the paraspinous incision and the pocket (Fig. 15-14). The catheter is then advanced through the tunnel (most tunneling devices place a hollow plastic sleeve in the subcutaneous tissue through which the catheter can be advanced from the patient's back to the pump pocket). The catheter is then trimmed to a length that allows for a small loop of catheter to remain deep to the pump and attach to the pump. The pump is placed in the pocket with a loop of catheter deep to the device (Fig. 15-15). This loop allows for patient movement without placing tension on the distal catheter and causing it to be pulled from the thecal sac. Two or more sutures should be placed through the suture loops or mesh enclosure surrounding the pump and used to secure the pump to the abdominal fascia. These simple retaining sutures prevent the pump from rotating or flipping within the pocket. The skin incisions are then closed

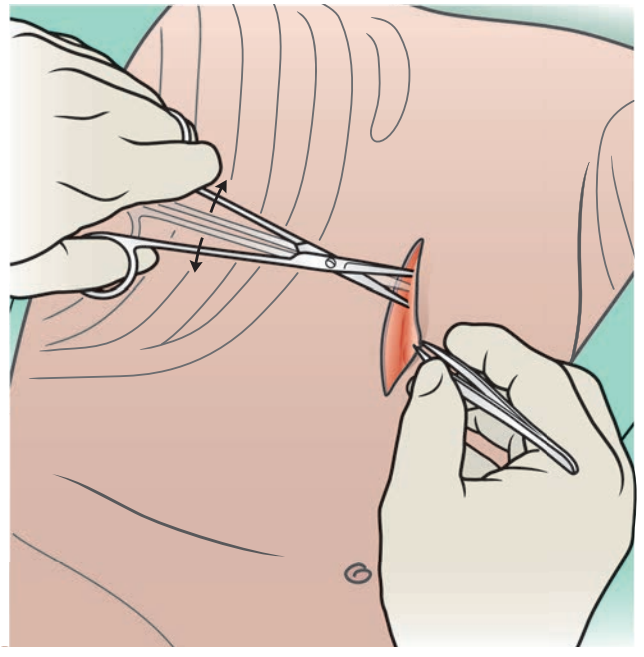

Figure 15-13.
A transverse incision is created in the abdominal wall midway between the umbilicus and the anterior axillary line, and a pocket of sufficient size is made to accommodate the pump using blunt dissection. The blunt dissection can be accomplished using the fingertips or by using surgical scissors and a repeated spreading (rather than cutting) motion.

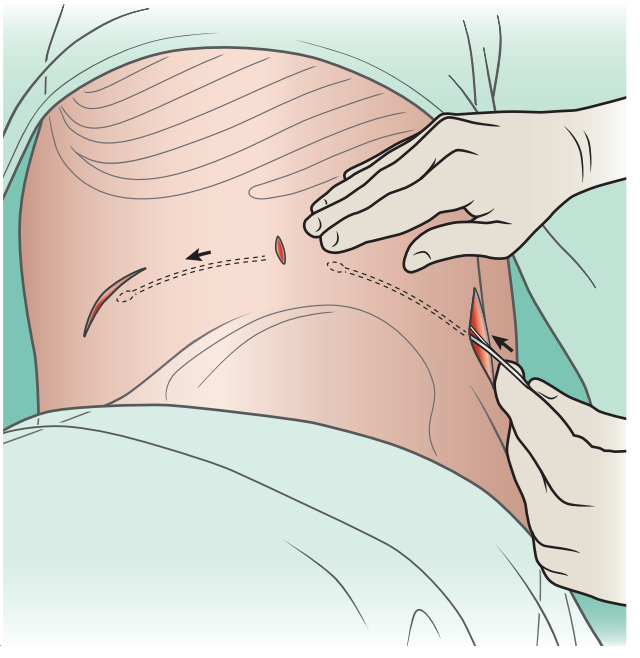

Figure 15-14.
A tunneling device provided by the manufacturer is used to position the catheter within the subcutaneous tissue between the paravertebral incision and the abdominal pump pocket. In large patients, the tunneling may require two segments: the first segment between the paravertebral incision and a small transverse incision in the mid-axillary line and a second segment from the mid-axillary line to the abdominal pump pocket.

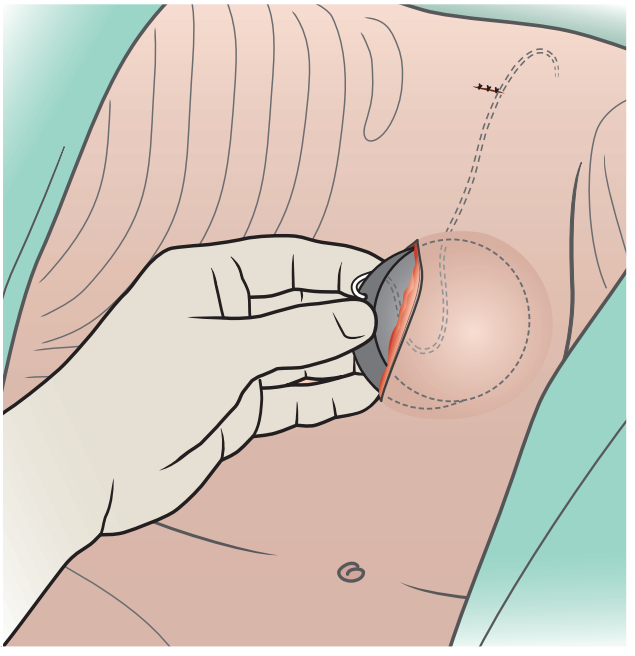

Figure 15-15.
After ensuring good hemostasis, the pump is placed within the pocket.

in two layers: a series of interrupted subcutaneous sutures to securely close the fascia overlying the pump and the catheter followed by a skin closure using suture or staples (Fig. 15-16).

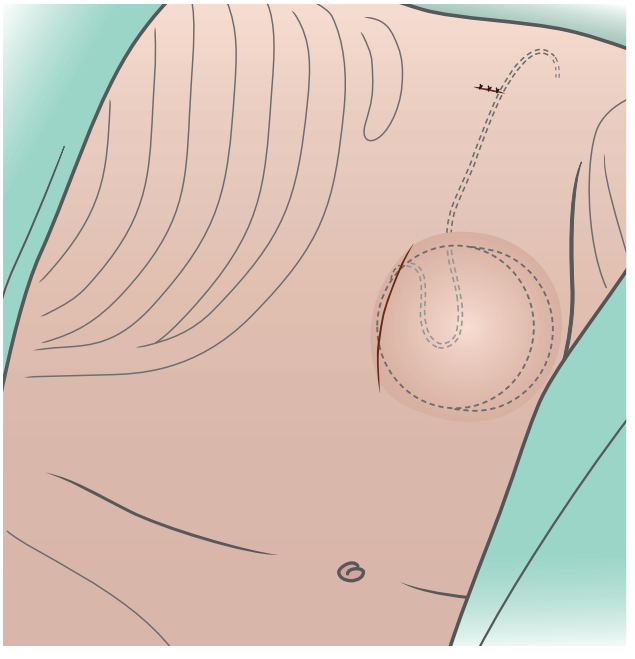

Figure 15-16.
The abdominal and paravertebral incisions are then closed in two layers: a layer of interrupted, absorbable suture within the subcutaneous tissue overlying the pump and catheter, and a separate layer within the skin.

Permanent Epidural Catheter Placement

For placement of a permanent epidural catheter, patient positioning and use of fluoroscopy are similar to those described for intrathecal catheter placement. The interspace of entry will vary with the dermatomes that are to be covered, particularly if local anesthetic solution is to be used. A typical loss-of-resistance technique is used to identify the epidural space, and a silastic catheter is threaded into the epidural space. A paraspinous incision is created, and the catheter is secured to the paraspinous fascia as described previously for intrathecal catheter placement.

Two types of permanent epidural systems are available: a totally implanted system using a subcutaneous port that is accessed using a needle placed into the port through the skin and a percutaneous catheter that is tunneled subcutaneously but exits the skin to be connected directly to an external infusion device.

To place a permanent epidural with a subcutaneous port, a 6- to 8-cm transverse incision is made overlying the costal margin halfway between the xiphoid process and the anterior axillary line. A pocket is created overlying the rib cage using blunt dissection (Fig. 15-17). The catheter is then tunneled from the paraspinous region to the pocket as described previously for intrathecal catheter placement and secured to the port. The port must then be sutured securely to the fascia over the rib cage. Care must be taken to ensure the port is secured

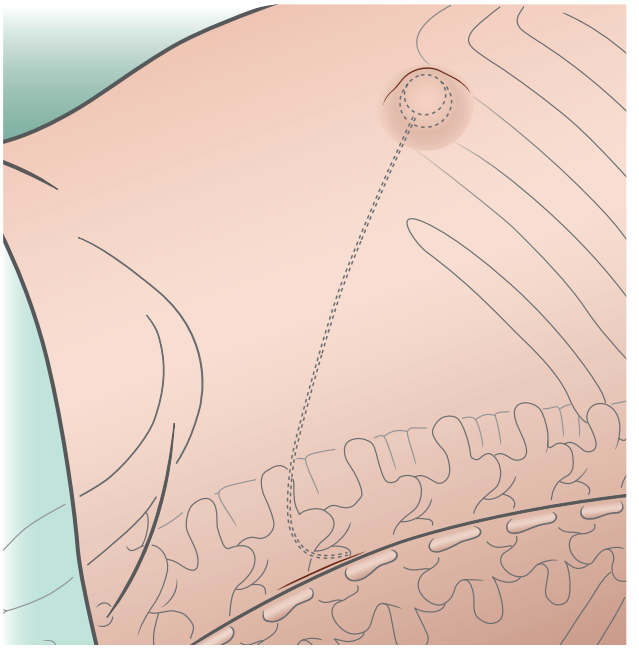

Figure 15-17.
Placement of a permanent epidural catheter with a subcutaneous access port. The epidural catheter is placed and tunneled to a pocket over the costal margin. The port is connected to the epidural catheter and sutured to the fascia overlying the inferior rib cage. The port must lie firmly in place over the ribs rather than the abdominal wall; without the support of the firm rib cage behind the port, it will be difficult to access.

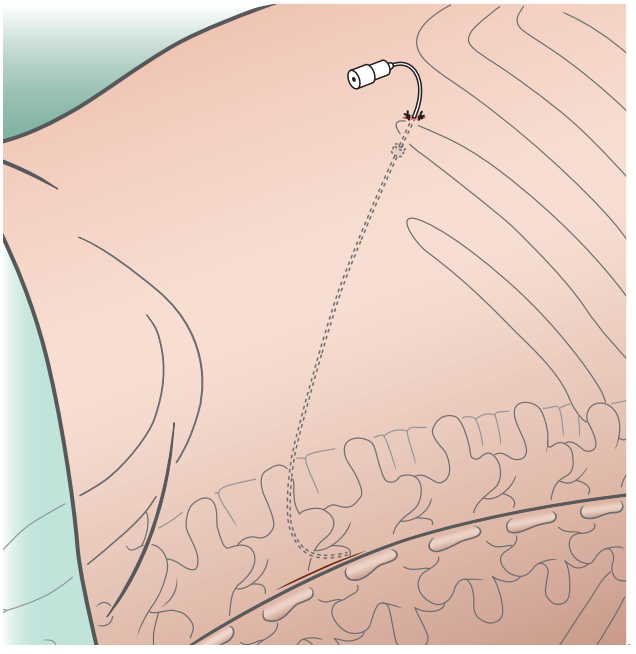

Figure 15-18.
Placement of a permanent percutaneous, tunneled epidural catheter. This type of catheter is typically supplied in two pieces: a distal, epidural portion and a proximal catheter length with a subcutaneous antibiotic-impregnated cuff and external access port. After placement of the epidural catheter and dissection through a paravertebral incision, the proximal catheter is tunneled from the costal margin to the paravertebral incision, and the catheter is pulled into the subcutaneous tissues until the antibiotic-impregnated cuff lies 1 to 2 cm from the chest wall incision within the subcutaneous tissue. The catheter segments are then trimmed, joined together using a connector supplied by the manufacturer, and secured to the paravertebral fascia. The skin entry site on the chest wall is secured around the exiting catheter using interrupted sutures.

firmly in a region that overlies the rib cage; if the port migrates inferiorly to lie over the abdomen, it becomes difficult to access. The rigid support of the rib cage holds the port firmly from behind, allowing for easier access to the port. The skin incisions are then closed in two layers: a series of interrupted subcutaneous sutures to securely close the fascia overlying the catheter followed by a skin closure using suture or staples.

To place a permanent epidural without a subcutaneous port, a tunneling device is extended from the paraspinous incision to the right upper abdominal quadrant, just inferior to the costal margin. A small incision (~0.5 cm) is made to allow the tunneling device to exit the skin. Percutaneous epidural catheters are supplied in two parts: the proximal portion of the catheter that is placed within the epidural space and the distal portion of the catheter that enters the abdominal wall and connects with the distal portion of the catheter. The distal portion of the catheter is now secured to the tunneling device and pulled through the incision in the abdominal wall subcutaneously to emerge from the paraspinous incision (Fig. 15-18). Many catheters are supplied with an antibiotic-impregnated cuff that is designed to arrest entry of bacteria along the track of the catheter. This cuff should be placed about 1 cm from the catheter's exit site along the subcutaneous catheter track. The proximal and distal portions of the catheter are then trimmed, leaving enough catheter length to ensure there is no traction on the catheter with movement. The two ends of the catheter are connected using a stainless steel union supplied by the manufacturer and sutured securely. The paraspinous skin incision is then closed in two layers: a series of interrupted subcutaneous sutures to securely close the fascia overlying the catheter followed by a skin closure using suture or staples. The skin incision at the epidural catheter's exit site in the right upper quadrant is closed around the base of the catheter using one or two simple, interrupted sutures.

Complications

Bleeding and infection are risks inherent to all open surgical procedures. Bleeding within the pump pocket can lead to a hematoma surrounding the pump that may require surgical drainage. Bleeding along the subcutaneous tunneling track often causes significant bruising in the region but rarely requires treatment. Similar to other neuraxial techniques, bleeding within the epidural space can lead to significant neural compression. Signs of infection within the pump pocket typically occur within 10 to 14 days following implantation but may occur at any time. Some practitioners have reported successful treatment of superficial infections of the area overlying the pocket with oral antibiotics aimed at the offending organism and close observation alone. However, infections within the pocket or along the catheter's subcutaneous course almost universally require removal of all implanted hardware and treatment with parenteral antibiotics to eradicate infection. Catheter and deep tissue infections can extend to involve the neuraxis, resulting in epidural abscess formation and/or meningitis. Permanent epidural catheters without subcutaneous ports have a higher infection rate than those with ports in the first weeks after placement, but both systems have a similar, high rate of infection when left in place for more than 6 to 8 weeks.

Spinal cord injury during initial catheter placement has been reported. This has led some practitioners to recommend placing the catheter only in the awake patient so the patient can report paresthesiae during needle placement. The risk of neural injury can be minimized by careful use of fluoroscopy to assure that the needle enters the thecal sac in the midline at an interspace that is below the level of the conus medullaris (L3/L4 or lower).

Wound dehiscence and migration are infrequent problems. Ensuring the size of the pocket is sufficient to prevent tension on the suture line at the time of wound closure is essential to minimize the risk of dehiscence. Port migration usually occurs because retaining sutures were omitted at the time of placement. Placing two or more sutures through the suture loops on the port and securely fastening them to the abdominal fascia will minimize the risk of migration.

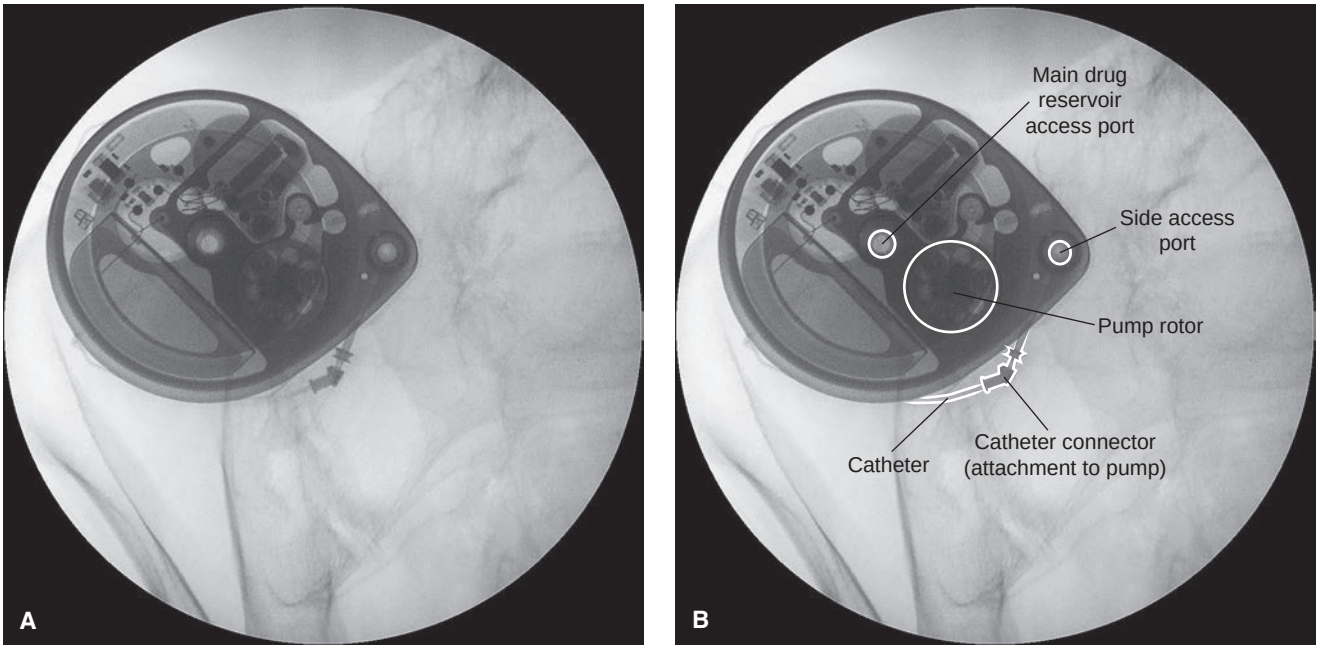

Figure 15-19.

A: Appearance of the Medtronic Synchromed II (Minneapolis, Minnesota, USA) 40-mL intrathecal drug delivery pump as seen in situ using fluoroscopy in the AP plane. **B:** Labeled image. Fluoroscopy can be used to readily identify the drug reservoir access port during routine periodic refilling of the pump using the 22-gauge Huber-type (noncoring) needle supplied by the manufacturer. By taking two sequential radiographs separated by several minutes, fluoroscopy can also be used to assess proper rotation of the rollers around the rotor in the peristaltic pump, as their position will change if the rotor is moving. Finally, fluoroscopy is essential when assessing the integrity of the catheter and its position within the CSF using the side access port. The side access port can be accessed with a 25-gauge needle; the side access port is specifically designed to prevent entry with the larger needle used for drug refills. Once the needle is in position, at least 0.3 mL of fluid must be withdrawn to clear the catheter of highly concentrated drug and prevent administration of an intrathecal bolus. Once the catheter has been cleared, radiographic contrast can be injected and the course of the catheter examined along its entire length to detect any dislodgement or leaks. When the catheter is in proper position within the thecal sac, contrast will accumulate along the inner borders of the thecal sac producing a typical lumbar myelogram. Following the side port study, the pump must be carefully programmed to deliver a precise bolus in order to refill the catheter with drug and prevent a period during which no drug is being delivered.

Subcutaneous collection of fluid surrounding the port (seroma formation) can be problematic. Percutaneous drainage of the sterile fluid collection is often successful in resolving the problem. The radiographic appearance of the pump on fluoroscopy and a brief overview of the use of fluoroscopy in troubleshooting a malfunctioning pump are shown in Fig. 15-19.

SUGGESTED READINGS

American Society of Anesthesiologists Task Force on Chronic Pain Management; American Society of Regional Anesthesia and Pain Medicine. Practice guidelines for chronic pain management: an updated report by the American Society of Anesthesiologists Task Force on Chronic Pain Management and the American Society of Regional Anesthesia and Pain Medicine. *Anesthesiology*. 2010;112:810–833.

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CHAPTER 16

Spinal Cord Stimulation System Placement

OUTLINE

Overview

The idea that direct stimulation of the ascending sensory tracts within the spinal cord might interfere with the perception of chronic pain is founded in everyday observations. We are all familiar with the fact that rubbing an area that has just been injured seemingly reduces the amount of pain coming from the injured region. The advent of transcutaneous electrical nerve stimulation (TENS), whereby a light, pleasant electrical current is passed through surface electrodes in the region of ongoing pain, reinforced the observation that stimulation of sensory pathways reduces pain perception in chronic pain states. In 1965, Patrick Wall, a neurophysiologist exploring the basic physiologic mechanisms of pain transmission, and Ronald Melzack, a psychologist working with patients who had chronic pain, together proposed the *gate-control theory* to explain how nonnoxious stimulation can reduce pain perception. In their theory, they proposed that second-order neurons at the level of the spinal cord dorsal horn act as a "gate" through which noxious stimuli must pass to reach higher centers in the brain and be perceived as pain. If these same neurons receive input from other sensory fibers entering the spinal cord, the nonnoxious input can effectively close the gate, preventing simultaneous transmission of noxious input. Thus, the light touch of rubbing an injured region or the pleasant electrical stimulation of TENS closes the gate to the noxious input of chronic pain. From this theory, investigators developed the concept of direct activation of the ascending fibers within the dorsal columns that transmit nonpainful cutaneous stimuli (e.g., light touch) as a means of treating chronic pain. We have learned much about the anatomy and physiology of pain perception since the gate-control theory was first proposed. It is unlikely that the simplistic notion of a gate within the dorsal horn is responsible for our observations, but the theory served as a useful concept in the development of spinal cord stimulation (SCS). Both the peripheral nerve fibers and the second-order neurons within the dorsal horn responsible for pain transmission become sensitized following injury, and anatomic changes, cell death, and altered gene expression are all likely to have a role in chronic pain. Direct electrical stimulation of the dorsal columns (referred to as SCS or dorsal column stimulation) has proven effective, particularly in the treatment of chronic radicular pain. The mechanism remains unclear, but direct electrical stimulation within the dorsal columns may produce retrograde changes within the ascending sensory fibers that modulate the intensity of incoming noxious stimuli.

Anatomy

The epidural SCS lead is placed directly within the dorsal epidural space just to one side of midline using a paramedian, interlaminar approach. Entry into the epidural space is performed several levels below the final intended level of lead placement. Typically, leads for stimulation of the low back and lower extremities are placed via the L1/L2 interspace, and those for upper extremity stimulation are placed via the C7/T1 interspace. Investigators have mapped the patterns of electrical stimulation of the dorsal columns and the corresponding patterns of coverage reported by patients with leads in various locations. In general, the epidural lead must be positioned 2 to 3 mm to the left or right of midline on the same side as the painful region to be covered. For lower extremity stimulation, successful coverage is usually achieved by placing the lead between the T8 and the T10 vertebral levels, whereas upper extremity stimulation usually requires lead placement between the occiput and the C3 vertebral levels. If the lead ventures too far from midline, stimulation of the spinal nerves will result. If the lead is placed too low, overlying the conus medullaris

(at or approximately below L1/L2), unpredictable patterns of stimulation may result. In the region of the conus, the fibers of the dorsal columns do not lie parallel to the midline; rather, they arc from the corresponding spinal nerve entering the spinal cord toward their eventual paramedian location several levels cephalad.

Patient Selection

Patient selection for SCS is empiric and remains a subject of some debate. In general, SCS is reserved for patients with severe pain that does not respond to conservative treatment. The pain responds best when relatively well localized because success of SCS depends on the ability to cover the entire painful region with electrical stimulation. Attaining adequate coverage is more difficult when pain is bilateral, often requiring two leads, one to each side of midline. When the pain is diffuse, it may be impossible to get effective coverage with stimulation using SCS. Among the best-established indications for SCS is chronic radicular pain with or without radiculopathy in either the upper or the lower extremities. The use of SCS to treat chronic, axial low back pain has been less satisfactory, but more recently results seem to be improving with the advent of dual lead systems and electrode arrays that allow for a broad area of stimulation. Randomized controlled trials (RCTs) comparing SCS with repeat surgery for patients with failed back surgery syndrome have demonstrated greater success in attaining satisfactory pain relief in those treated with SCS. More recent, small RCTs also suggest significant improvement in pain relief and physical function in patients with complex regional pain syndrome (CRPS) who are treated with SCS in conjunction with physical therapy when compared with physical therapy alone. Prospective observational studies indicate an overall success rate of about 50% (defined as at least 50% pain reduction and ongoing use of SCS 5 years following implantation) in mixed groups of patients with ongoing low back and/or extremity pain following prior lumbar surgery. The usefulness of psychological screening prior to SCS remains controversial; some investigators have suggested that screening for patients with personality disorders, somatoform disorder, or hypochondriasis may improve success rate of SCS.

Once a patient is selected for therapy with SCS, a trial is carried out. Most physicians now conduct trials by placing a temporary, percutaneous epidural lead and conducting the screening using an external device as an outpatient procedure to judge the effectiveness of this therapy before a permanent system is implanted. Some carry out the trial of SCS using a surgically implanted lead that is tunneled using a lead extension that exits percutaneously. The strictly percutaneous trial lead is simpler to place and does not require full operating room setup, but the lead must be removed and replaced surgically following a successful trial. The surgically implanted trial lead requires placement in the operating room and surgical removal if the trial is unsuccessful. If the trial is successful, the implanted trial lead can remain, and the second procedure to place the impulse generator is brief, not requiring the placement of a new epidural lead. In either case, after successful trial stimulation, a permanent system is placed and the lead is positioned to produce the same pattern of stimulation that afforded pain relief during the period of trial stimulation.

Level of Evidence

Quality of Evidence and Grading of Recommendation

Grade of Recommendation/Description	Benefit vs. Risk and Burdens	Methodological Quality of Supporting Evidence	Implications
RECOMMENDATION: *SCS. SCS may be used in the treatment of persistent radicular pain in patients who have not responded to other therapies. It may also be considered for other selected patients (e.g., those with CRPS, peripheral neuropathic pain, peripheral vascular disease, or postherpetic neuralgia). Shared decision making regarding SCS should include a specific discussion of potential complications. An SCS trial should be performed before considering permanent implantation of a stimulation device.*			
2B/weak recommendation, moderate-quality evidence	Benefits closely balanced with risks and burden	II-1: RCTs with important limitations (inconsistent results, methodologic flaws, indirect, or imprecise) or exceptionally strong evidence from observational studies	Weak recommendation, best action may differ depending on circumstances or patients' or societal values

There are several hundred case reports and observational trials that report on the use of SCS for a variety of painful disorders that involve the trunk and extremities. There is a limited amount of high-quality evidence available about the technique. One RCT reports effective pain relief for patients with CRPS at follow-up assessment periods to 2 years when SCS in combination with physical therapy is compared with physical therapy alone. One RCT reports effective pain relief during an assessment period of 6 months when patients with persistent pain after prior lumbar spinal surgery are treated with SCS when compared with reoperation. Studies with observational findings report that SCS also provides pain relief for other conditions (e.g., peripheral neuropathic pain, peripheral vascular disease, or postherpetic neuralgia). Reported adverse effects and complications include insertion-site pain, infection, lead dislodgement, and device/lead failure.

Expert recommendations regarding the use of SCS are largely supportive of the use of this modality in selected

patients. The American Pain Society Low Back Pain Guideline Panel published a report in 2009, concluding, "In patients with persistent and disabling radicular pain following surgery for herniated disc and no evidence of a persistently compressed nerve root, it is recommended that clinicians discuss risks and benefits of spinal cord stimulation as an option (weak recommendation, moderate-quality evidence). It is recommended that shared decision-making regarding spinal cord stimulation include a discussion about the high rate of complications following spinal cord stimulator placement." The American Society of Anesthesiologists Task Force on Chronic Pain Management published a 2010 Practice Guideline, offering the following recommendations: "Spinal cord stimulation may be used in the multimodal treatment of persistent radicular pain in patients who have not responded to other therapies. It may also be considered for other selected patients (e.g., those with CRPS, peripheral neuropathic pain, peripheral vascular disease, or postherpetic neuralgia). Shared decision making regarding spinal cord stimulation should include a specific discussion of potential complications associated with spinal cord stimulator placement. A spinal cord stimulation trial should be performed before considering permanent implantation of a stimulation device."

SCS is an invasive and expensive treatment modality that provides moderate long-term pain reduction in selected patients, primarily those with persistent radicular pain after prior spinal surgery. The available evidence for long-term efficacy is modest and the associated risks are low. Expert opinion from different consensus groups is consistent but highlights the empiric nature of patient selection.

Positioning

Placement of a percutaneous trial spinal cord stimulator lead can be carried out in any location that is suitable for epidural catheter placement. This may be done in the operating room, but it can easily and safely be carried out in any location that allows for adequate sterile preparation of the skin and draping of the operative field and that has fluoroscopy available to guide anatomic placement. Using a strictly percutaneous trial, the trial lead is placed in the same fashion used for permanent lead placement, but the lead is secured to the skin without any incision for the trial period.

Before permanent spinal cord stimulator implantation, discuss with the patient the location of the pocket for the impulse generator. The regions most suitable for placement are the lower quadrant of the abdomen or the lateral aspect of the buttock. Once the site is determined, mark the proposed skin incision with a permanent marker while the patient is in the sitting position. The position of the pocket is deceptively difficult to determine once the patient is lying on his or her side. If the location is not marked, the pocket is often placed too far lateral within the abdominal wall. Placement of the impulse generator within the buttock allows for the entire procedure to be carried out with the patient in the prone position and simplifies the operation by obviating the need to turn from the prone to lateral position halfway through implantation.

Implantation of a spinal cord stimulator lead and impulse generator is a minor surgical procedure that is carried out in the operating room using aseptic precautions, including skin preparation, sterile draping, and the use of full surgical attire (Fig. 16-1). The procedure must be conducted using local anesthesia and light enough sedation that the patient can report where he or she feels the electrical stimulation during lead placement.

The patient is positioned on a radiolucent table in the prone position (see Fig. 16-1). Initial lead placement can be carried out with the patient in a lateral decubitus position; however, even small degrees of rotation along the spinal axis can make positioning of the lead difficult. The arms are extended upward so they are in a position of comfort well away from the surgical field. The skin is prepared, and sterile drapes are applied. For stimulation in the low back and lower extremities, the radiographic C-arm is positioned directly over the thoracolumbar junction to provide an anteroposterior view of the spine. Care must be taken to ensure the x-ray view is not rotated by observing that the spinous processes are in the midline, halfway between the vertebral pedicles (Fig. 16-2).

Surgical Technique

The L1/L2 interspace is identified using fluoroscopy. The epidural needle supplied by the device manufacturer must be used to ensure the lead will advance through the needle without damage. The needle is advanced using a paramedian approach, starting 1 to 1.5 cm lateral to the spinous processes and somewhat caudad to the interspace to be entered. The needle is directed to enter the spinal space in the midline, with an angle of entry no >45 degrees from the plane of the epidural space (Figs. 16-2 and 16-3). If the angle of attack of the needle on initial entry into the epidural space is too great, the epidural lead will be difficult to thread as it negotiates the steep angle between the needle and the plane of the epidural space. The shallower the angle of attack, that is, the closer that the plane of the needle shaft is to the plane of the posterior epidural space, the easier it will be to thread the lead directly along the midline of the posterior epidural space. The epidural space is identified using a loss-of-resistance (LOR) technique. The electrode is then advanced through the needle and is directed to remain to one side of midline in the dorsal epidural space as it is threaded cephalad under fluoroscopic guidance (Figs. 16-4 and 16-5). The electrode contains a wire stylette with a slight angulation at the tip; gentle rotation of the electrode as it is advanced allows the operator to direct the electrode's path within the epidural space (Fig. 16-6). For stimulation in the low back and lower extremities, the electrode is initially positioned 2 to 3 mm from the midline on the same side as the patient's pain between the T8 and the T10 vertebral levels (Fig. 16-7).

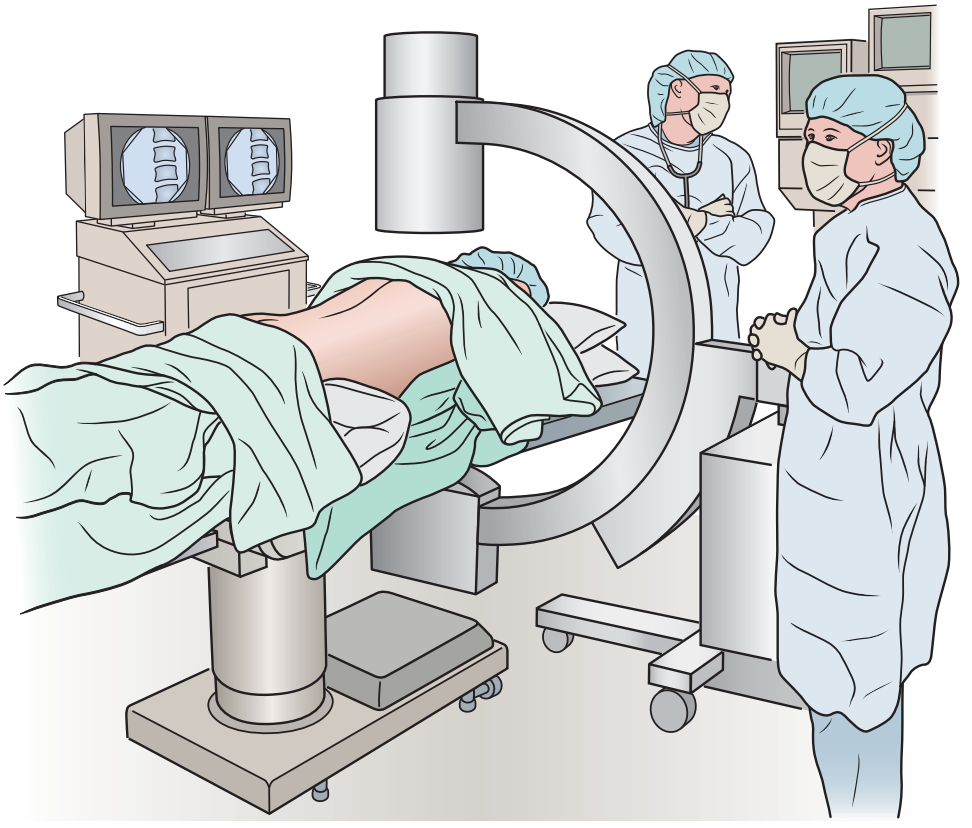


Figure 16-1.
View of typical operating room arrangement during spinal cord stimulator implantation. The patient is placed in the prone position with the C-arm in place for an anterior-posterior view of the thoracolumbar spine.

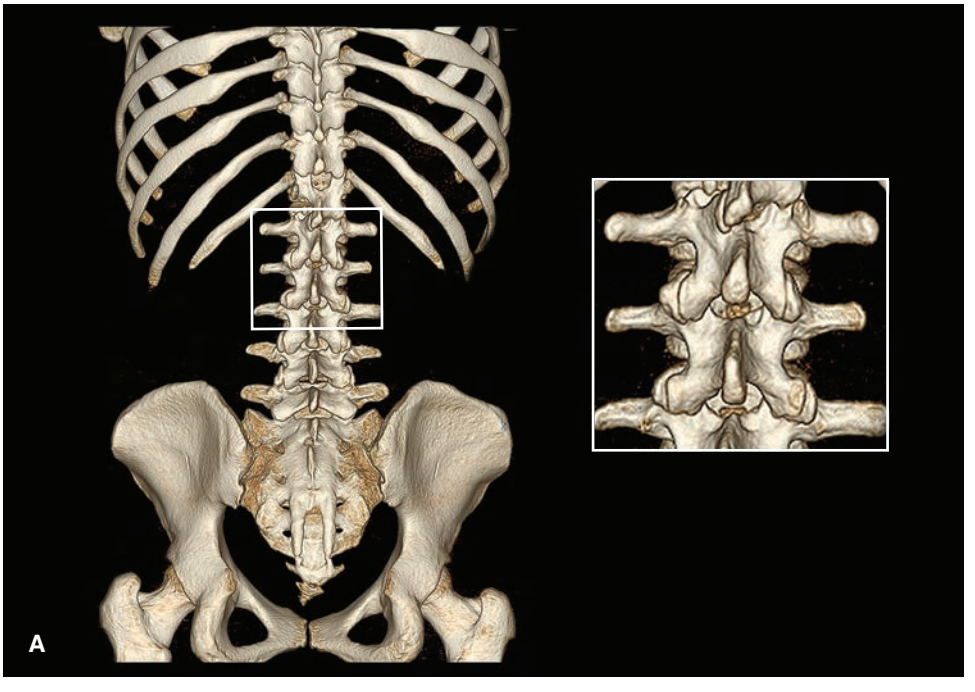


Figure 16-2.
A: Bony anatomy relevant to placement of a percutaneous SCS lead for stimulation of the low back and/or lower extremities. Three-dimensional reconstruction computed tomography of the lumbar spine as viewed during the posterior approach used for percutaneous SCS lead placement. **Inset** matches the anatomic area in the radiographs shown in **(B)** and **(C)**. *(Cont.)*

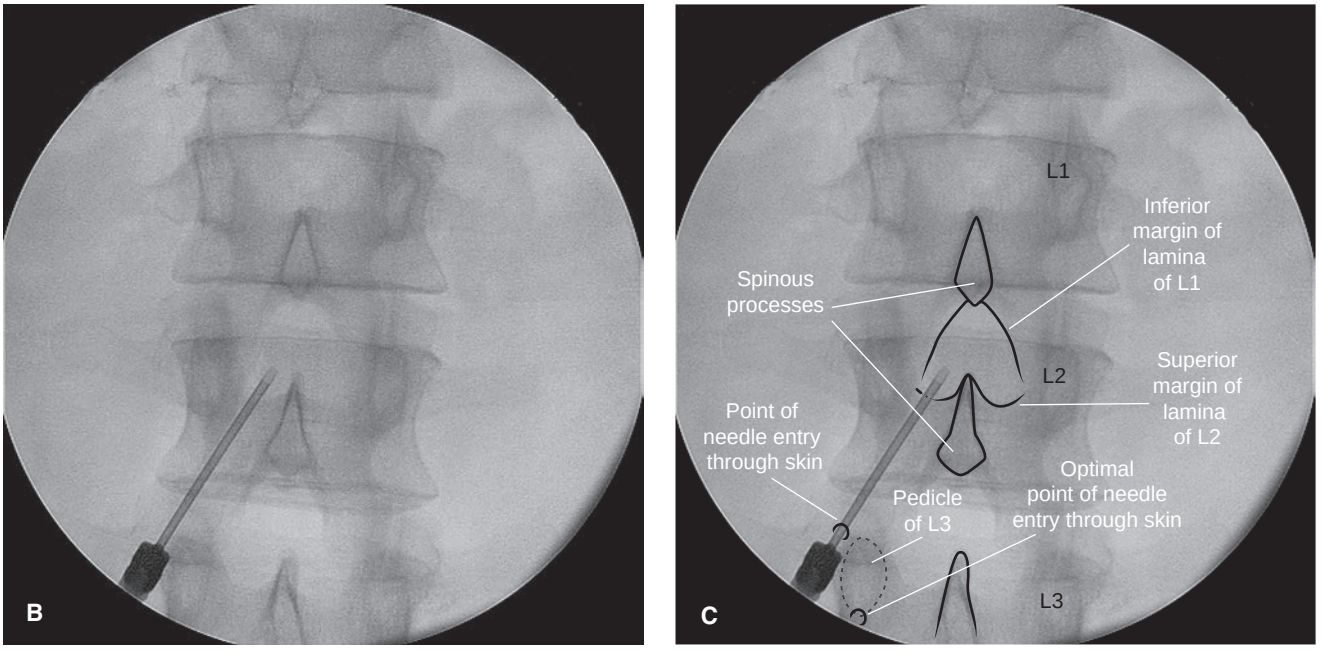


Figure 16-2. ***(Continued)***

B: Anterior-posterior radiograph of initial epidural needle placement for insertion of an epidural SCS electrode. The C-arm must be carefully aligned to ensure there is no rotation, with the spinous processes aligned in the midline, midway between the vertebral pedicles. The skin entry point for the epidural needle is placed just inferior to the inferior margin of the pedicle one full interspace below the interspace to be entered (typically L1/L2 for lower extremity and/or low back stimulation with skin entry just inferior to the L3 pedicle). The entry point in this illustration is more lateral and superior than desirable, resulting in steeper than desired angle of needle entry. The needle should enter the interspace well below the lamina of the vertebra bordering the superior aspect of the interspace and just to the left or right of midline on the side where you are attempting to advance the electrode. **C:** Labeled image.

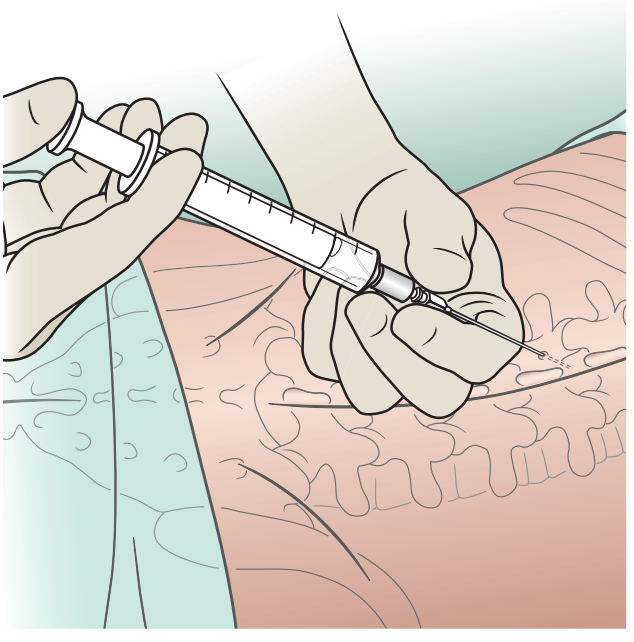


Figure 16-3.

Localization of the epidural space using an LOR technique. The long and open bevel of the modified Tuohy needle used for epidural spinal cord stimulator lead placement rarely yields the clear LOR practitioners are accustomed to when using standard-size epidural needles. One method that can reduce the incidence of false LOR is to advance the epidural needle under fluoroscopic guidance and seat the tip on the superior margin of the lamina that borders the inferior aspect of the interspace to be entered. The area is then bathed with a small amount of local anesthetic to reduce discomfort, and the needle is "walked" over the lamina and into the interlaminar space. Once over the edge of the lamina, the needle will enter the ligamentum flavum, and LOR is used during the last few millimeters of needle advancement to identify the epidural space.

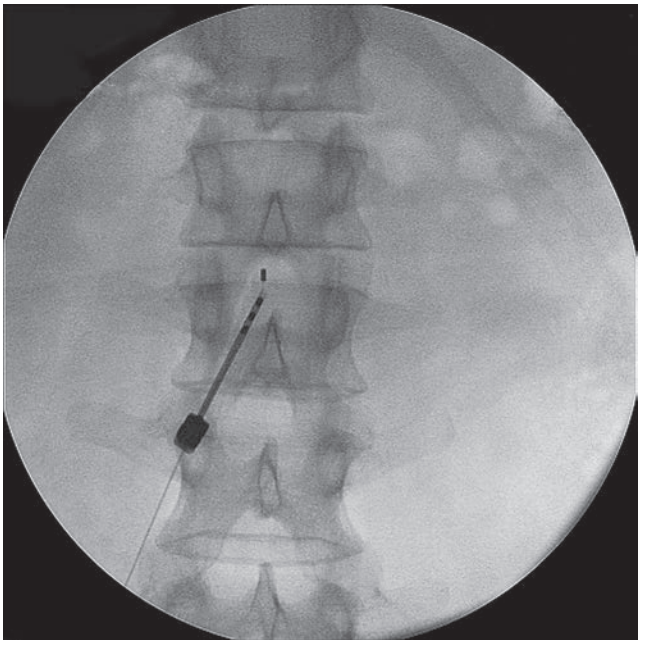


Figure 16-4.
Anterior-posterior radiograph of epidural needle in the final position with the epidural SCS electrode exiting the needle to enter the epidural space. The electrode should be advanced just a few millimeters from the midline to the side where it is to be placed for stimulation.

The final electrode position is determined by connecting the electrode with an external impulse generator and asking the patient where the pattern of stimulation is felt. In general, cephalad advancement will result in stimulation higher in the extremity and caudad movement will lead to stimulation lower in the extremity. However, if the lead is angled even slightly from medial to lateral, the pattern of stimulation may change less predictably with movement of the electrode (e.g., cephalad advancement can lead to stimulation lower in the extremity under these circumstances). The final electrode position should be recorded using radiography so a permanent lead can be placed in the same position (see Fig. 16-7). For trial stimulation, the needle is then removed, the electrode is secured to the back, and a sterile occlusive dressing is applied (Fig. 16-8). The patient is instructed in the use of the external pulse generator and scheduled to return in 5 to 7 days for assessment of his or her response and removal of the trial lead. Cervical lead placement is carried out using a similar technique (Figs. 16-9 and 16-10); entry for cervical lead placement is commonly at the T1/2 or T2/3 level. Two leads are required to provide stimulation in both extremities and the use of two leads improves the ability to provide adequate stimulation of the low back. Dual leads can be placed either via two adjacent

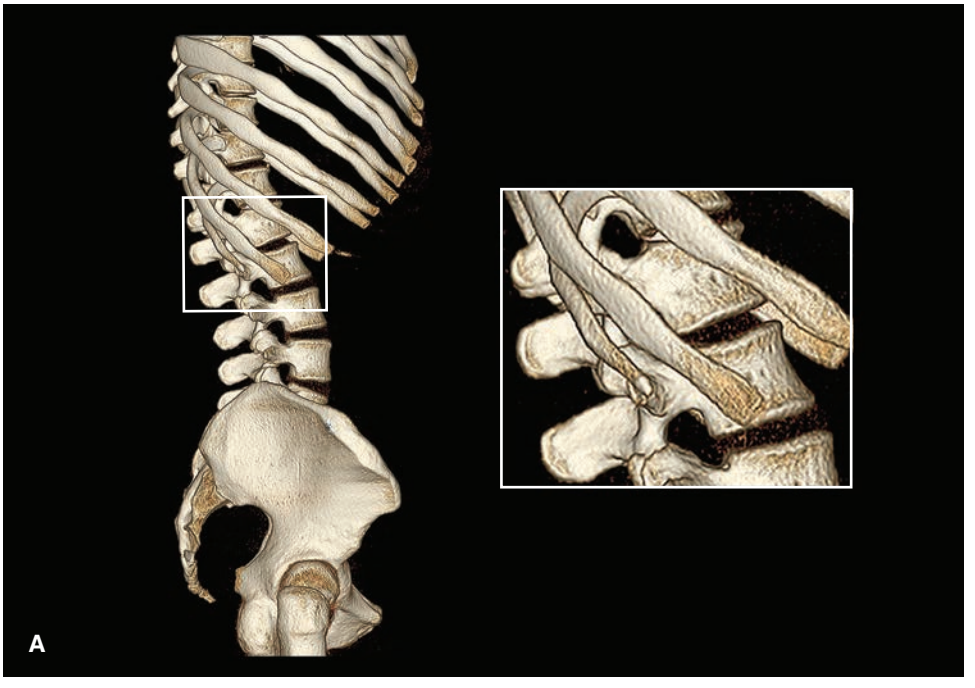


Figure 16-5.
A: Bony anatomy relevant to placement of a percutaneous SCS lead for stimulation of the low back and/or lower extremities. Three-dimensional reconstruction computed tomography of the lumbar spine as viewed in the lateral projection used for verifying lead position in the posterior epidural space. **Inset** matches the anatomic area in the radiographs shown in **(B)** and **(C)**. *(Cont.)*

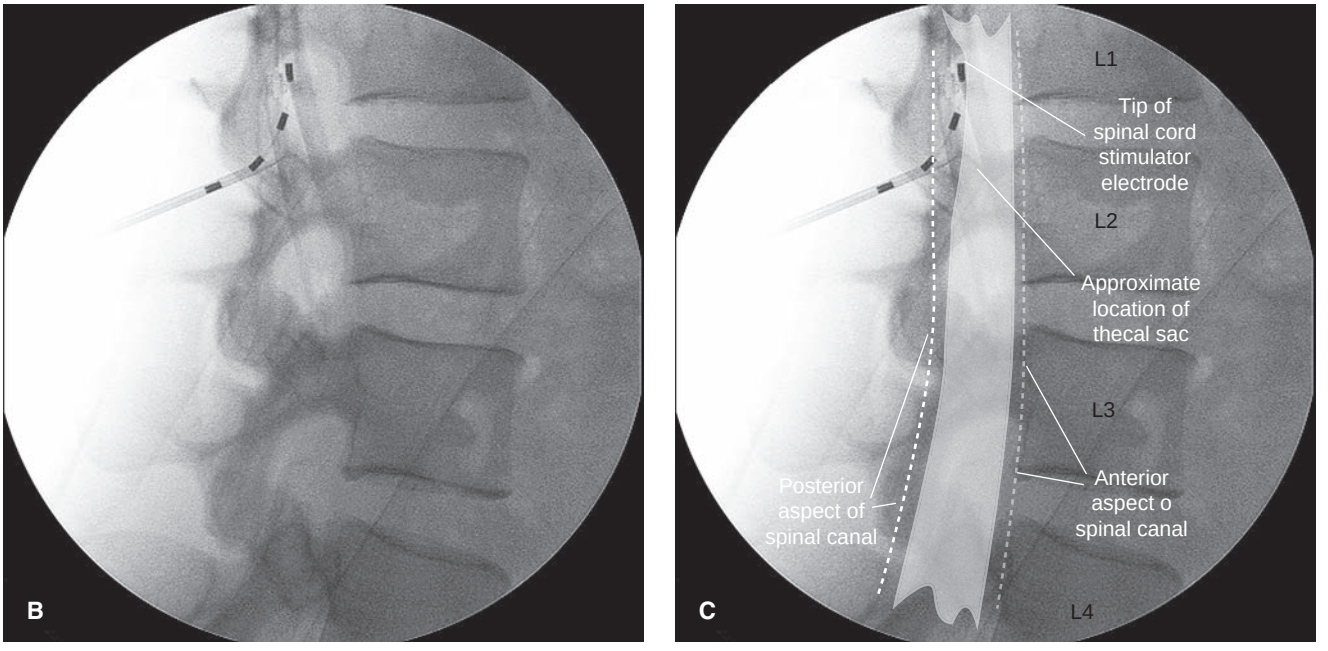


Figure 16-5. *(Continued)*
B: Lateral radiograph of the epidural needle in the final position and the SCS electrode exiting the needle to traverse along the dorsal aspect of the epidural space. If the electrode deviates too far from midline during advancement, it can easily pass around the lateral aspect of the dural sac and course superiorly along the ventral aspect of the epidural space. Ventral electrode placement should be suspected if the patient reports torso stimulation at very low amplitude and can be easily confirmed using lateral radiography.
C: Labeled image.

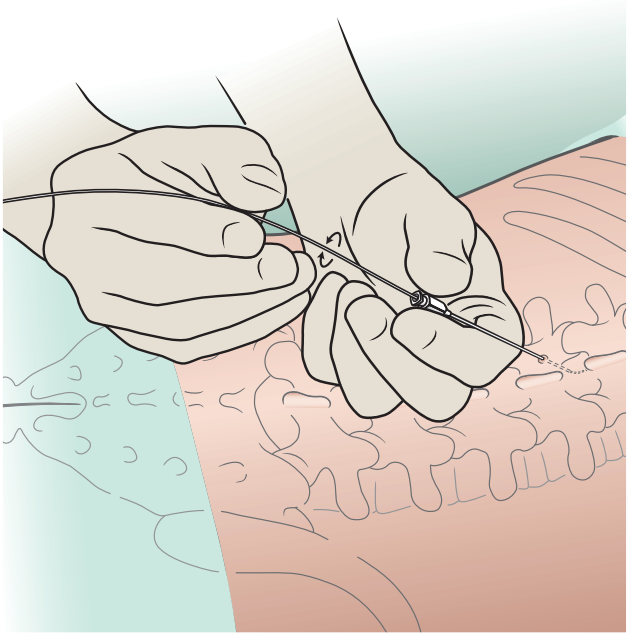


Figure 16-6.
Technique for advancing the epidural SCS electrode. The electrode contains a wire stylette that has a slight angulation at the distal tip. The electrode can be directed medially or laterally as it is advanced under fluoroscopic guidance by using a slight twisting motion on the proximal electrode that changes the direction of the tip.

vertebral interspaces (Fig. 16-11) or via the same vertebral interspace (Fig. 16-12).

During permanent implantation, the procedure for initial lead placement is identical to that for trial stimulation. Once the final lead position is attained and the optimal pattern of stimulation is confirmed, the lead must be secured, a pocket for the impulse generator must be created, and the lead tunneled beneath the skin to connect to the impulse generator. Following initial lead placement, the epidural needle is withdrawn slightly (~1 to 2 cm) but left in place around the lead within the subcutaneous tissues to protect the lead during the subsequent incision and dissection. A 5- to 8-cm incision parallel to the axis of the spine is extended from cephalad to caudad to the needle, extending directly through the needle's skin entry point (Fig. 16-13). The subcutaneous tissues are divided using blunt dissection until the lumbar paraspinous fascia is visible surrounding the needle shaft. The stylette is then removed from the lead, and the needle is withdrawn, using care not to dislodge the electrode (Fig. 16-14). The lead is then secured to the paraspinous fascia using a specific anchoring device supplied by the manufacturer (Fig. 16-15).

If lead placement has been carried out in the prone position and the impulse generator is to be placed in the abdominal wall, the lead must be coiled beneath the skin, the paraspinous incision temporarily closed using staples, and a sterile occlusive dressing applied. The

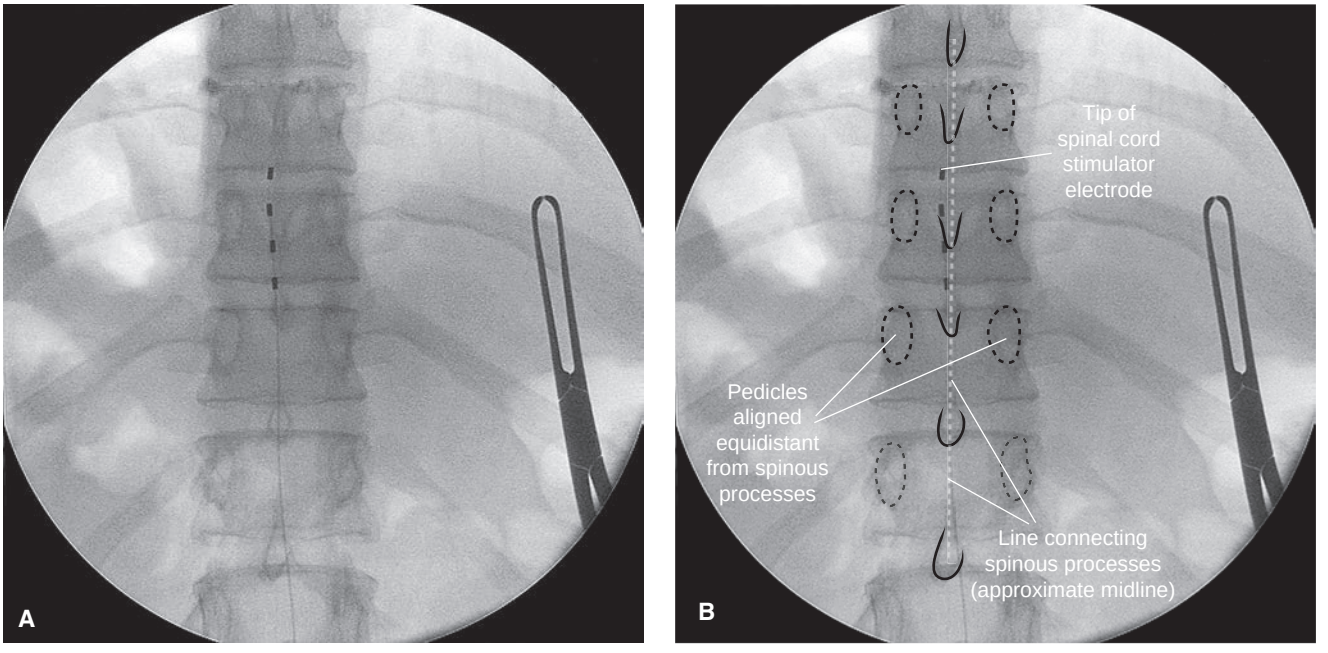


Figure 16-7.

A: Anterior-posterior radiograph of the epidural SCS electrode in the final position for stimulation of the left lower extremity. The tip of the electrode is adjacent to the inferior vertebral endplate of T9. A line connecting the spinous processes corresponds to the midline. Note that the lead lies just to the left of midline and has a slight medial-lateral angulation. Optimally, the electrode's course should be parallel to midline so any migration is most likely to move adjacent electrodes into similar positions to one another. **B:** Labeled image.

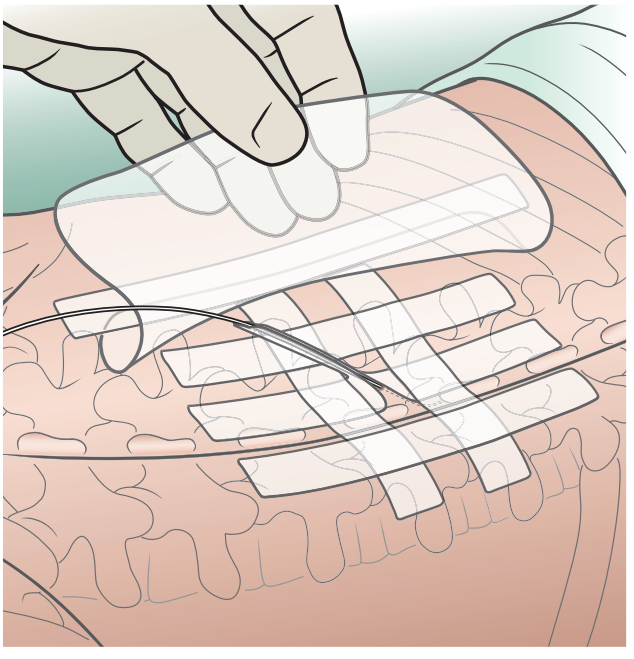


Figure 16-8.

Lead anchor and dressing for temporary lead placement. Sterile bandage strips are placed along the course of the electrode as it exits the skin and then crisscrossed at the base of the electrode to anchor it firmly in place. A sterile occlusive dressing is then applied.

sterile drapes are then removed, and the patient is repositioned in the lateral decubitus position with the side where the abdominal pocket will lie upward. After repeat preparation of the skin and application of sterile drapes, attention is turned to creating the pocket within the patient's abdominal wall or overlying the buttock (when the impulse generator is placed over the buttock, this site is included in the initial skin preparation and draping). An 8- to 10-cm transverse incision is made along the previously marked line and a subcutaneous pocket is created using blunt dissection (Fig. 16-16). The pocket should always be created caudad to the incision; if the pocket is placed cephalad to the incision, the weight of the impulse generator on the suture line is likely to cause wound dehiscence. In many patients, the blunt dissection can be accomplished using gentle but firm pressure with the fingers. It is simpler and less traumatic to use a small pair of surgical scissors to perform the blunt dissection using repeated opening (*not closing or cutting*) motions or with an electrocautery device used in the cutting mode. After creating the pocket, the impulse generator is placed in the pocket to ensure the pocket is large enough. The impulse generator should fit completely within the pocket without any part of the device extending into the incision. With the device in place, the wound margins must fall into close apposition. There

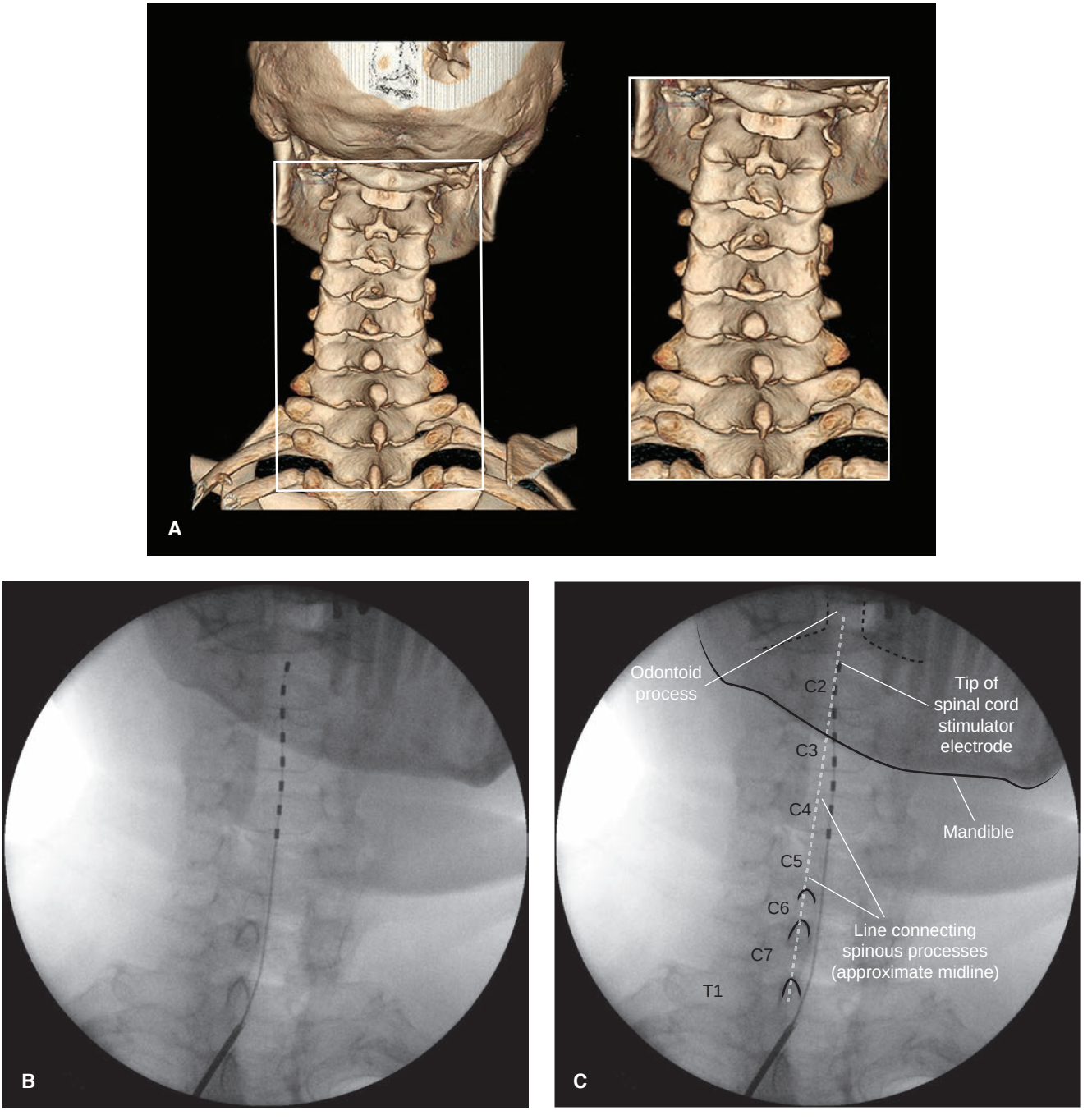
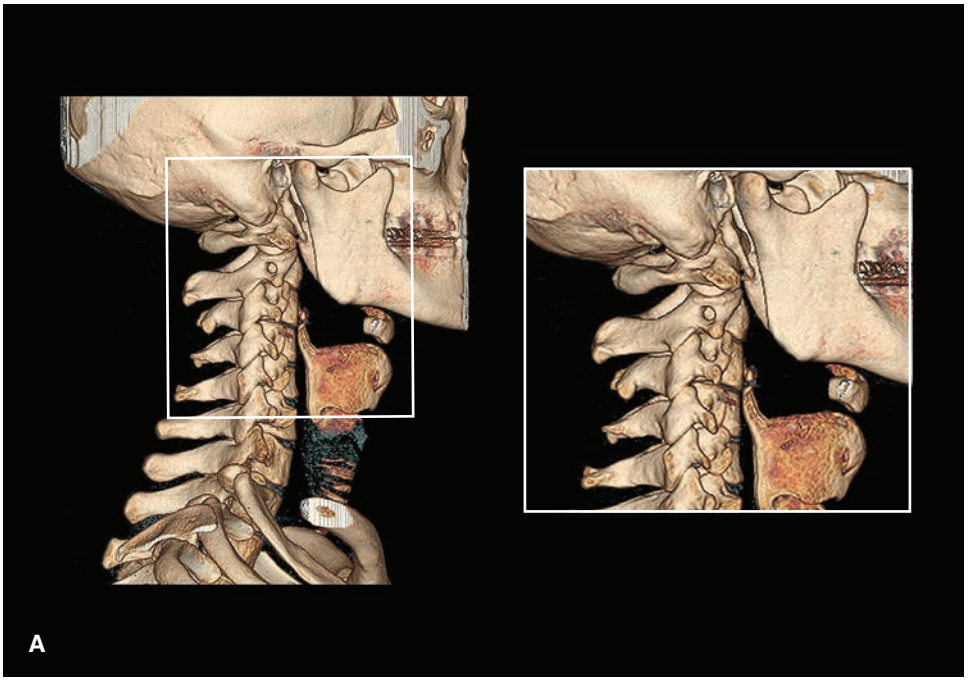
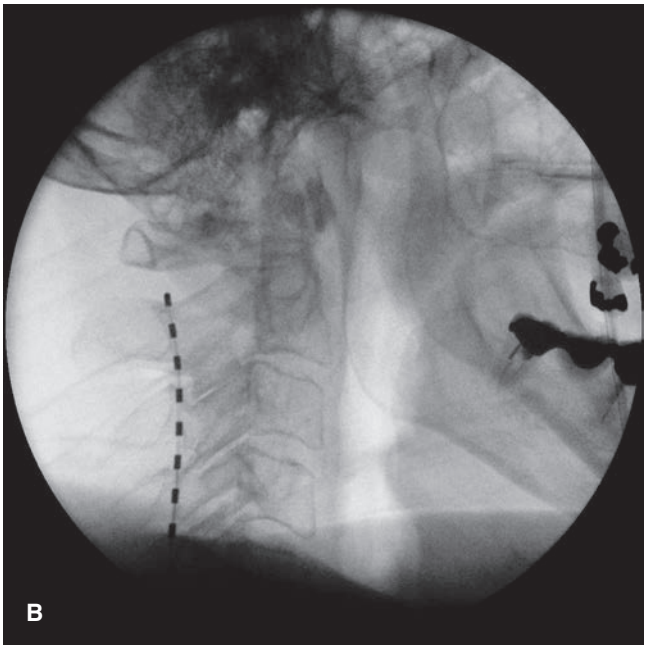


Figure 16-9.

A: Bony anatomy relevant to placement of a percutaneous SCS lead for stimulation of the upper extremities. Three-dimensional reconstruction computed tomography of the cervical spine as viewed during the posterior approach used for percutaneous SCS lead placement. **Inset** matches the anatomic area in the radiographs shown in **(B)** and **(C)**. **B:** Anterior-posterior radiograph of epidural needle placement for insertion of a cervical epidural SCS electrode. The patient must face directly forward without any rotation of the head and the C-arm must be carefully aligned to ensure there is no rotation, with the spinous processes aligned in the midline, midway between the vertebral pedicles. The skin entry point for the epidural needle is placed just inferior to the inferior margin of the pedicle two interspaces below the interspace to be entered (typically T1/T2 for upper extremity stimulation with skin entry just inferior to the T3 pedicle). The needle should enter the interspace well below the lamina of the vertebra bordering the superior aspect of the interspace and just to the left or right of midline on the side where you are attempting to advance the electrode. In this case, the top portion of the lead appears to be on midline and the lower portion of the lead slightly right of midline. The top of the lead projects over the C2 vertebral body. The patient reported good stimulation extending from the right shoulder to the right hand using the middle electrodes of this lead. **C:** Labeled image.





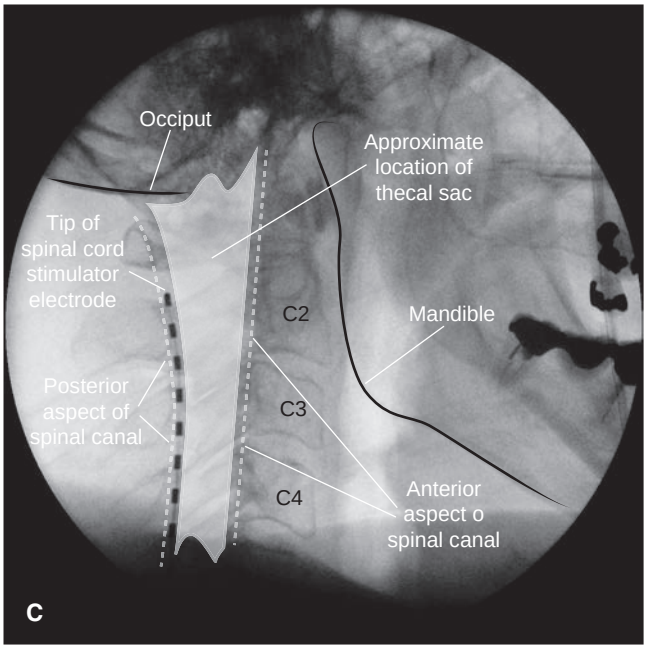


Figure 16-10.

A: Bony anatomy relevant to placement of a percutaneous SCS lead for stimulation of the upper extremities. Three-dimensional reconstruction computed tomography of the cervical spine as viewed in the lateral projection used for verifying lead position in the posterior epidural space. **Inset** matches the anatomic area in the radiographs shown in **(B)** and **(C)**. **B:** Lateral radiograph showing the SCS along the dorsal aspect of the epidural space. If the electrode deviates too far from midline during advancement, it can easily pass around the lateral aspect of the dural sac and course superiorly along the ventral aspect of the epidural space. Ventral electrode placement should be suspected if the patient reports stimulation in the face or neck at very low amplitude and can be easily confirmed using lateral radiography. **C:** Labeled image.

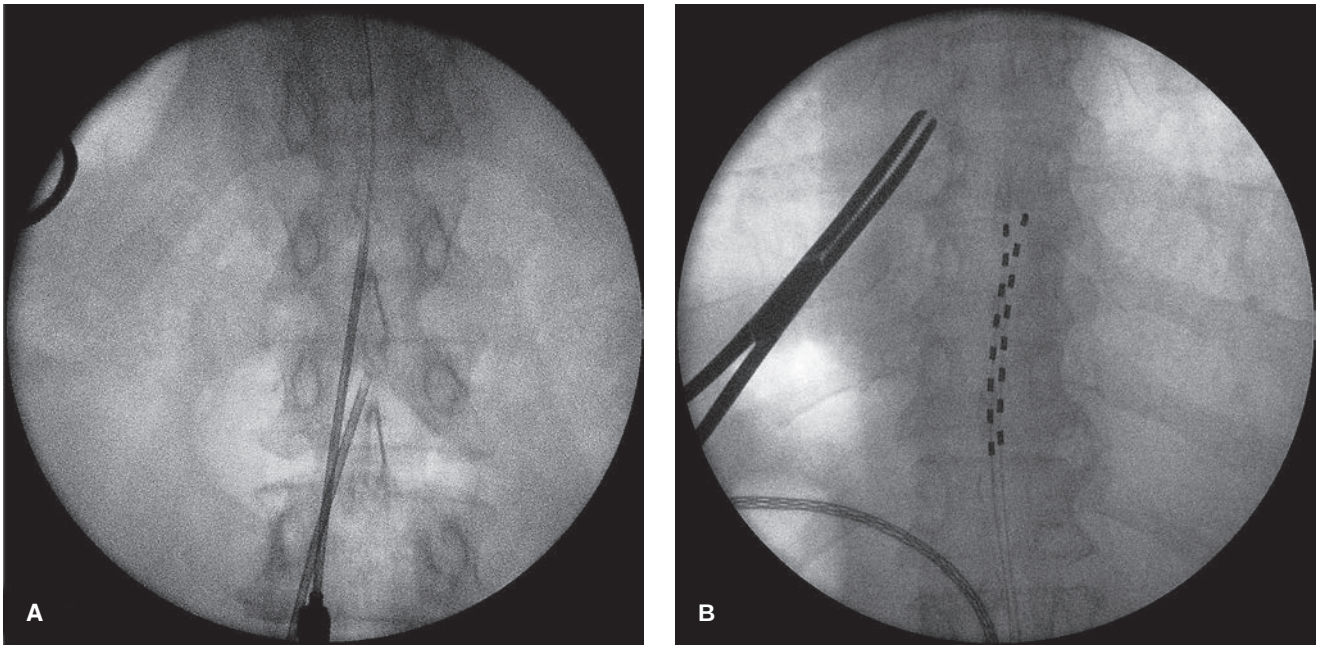


Figure 16-11.

A: Anterior-posterior radiograph of initial epidural needle placement for insertion of dual epidural SCS electrodes using two adjacent interspaces. The C-arm must be carefully aligned to ensure there is no rotation, with the spinous processes aligned in the midline, midway between the vertebral pedicles. The skin entry point for the epidural needle is placed just inferior to the inferior margin of the pedicle one full interspace below the interspace to be entered (typically L1/L2 for lower extremity and/or low back stimulation with skin entry just inferior to the L3 pedicle). Two leads can be placed by entering at two adjacent interspaces; here the needles are in position in the posterior epidural spaces at the L1/L2 and L2/L3 levels. **B:** Final electrode position for use of dual leads. In this case, the left lead appears to be on midline and the right lead slightly right of midline. The top of each lead projects over the inferior endplate of the T9 vertebral body. The patient reported good stimulation extending from the buttocks to both feet using the middle electrodes of each lead.

should be no tension on the sutures during closure of the incision or the wound is more likely to dehisce.

After the pocket creation is completed, a tunneling device is extended within the subcutaneous tissues between the paraspinous incision and the pocket (Fig. 16-17). The electrode is then advanced through the tunnel (tunneling devices vary and are specific to each manufacturer). The means with which the electrode is connected to the impulse generator also varies by manufacturer; some devices use a lead extension that connects the impulse generator and the lead, whereas others use a one-piece lead that is connected directly to the impulse generator. After tunneling, the lead or lead extension is connected with the impulse generator. Any excess lead is coiled and placed behind the impulse generator within the pocket (Fig. 16-18). This loop allows for patient movement without placing tension on the distal electrode and causing it to be pulled from the epidural space. The skin incisions are then closed in two layers: a series of interrupted subcutaneous sutures to securely close the fascia overlying the impulse generator within the pocket and the electrode over the paraspinous fascia followed by a skin closure using suture or staples (Fig. 16-19). Alternately, according to patient preference, the impulse generator can be placed in a pocket overlying the buttock, using care to remain well below the superior margins of the iliac crest (Fig. 16-20). In recent years, the majority of practitioners have switched to placing the impulse generator over the buttock based on patient preference. This also allows the entire procedure to be performed with the patient in the prone position.

Complications

Bleeding and infection are risks inherent to all open surgical procedures. Bleeding within the impulse generator pocket can lead to a hematoma surrounding the generator that may require surgical drainage. Bleeding along the subcutaneous tunneling track often causes significant bruising in the region but rarely requires treatment. Similar to other neuraxial techniques, bleeding within the epidural space can lead to significant neural compression. Signs of infection within the impulse generator

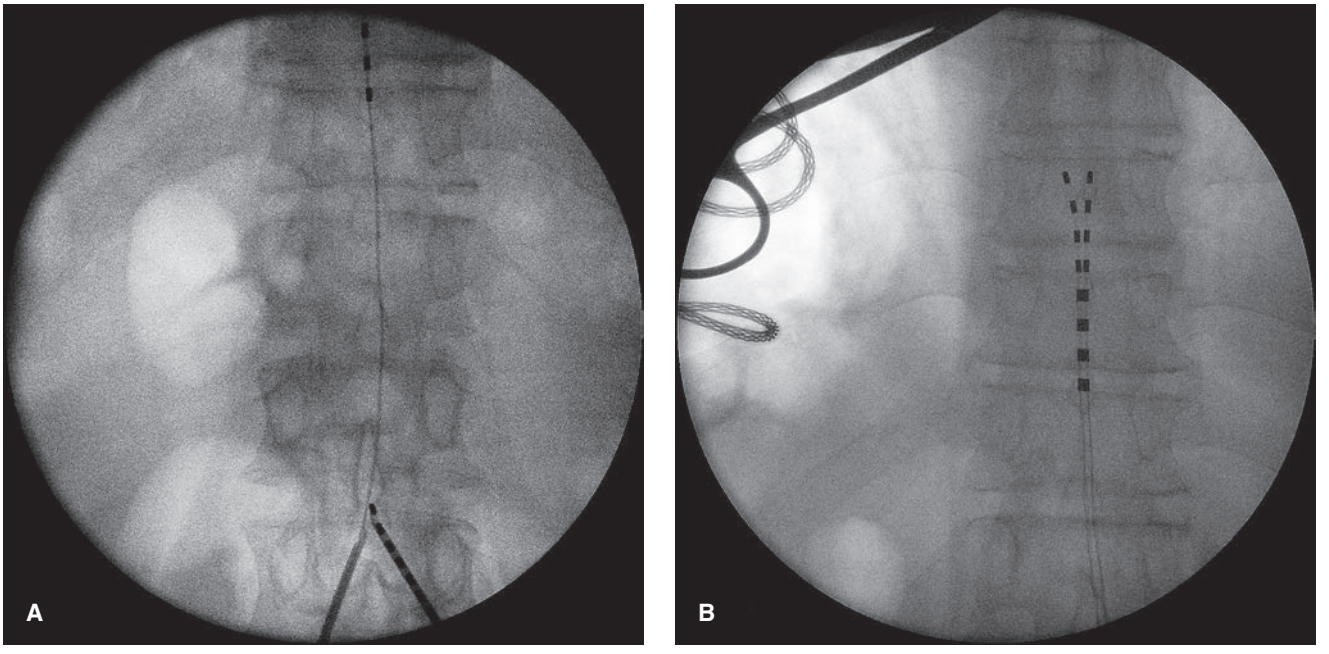


Figure 16-12.
A: Anterior-posterior radiograph of initial epidural needle placement for insertion of dual epidural SCS electrodes using a single interspace. The C-arm must be carefully aligned to ensure there is no rotation, with the spinous processes aligned in the midline, midway between the vertebral pedicles. The skin entry point for the epidural needle is placed just inferior to the inferior margin of the pedicle one full interspace below the interspace to be entered (typically L1/L2 for lower extremity and/or low back stimulation with skin entry just inferior to the L3 pedicle). Two leads can be placed by entering a single interspace, with one needle entering from each side of midline; here both needles are in position in the posterior epidural space at the L1/L2 level. Alternatively, both needles can be placed from one side of midline into the same interspace. This simplifies the process of anchoring two leads, as they can be sutured to the paraspinous fascia through the same skin incision in close proximity. Great care must be taken to keep some separation between the needles when advancing two needles through the same interspace, as it is feasible that damage to the first electrode can be caused as the second needle is placed. **B:** Final electrode position for the use of dual leads. In this case, both leads appear to be close to midline. The top of each lead projects over the superior endplate of the T9 vertebral body. The patient reported good stimulation extending from the buttocks to both feet using the middle electrodes of each lead.

pocket typically occur within 10 to 14 days following implantation but may occur at any time. Some practitioners have reported successful treatment of superficial infections of the incision overlying the pocket with oral antibiotics aimed at the offending organism and close observation alone. However, infections within the pocket or along the lead's subcutaneous course almost universally require removal of all implanted hardware and treatment with parenteral antibiotics to eradicate infection. Lead and deep tissue infections can extend to involve the neuraxis and result in epidural abscess formation and/or meningitis.

There is a significant risk of dural puncture during initial localization of the epidural space using the LOR technique. The epidural needle used for electrode placement is a Tuohy needle that has been modified by extending the orifice to allow the electrode to pass easily. This long bevel often results in equivocal LOR. It is not uncommon to have minimal resistance to injection along the entire course of needle placement. To minimize the risk of dural puncture, the needle tip can be advanced under fluoroscopic guidance and first seated on the margin of the vertebral lamina (using care to place additional local anesthetic during advancement). In this way, the depth of the lamina is certain, and the needle need only be advanced a small distance over the lamina, through the ligamentum flavum, and into the epidural space. LOR is used only during the final few millimeters of needle advancement over the lamina. If dural puncture does occur, there is no clear consensus on how to proceed. Some practitioners

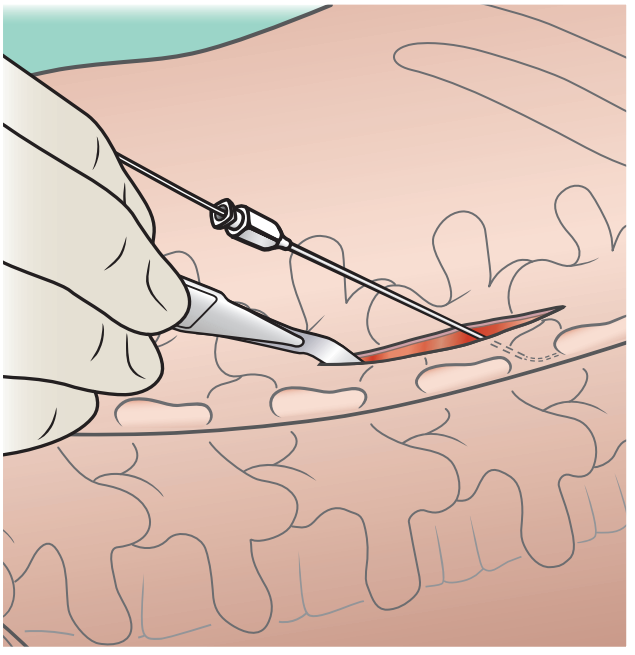


Figure 16-13.
Paraspinous incision. A 5- to 8-cm incision is made through the skin and subcutaneous tissues in a cephalad-caudad direction parallel to midline and to include the needle exit site in the middle of the incision. The needle is left in place around the electrode to protect it from damage during incision and dissection. Blunt dissection is used to divide the subcutaneous tissues and expose the paraspinous fascia.

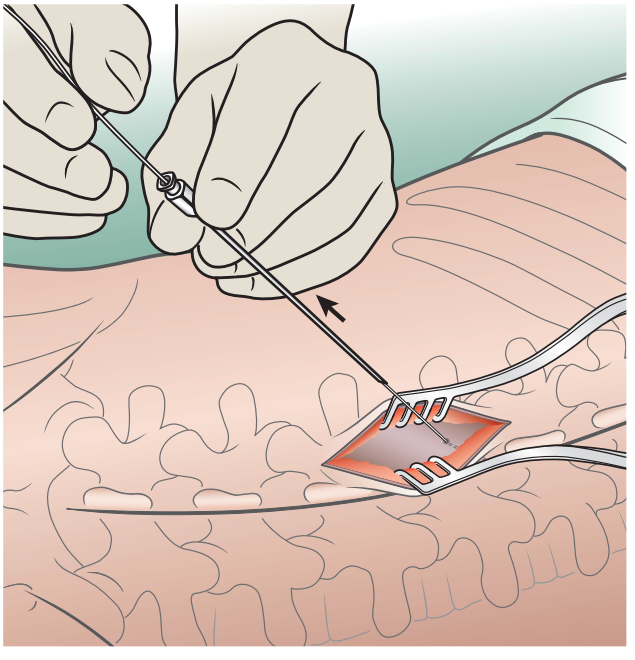


Figure 16-14.
Epidural needle removal. Once the paraspinous fascia has been exposed, the stylette and needle are removed, using care not to dislodge the epidural electrode.

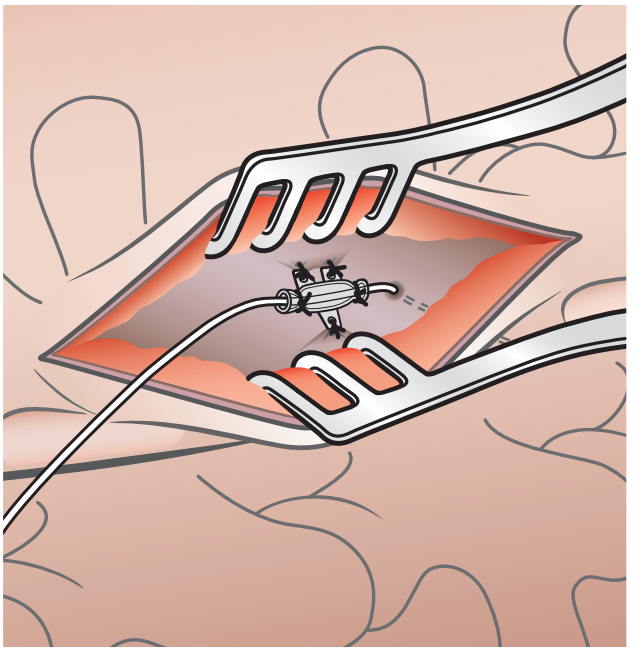


Figure 16-15.
Using a lead anchor supplied by the manufacturer, the electrode is secured to the paraspinous fascia. Once the anchor has been positioned over the electrode, separate sutures should be first placed circumferentially around the anchor and tightened securely so the anchor is firmly in place around the electrode. The anchor is then sutured to the fascia. Attempts to fasten the anchor to the fascia and the lead with a single set of sutures inevitably lead to a loose anchor and increase the likelihood of lead migration. Newer anchoring devices that fasten securely to the lead without the need for circumferential sutures are now available and have simplified the lead anchoring process.

will abandon the lead placement and allow 1 to 2 weeks before reattempting placement. This approach allows the practitioner to watch and treat postdural puncture headache, which is nearly certain to occur. Other practitioners will proceed with lead placement through a more cephalad interspace. If postdural puncture headache ensues and fails conservative treatment, epidural blood patch is then placed at the level of the dural puncture. Spinal cord and nerve root injury during initial lead placement have been reported. Placing the epidural needle and lead in the awake, lightly sedated patient able to report paresthesiae should minimize the risk of direct neural injury.

The most frequent complication following spinal cord stimulator placement is lead migration. The first line of defense is to ensure the lead is firmly secured to the paraspinous fascia. Suturing the lead to loose subcutaneous tissue or fat is not adequate. Postoperatively, the patient must be clearly instructed to avoid bending and twisting at the waist (lumbar leads) or bending and twisting the neck

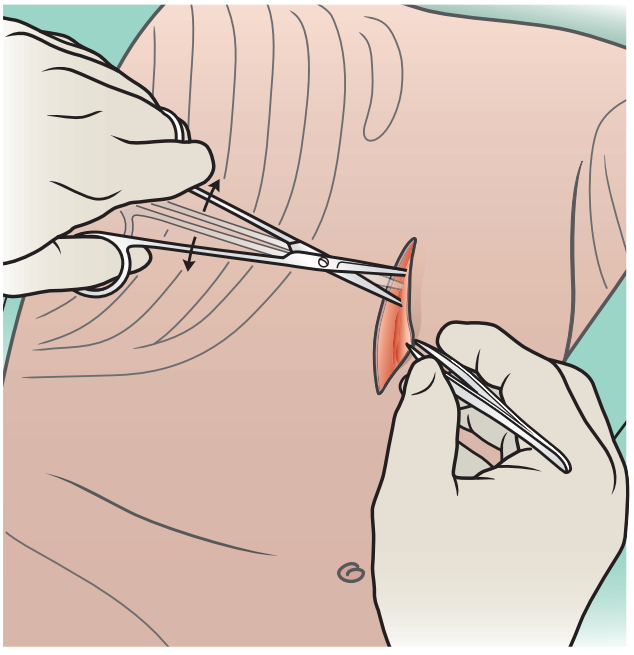


Figure 16-16.
Creation of a subcutaneous pocket for the implanted pulse generator. An 8- to 10-cm transverse incision is created just below the costal margin, using care to avoid placement too lateral. The skin is incised using a sharp scalpel, and the subcutaneous pocket is then created using blunt dissection (using surgical scissors in an opening rather than a closing or cutting motion works effectively).

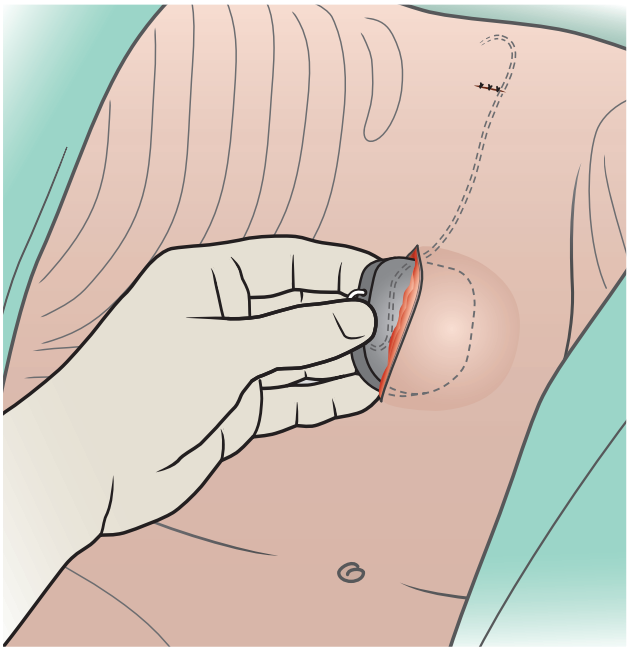


Figure 16-18.
Placement of the implanted pulse generator into the subcutaneous pocket. Any excess lead is coiled behind the impulse generator, and care is used to ensure the pocket is large enough to prevent any tension on the margins of the incision. The impulse generator and lead should fit well inferior to the incision so risk of damage is minimized at the time of subsequent operation for battery change.

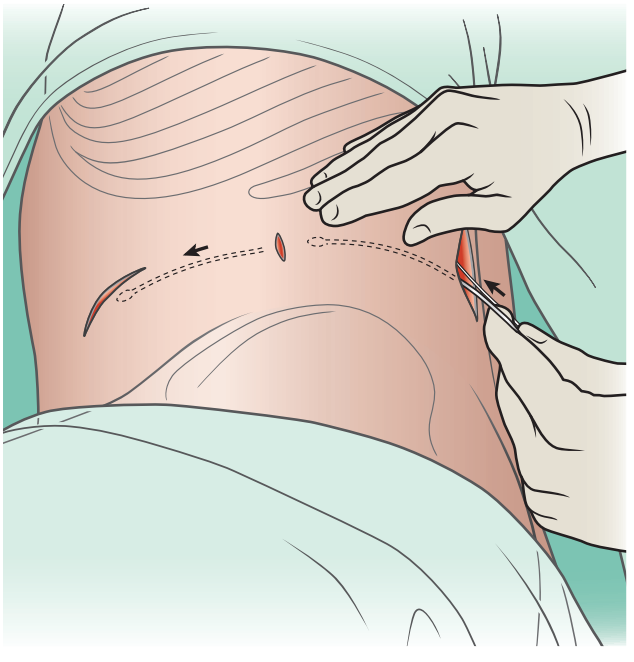


Figure 16-17.
Subcutaneous tunneling of the electrode. Using the device provided by the manufacturer, a subcutaneous tunnel is created, and the electrode is passed from paraspinous region to the pocket. Care must be taken to continuously palpate the tip of the tunneling device as it is being advanced to ensure the depth of the subcutaneous track is neither too deep nor too shallow. Excess depth can lead to entry into the abdominal cavity, whereas too shallow of a tunnel can lead to skin perforation or visible puckering of the skin along the subcutaneous track. In large patients, the tunneling often requires two segments: the first segment between the paravertebral incision and a small transverse incision in the mid-axillary line, and a second segment from the mid-axillary line to the abdominal pocket.

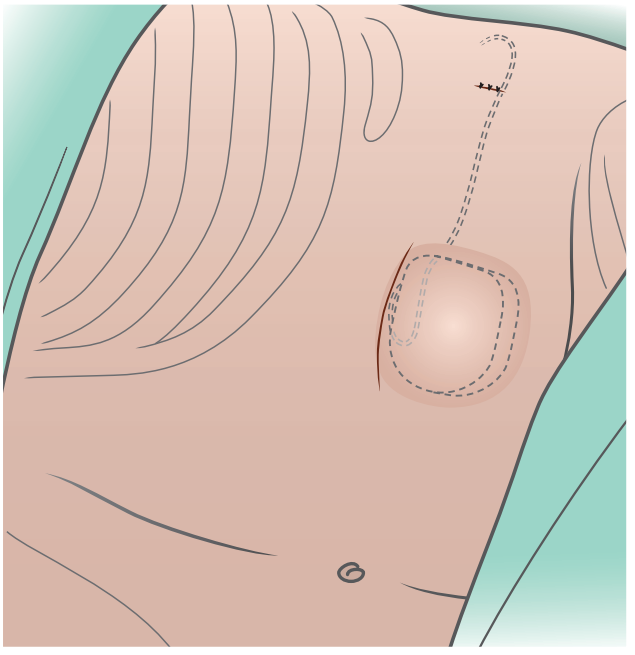


Figure 16-19.
Wound closure. The pocket is closed in two separate suture layers. The subcutaneous tissues are closed over the impulse generator and the lead in the paraspinous region, using interrupted, absorbable suture followed by a separate skin closure using staples or sutures (simple interrupted or running subcuticular for better cosmesis).

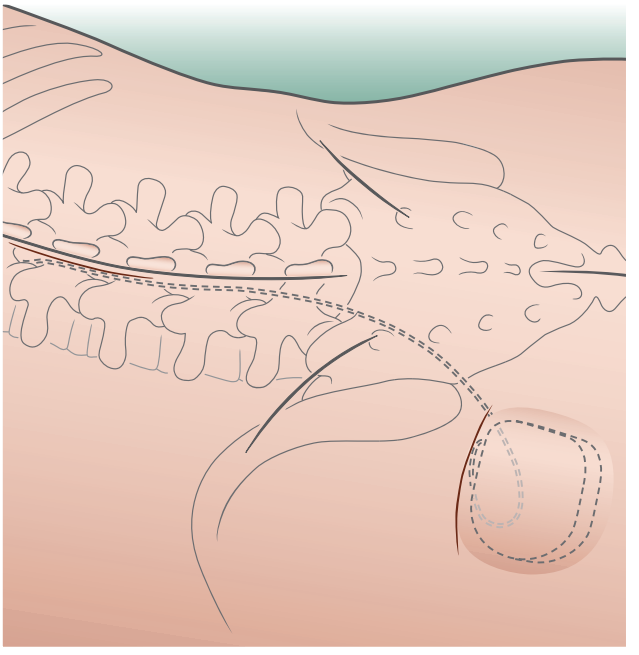


Figure 16-20.
Alternate pocket location over the buttock. Some practitioners and patients prefer to place the implanted pulse generator over the buttock. This allows for the entire implant procedure to be carried out in the prone position. Care should be used to ensure the pocket is well below the bony margins of the iliac crest. Placement too near the iliac crest can lead to marked discomfort on sitting as the impulse generator is forced against the bone.

(cervical leads) for at least 4 weeks after lead placement. Placing a soft cervical collar on those who have had a cervical lead placed provides a ready reminder to avoid movement. Lead fracture may also occur, often months or years after placement. Avoiding midline placement or tunneling the lead across midline will reduce the incidence of fracture caused by compression of the lead on bone. Lead fracture is signaled by a sudden loss of stimulation and is diagnosed by checking lead impedance using the spinal cord stimulator programmer.

Wound dehiscence and impulse generator migration are infrequent problems. Ensuring the size of the pocket is sufficient to prevent tension on the suture line at the time of wound closure is essential to minimize the risk of dehiscence.

Subcutaneous collection of fluid surrounding the impulse generator (seroma formation) can be problematic and typically follows generator replacement. Percutaneous drainage of the sterile fluid collection is often successful in resolving the problem.

SUGGESTED READINGS

American Society of Anesthesiologists Task Force on Chronic Pain Management; American Society of Regional Anesthesia and Pain Medicine. Practice guidelines for chronic pain management: an updated report by the American Society of Anesthesiologists Task Force on Chronic Pain Management and the American Society of Regional Anesthesia and Pain Medicine. *Anesthesiology*. 2010;112:810–833.

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QUALITY OF EVIDENCE AND GRADING OF RECOMMENDATIONS

Quality of Evidence

I: Evidence obtained from at least one properly randomized controlled trial

II-1: Evidence obtained from well-designed controlled trials without randomization

II-2: Evidence obtained from well-designed cohort or case-control analytic studies, preferably from more than one center or research group

II-3: Evidence obtained from multiple time series with or without the intervention. Dramatic results in uncontrolled experiments (such as the results of the introduction of penicillin treatment in the 1940s) could also be regarded as this type of evidence

III: Opinions of respected authorities, based on clinical experience descriptive studies and case reports or reports of expert committees

From Berg AO, Allan JD. Introducing the third U.S. Preventive Services Task Force. *Am J Prev Med.* 2001;20:21–35.

Grading of Recommendations

Grade of Recommendation/ Description	Benefit vs. Risk and Burdens	Methodologic Quality of Supporting Evidence	Implications
1A/strong recommendation, high-quality evidence	Benefits clearly outweigh risk and burdens, or vice versa	RCTs without important limitations or overwhelming evidence from observational studies	Strong recommendation, can apply to most patients in most circumstances without reservation
1B/strong recommendation, moderate-quality evidence	Benefits clearly outweigh risk and burdens, or vice versa	RCTs with important limitations (inconsistent results, methodologic flaws, indirect, or imprecise) or exceptionally strong evidence from observational studies	Strong recommendation, can apply to most patients in most circumstances without reservation
1C/strong recommendation, low-quality or very low-quality evidence	Benefits clearly outweigh risk and burdens, or vice versa	Observational studies or case series	Strong recommendation but may change when higher quality evidence becomes available
2A/weak recommendation, high-quality evidence	Benefits closely balanced with risks and burden	RCTs without important limitations or overwhelming evidence from observational studies	Weak recommendation, best action may differ depending on circumstances or patients' or societal values
2B/weak recommendation, moderate-quality evidence	Benefits closely balanced with risks and burden	RCTs with important limitations (inconsistent results, methodologic flaws, indirect, or imprecise) or exceptionally strong evidence from observational studies	Weak recommendation, best action may differ depending on circumstances or patients' or societal values
2C/weak recommendation, low-quality or very low-quality evidence	Uncertainty in the estimates of benefits, risks, and burden; benefits, risk, and burden may be closely balanced	Observational studies or case series	Very weak recommendations; other alternatives may be equally reasonable

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