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Lumbar Spinal Neuroaxial Procedures

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LUMBAR TRANSFORAMINAL EPIDURAL STEROID INJECTION

Lumbar radicular pain (in the past referred to as sciatica) and lumbar radiculopathy are problems frequently encountered by the interventional pain physician. These entities result from inflammation and irritation of the spinal nerves and the dorsal root ganglion (1,2). The most common etiology for these symptoms is a herniated nucleus pulposus or foraminal stenosis secondary to spondylosis.

Regarding radicular pain, it is well known that compression alone cannot account for these symptoms, in that mechanical manipulation of nonpathologic nerves during surgical procedures evokes numbness and paresthesia rather than pain (3,4). Substances known to be highly inflammatory, such as phospholipase A2, metalloproteases, and nitric oxide, have been shown to be present within disc material and are present at high levels around the segmental neural structures in cases of disc disruption. In experimental models, these same substances can produce pain and inflammatory changes (5–9). This chemical inflammatory response has been indicated as the primary cause of most radicular-type of pain (10–12). A corticosteroid, methylprednisolone, applied to the neural structures has been shown to reduce some of the experimentally induced inflammatory changes (13).

Injecting corticosteroids into the epidural space has been the mainstay for the conservative treatment of sciatica (14). Although the original technique described injection via the S1 posterior foramen, the interlaminar and caudal approaches to the epidural space historically became predominant in the United States. Questions about the efficacy of introducing corticosteroids into the dorsal epidural space, and the anatomically far-removed caudal canal, have been presented in reviews of the subject (15–18). In addition, with fluoroscopically guided spinal injections becoming more common, if not the norm, precise access to the intervertebral foramen, as well

as the pain generators, is possible through a safe and reliable technique. Injection of corticosteroids into the intervertebral foramen, and segmental nerve canal, allows for a concentrated application of steroid around the inflamed neural structures. Anecdotal and good controlled trials have shown long-term clinical outcomes using a transforaminal approach for intraspinal steroid therapy, this technique seems to provide better relief than blind interlaminar technique. (19–24) This is not surprising in that placement of injectate into the dorsal epidural space by the interlaminar or transflaval approach will often fail to reach the target structures, that is, the segmental nerve and dorsal root ganglion, which lie ventral and lateral. This is especially true when pathology, such as scarring, further impedes the flow of medications. In addition, the interlaminar approach may not be appropriate post surgery, due to removal of the ligamentum flavum and adherence of the dura to the dorsal structures.

However, advantages of transforaminal corticosteroid injection come with increased complexity, requiring technical expertise, and bringing with it a significantly increased risk of morbidity. As with all interventional pain procedures, extensive clinical experience and good medical judgment is required to assess each patient's clinical condition and to offer an algorithm leading to the proper diagnosis and treatment.

INDICATIONS

The primary indication for transforaminal epidural steroid injection is radicular pain resulting from irritation and inflammation of the dorsal root ganglion and other neural structures in its vicinity.

CONTRAINDICATIONS

As with all spinal injections, contraindications include patients with significant bleeding diathesis, systemic or local infections at the procedure site, mental state making

communication difficult, including heavy sedation, and patients who are uncooperative. Surgical posterior fusion, with or without hardware, severe degenerative changes, large lateral disc displacement, and severe facet hypertrophic changes result in altered anatomy increasing the difficulty and risks. Substandard radiographic equipment, imaging tables, supplies and equipment, facility layout, and support staff untrained in interventional pain procedures will degrade the quality of care and can significantly increase risks.

PREPROCEDURE STUDIES

If the patient reports a history of prolonged bleeding or easy bruising, or is currently taking medications that interfere with blood coagulation, then appropriate coagulation studies are obtained prior to the procedure to assess elevated bleeding risk. Care and consideration should be taken when stopping these medications as to the reasons they were initially prescribed. Medications known to interfere with clotting are stopped at an appropriate time prior to the procedure (25). Stopping anticoagulation medications should be coordinated with the prescribing physician.

INFORMED CONSENT

Transforaminal injections carry risks of nerve damage from direct needle trauma, perforation of the dura, infection, and bleeding. Unrecognized, unintentional arterial

injection with particulate corticosteroids can have catastrophic sequelae and is the possible mechanism for ischemia of the spinal cord with paraplegia, which has been much discussed. Informed consent should be obtained, explaining these risks.

ANATOMY

The dimensions of the intervertebral foramen are defined by the pedicles above and below, the dorsal aspect of the vertebral bodies, above and below, the posterior disc annulus, the zygapophyseal joint, and the ligamentum flavum. The contents of the foramen include the nerve root, arteries, veins, connective tissue, and fat. There are no “empty spaces” in the normal anatomy of the spine. Every point in and around the foramen where a needle can be placed is occupied by some tissue. The goal of transforaminal injections is to place the needle tip outside the segmental nerve and dorsal root ganglion and avoid the vascular structures. Degenerative processes and spinal roto-scoliosis can greatly alter the anatomy. The space is highly vascular, and increased venous engorgement can occur in response to space-occupying lesions.

In a true anteroposterior (AP) view, a so-called “safe triangle” has been described, although in fact it is a “safer” triangle (Figures 17-1 and 17-2) (26,27). The upper border is a transverse line running lateral from a point under the pedicle at the “6:00 o’clock” position, when the pedicle is

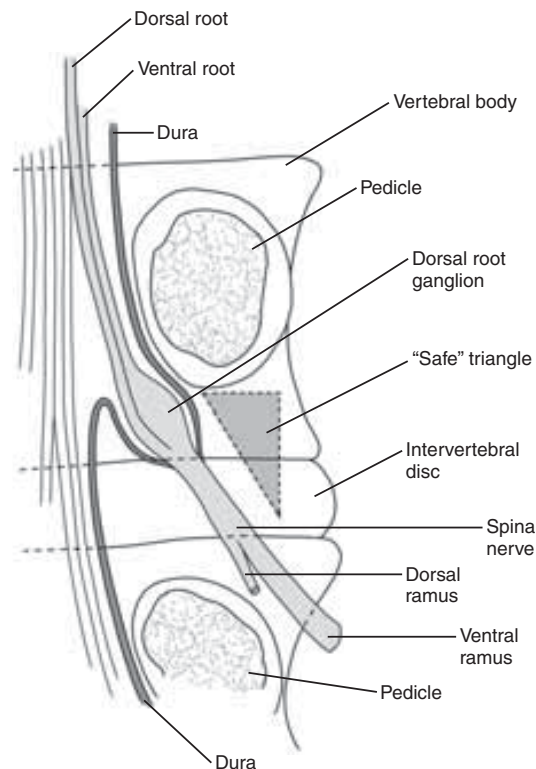


FIGURE 17-1

Illustration of transforaminal injection “safe zone” and contiguous structures.

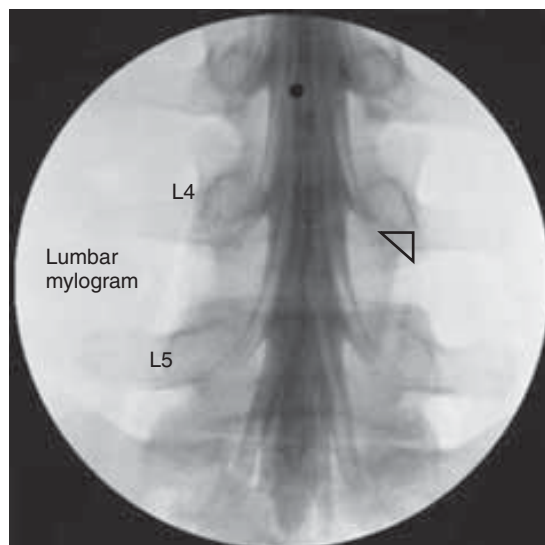


FIGURE 17-2

Lumbar transforaminal “safe zone” overlying AP view of lumbar myelogram. Note extent of dural root sleeves.

seen as a clock face, to the lateral pedicular line. The lateral boundary is a sagittal line extending caudad from the lateral aspect of the pedicle to the segmental nerve, and the hypotenuse connects the two lines and runs parallel to the lateral border of the nerve. Although in the vast majority of individuals, the dural investment of the segmental nerve root ends medial to the “6 o’clock” position, dural ectasia may be present with dural cysts within the lateral foramen. However, for the most part, a needle placed anywhere within this imaginary triangle would not be expected to risk dural, neural, or arterial impingement unless the anatomy of the region has been significantly changed due to surgical or degenerative changes.

The “magnus ramus radicularis anterior”, i.e. great radicular, or medulary artery, was first described by Adamkiewicz and is often referred to by his name, that is, the artery of Adamkiewicz (28). The microanatomy has been elegantly reported as to origin and course (29). This vessel is the major arterial supply of the anterior spinal artery of the thoracolumbar spinal cord. This artery is found on the left approximately 80% of the time, and the origin is known to be from T9-L2 in the great majority of specimens. The artery courses medially through the rostral or mid portion of a foramen, and lies in close proximity to the dorsal root ganglion-ventral root complex. Injection into, or damage to, this artery including emboli derived from particulate corticosteroid injectate has been proposed as the probable etiology of paraplegia and other neurological sequelae associated with transforaminal injection procedures (30,31). Branches of the artery of Adamkiewicz lie in and around each foramen and supply various structures, including the spinal nerve, and dorsal and ventral roots, and go on to anastomose with vessels arising from the conus medullaris.

EQUIPMENT

Although historically lumbar transforaminal, or paravertebral somatic nerve blocks, were performed by blind, nonfluoroscopic-guided techniques, this is no longer an acceptable medical practice in any community (32). Fluoroscopy is required when performing lumbar transforaminal injections, and a fluoroscope capable of excellent image quality is a necessity. A C-arm fluoroscope, which allows the x-ray beam to be directed from any angle, has advantages and is the instrument of choice utilized by the vast majority of spinal injectionists. The ability to save the last image is a must. Low-dose and pulsed x-ray modes are of great benefit to minimize overexposure to the radiation inherent in any fluoroscopically guided procedure. A sterile cover over the image intensifier allows optimum positioning of the fluoroscope and fine adjustments during the procedure. Although not a standard of care at the present, digital subtraction angiography (DSA) is being widely used to ensure adequate visualization of the contrast pattern and prevent possible unintentional arterial injection.

Although advocated by a small group of practitioners, computed tomography (CT)-guided transforaminal injections are not appropriate and offer no benefit and increased risk. With CT, although the skin insertion point is exactly visualized, needle advancement toward the target endpoint is essentially performed with no x-ray guidance. This results in additional discomfort to the patient and an increased chance of needle misadventures. In addition, CT use necessitates the injection of contrast without active, real-time, x-ray visualization. Vascular injection would in all likelihood be missed due to the rapid clearing of the contrast in an artery or vein. No literature exists as to any benefit of using CT, and the increased exposure to radiation by

the patient is a real concern. In guidelines as published by the International Spine Intervention Society (ISIS) and PASSOR (Physiatric Association of Spine, Sports and Occupational Rehabilitation), CT imaging is specifically not mentioned (33,34). It can therefore be inferred that it is not recommended. There is at least one case in the literature where a transforaminal L2 injection was performed with CT guidance, with resultant spinal cord infarction and severe permanent neurological complications (35). The lesion was presumed to be secondary to injection into the artery of Adamkiewicz, which as noted earlier, is the dominant arterial supply of the anterior spinal artery of the thoraco-lumbar spinal cord. Contrast was not utilized in this mishap, although it is questionable whether its use would have prevented this disastrous outcome since real-time imaging during injection of contrast cannot be utilized. CT is simply not the appropriate imaging modality for transforaminal injections at any level.

A radiolucent procedure table compatible with the fluoroscope is utilized. Intravenous access is advocated by some. Monitoring equipment, including pulse oximetry, noninvasive blood pressure, and EKG should at the least be immediately available. Oxygen, airway supplies, emergency drugs, suction and other resuscitation equipment and supplies should be in the procedure room and checked on a regular basis. Well-trained personnel who are able to assist the physician, monitor the patient, and operate the fluoroscope are essential to lessen complications and improve safety. Appropriate radiation protection and radiation exposure monitors should be provided for all personnel in the room.

Procedure needles typically 22- or 25-gauge of 3.5–5.0 inches in length are utilized. When a two-needle technique is required, a shorter, slightly larger-gauge introducer needle is also used. Sharp-tipped needles, Quinke or Chiba, are employed by the vast majority of injectionists when performing lumbar transforaminal injections. A small bend placed at the tip opposite the bevel, in the direction of the point, to aid in needle control during insertion, is desirable (36). This bend allows change of direction of the needle by rotation during insertion. Occasionally, when the two-needle technique is required, a large bow in the needle is utilized to negotiate around obstacles such as intertransverse fusion masses (Figures 17-3, 17-25, and 17-26). Although there is no explicit evidence against their continued use, some eminent authorities have stated that the use of sharp needles should be curtailed and blunt needles utilized to reduce the complication rate of unintentional vascular injection. This argument has been addressed in a recent publication (36). Because a point is lacking in blunt needles, being a truncated cylinder, such needle cannot pierce the skin without an introducer, and advancement will be difficult through any dense tissue. Although blunt needles may have a bend on the tip, they are harder to control and require larger gauges. In addition, their supposed advantage of lowering the frequency of intervascular injections has been shown to be false. In a recent small, thus far unpublished study, more intravenous injections were noted with blunt



FIGURE 17-3

Equipment used in lumbar transforaminal injections. From left to right: Skin marker, pointer, 25-gauge 1-1/2-inch needle for skin anesthesia, 25-gauge 3-1/2-inch procedure needle with mild curve at distal tip; 22-gauge, 5-inch procedure needle with mild curve at distal tip; 22-gauge, 9-inch procedure needle with significant curve through 18-gauge 3.5-inch introducer needle; 5–6-cc syringe for skin local anesthetic; 3-cc syringe for injectate (corticosteroid with or without local anesthetic); 3-cc syringe with extension tubing for contrast.

than sharp needles (Figure 17-4) (37). In short, blunt needles are not a substitute for excellent technique, precise needle placement, and vigilance in interpretation of the contrast test dose, that is, a trained, skilled operator.

Skin preparation with an iodine-based solution (e.g., Povidone-iodine), or chlorhexidine, with or without alcohol, followed by draping with sterile towels or a fenestrated drape is advocated. Sterile gloves, a metal pointer to allow determination of the skin entry point while using fluoroscopy, and a sterile skin marker should be provided. Syringes

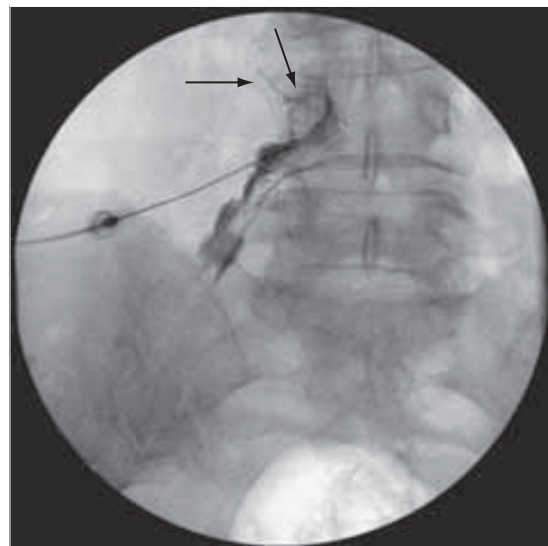


FIGURE 17-4

Left L5 transforaminal injection using a blunt needle and intra-vascular injection. (Courtesy of Kevin Pauza, MD.)

of 3 and 5 cc are utilized. A small-bore, low-volume extension tubing allows contrast to be injected under active fluoroscopy to confirm nonvascular needle placement without irradiation of the hands. In addition, extension tubing minimizes the movement of the needle while syringes are being changed.

Sedation, although not required in the vast majority of cases, is advocated by some physicians. To a large extent, regional bias and patient expectation, rather than medical necessity, appear to dictate this practice, since the discomfort experienced during a transforaminal injection by a competent practitioner with small-gauge needles is minimal. If the physician chooses to sedate his patients, intravenous access and monitoring are mandatory. Midazolam in a dose of 1–2 mg, should be adequate to provide sedation. It is unacceptable to render the patient unconscious during any spinal injection procedure. If a patient demands a level of sedation in excess of that which the physician feels reasonable, a psychological overlay should be considered, the risk–benefit ratio explored, and the procedure possibly canceled. Although small doses of analgesics (fentanyl 50 mcg, meperidine 50 mg, or morphine 5 mg) may lessen the discomfort of the injection, if any diagnostic trend is to be forthcoming, these opioids may render any response by the patient questionable.

The use of a water-soluble, nonionic contrast medium, iohexol (Omnipaque) or iopamidol (Isovue), must be utilized in all fluoroscopically guided spinal injections to ensure that the injectate is covering the proposed target—the spinal nerve and dorsal root ganglion in the case of transforaminal injections—and that no arterial, or marked venous, uptake is noted. The contrast solution concentrations between 180 and 240 are adequate for this purpose.

The primary purpose of a lumbar transforaminal injection is placement of an anti-inflammatory agent, corticosteroids, in the vicinity of, and bathing the possibly inflamed structures generating the radicular type pain. As noted previously, many of the catastrophic problems associated with this procedure appear to be due to spinal cord ischemic infarction, associated with injection of particulate corticosteroids into the radicular artery. Therefore, common sense dictates that a less particulate agent may offer some margin of safety. Methylprednisolone, due to its large particulate formulation, might not be considered the best choice for this application. Rather, triamcinolone 40–80 mg, betamethasone 6–18 mg, or dexamethasone 4–12 mg might be a better alternative. Derby et al.³⁸ have recently compared red blood cell size to the particle and aggregate size of the frequently used corticosteroid solutions and concluded that dexamethasone “will not cause arterial or capillary obstruction if inadvertently injected into a vertebral or radicular artery.” (38)

Although the main purpose of a transforaminal injection is delivery of corticosteroids, local anesthetics are often utilized. The amide group of local anesthetics, without preservative, is preferred due to the allergenic

profiles. Lidocaine is an extremely safe, versatile, and inexpensive medication. It is often used for skin infiltration in the 1% (10 mg/cc) concentration. For the transforaminal injectate, 2–4% (20–40 mg/cc) is preferred. Bupivacaine 0.5–0.75% (5–7.5 mg/cc), a longer-duration, amide-type local anesthetic, can be substituted for lidocaine. Less than 1 cc of local anesthetic, total volume 1.5–2 cc, needs to be used for transforaminal injections.

The local anesthetic response can validate the procedure, in that if local anesthetic is utilized with the corticosteroid, and the pain is decreased markedly in the postprocedure period, by inference the pain generator has been addressed.

Karasek and Bogduk³⁹ reported a case of temporary neurological deficit while performing a transforaminal injection, following injection of a small aliquot of local anesthetic (0.8 cc of 2% lidocaine). A transforaminal injection was confirmed by prior injection of contrast, and although some venous uptake was noted, no arterial pattern was appreciated. Although this occurred during a cervical rather than lumbar, transforaminal injection, the result of a lumbar injection into the medullary artery would be expected to be analogous. In response to this and other cases, some have maintained that a “test dose” of local anesthetic, followed by a 1- to 2-minute period where the patient is observed and examined for neurological deficits, might prevent unintentional injection of corticosteroids into a radicular artery, with possible devastating sequelae (30).

Warning: Spinal injections in the pain patient, whether for diagnosis or therapy, should be performed only by physicians who have the extensive training required to evaluate such patients, interpret imaging studies, perform the procedures in a safe manner, and analyze in real time the radiographic information obtained during the procedure.

NEEDLE PLACEMENT TECHNIQUE

Although various techniques for the accessing of the lumbar inter vertebral foramen have been proposed, the majority target the subpedicular area, that is, the rostral and ventral portion, of the intervertebral foramen (27,40). Recently, a “retroneural” approach has been described which results in the needle tip being placed subpedicular, but in the mid-foramen slightly dorsal to the segmental nerve than seen in the more classic position (1).

The purported advantage to this retroneural approach is that it attempts to address the problem of unintentional injection into the artery of Adamkiewicz, which as noted earlier, courses medially through the mid or rostral portion of the foramen, enters the dura, and supplies the anterior spinal artery, occlusion of which has been proposed to be associated with paraplegia and other neurological sequelae. However, the above is supposition based on anatomical dissections, and no true evidence exists indicating that the retroneural approach is clinically safer. Additionally, all

studies used to validate the efficacy of transforaminal deposition of steroids utilized the classic, more ventral needle tip position (19–22). Clinically, the difference between the retroneural and the more ventral needle placement is often merely a matter of needle insertion depth, with little actual difference in skin entry or needle insertion targets.

When a C-arm fluoroscope is utilized for lumbar transforaminal injections, the patient is placed in prone position. Often a pillow under the upper abdomen will decrease the physiologic lumbar lordotic curve and allow for optimum visualization. Depending on target level, the lower thoracic, lumbar, and/or sacral regions are prepared and draped in a sterile manner.

Accurate target identification requires that an examination of the lumbar spine by fluoroscopy precede any needle placement. Verification that five lumbar, non-rib-bearing vertebral bodies are present must be ensured. Approximately 10% of the population will be noted to have either a nonsacralized S1, or sacralized L5 vertebra, which can lead to misidentification of the level being treated and any diagnostic inferences derived. Using an AP image, the pedicle corresponding to the targeted foramen is identified. To ensure a true AP image, using cephalad-caudad tilt of the image intensifier, the inferior end-plate just caudad to the pedicle identified is “squared,” that is, the x-ray beam passes tangentially. The inferior end-plate should be seen as a line rather than an oval. For example, if the target is the L4 foramen, dorsal root ganglion (DRG) and segmental nerve, the L4 pedicle is identified and the fluoroscope is maneuvered until the beam is parallel to the inferior end-plate of L4, which is seen as a single line.

The final needle-tip target is within the foramen, subpedicular, approximately halfway between the ventral and dorsal extent of the pedicle when imaged in a true lateral view. This location will place the needle tip rostral and lateral to the DRG and segmental nerve, and dorsal to the anterior radicular artery.

In most spinal injections, a down-the-beam, so-called “tunnel vision” is best utilized. This involves aligning the skin entry point with the anatomical target. This technique obviates the need to guess at the correct angle of needle insertion, and if the anatomy lying between the skin and target structure is well known to the injectionist, offers the safest approach. After the target level is identified and the end-plate “squared,” as detailed earlier (Figures 17-5 and 17-15) to ensure a true AP view, the C-arm is then rotated until an ipsilateral oblique view projects the superior articular process (SAP) of the infrasegmental level so that it appears to lie under the 6 o’clock position of the target pedicle (Figures 17-6 and 17-16). The skin is marked over the target, caudal to the pedicle. If a needle larger than 25 gauge is used, a skin wheal is made, through which the procedure needle is introduced. The needle is slowly and carefully advanced through the tissues toward the target (Figures 17-6, 17-7, and 17-17). Intermittent, spot fluoroscopic images are used throughout the needle insertion while the needle is advanced in small increments. If the

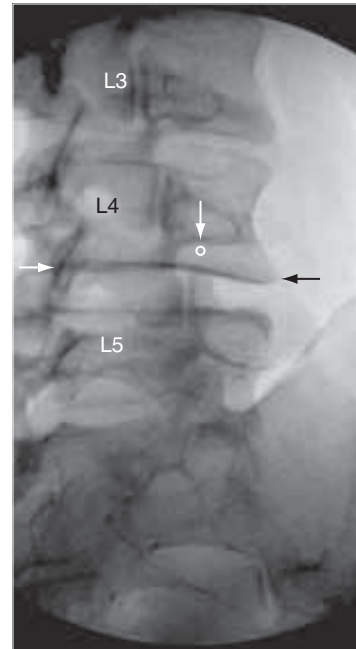


FIGURE 17-5

Right oblique view of lumbar spine with target for a right L4 transforaminal injection indicated. Note that the inferior end plate of L4 is parallel to x-ray beam and SAP of L5 is positioned under the “6:00” position of the L4 pedicle.

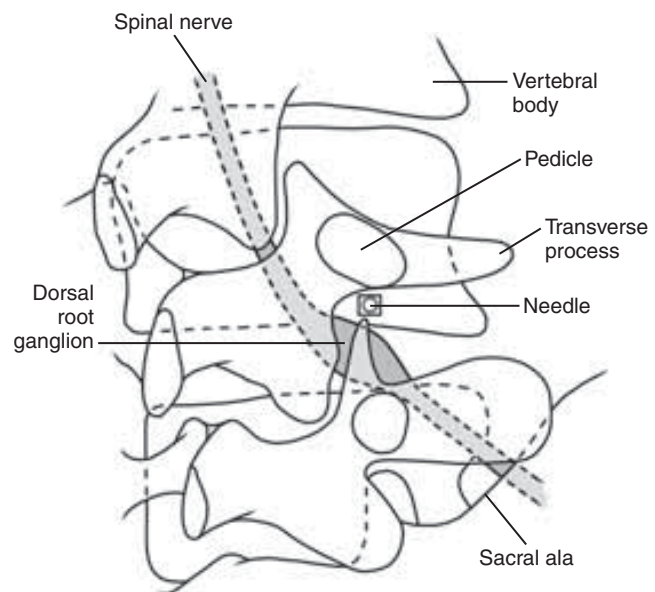


FIGURE 17-6

Illustration of needle placement for an idealized right L4 transforaminal injection. Note position of needle lateral and rostral to the segmental nerve.

needle is noted to stray from the desired course, it is slightly withdrawn, rotated, and utilizing the bent tip, advanced along the corrected direction. The needle should not be allowed to stray medial to the superior articular process (SAP), 6 o’clock position, or lateral to the lateral-pedicular line. Although not required, touching the caudal aspect of the pedicle shadow, which is the caudad aspect of the

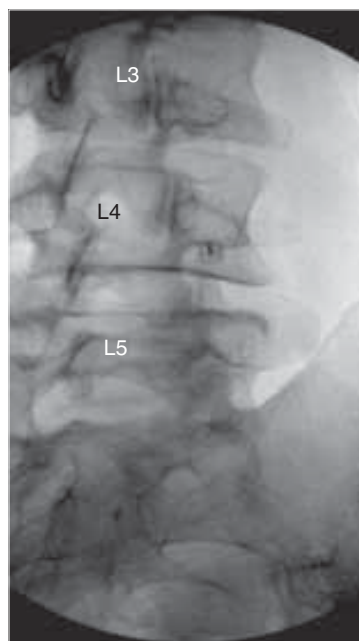


FIGURE 17-7

Right oblique view of the lumbar spine. Needle in place for L4 transforaminal injection.

transverse process or lateral lamina, ensures verification of depth prior to entering the foramen. The needle can then be slightly withdrawn so that the tip is not restricted by bone, and using the slight bend at the tip, rotated and advanced so as to “slide off” into the rostral aspect of the foramen. Needle insertion continues until either resistance to further advancement is noted or the patient experiences a dysethetic radicular-type pain.

If resistance is met during needle insertion, a lateral fluoroscopic view should be obtained. If a posterior element of the spine, transverse process, lamina, or SAP is preventing passage, the bend in the needle tip can be utilized to pass around the structure. Occasionally, withdrawal of the needle up to 5 mm may be required to bypass the impeding structure. If on lateral view the needle is noted to have contacted the dorsal-lateral aspect of the vertebral body, withdrawal 2–3 mm is advised. This lessens the chance of the radicular artery having been “trapped” between bone and needle and accidentally cannulated.

If radicular pain is noted by the patient at any point during needle insertion, the spinal nerve or DRG may have been touched, and the needle should be immediately withdrawn a small amount. If marked pain continues after withdrawal of the needle, termination of the procedure should be considered after documenting the needle position with AP, oblique and lateral fluoroscopic spot films. If the pain is noted to abate, a lateral view should be obtained. If the needle tip is noted to lie within the foramen, and on AP view the tip is seen to be within the “safe triangle,” the procedure should proceed without further needle advancement.

Verification of final needle position by fluoroscopy in AP and lateral views is mandatory at this stage of the procedure. In the AP view (Figures 17-8, 17-9, 17-18, and 17-27), the needle tip should be positioned just caudal to the pedicle shadow under the 6 o’clock position, while a lateral image (Figures 17-10, 17-11, 17-19, and 17-28) will find the

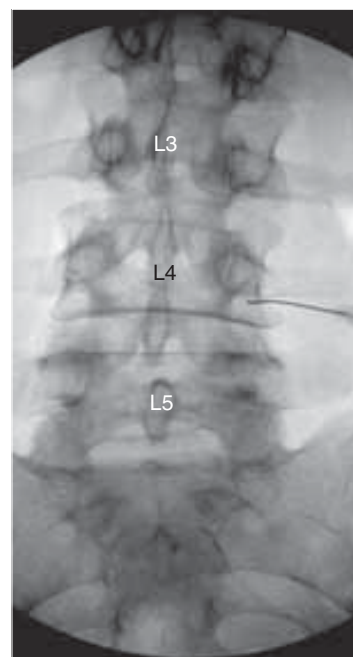


FIGURE 17-8

Anterior posterior view of lumbar spine. Needle in final position for L4 transforaminal injection. Note needle tip is in excellent position just lateral to the “6:00” position under the L4 pedicle.

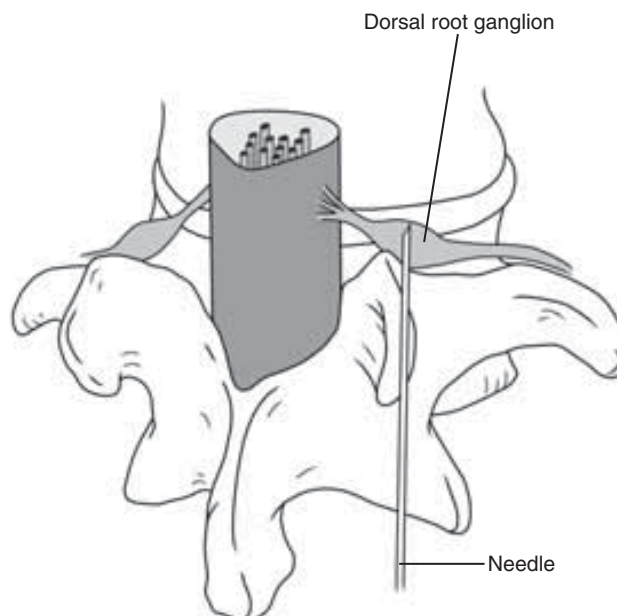


FIGURE 17-9

Illustration with a slight right oblique orientation of lumbar spine. Final needle position for a lumbar transforaminal. Note needle tip is lateral and rostral to the DRG and segmental nerve in the mid-portion of the foramen.

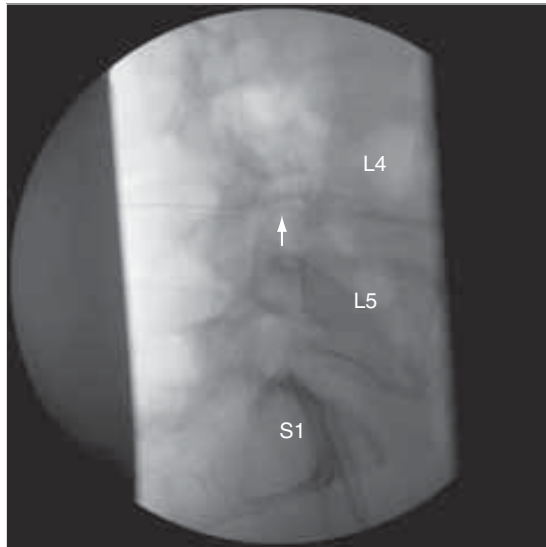


FIGURE 17-10

Lateral view with needle in excellent position within the L4 foramen, subpedicular and in the middle aspect of the foramen.

tip in the mid or ventral aspect of the foramen and subpedicular. The needle tip will lie lateral and rostral to the segmental nerve and DRG (Figures 17-9 and 17-11). If required, further adjustment of the needle into the correct position can be entertained.

Once needle tip position is noted to be within the target zone, a contrast-containing syringe with low-

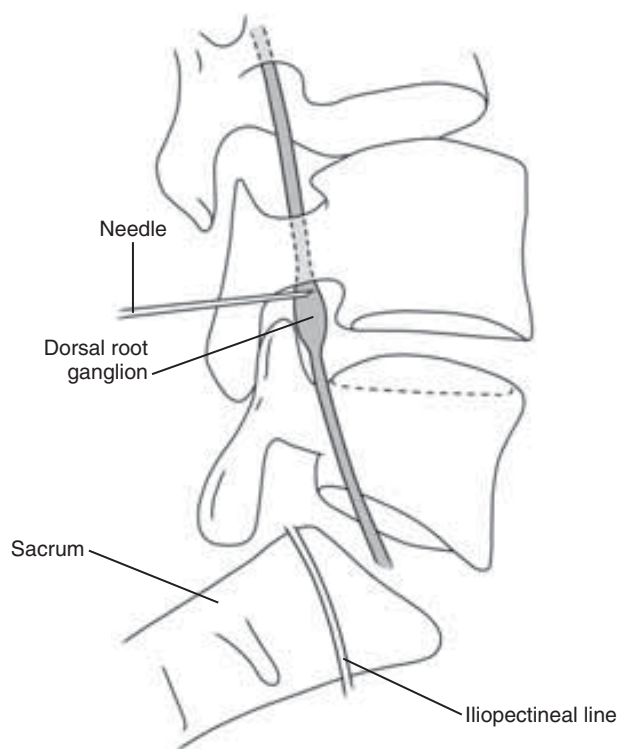


FIGURE 17-11

Illustration of a L4 transforaminal injection (lateral view). Note needle tip in the middle aspect of the foramen lateral to the DRG.

volume extension is attached to the procedure needle. Using AP, real-time imaging, with digital subtraction angiography (DSA) if available, a small volume of contrast medium (0.25–0.5 cc) is injected. If no vascular uptake is noted, an additional 0.5–1.0 cc is injected to verify that the injectate will cover the desired target structure, that is, the pain generator and site of suspected inflammation. Total contrast volumes of 1.0–1.5 cc are usually adequate. Contrast should be seen to flow medially from the needle tip, through the foramen, and rostral around the pedicle, covering the segmental nerve and DRG (Figures 17-12a–e, 17-13, 17-20, 17-21 and 17-26). Volume of contrast required to cover the target structure should be noted. If an aberrant contrast pattern is observed, the injection should be stopped, needle repositioned, and further contrast injected. If a vascular pattern is noted, determination of whether it is arterial or venous must be made. As noted earlier, an injection into a radicular artery can have disastrous results. Any vascular structure noted to flow medially and seen to end at the midline in AP view must be considered arterial until proved otherwise (Figures 17-23 and 17-24). If a radicular arterial pattern is evidenced, the needle should be withdrawn and the procedure terminated and rescheduled at a later time.

Venous contrast patterns may be noted to flow laterally or will cross to the contralateral side in AP view. If the contrast pattern evidences a venous pattern the needle position should be readjusted and contrast re-injected. If the repositioning affords a pattern covering the target, without vascular uptake, the procedure can continue. If a significant venous injection is noted with multiple repositionings, the procedure should be terminated.

Spread of contrast laterally along the ventral ramus, rather than medially, warrants repositioning of the needle since the target structure, that is, the DRG, is not being addressed. A lateral view (Figures 17-14 and 17-22) should confirm contrast in the foramen and ventral epidural space.

Occasionally, if an obstacle, such as an intertransverse fusion mass, is present, a two-needle technique is required in order to gain access to the intervertebral foramen. This entails the use of a larger gauge introducer needle, which is inserted laterally and slightly ventral to the obstruction. A second, smaller-gauge procedure needle, with varying degrees of curve at the distal end, is then advanced through the introducer needle (Figures 17-3, 17-25, and 17-26). As the procedure needle emerges from the introducer needle, the curve is reinstated and maneuvered into the target area. Once the procedure needle passes from the distal end of the introducer needle, the latter may be withdrawn slightly as the former needle is advanced. Due to the myriad variations that may be encountered, a more detailed discussion is not possible in this venue. Care must be taken at all times due to significant loss of needle control due to the needles extreme curved profile. Confirmation of needle position with contrast is described in Figures 17-25 and 17-26.

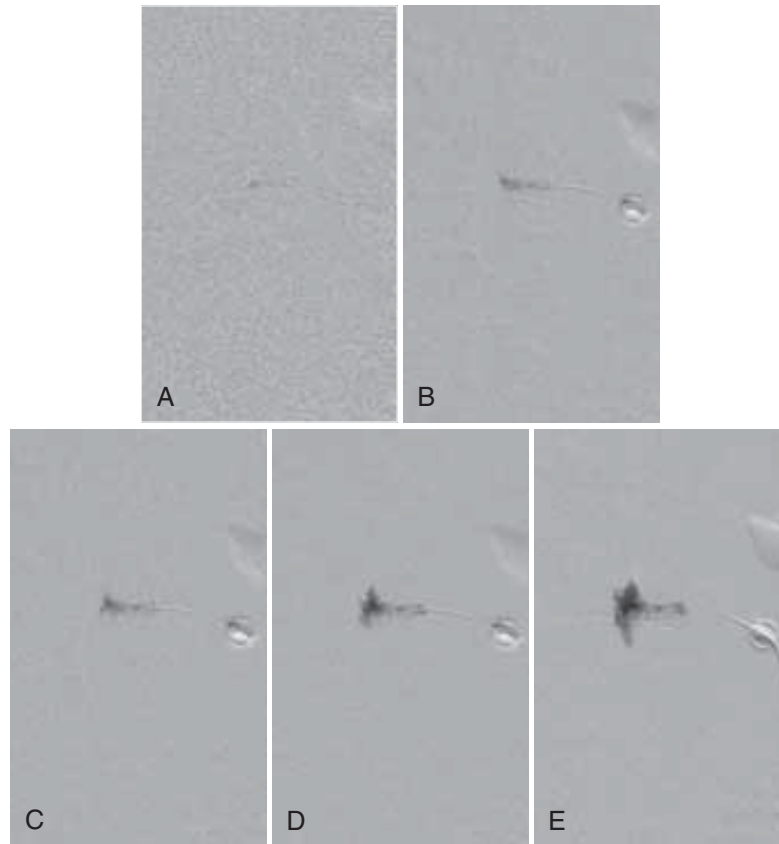


FIGURE 17-12

(A to E) Sequential digital subtraction angiography, digital subtraction angiography, images of a L4 transforaminal injection. Note flow through foramen, around pedicle within the nerve canal and into the epidural space without vascular uptake.

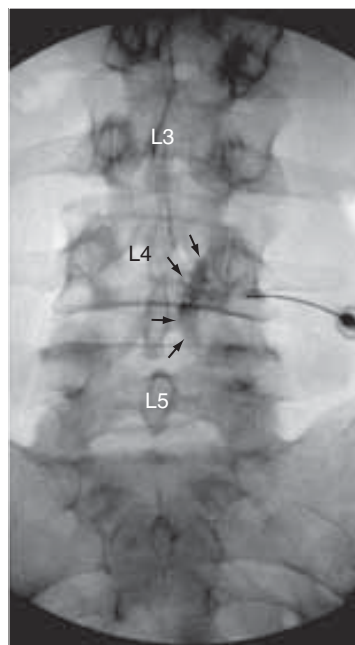


FIGURE 17-13

Plain film anteroposterior of L4 transforaminal injection with contrast. Note flow through foramen into the lateral epidural space.

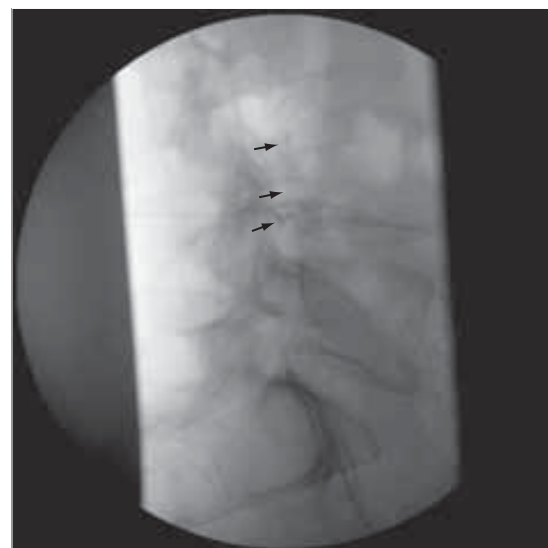
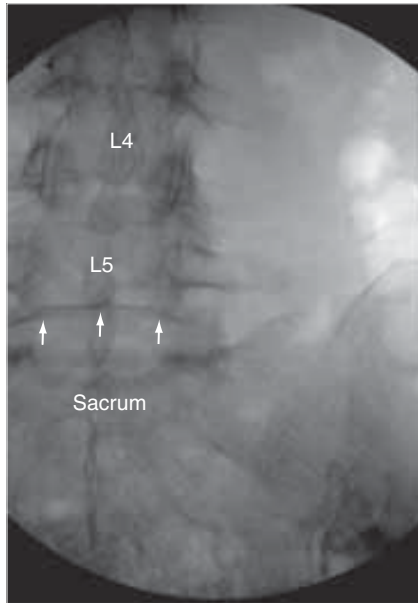
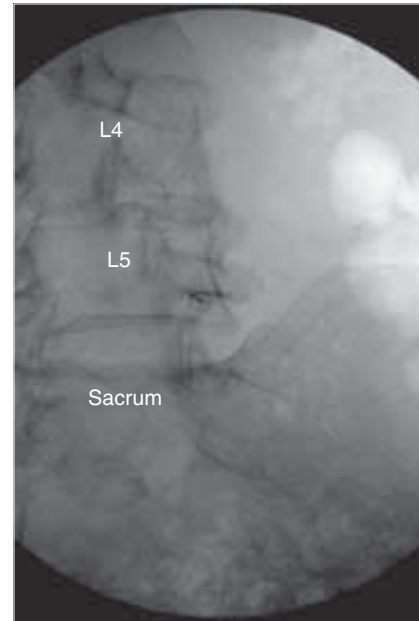


FIGURE 17-14

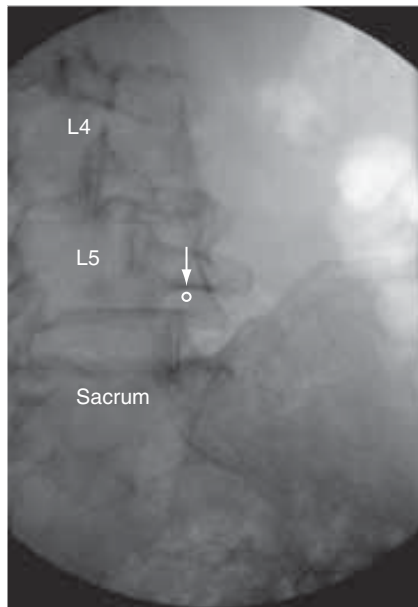
Lateral view of L4 transforaminal injection. Note contrast in foramen and ventral epidural space.

**FIGURE 17-15**

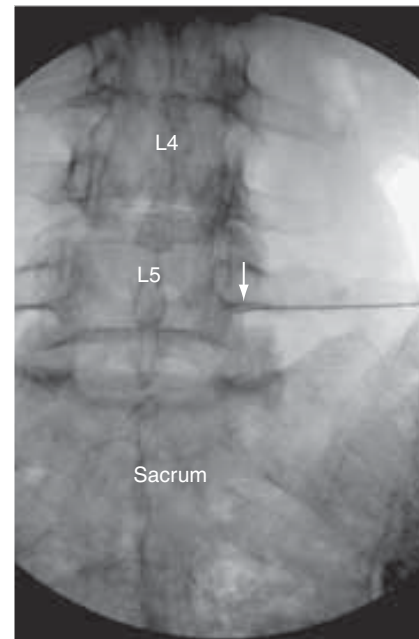
Scout AP image for right L5 transforaminal injection. Note inferior end plate of L5 is parallel to x-ray beam.

**FIGURE 17-17**

Ipsilateral oblique view with 25-gauge needle in place for a right L5 transforaminal injection.

**FIGURE 17-16**

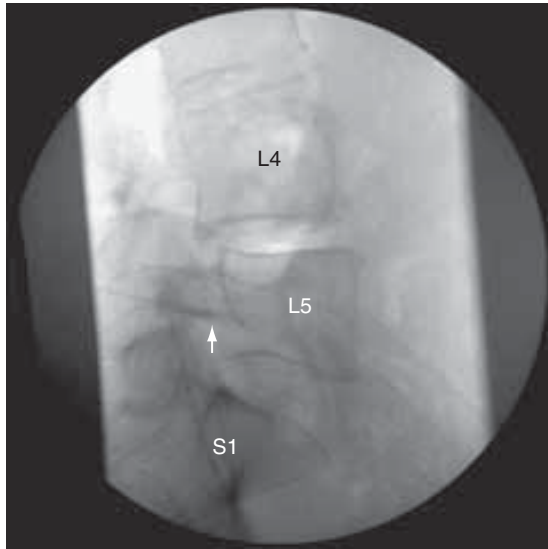
Right oblique initial view of lumbar spine for L5 transforaminal injection. Open circle indicates target. Note SAP of S1 appears to be under the “6:00” position of the L5 pedicle.

**FIGURE 17-18**

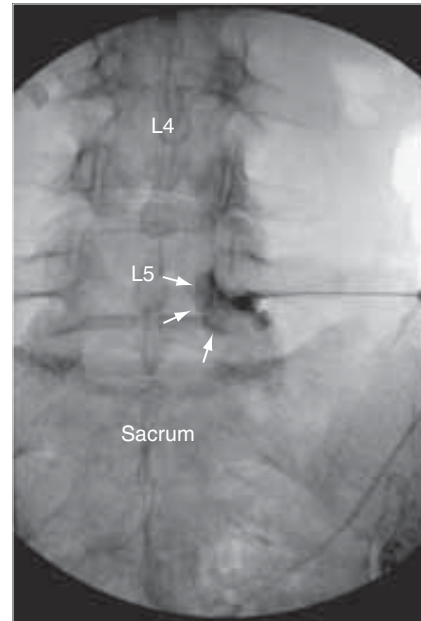
AP view of needle in final position for L5 transforaminal injection. Note needle tip is seen as lying under the “6:00” position of the L5 pedicle.

On rare occasions, although the needle tip is seen to lie in proper position by the bony landmarks, some radiolucent structure might, in fact, have been penetrated. Figures 17-27 to 17-31 demonstrate needle entry into a far lateral intervertebral disc extrusion with cephalad migration, producing an unintentional discogram with injection of contrast.

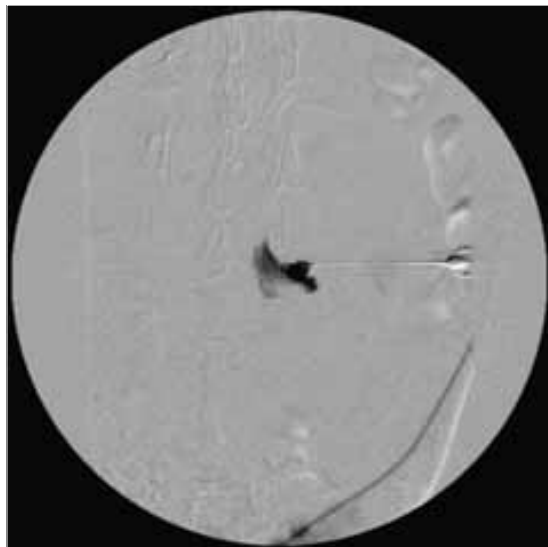
Needle placement and injection between the dura and arachnoid layers, a subdural injection, is a rare occurrence (Figures 17-32 and 17-33) and must be differentiated from an intrathecal placement. Subdural contrast will be noted to be maintained in a cyst-like structure and does not layer out in the ventral thecal sac as will be seen with an intrathecal injection. In addition, the contrast will not be

**FIGURE 17-19**

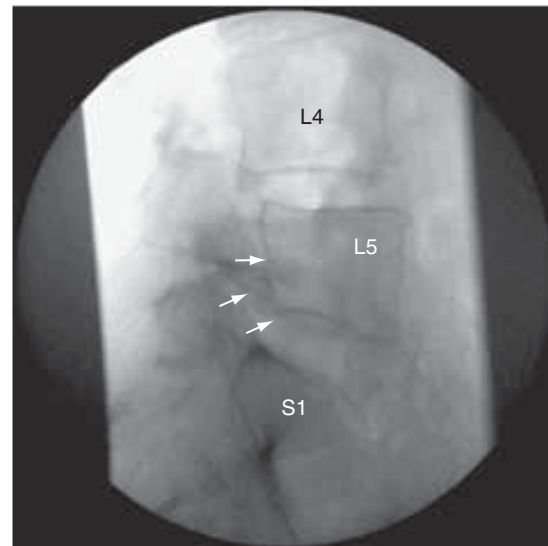
Lateral view with needle in excellent position within the L5 foramen, subpedicular and in the middle aspect of the foramen.

**FIGURE 17-21**

Excellent contrast pattern for an L5 transforaminal injection.

**FIGURE 17-20**

Digital subtraction angiography image of a L5 transforaminal injection. Note flow of contrast around the pedicle into the epidural space without intravascular pattern evident.

**FIGURE 17-22**

Lateral view of the L5 foramen with contrast within the foramen and ventral epidural space.

diluted by the cerebral spinal fluid (CSF). Often aspiration and injection of the contrast can be seen to produce rapid changes in the volume of the contrast body. If a subdural injection is noted, the needle can be slightly withdrawn and repositioned, followed by confirmation of good placement with reinjection of contrast. Unlike subdural placement, if an intrathecal pattern is observed, the procedure should be terminated.

The capsule of the zygapophyseal (i.e., facet) joint covers the inferior and superior articular processes and is known to be loose at the superior pole. The capsule “balloons upwards toward the base of the next transverse process.” (2) While excellent position may be noted in AP and lateral views while performing a transforaminal injection, there is a small probability of its being within the superior capsule of the zygapophyseal joint. This is

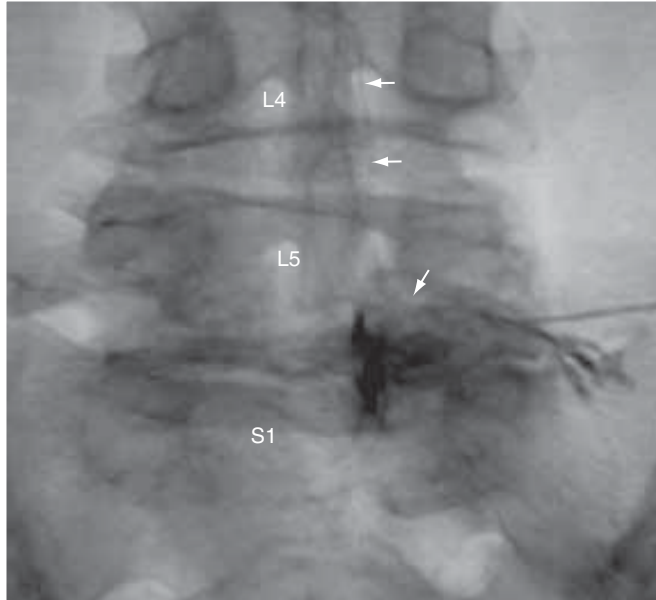


FIGURE 17-23

Right L5 transforaminal injection. Arrows indicate contrast within the radicular artery, artery of Adamkiewicz, and anterior spinal artery. (Courtesy of Way Yin, MD.)

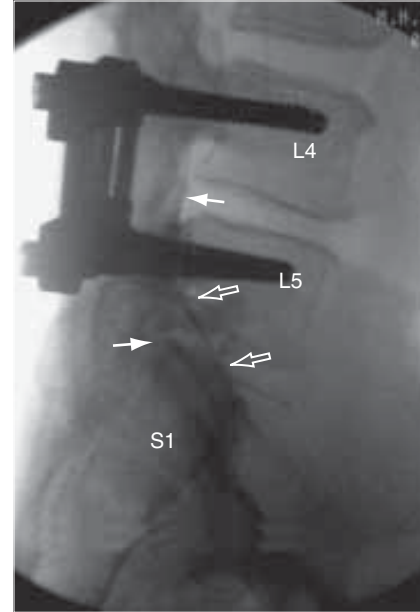


FIGURE 17-25

Lateral view of dual needle technique. Open arrow indicates tip of needle within the L5 foramen. Solid arrows note contrast within the foramen, epidural space and following segmental nerve.

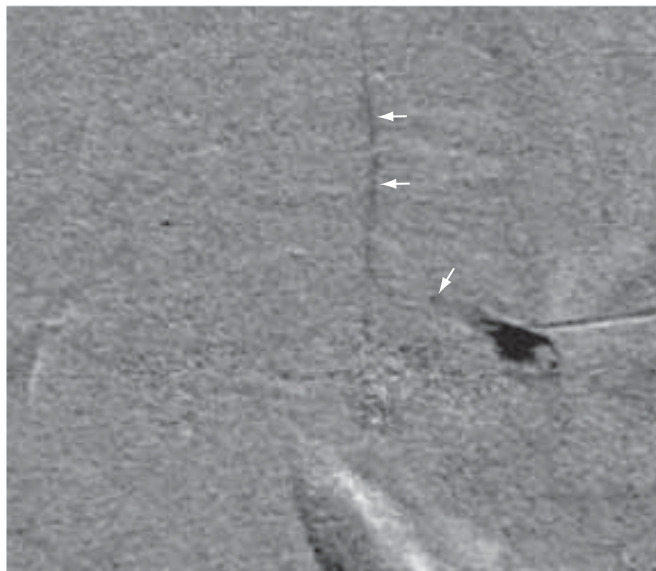


FIGURE 17-24

DSA image of the right L5 transforaminal injection seen in Figure 17-23. Note relative ease in visualization of the radicular and anterior spinal artery as compared with the previous figure. (Courtesy of Way Yin, MD.)

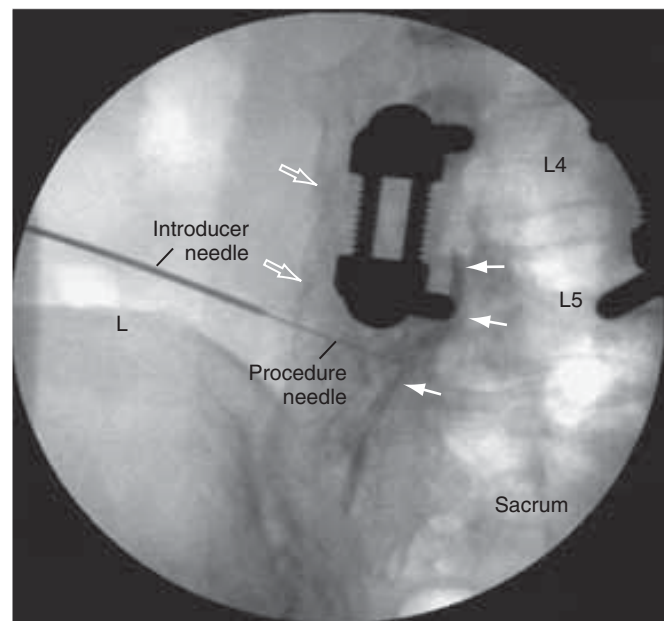
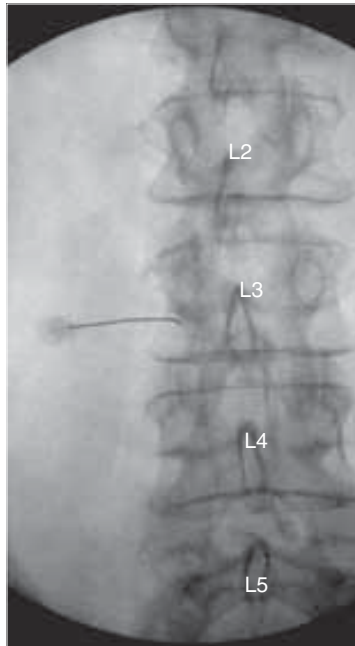


FIGURE 17-26

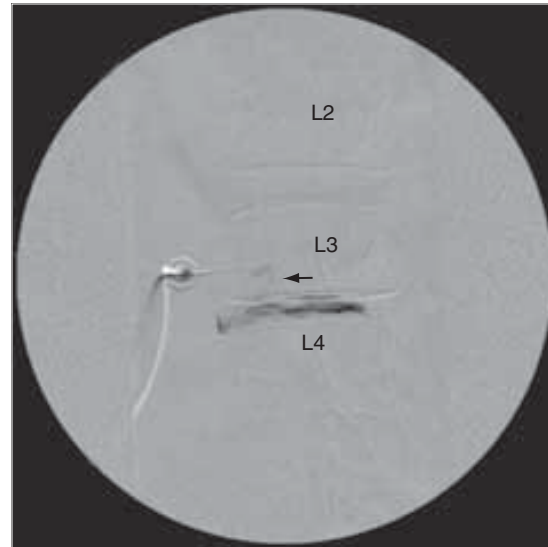
Anteroposterior view of intertransverse fusion mass with L5 transforaminal injection utilizing a dual needle technique. Open arrows indicate lateral aspect of fusion mass. Note 18-gauge introducer needle lateral to fusion mass with 22-gauge curved procedure needle proceeding ventral to mass into foramen. Solid arrows indicate contrast within epidural space.

seen most often during an L5 transforaminal injection (Figure 17-34). If a “Z” joint arthrogram is noted, the needle must be repositioned and additional contrast injected. Often advancing the needle as little as 1–2 mm is enough so that the needle tip is ventral to the capsule and a good transforaminal contrast pattern noted.

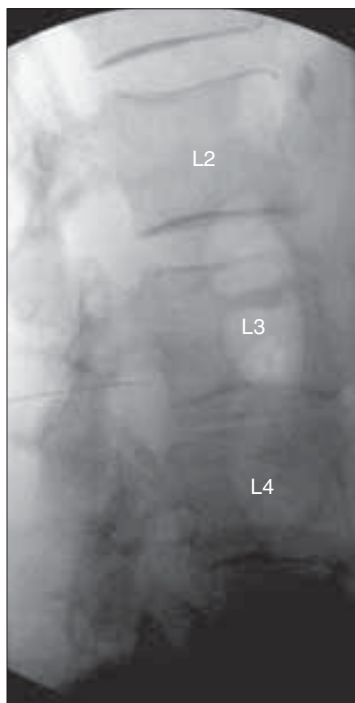
Although extremely rare, an intraneural injection is possible, especially if heavy sedation is utilized. If not overly sedated, excruciating radicular dysethetic pain would be evidenced by the patient. Injection into the epineurium might occur without marked discomfort; however, the contrast pattern would evidence

**FIGURE 17-27**

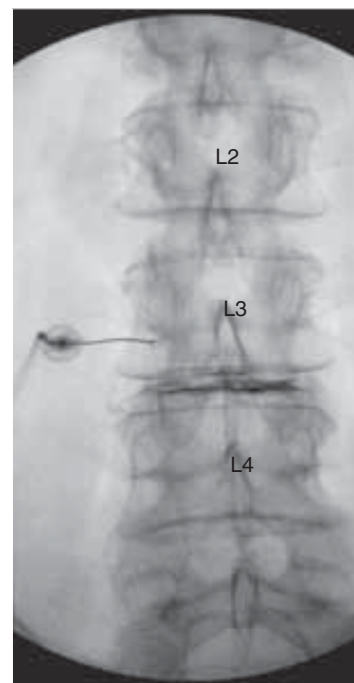
Anteroposterior view of needle in excellent position for a left L3 transforaminal injection.

**FIGURE 17-29**

Digital subtraction angiography anteroposterior image during injection from Figures 17-27 and 17-28. Note contrast flow into intervertebral disc through disc extrusion within foramen.

**FIGURE 17-28**

Lateral view of needle in excellent position within the L3 foramen.

**FIGURE 17-30**

Anteroposterior view of disc injection via extruded disc material.

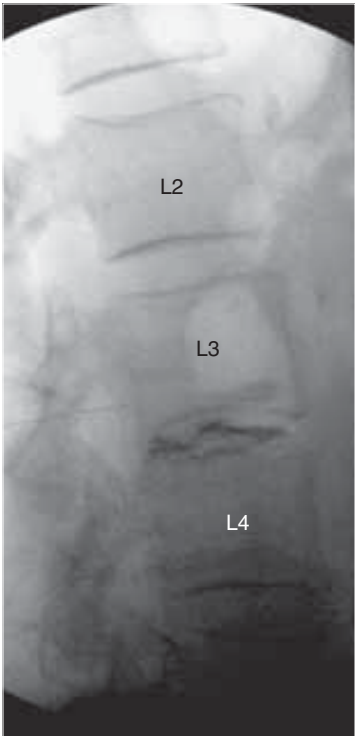


FIGURE 17-31
Lateral view following injection into disc extrusion with unintentional discogram.

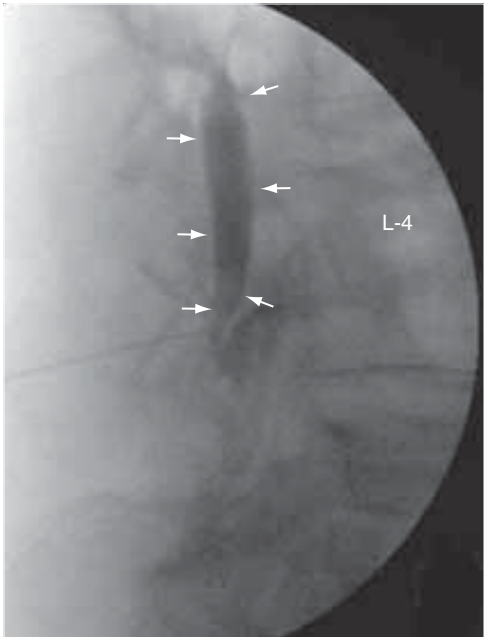


FIGURE 17-33
Lateral view of subdural injection during L4 transforaminal injection

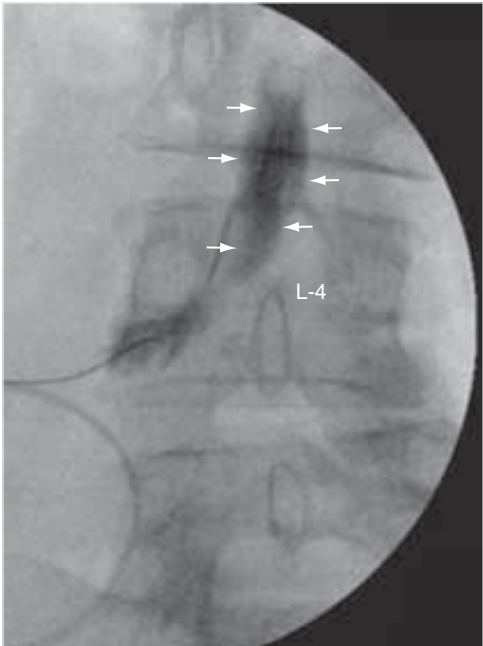


FIGURE 17-32
Anteroposterior image of left L4 transforaminal injection with subdural pattern.

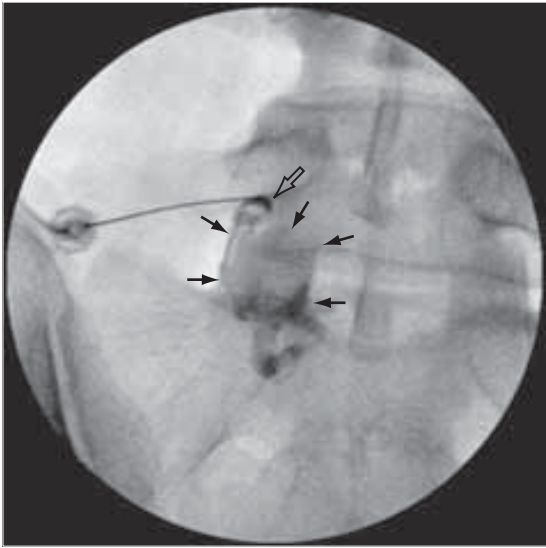


FIGURE 17-34
Unintentional intra-articular zygapophyseal, facet, joint injection during L5 transforaminal injection. Open arrow indicates needle tip in superior capsule of the joint.

outline of the nerve within the intrathecal space (Figure 17-35).

Final permanent documentation following a lumbar transforaminal injection should include AP and lateral images with and without contrast, and DSA if utilized.

INJECTION OF THERAPEUTIC AGENT

Following confirmation of needle placement and evidence of a good contrast pattern, the syringe containing the contrast is disconnected from the extension tubing and replaced by one containing the therapeutic agent(s). Care is taken to remove all air from the syringe. A mixture of local anesthetic and corticosteroid can be utilized. As discussed earlier, some evidence suggests that injecting the local anesthetic may provide an additional margin of safety. The minimum volume of injectate is dictated by the volume of contrast required to adequately cover the target structure, usually between 1.5–2cc.

During injection the patient might be aware of a pressure paresthesia, that is, paresthesia or dysesthesia into the lower extremity. If this is not severe, injection can proceed, and the patient queried on whether the paresthesia is in the same distribution as their usual pain, that is, concordant with, and notation of this made on the procedure note. If extreme pain is noted, slight repositioning of the needle may alleviate or lessen the discomfort and the procedure continued. If severe pain on injection continues after needle reposition, the procedure should be terminated.

POSTPROCEDURE CARE

Once the therapeutic agent has been injected, the needle is removed, skin cleaned of any blood and antiseptic preparation, and a sterile adhesive dressing applied. The patient is



FIGURE 17-35

Intraneural injection, probably into epineurium, during L5 transforaminal injection with intrathecal and possible subdural spread of contrast. (Courtesy of Michael Hammer, MD.)

then taken to a recovery room where he or she is observed by trained personnel with physiologic monitoring utilized. Any complications must be diagnosed and managed in a timely and appropriate manner. Unless a problem is noted, a recovery period of 30 minutes is adequate in most instances. Assistance with initial standing and walking is prudent given the possibility of motor blockade secondary to local anesthetic.

Prior to discharge, and during the period between the time of onset and duration of the local anesthetic, the patient is evaluated as to any change in the preprocedure pain. Assessment must include provocative movements that elicited pain prior to the procedure. A neurologic examination to document neurological changes, such as numbness in the L5 dermatome or weakness in extensor hallucis longus, validates the procedure. If a local anesthetic was utilized and no reduction of pain realized, either a technical problem exists or the diagnosis must be reconsidered. This assessment must be included in the procedure note.

CLINICAL APPLICATION

The sole indication for lumbar transforaminal injection of corticosteroids is treatment of radicular pain. Patient response dictates whether repetition of the injection is justified. If no relief is noted in the immediate postprocedure period and local anesthetic of an appropriate concentration was utilized, the diagnosis must be questioned and possibly a different transforaminal level targeted at a future session or further evaluation considered. When greater than 70% pain relief is noted in the immediate postprocedure period, it can be assumed that this is in response to the local anesthetic effect on the pain generator. A positive corticosteroid response might then be considered if the patient were seen to benefit from the injection for days to weeks. Transforaminal injections should be repeated no more often than at 7-day intervals and limited to a maximum of 3 within a 6-month period. Patients responding to transforaminal corticosteroid injections require an average of approximately two injections (19–22).

SUMMARY

The literature indicates that nonfluoroscopically guided interlaminar, transflaval, epidural injection of corticosteroids is of little or no value in the treatment of “sciatica,” that is, lumbar radicular pain (23,24). On the other hand, several papers have left little doubt that transforaminal injections provide long-term benefit in the same patient population (19–22). As with all spinal injections, there can be significant risks involved with transforaminal epidural injections. However, these risks are well managed if meticulous technique and due diligence are prac-

ticed by well-trained physicians. Today, transforaminal injections should always be considered the treatment of choice for lumbosacral radicular pain when conservative measures have failed and prior to surgical intervention. This procedure should no longer be thought of as “special” or exotic; rather, it must be considered as fundamental and within the armamentarium of all physicians who claim to practice standard of care for interventional pain management.

LUMBAR SPINAL NERVE BLOCK

HISTORY

Diagnostic lumbar spinal nerve blocks are used to evaluate the cause of sciatica in patients reporting lower extremity pain.⁴¹⁻⁴⁹ In these patients, the precise mechanism is not always clear and the MRI may not reveal the etiology since it provides only anatomic information.^{42,48} Alternatively, nerve root damage seen on an MRI may not be the cause of the pain. To further elucidate the pain generator, diagnostic lumbar spinal nerve root block has been advocated.⁴¹⁻⁴⁹ The procedure involves anesthetizing the affected nerve root with a small amount of local anesthetic in order to determine the patient's response. If the pain is relieved, this supports the hypothesis that the suspected nerve is causative. If the pain persists despite successfully anesthetizing the targeted nerve, then the hypothesis is refuted.⁵⁰ MacNab et al.⁴⁵ first reported on the technique of selective nerve root injection in 1971. Since that time it has been used extensively as a physiological means of evaluating the etiology of sciatica.

Prior to the pervasive use of fluoroscopy, the procedure was performed by contacting the ventral ramus of the spinal nerve outside of the intervertebral foramen. Performance of this procedure involved contacting the nerve and resulting in a radicular dysthetic sensory complaint by the patient. Refinements in fluoroscopic techniques led to modification of the target to contact the spinal nerve where it lies within the intervertebral foramen.⁵⁰ The advantage of this approach is that it lessens the risk of needle trauma to the nerve root.

ANATOMY

There are five paired lumbar nerves that exit their respective foramina from the L1-L2 to the L5-S1 levels.⁵¹ Rootlets come off the dorsal and ventral surface of the spinal cord to form the dorsal and ventral nerve roots.^{51,52} These join to form the spinal nerve in the region of the intervertebral foramen. The spinal nerve is relatively short and immediately divides into anterior and posterior primary divisions.^{51,52} Just as the orientation of the lumbar zygapophyseal joints differ from L1-2 to L5-S1, the lumbar

nerves exit their respective foramina at different angles from L1 through L5.⁵³ At L1 the nerves exit downwards and forward at an acute angle, whereas at L5 the nerves exit somewhat horizontally and at a more obtuse angle (Figures 17-36).

Located in the upper aspect of the foramen is a quadrant known as the safe triangle.⁵⁰ A needle placed in this location will allow infiltration of the nerve without risk of injury to other structures including the exiting nerve root. The safe triangle has an imaginary base tangential to the pedicle, a side in line with the outer margin of the intervertebral foramen, and a hypotenuse formed by the spinal nerve in an AP view (Figures 17-1 and 17-2).

The anatomy of the arterial system is important when performing spinal injections because some of the vessels that supply the spinal nerve roots also anastomose with the anterior spinal artery (Figure 17-37).⁵² Injection into the medullary artery has been discussed previously. Injection of particulate corticosteroid preparations appears to be the cause of the severe neurological complications seen.^{49,54,55} However, corticosteroid use is not indicated in this purely diagnostic procedure. In a single case report, injection into a cervical medullary artery has been postulated as the cause of temporary paralysis secondary to local anesthetic effect on this cord.⁵⁶

INDICATIONS

Conservative treatment options should be tried and have failed to produce a benefit before considering this procedure, although no conservative treatment has been proven to provide definitive benefit.^{47,50} Patients should not be considered for this procedure until 6 weeks have passed

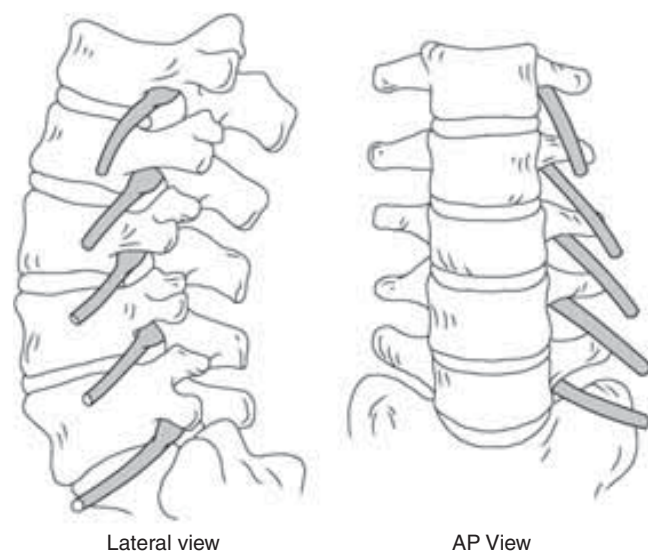


FIGURE 17-36

Direction of the lumbar nerve roots as they exit the foramen.

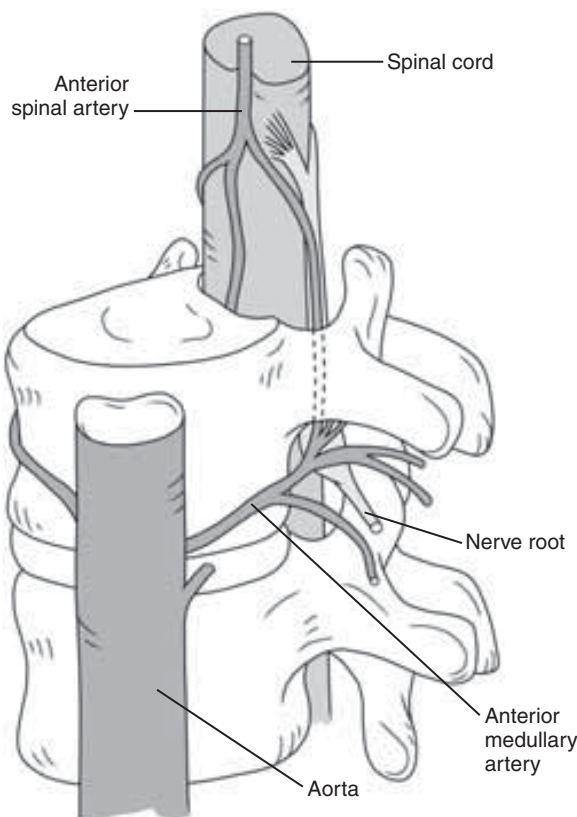


FIGURE 17-37
Anterior medullary artery.

since the onset of symptoms. The majority of patients will have healed during this time. Those who have not may require a more invasive approach.

The indication for diagnostic lumbar or sacral spinal nerve block is to investigate the cause of radicular symptoms in the following patients:

- Imaging studies implicate more than one nerve as a possible cause of the symptoms.
- Imaging studies are difficult to interpret due to previous surgery.
- Clinical features do not suggest a specific spinal segment.
- Clinical symptoms suggest radicular involvement, but the MRI appears “normal.”^{41,42,48,50,52}

Contraindications, equipment, and pre-procedure testing have been discussed previously.

DRUGS

- Water-soluble, nonionic contrast such as Iovue or Omnipaque 200 or 240
- Preservative-free local anesthetic such as 2 or 4% lidocaine or 0.5 or 0.75% bupivacaine
- 1% lidocaine to anesthetize a skin wheal

PREPARATION OF PATIENT

Informed consent should be obtained prior to the procedure.

History

The patient will commonly complain of pain, numbness, tingling, or paresthesia confined to one or two dermatomes. Weakness may also be noted. The pain is most often felt in the lower extremity if the lower lumbar or upper sacral nerve roots are involved. The pain travels in a narrow band and is burning, shooting, or lancinating in nature. The pain is more often below the knee and above it, and it is felt both deep and superficially in the involved extremity.⁴¹

Physical Exam

The following exam findings may be seen alone or in combination:

- Dural tension signs (positive straight leg raise, femoral stretch, etc.)
- Weakness in the involved muscle groups
- Numbness or hypoesthesia to touch or noxious stimuli
- Decreased reflexes

Imaging and Neurodiagnostic Studies

- MRI or CT should be done in all cases of suspected radicular pain or radiculopathy.
- EMG can be helpful to differentiate radicular from peripheral neuropathy.

Preprocedure Medication

As discussed previously, sedation is rarely medically indicated or required. In that selective spinal nerve blocks are utilized to obtain diagnostic information by reduction of pain immediately post-procedure, no analgesics should be administered pre-, peri-, or post-procedure.

PROCEDURE

Patient Positioning

See previous discussion.

Technique

The target for a lumbar selective nerve block is above the nerve with the needle tip located at the six o'clock position relative to the pedicle when seen in an AP view.⁵⁰ The procedure is performed by first squaring the inferior vertebral end plate and then rotating the image intensifier into an oblique position toward the affected side until the target point is not obstructed by the superior articular process, lamina, or transverse process (Figure 17-38). This

**FIGURE 17-38**

This image shows the starting position for the needle on the skin. Note the location of the pedicle just inside the border of the vertebral body. Also note the location of the superior articular process approximately one third of the way across the end plate of the vertebral body. This serves as a visual guide for the correct amount of obliquity.

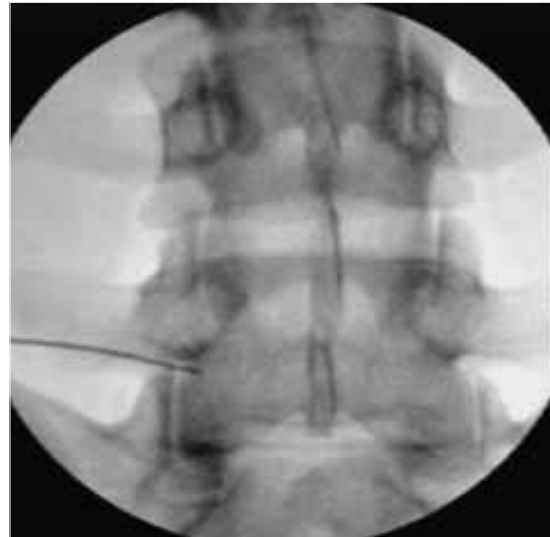
usually requires that the C-arm is obliqued until the pedicle is seen at or just inside the shadow of the vertebral body (about 20–25 degrees) (Figure 17-39).

The skin is anesthetized, and the needle is advanced down the x-ray beam toward the superior aspect of the foramen. As the needle is advanced, rotating into an AP projection and visualizing the extent of medial

**FIGURE 17-39**

This shows the final needle position in the safe triangle.

placement helps to determine needle depth. If further insertion is required, rotate back to an oblique view 6 o'clock and advance. Continue to advance and check depth until the needle tip is located at the 6 o'clock was previously used position relative to the pedicle (Figure 17-40). A lateral view is then checked (Figure 17-41). The needle tip should appear in the superior aspect of the foramen. Ideally, the tip should appear in the middle of the foramen in the anterior posterior or parasagittal plane. This way, the tip is located slightly dorsal to the location of the anterior medullary artery as it enters the foramen.

**FIGURE 17-40**

This is an anteroposterior view with the needle tip located at the 6 o'clock position.

**FIGURE 17-41**

This is a lateral view showing the needle tip slightly posterior to the vertebral body. This avoids contact with the anterior medullary artery as it enters the foramen.

Confirm needle placement by injection of a small amount (<0.5 ml) of contrast medium under live fluoroscopy. The usual volume should not exceed 0.5 ml or the injection may lose specificity for a single nerve. A short IV extension can be attached to the needle hub for this purpose. The injectionist should be watching for a wisp of dye spreading into the central canal (indicating uptake by an anterior medullary artery) while the x-ray is on (Figure 17-42). The dye pattern should outline the spinal nerve root (Figure 17-43). The dye should not spread distal to the edge of the vertebral body or more proximal than the superior aspect of the pedicle (Figure 17-44). This pattern ensures that the injection is specific to the involved spinal nerve root (Figures 17-45 to 17-50). The injection should be terminated if dye is seen spreading into the central canal or into the intrathecal space to prevent serious complications. The needle should be repositioned if venous uptake is seen, since this finding indicates that the injectate instillation is intravascular rather than into the desired foraminal location and would interfere with the diagnostic utility.⁵⁷⁻⁵⁹

The volume of local anesthetic injected should correspond to the volume of dye used. For example, if 0.3 ml was seen outlining the nerve, then no more than 0.3 ml of local anesthetic should be injected. The most commonly used anesthetics are 0.5 or 0.75% bupivacaine or 2% or 4% lidocaine. Assuming that the injected local anesthetic contacts the targeted nerve, it should relieve symptoms if the nerve is responsible for production of the patient's symptoms. This can be ensured by observing that contrast dye outlines the targeted nerve. To ensure that the anesthetic does not spread to adjacent structures, a low volume (less than 0.5 ml) should be used. In a study using CT scanning to analyze the percent of patients



FIGURE 17-43

This is the lateral view after dye injection showing dye spreading within the epidural space but not extending to the foramen above.

showing spread of dye into the lumbar plexus, the group who received the lowest volume of dye (0.5 ml) had the fewest number of patients who exhibited spread to the lumbar plexus compared to with those who received more (1–2 ml).⁴⁹

COMPLICATIONS

Bleeding and infection are commonly listed but rare complications. Mechanical nerve root damage can occur if the needle inadvertently contacts the nerve. Starting in



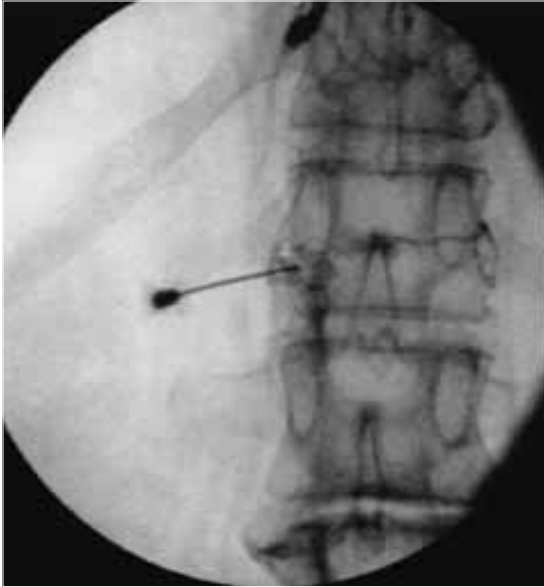
FIGURE 17-42

This shows dye outlining the nerve, but not extending laterally beyond the pedicle or superiorly beyond the border of the vertebral body.



FIGURE 17-44

This shows postinjection dye spread. Again, note that the dye does not extend beyond the image of the pedicle superiorly.

**FIGURE 17-45**

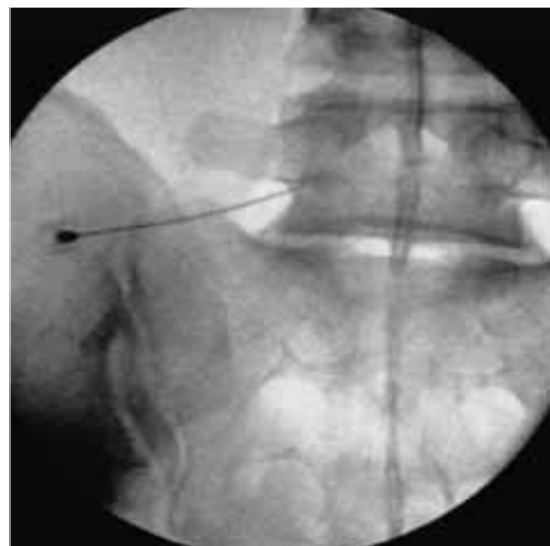
This shows dye filling veins within the epidural space. Injection here could not be considered diagnostic.

**FIGURE 17-47**

This shows a needle being advanced down to the superior articular process that is rather large and is obstructing passage of the needle.

**FIGURE 17-46**

This shows dye filling the dural root sleeve and extending into the intrathecal space. Note the smooth appearance of the dye and the fact that it appears on both sides of the spine.

**FIGURE 17-48**

This shows an anteroposterior view prior to dye injection.

too oblique a position can result in intrathecal placement of local anesthetic, resulting in temporary lower extremity paralysis. Intrathecal placement may also occur if the needle is advanced beyond the 6 o'clock position in a patient with long dural root sleeves. Another uncommonly encountered complication is placement of the needle tip into the facet joint in those patients with a

large superior articular process. Minor complications include facial flushing, nonpositional headache, leg pain, vasovagal reaction, back pain, and intraoperative hypertension.⁴⁹ Complications arising from injection of the medullary artery have been discussed previously, but have never been noted with injection of local anesthesia alone.

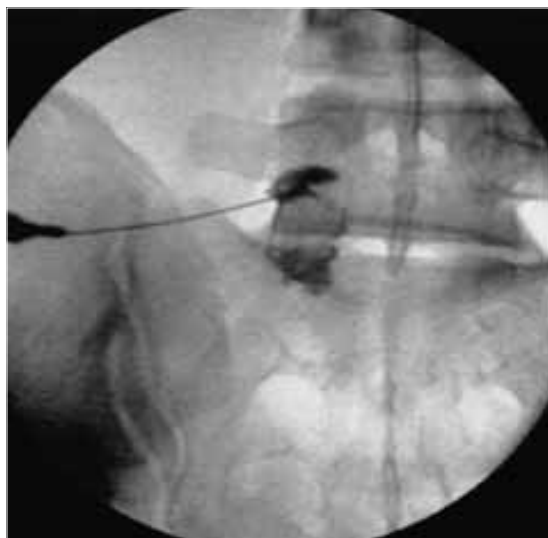


FIGURE 17-49

This shows an anteroposterior view of the dye outlining the facet joint.

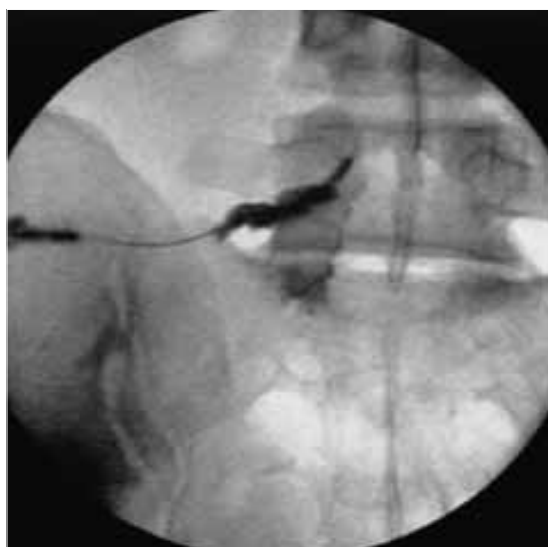


FIGURE 17-50

This is an anteroposterior view of the dye injection after slightly advancing the needle outlining the facet joint and nerve root. This can be avoided by angling the C-arm more steeply (to square the inferior end plate). This would throw the superior articular process inferiorly enough to allow passage of the needle.

EFFICACY

In a study examining the positive predictive value of the procedure, 62 patients who had undergone lumbar spinal nerve root block were explored at surgery.⁴² Eighty-five percent of patients whose pain was relieved by the procedure showed pathology at surgery. The ISIS guidelines state that this implies that the false-positive rate of lumbar nerve blocks is low and, therefore, the specificity is

high. In those patients with negative response to lumbar nerve block who underwent surgery, pathology that was found involved multiple levels or anomalous nerve roots. The ISIS guidelines report on another study measuring sensitivity by performing spinal nerve blocks in 46 patients with clinical and radiological evidence of nerve root compression subsequently confirmed at surgery.⁵⁰ The sensitivity was reported at 100%, with 95% confidence intervals of 88–100%. The same study estimated specificity by performing blocks in 23 patients at asymptomatic nerve levels. No false-positive responses were noted, and the authors concluded that the specificity was approximately 90%.

LUMBAR DISCOGRAPHY

There is no doubt that the lumbar intervertebral disc can hurt and has the necessary innervation to be a clinically significant source of pain.^{60,61} Discitis provokes excruciatingly intense pain, and probing disc protrusions during awake surgery is painful.⁶² What is controversial is not whether the disc is a source of pain, but whether disc pain can be reliably diagnosed.

Regardless, discography is the only available means for diagnosing lumbar discogenic pain. Because discography is a provocation test requiring reproduction of the patient's pain by stressing the disc with an injection of contrast medium, the response is dependent on the intensity of the provocation stimulus. In addition, the response is subjective and therefore there may be confounding factors other than the intensity of the stimulus. Since its introduction in 1948,⁶³ discography has been mostly evaluated without stipulating or requiring how strongly the disc is stimulated and often without requirements of the intensity of required provoked pain. Taxonomically unsound, emerging standards require unambiguous operational criteria that establish a threshold intensity for both pain response and stimulation intensity. Both require a precise method to apply the stimulus and strict criteria for interpretation.

PATIENT SELECTION

Discography was first used to diagnose protrusions in preparation for surgical interventions in patients with radicular pain.^{63,64} Prior to the introduction of CT in the 1980s, and later MRI, plain film x-ray and myelography were the only imaging studies available to assess pathology in the spine. Since myelography could only evaluate the thecal sac, dural root sleeves, and structures within the dural sac, lateral protrusions could not be visualized. Since Lindblom first advocated the use of discography to diagnose disc protrusions, modern imaging techniques have made this indication obsolete and interesting only from a historical perspective.

Discography is not an initial screening examination. Disc stimulation follows failed conservative treatment modalities and is only used when other less invasive diagnostic tests are inconclusive. Discography is highly invasive, and irreversible surgical procedures may be chosen based on the results.

Indications

The primary purpose of discography is to examine the intervertebral disc by mechanical stimulation to help determine whether or not the disc is painful and to evaluate the extent of internal annular or end-plate disruption. Inclusion criteria include the following:

- Failed conservative treatment for low back pain of probable spinal origin.
- Pain has been ongoing for more than 3 months.
- Other pain generators have been ruled out.
- Symptoms are clinically consistent with disc pain.
- Symptoms are severe enough to consider surgery or percutaneous interventions.
- Surgery is planned, and the surgeon desires an assessment of the adjacent disc levels.
- The patient is capable of understanding the nature of the technique and can participate in the subjective interpretation.
- The patient needs to know of the source of his or her pain.

Contraindications

Contraindications are summarized below.

- Patient is unable or unwilling to consent to the procedure.
- Inability to assess patient response during the procedure.
- Inability of patient to cooperate.
- Known localized or systemic infection.
- Pregnancy.
- Anticoagulants or bleeding diathesis.

Relative contraindications to discography follow:

- Allergy to contrast medium, antibiotics, or local anesthetics.
- Significant psychological overlay.
- Any other condition, medical, anatomical or psychological, that would increase the risk of the performance of the examination to unsafe levels.

PROCEDURE CONSIDERATIONS

A medical history is taken and a physical examination is performed to ensure the discographer that there are no contraindications and the patient is an appropriate candidate for the procedure. If intravenous sedation is to be utilized, NPO (no oral intake) status is verified according

to institutional guidelines. In females of childbearing age, pregnancy must be ruled out.

If the patient has a history of allergies to nonionic water-soluble contrast media iohexol or iopamidol, or other drugs, the risks versus benefits of the procedure must be weighed and discussed with the patient. In the case of iodine allergies, one can pretreat patients with corticosteroids and H1 and H2 blockers prior to the procedure. If the risk of allergic reaction to contrast is significant, saline instead of contrast can be used, or add a very small amount of gadolinium to the saline and obtain an MRI directly after the procedure.^{65,66}

Informed consent should include discussion of the purpose of the procedure, risks, complications, and alternative diagnostic tests. Patients should be told that the procedure is potentially painful, and during the stimulation of the disc, a description of this discomfort will be required in regards to concordance and intensity as compared with their ongoing complaint.

Intravenous access is standard. Because disc space infection is the most common complication, prophylactic antibiotic (cefazolin 1 g, gentamicin 80 mg, clindamycin 900 mg, or ciprofloxacin 400 mg) is administered intravenously within 30 minutes of needle insertion. Aminoglycosides are not needed for postprocedural prophylaxis.⁶⁷ In sheep studies, Fraser et al.⁶⁸ noted antibiotic levels in the annulus 30 minutes following intravenous administration, but none were demonstrated at 60 minutes. In addition to intravenous antibiotics, many discographers mix between 1 and 6 mg per milliliter of cefazolin or an equivalent dose of another antibiotic with the contrast injected into the disc.⁶⁹⁻⁷² Klessig et al.⁷² note that cefazolin and gentamicin 1 mg/cc, and clindamycin 7.5 mg/cc, exceed the minimum inhibitory concentrations (MICs) for the three most common organisms implicated in discitis, *Escherichia coli*, *Staphylococcus aureus*, and *Staphylococcus epidermidis*.

Intravenous sedation will increase patient compliance during the procedure. Medications are titrated according to the patient's response to avoid oversedation during the testing phase. Intravenous midazolam provides effective sedation during discography in doses between 2.0 and 5.0 mg, but often causes amnesia, which may or may not be a desired consequence. The ultra-short-acting hypnotic, propofol, is used by many injectionists who have an anesthesia background. Propofol produces rapid sedation and amnesia during the needle insertion, but due to the short half-life, the patient can be awake when the discs are stimulated. Patients should be fully monitored and personnel competent in airway management and resuscitation should be present during the procedure. General, epidural, or spinal anesthesia is inappropriate.

How much and which drug to use for preoperative sedation varies depending on the discographer's convictions. Some discographers feel that opioids⁷³⁻⁷⁵ should not be utilized prior to or during discography,

unless the patient is taking chronic long-acting medications. Their reasoning maintains that since discography is a provocative test, pain intensity needs to be compared and quantified in relation to the patient's usual pain intensity, and opioid analgesics could attenuate a pain response and cause a higher rate of false negatives. On the other hand, others⁷⁶ argue that giving a small dose of analgesics (meperidine 50 mg, fentanyl 50 mcg, or morphine 5 mg) prior to the procedure will help decrease the rate of false positives in patients with clinically insignificant discogenic pain. Most discographers do, however, agree that patients who are taking narcotics regularly and have been NPO 6 hours prior to the procedure will have an exaggerated pain response if they are undergoing early narcotic withdrawal.

Discography can be performed in any procedure room appropriate for aseptic procedures. Safety concerns require imaging equipment that provides good visualization of the relevant spinal anatomy. One must be able to view the spine in AP, lateral, and oblique projections. Although bi-plane fluoroscopy can be utilized, most discographers use C-arm fluoroscopic units that allow the discographer to obtain fluoroscopic views without repositioning the patient. Most also use a radiolucent procedure table that can be raised and lowered as needed. Monitoring equipment should include pulse oximetry, noninvasive blood pressure, and EKG. Oxygen, airway supplies, emergency drugs, suction, and other resuscitation equipment and supplies should be immediately available. There should be adequate personnel to monitor the patient and operate the fluoroscope.

Sterile technique requires preparation of the skin and draping analogous to that used for surgery. Povidone-iodine 10% (Betadine solution), and/or DuraPrep (iodophor 0.7% and isopropyl alcohol 74%) is the preparation of choice. If the patient indicates allergies to the above, chlorhexidine and alcohol can be substituted safely. Standard draping is utilized to provide a sterile field and may include the use of sterile towels and fenestrated drapes as per the injectionist's preference. The procedure room staff should be dressed in clean clothes (scrub suits). Masks and surgical caps are mandated by anyone coming in close proximity to the sterile field. Many injectionists scrub, gown, and glove as for an open surgical procedure. The C-arm image intensifier should also be draped.

Although the history and physical examination can be used to select levels, most discographers select levels based on the appearance of the MRI T2-weighted images. Most will include any disc that has a decreased signal intensity on the T2-weighted image and will often include adjacent less degenerated disc as a control. Rarely is it necessary to inject more than four segments. When injecting, the patient should be blind as to the onset and level of stimulation.

TECHNIQUE

Prior to the late 1960s, disc puncture was performed using a posterior interpedicular, or transdural, approach. This technique is seldom utilized today because it requires puncture of the dura. A lateral, or extrapedicular, approach is now used,^{77,78} except in rare situations where anatomical variation or postsurgical changes prevent disc access using the lateral approach.

Although some physicians perform discography with the patient in a lateral position, most position the patient in a prone position with a bolster placed under the upper abdomen to slightly flex the spine and decrease the normal lumbar lordotic curve. Monitoring and light sedation are initiated. The lower thoracic, lumbar and upper sacral and gluteus regions are prepped and draped as discussed earlier.

The target disc is identified using an AP view (Figure 17-51). The image intensifier of the C-arm is then tilted in a cephalad-caudad direction until the subchondral end plate of the vertebral body, caudad to the target disc, is parallel to the x-ray beam. The subchondral plate will be seen as a line rather than an oval. To ensure against the patient mistaking the discomfort from needle placement for provoked pain secondary to disc stimulation, the disc is preferentially approached from the opposite side of the patient's usual pain. When the patient's pain is central, bilaterally equal, or there are anatomical variations that prevent disc puncture from

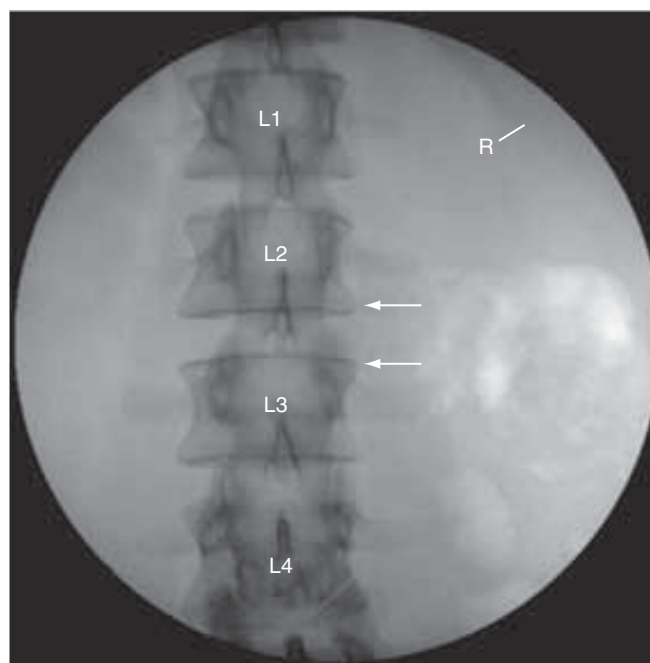


FIGURE 17-51

Anteroposterior view of lumbar spine. Arrows indicate end plates parallel to x-ray beam. R, 12th rib.

the contralateral side of the pain, needle insertion from either side is appropriate.

After squaring the end plate, the C-arm is rotated to an oblique view until the tip of the superior articular process (SAP) of the level below appears to lie under the approximate midpoint of the subchondral plate of the inferior end plate of the disc above (Figures 17-52 and 17-54). This positioning of the fluoroscope allows needles to be passed using “tunnel vision” (i.e., parallel to the beam when the skin puncture site is aligned with the target structure) just lateral to the SAP (Figures 17-53 and 17-59). The needle will travel under the segmental nerve, which courses medial to lateral, and dorsal to ventral, and will puncture the annulus fibrosus of the disc at the midpoint of the disc when seen in lateral and AP views (Figures 17-56 and 17-57).

Once the oblique view as described earlier is obtained, the skin is marked overlying the target (see Figure 17-52 and Figure 17-54). A skin wheal is made using a 25-gauge, 1.5-inch needle with lidocaine 1% (~1 cc). A 25- or 22-gauge, 3.5-inch needle is then advanced, using “tunnel vision,” that is, parallel to the x-ray beam, to the level of the SAP, and lidocaine (~4–5 cc) is injected while withdrawing the needle, creating an anesthetized track (see Figure 17-55). One should be careful not to anesthetize the dorsal root ganglion within the foramen. Besides obscuring nerve root impalement, the sinu vertebral and ramus communicans nerves will partially anesthetize the disc.

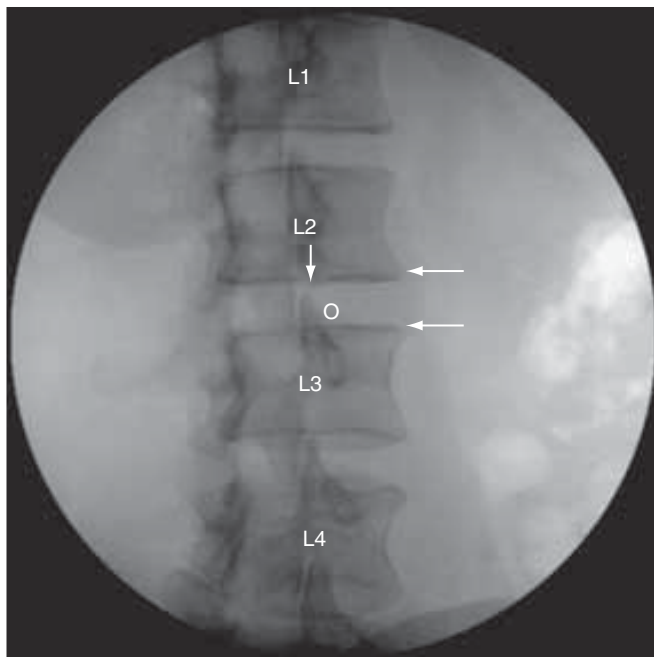


FIGURE 17-52

Right oblique view. Tip of the superior articular process (SAP) of L3 appears to lie under the approximate midpoint of the inferior end-plate of the L2 vertebral body (black arrow). Open circle represents target.

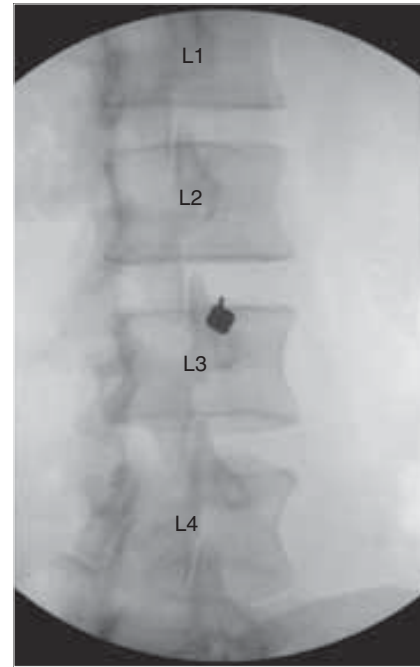


FIGURE 17-53

Right oblique view with introducer needle in place at L2-L3.

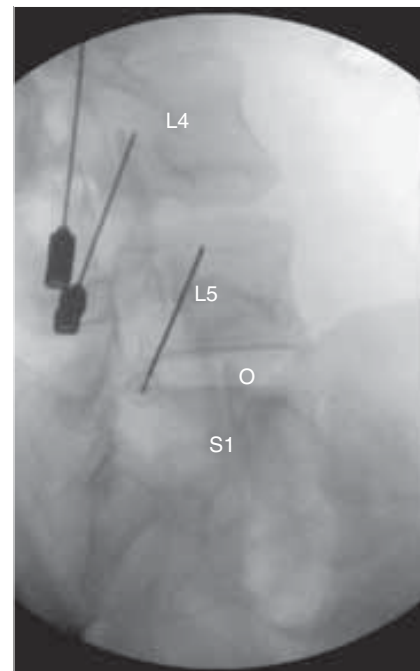
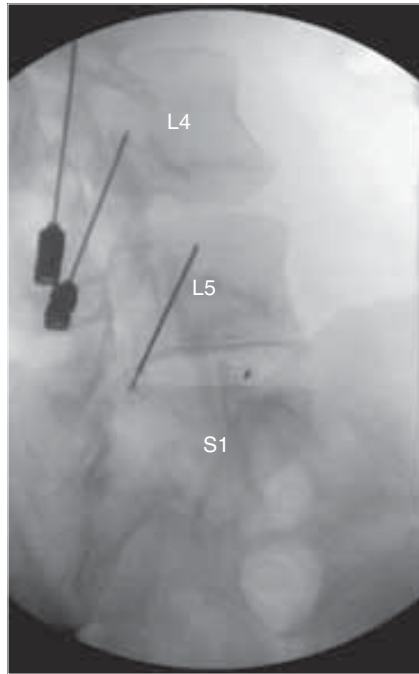
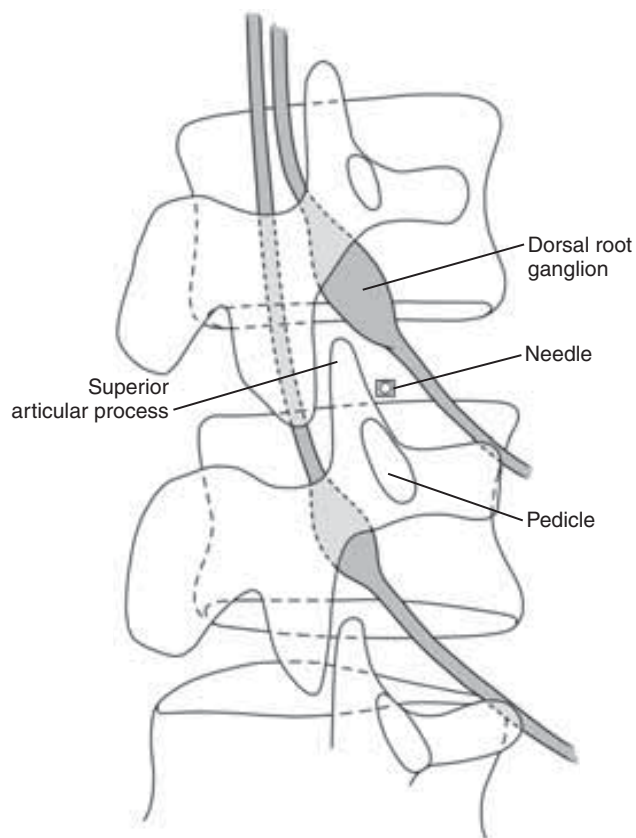


FIGURE 17-54

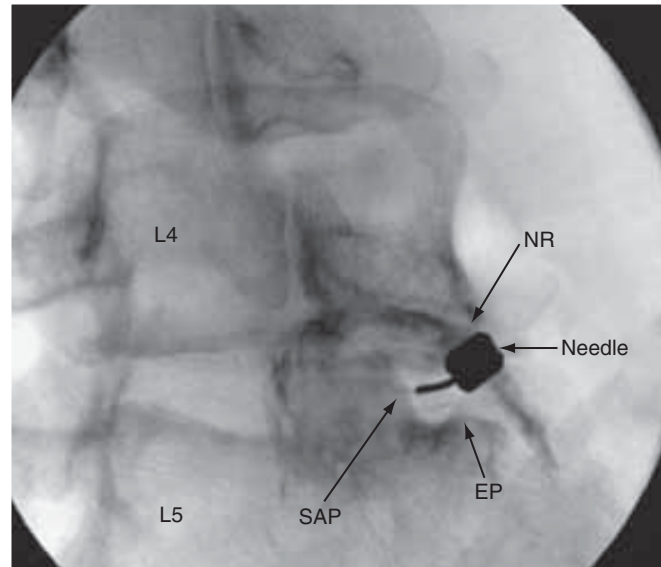
Right oblique view with end plates of L5-S1 parallel to beam. Superior articular process of S1 positioned as closely as possible to the midpoint of the inferior end plate of L5. Open circle indicates target. Introducer needles in place at L2-3, L3-4, and L4-5. Note differing angles needed to access each disc.

**FIGURE 17-55**

Right oblique view with end plates of L5-S1 parallel to beam. 25-gauge 3-1/2-inch spinal needle in place, parallel to beam, to anesthetize a track of tissue down to superior articular process level.

**FIGURE 17-56**

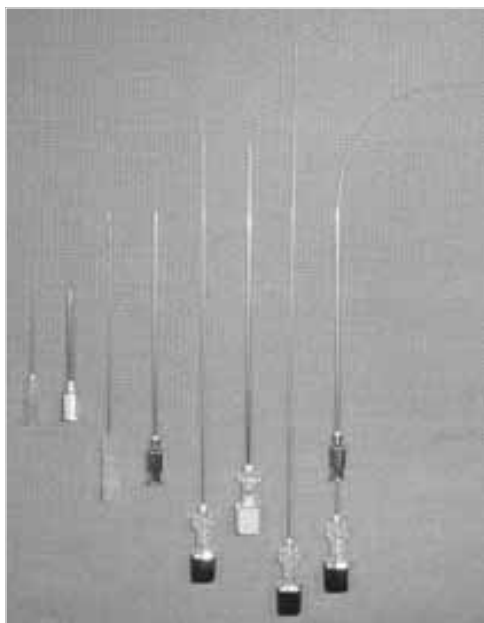
Course of segmental nerve running medial to lateral in close proximity to target. o, needle in position.

**FIGURE 17-57**

Needle in place at L4-L5 intervertebral disc following transforaminal injection of contrast. Note needle medial and caudal to segmental nerve. EP, superior end plate of L5; NR-L4, ventral ramus; SAP, superior articular process.

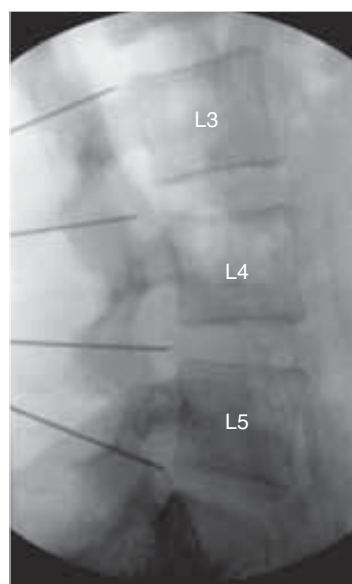
A one- or two-needle technique may be used. Prior to the routine use of prophylactic antibiotics, Fraser et al.⁷⁹ reported a rate of discitis with single nonstyletted needles of 2.7% versus 0.7% when a double-needle technique with stylettes was employed. Using a single styletted needle technique, Aprill⁷⁰ has reported one case of discitis in approximately 2000 patients (~0.05% per patient); however, both the North American Spine Society⁸⁰ and the International Spinal Injection Society⁷⁶ recommend a two-needle approach.

The two-needle technique utilizes a shorter, larger-gauge introducer needle through which a longer, smaller-gauge needle is advanced past the tip of the introducer needle and into the targeted intervertebral disc. The introducer needles are 18- or 22-gauge, 3-1/2 or 5 inches, while the complementary disc puncture needles are 22- or 25-gauge and 6 or 8 inches. The body habitus of the patient often dictates the combination of needles used at each level. Both the introducer and disc puncture needles should be styletted to prevent skin from being picked up and introduced into the disc. Many advocate a slight bend, opposite the bevel, placed at the tip of the disc puncture needle to enable the operator to control the course of (i.e., “steer”) the needle during advancement.⁸¹⁻⁸⁴ At times, a larger curve on the distal third of the disc puncture needle must be utilized to compensate for less than ideal anatomy or postsurgical change (Figure 17-58). The introducer needle is passed through the skin wheal at the skin puncture point, using a down-the-beam, “tunnel- vision” technique toward the disc entry site (see Figures 17-53 and 17-69). Forward advancement is stopped at the

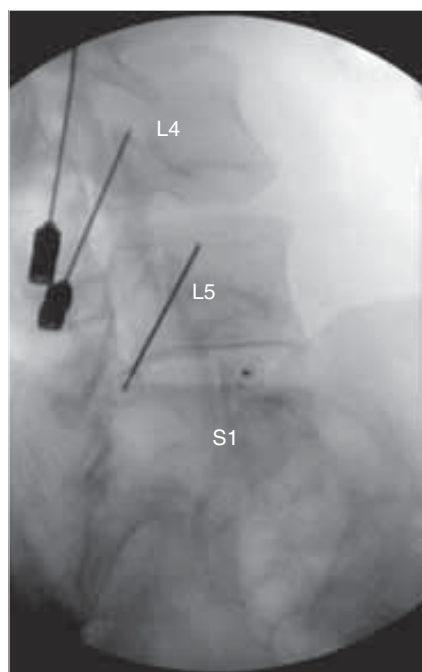
**FIGURE 17-58**

Needles utilized for discography. From left to right: 25-gauge 1-1/2-inch needle for skin anesthesia; 15-gauge, 1-1/2-inch needle for skin puncture; 25-gauge 3-1/2-inch for deeper anesthesia; 18-gauge 3-1/2-inch introducer; 22-gauge, 6-inch disc puncture with bend at tip; 18-gauge, 5-inch introducer; 22-gauge, 8-inch disc puncture with bend at tip; 22-gauge, 8-inch, curved disc puncture needle with marked curve through 3-1/2-inch introducer needle.

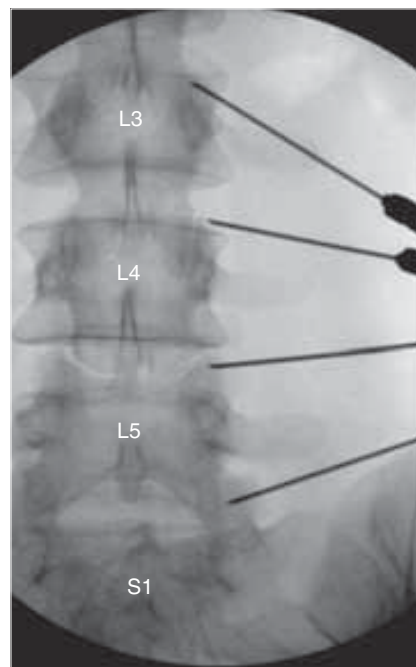
approximate level of the SAP, although placement within the foramen is acceptable. A lateral view with the fluoroscope is used to check needle depth (Figure 17-60). An AP view will indicate the needle tip as lying at the lateral extent of the intervertebral disc (Figure 17-61). The stylette is removed from the introducer, and the longer, smaller-gauge disc puncture needle is advanced slowly

**FIGURE 17-60**

Lateral view. All introducer needles in place, at or just ventral to the posterior elements.

**FIGURE 17-59**

Right oblique view. Introducer needles in place at L5-S1, L4-L5, L3-L4, and L2-L3. Note that correct placement of each introducer needle requires a different angle of entry.

**FIGURE 17-61**

Anteroposterior view. All introducer needles in place in close proximity to the lateral aspect of each intervertebral disc.

under active lateral fluoroscopy. The needle will be seen to transverse the intervertebral foramen, and firm resistance will be noted as the needle touches and enters the annulus fibrosis.

Because the ventral ramus crosses the posterior-lateral aspect of the disc in close proximity to the disc entry site, if at any point during advancement of the needles radicular type dysesthesia is noted by the patient, insertion of the needle is stopped, the needle is partially withdrawn, and its course is altered and redirected toward the disc. A slight bend of the tip on the disc puncture needle facilitates this change of direction (see Figure 17-58). If more aggressive direction changes are required, the introducer needle can be withdrawn and redirected as well. Often redirection of the needle in a more caudal medial direction will allow insertion of the needle under the segmental nerve.

After the annulus is contacted, using active lateral fluoroscopy, the needle should be advanced into the center of the disc, that is, into the nucleus pulposus. As the outer third of the annulus is abundantly supplied with nerve endings, some axial discomfort, with referral into the thigh or buttock, is often felt by the patient. AP and lateral projections are used to ensure good needle placement, and spot films are saved for documentation prior to injection of contrast (Figures 17-62 and 17-63).

Although the above technique can be utilized for disc puncture in more than 95% of lumbar disc levels, occasionally, due to anatomical variations (i.e., overriding iliac crest, osteophytes), or postsurgical changes (i.e., posterior intertransverse fusion mass or fusion hardware), variations in the procedure must be utilized.

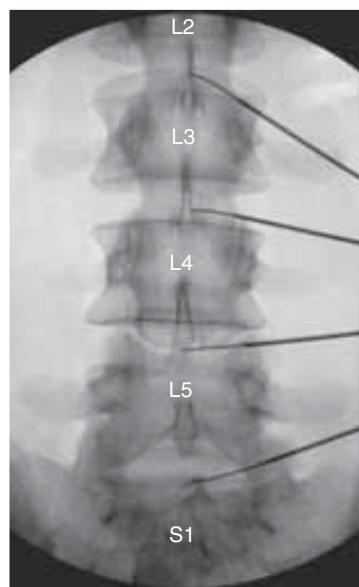


FIGURE 17-62

Anteroposterior view. Disc puncture needles verified as lying in the center, nucleus pulposus, of each intervertebral disc.

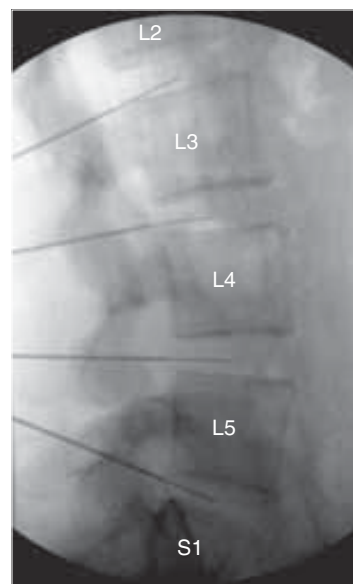


FIGURE 17-63

Lateral view. Disc puncture needles have been advanced under active lateral fluoroscopy into the center, nucleus pulposus, of each intervertebral disc.

A detailed description of the myriad modifications with which a discographer might be faced is beyond the scope of this forum; however, most involve either a more lateral or more medial needle insertion with the disc-puncture needle bent or curved to varying degrees (Figures 17-64, 17-65, and 17-66).

Rarely, the posterior interpedicular, transdural approach must be utilized to gain access to the disc

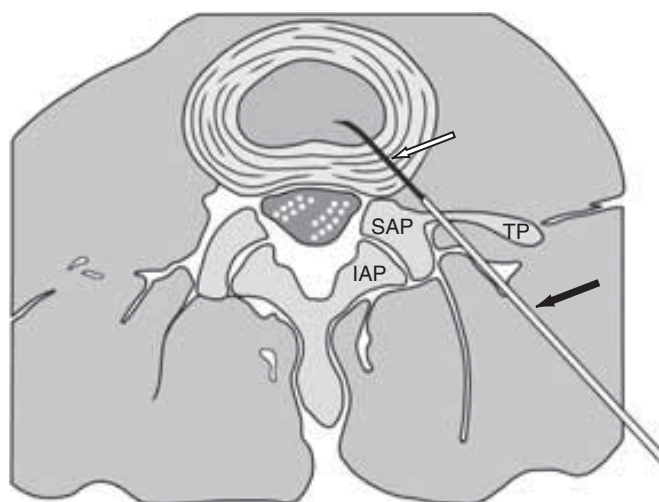
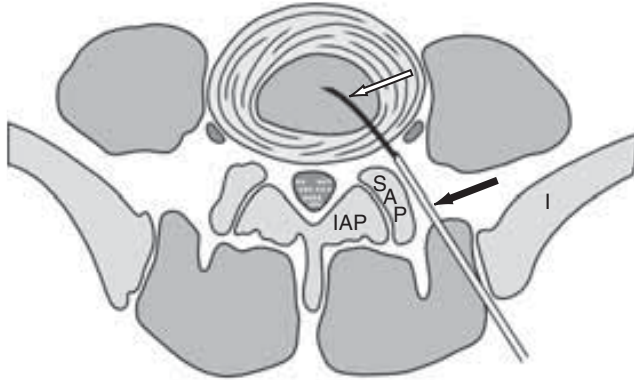


FIGURE 17-64

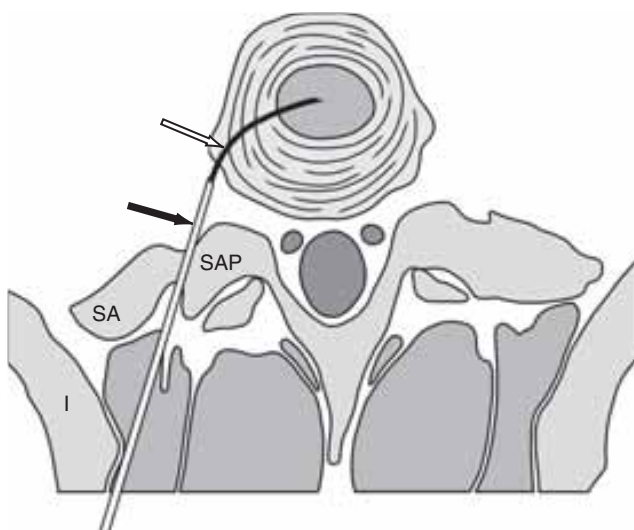
Straight approach to disc access. Small bend in distal 1 cm of disc puncture needle to aid in needle control. closed arrow, introducer needle; inferior articular process; open arrow, disc puncture needle with bent tip; SAP, superior articular process; TP, transverse process.

**FIGURE 17-65**

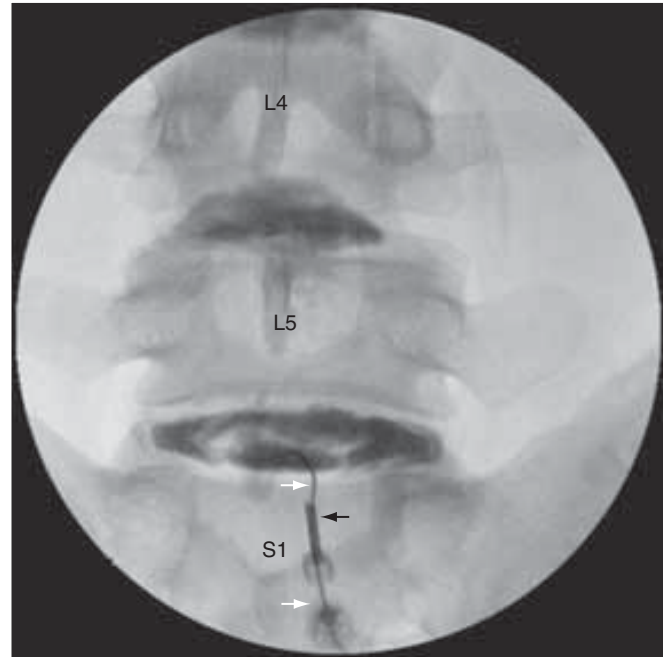
Moderate bend in needle utilized to gain access to disc nucleus. Closed arrow, introducer needle; I, ilium; IAP, inferior articular process; open arrow, slightly curved disc puncture needle; SAP, superior articular process.

(Figure 17-67). This approach increases the chance for morbidity since the dura is punctured twice. Risks and benefits of this technique must be weighed. At levels above the L3-4 intervertebral disc, the posterior approach should not be utilized since the chance of impaling the spinal cord is high.

Once all needles are positioned within the nuclei pulposi of the discs to be stimulated, injection can proceed. The patient should be blinded as to disc level and the initiation of the injection. At this point, the patient must be conversant enough to describe any sensations produced by the disc stimulation.

**FIGURE 17-66**

Significant curve on needle required to gain access to nucleus. Closed arrow, introducer needle; I, ilium; open arrow, curved disc puncture needle; SA, sacral ala; SAP, superior articular process.

**FIGURE 17-67**

Anteroposterior view. Posterior, that is, interpedicular or transdural approach to the intervertebral disc. Closed arrow, introducer needle, 18-gauge, 1-1/2-inch; open arrow, 22-gauge, disc puncture needle.

Only nonionic myelographic contrast agents (isohexol or iopamidol) with added antibiotic¹³ should be utilized. Using active fluoroscopy, the injectate is slowly injected into the disc. A manometer-syringe is preferred, but a 3-cc syringe is a much less-than-ideal substitute. Once the intrinsic or opening pressure of the disc is exceeded, contrast will be seen flowing into the disc nucleus. As the nucleus is filled, the disc space height is known to increase rather than axial cross-sectional area.⁸⁵ Pressure is applied slowly, in 0.5-ml aliquots, until one of the following four endpoints is noted: 3.5-ml volume is reached, significant pain is noted by the patient, epidural or vascular pattern is evident, or a maximum pressure of 90psi, or 50–70psi above opening (psi a.o.) has been reached.^{86,87}

During pressurization of the disc, parameters of the injection are recorded on a standardized form by procedure room personnel. The opening volume and pressure are recorded. At predetermined increments, personnel should record the volume injected, static and dynamic pressures, pain description (none, nonconcordant, concordant), vocal or physical patient pain response, pain intensity, and the observed contrast pattern as visualized in the AP and lateral fluoroscopic projections.

Although a 3-cc syringe and manual thumb pressure are still utilized by some, the emerging standard is to use a manometer to accurately quantify the opening pressure and the pressures generated during disc injection. When utilizing a 3-cc syringe, it is difficult to maintain digital (thumb) pressure of over 60–75 psi.⁷⁰ Therefore, with the 3-cc syringe technique (i.e., nonmanometric), pressures

can be described as low or high with a variable degree of accuracy. Although the exact quantification of pressure by manometry during provocation discography should be considered as the most appropriate technique, nonmanometric studies should not be automatically assumed to be invalid, but rather suboptimal and highly operator-dependent.

Anteroposterior and lateral images of all discs injected must be saved for a permanent record of the study. These images should include AP and lateral both pre- and post-contrast (Figures 17-68 to 17-72).

STRUCTURAL INTERPRETATION

In 1986, Adams et al.⁸⁸ described the contrast patterns seen on the lateral x-ray view of 139 cadaver spines after injecting contrast into the lumbar discs. In order of progressing disc degeneration, patterns were classified as cotton ball, lobular, irregular, fissured, and ruptured. They found that when contrast media is injected into the disc nucleus, contrast media first pushes the disc matrix aside and creates pools of fluid. Fluid then slowly mixes with the matrix caused by the swelling pressure of the hydrophilic proteoglycans and diffusion. Because mixing and diffusion are slow, the location of the pools depends on the degree of fibrosis of the nucleus and any fissures present in the annulus. In other words, the terminology describes successive degrees of degeneration visualized by the pooling of contrast.

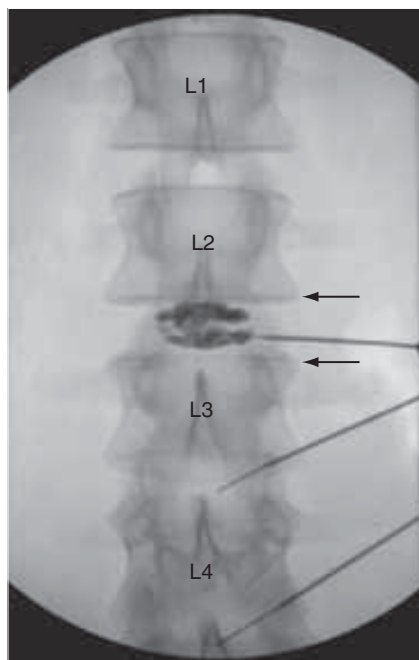


FIGURE 17-68

Anteroposterior view. Injection into L2-L3 intervertebral disc. Note that end plates are parallel to x-ray beam. Normal pattern of contrast.

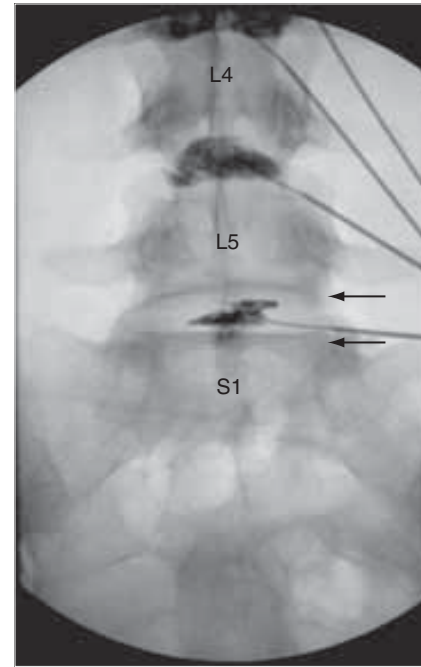


FIGURE 17-69

Anteroposterior view. Injection into L5-S1 intervertebral disc. Note that end plates are parallel to x-ray beam. Pattern not grossly abnormal.

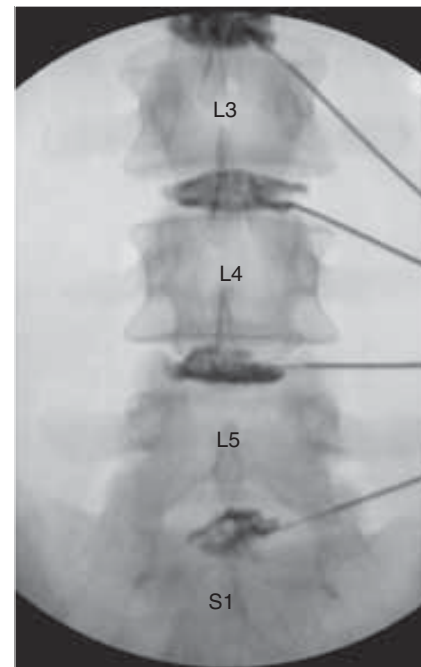
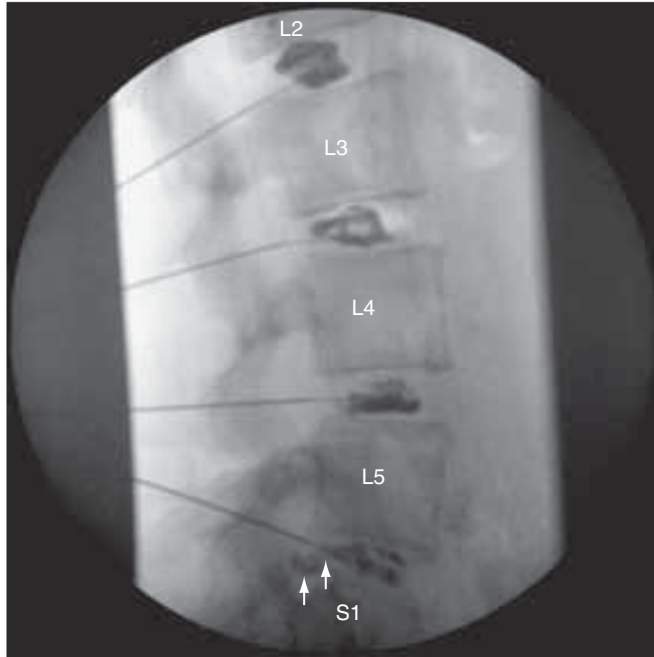


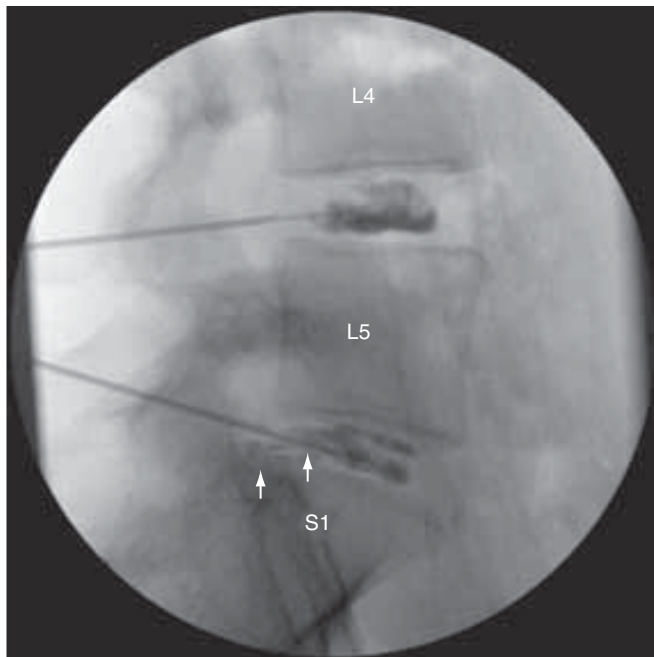
FIGURE 17-70

Anteroposterior view following injection into intervertebral discs. No gross pathology noted.

Although this descriptive classification is used to describe the contrast pattern seen on the fluoroscopy images during the discogram, a CT scan performed following contrast media injection provides the most detailed view of the internal disc architecture.⁸⁹ The extent of degeneration is described by dividing the disc as seen

**FIGURE 17-71**

Lateral view following injection into intervertebral discs. Note posterior annular disruption in the L5-S1 intervertebral disc.

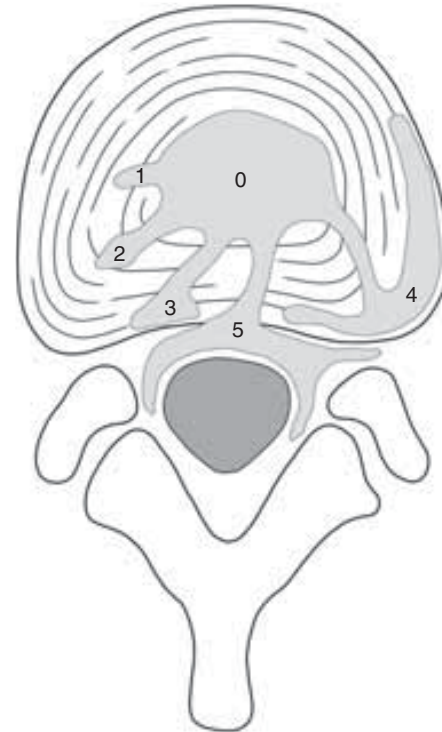
**FIGURE 17-72**

Lateral view with magnification. Note significant annular disruption at L5-S1 with associated protrusion. During stimulation of this intervertebral disc, marked concordant pain was noted by the patient at low pressure.

in an axial image into four quadrants.⁹⁰ If contrast is contained within the nucleus, then no quadrants are disrupted, but when disrupted the extent is described by indicating the location, such as single-quadrant, left posterior lateral; or two-quadrant disruption including the

right posterior lateral and right lateral quadrants. In addition to describing the extent, a grading scale is typically used to describe the degree of radial and annular disruption.^{90,91} As visualized on the axial CT images following discography, annular tears are graded based on how far radial annular fissures extend into the outer annulus, the degree of circumferential disruption, and whether there was rupture through the outer annulus (Figure 17-73). A grade 0 nuclear pattern indicates no annular disruption (Figures 17-74 to 17-77); grade 1 fissures are into the inner annulus only (Figures 17-78 and 17-79); grade 2 into the middle and outer annulus (Figures 17-80 and 17-81); grade 3 into the periphery, or outer third, of the annulus (Figures 17-82 and 17-83); grade 4 annular tear is a grade 3 annular tear with spread of contrast medium circumferentially within the substance of the annulus fibrosus, subtending a greater than 30-degree arc at the disc center (Figures 17-84 and 17-85); grade 5 annular tear represents spread of contrast through the outer annulus, and thus could involve either a grade 3 or grade 4 annular disruption (Figures 17-86 to 17-89).

When extensive disruption of the normal intervertebral disc architecture is present, no discrete annular tear(s) may be noted (Figure 17-90). Pain with disc stimulation may or may not be elicited.

**FIGURE 17-73**

Modified Dallas Discogram Scale. Grade 0—no annular disruption; grade 1—radial disruption into the inner third of the annulus; grade 2—contrast spread into the middle third of the annulus; grade 3—contrast into the innervated outer third of the annulus; grade 4—grade 3 with >30-degree circumferential tear; grade 5—spread of contrast into epidural space.

**FIGURE 17-74**

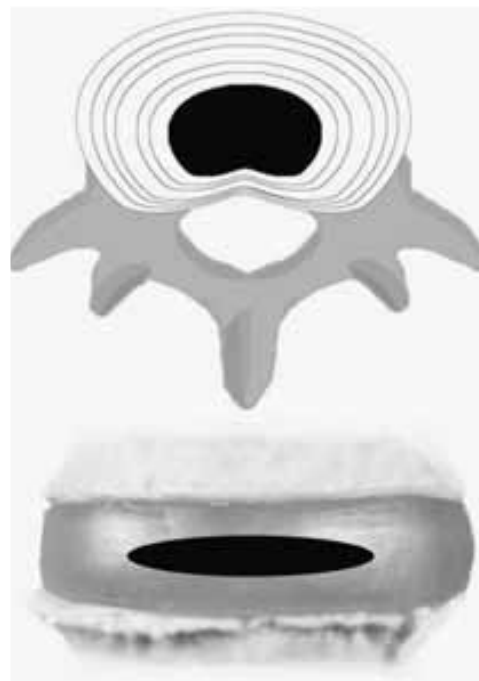
L2-L3, grade 0 with no disruption of the annulus. From postdiscogram study of Figures 17-68, 17-70 and 17-71.

**FIGURE 17-76**

L4-L5, grade 0 with no annular disruption. From postdiscogram CT of Figures 17-69, 17-70, 17-71, and 17-72.

**FIGURE 17-75**

L3-L4, grade 0 with no annular disruption. From postdiscogram CT of Figures 17-69, 17-70, and 17-71.

**FIGURE 17-77**

Axial and lateral illustrations of a grade 0 nuclear pattern.

The degree of annular disruption is important primarily as it relates to pain provocation during stimulation and therefore its possible likelihood of identifying a symptomatic disc. The relation between disc morphology and clinically significant discogenic pain is, however, controversial. The frequency of morphologic abnormalities revealed by discography in the back pain population is high and increases with age,^{92,93} putatively from painless degenerative changes.⁹³ Discrepancies between morphologic appearance and pain provocation have also been described.⁹⁴ Millette and Melanson⁹⁵ retrospectively reported that concordant pain was provoked by injection in only 37% of

patients with a morphologic abnormality documented by discography. Antti-Poika et al.⁹⁶ reported only a 52.8% concordant pain provocation rate in discs with discographically abnormal morphology.

While degenerative morphologic changes are not necessarily associated with a symptomatic disc, annular tears are associated with pain provocation during discography.^{86,97} Vanharanta et al.⁹³ found that pain reproduction during

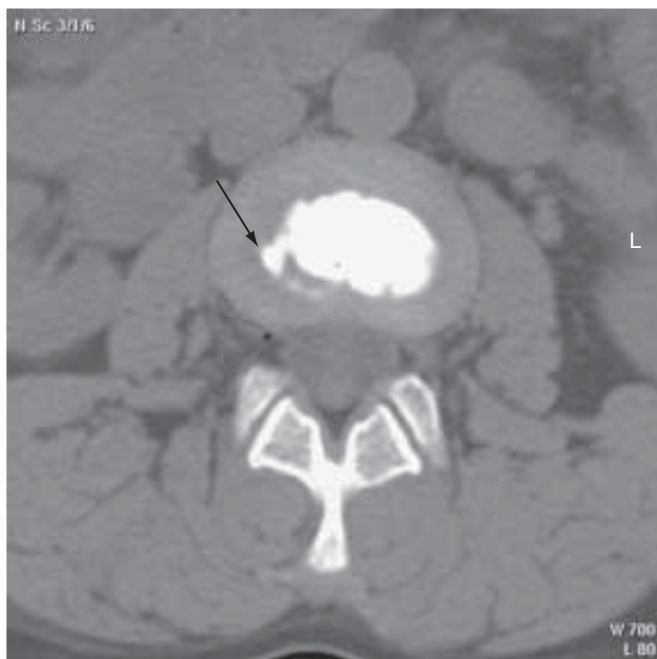


FIGURE 17-78
Grade 1 annular disruption. Contrast into medial third of the annulus.



FIGURE 17-80
Grade 2 annular disruption. Contrast into middle third of the annulus.



FIGURE 17-79
Axial and lateral illustrations of a grade 1 nuclear pattern.

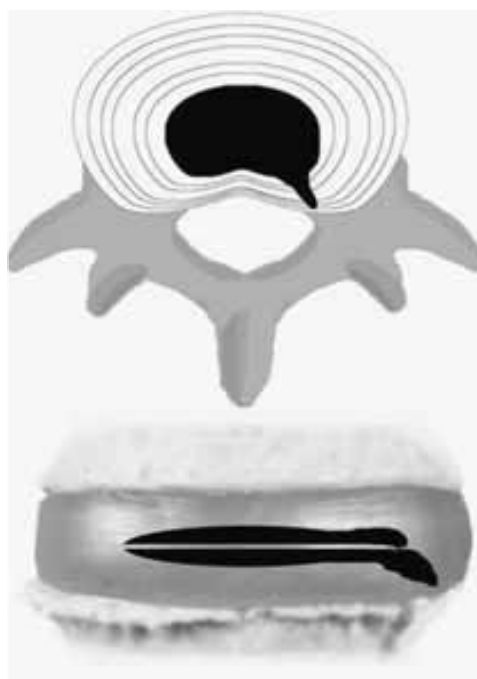
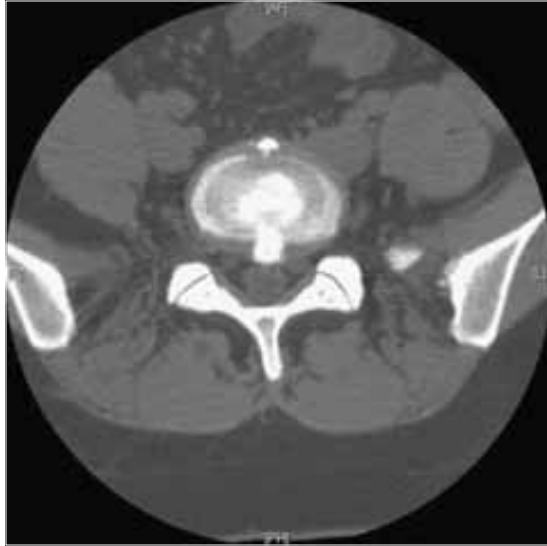


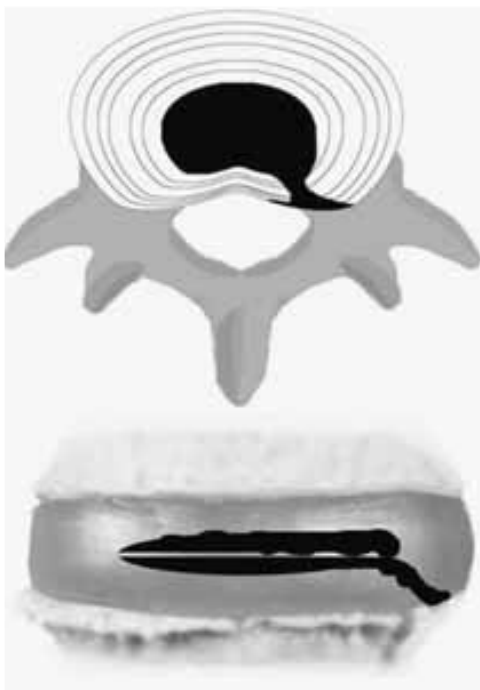
FIGURE 17-81
Axial and lateral illustrations of a grade 2 nuclear pattern.

**FIGURE 17-82**

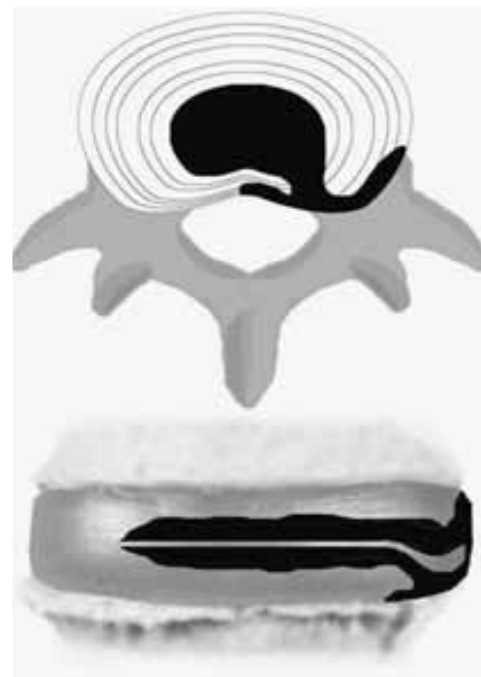
L5-S1, grade 3 annular disruption with associated protrusion. From postdiscogram CT of Figures 17-71 through 17-74.

**FIGURE 17-84**

Grade 4 disruption into the outer third of the annulus with >30 degrees circumferential tear.

**FIGURE 17-83**

Axial and lateral illustrations of a grade 3 nuclear pattern.

**FIGURE 17-85**

Axial and lateral illustrations of a Grade 4 nuclear pattern.

discography correlated with the extent of annular disruption. Grades 0 and 1 disruptions are rarely painful, but 75% of grade 3 disruptions were associated with exact or similar pain reproduction. Conversely, 77% of discs with exact or similar pain reproduction exhibited grade 3 annular disruptions. Grade 2 disruptions were less regularly associated with pain reproduction. Using strict criteria and pressure controlled discography, Derby et al.⁹⁸ similarly

showed a relatively high rate of symptomatic disc (94.6%, 88/93 symptomatic discs). Like the former study, they found that symptomatic disc rates in grades 1 and 2 discs were extremely low (2/93 and 3/93), respectively. Higher pain intensities were observed in grade 3–5 discs relative to grade 0–2 discs at the same pressure, and thus supporting the importance of annular disruption reaching the outer annulus for pain generation. Although not statistically

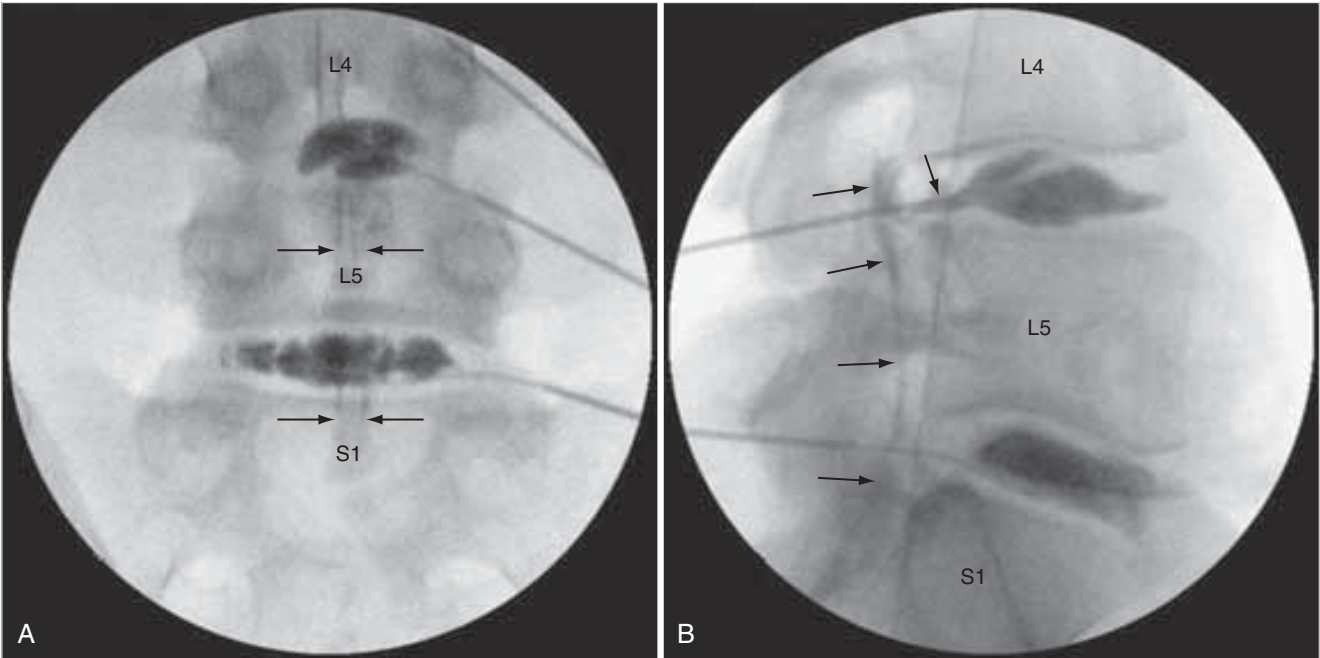


FIGURE 17-86
Grade 5 annular disruption L4-L5 with epidural spread of contrast.

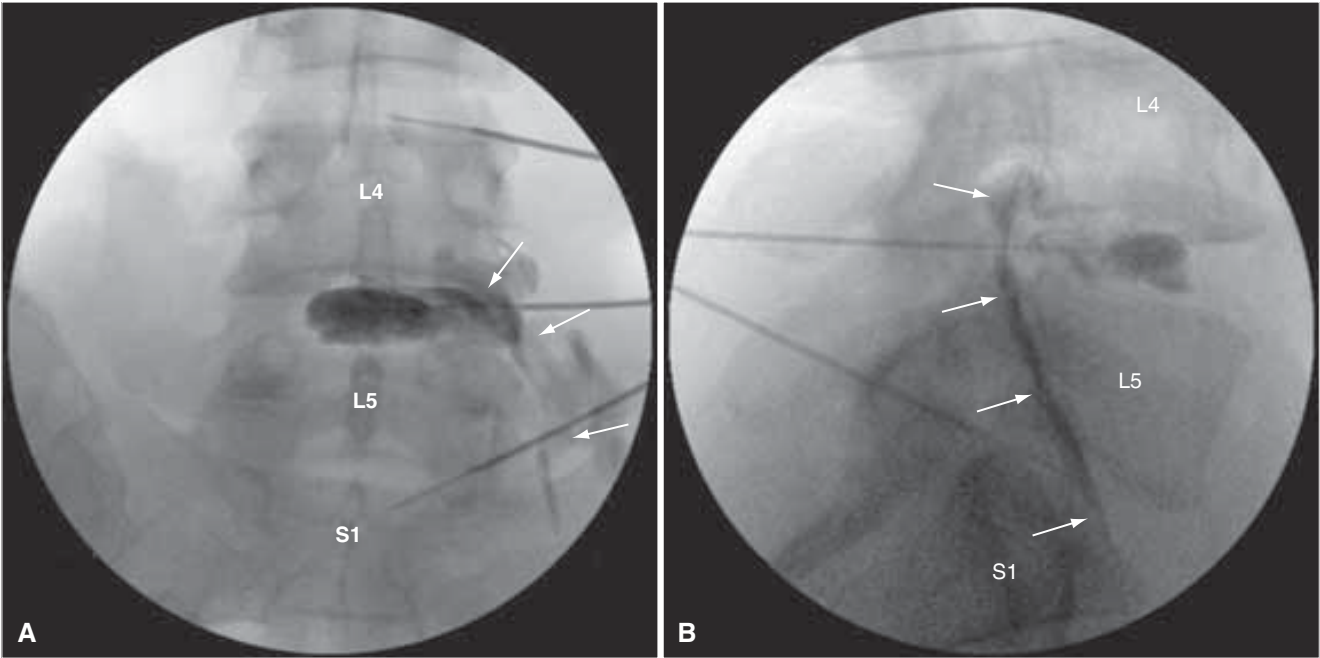
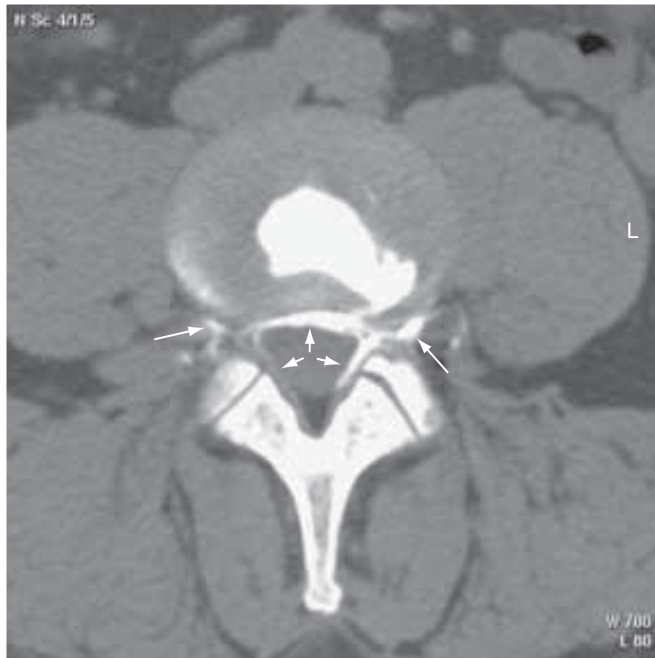


FIGURE 17-87
Injection into the L4-L5 intervertebral disc with foraminal spread of contrast, and an obvious radicular pattern. Might the inflammatory chemical milieu of the nucleus pulposus be causing the radicular pain noted in some patients without a comprehensive lesion?

**FIGURE 17-88**

Grade 5 annular disruption. Contrast seen to spread into the epidural space and foramen bilaterally secondary to full-thickness disruption.

**FIGURE 17-89**

Axial and lateral illustrations of a grade 5 nuclear pattern.

significant, there was more severe pain intensity with increasing pressure in discs with circumferential extension of tearing (grade 4) and contrast media leakage through the outer annulus (grade 5) than in discs with only radial tearing to the outer annulus (grade 3). Theoretically, more nocicep-

**FIGURE 17-90**

No discrete annular tear noted, but extensive disruption of normal internal disc architecture is present.

tive structures would be exposed in grade 4 and 5 discs than in grade 3 discs and thus might account for the increased intensity of pain provocation. Furthermore, leakage of contrast through the outer annulus could stimulate innervated structures outside the disc and should be taken into consideration when interpreting the results. In addition, discs classified as low-pressure sensitive (6 or greater concordant pain provocation at ≤ 15 psi a.o. pressure) showed no significant differences at each annular disruption grade; however, there was a decreasing rate of low-pressure sensitive discs with increasing annular disruption from grade 3 to grade 5 (62.5% at grade 3, 39.4% at grade 4, and 34.2% at grade 5).

Despite the strong correlation between annular tears and disc disruption in symptomatic patients, in asymptomatic volunteers undergoing discography, Derby et al.¹¹² found no correlation between pain and the extent of annular disruption. Although nearly all discs that were painful had a grade 3 annular tear, an equal number of such discs were not painful.

PROVOCATION STIMULUS

As defined by Bogduk, provocative discography is conceptually an extension of the physical examination, tantamount to palpating for tenderness. The stimulus is typically created by the injection of nonionic contrast medium that provides a distending force on a fissured annulus and end plates. How closely this stimulus mimics a physiologic load on the disc is speculative. Normally compressive loads are placed on the disc. A healthy, well-hydrated nucleus buffers these loads by tensing the surrounding inner annulus, but in a

“degenerated” disc the dehydrated and fragmented nucleus becomes ineffective and the compressive loads are transferred to the middle and innervated outer annulus and longitudinal ligaments.

Lee et al.⁹⁹ studied the pressure effects on the nucleus and outer annulus in pig cadaver discs. Using two pressure transducers, they measured the differences in pressure patterns between the nucleus pulposus and the outer third of the annulus fibrosis during intradiscal injection both in the intact annulus and after making a grade 2 to 3 annular tear. When the annulus was intact, the intact annulus buffered the distending pressure of the injected contrast media, and even with consistent pressures above 150 psi, the outer annular pressures remained at a relatively lower pressure. In comparison, when the annulus was torn, the periannular pressure continuously increased proportionally to the intradiscal pressure. The differences were approximately 0 until 45 psi, when a small pressure difference between 20 to 25 psi was observed. Although not reported, the study also showed that the pressures directly measured within the nucleus were almost exactly the same as the pressures recorded on the external pressure-monitoring device attached to the syringe.

The expanding tensional loads placed on the annulus while injecting contrast media may therefore differ from the compressive loads of activities of daily living that stress both the nucleus and annulus. In the situation where the inner annulus is intact and the patient's pain is caused by an outer rim tear, distention with contrast may under-load the outer annulus, which could result in a false-negative response. Discs with an intact annulus may therefore need to be evaluated using different techniques. In fact, the studies of asymptomatic volunteers in the Walsh et al.,⁸⁶ Carragee and colleagues,¹⁰⁰ and Derby and associates⁹⁸ studies all showed negative responses (no false positives) when the inner annulus was intact. On the other hand, the measured intranuclear pressure as measured on the injecting syringe during manometric discography accurately reflects the increase in outer annular pressure and will permit the evaluation of pain caused by a graded increase in outer annular tension created by increasing volumes of contrast medium.

As a provocation test, discography is characterized by the liability inherent in all provocation tests; the response may be dependent on the intensity of provocation, and therefore one could therefore argue that since measuring and recording injected pressures should provide better inter- and intra-observer consistency compared to estimating manual injection pressures or ignoring them altogether. Furthermore, because one is attempting to mimic a physiologic load, typical loads experienced by discs with various grades of internal disruption during activities of daily living should be appreciated.

In an unloaded position, the intrinsic pressure of the disc nucleus is created by the osmotic swelling pressure of proteoglycans resisting the tensional compressive

force of the anterior and posterior longitudinal ligaments. This opening pressure can be indirectly measured using the pressure at which contrast medium is first seen entering the disc while injecting through a 22–25-gauge needle. In the early 1990s, Derby¹⁰¹ showed that the direct nuclear pressures could be measured with a hand-held manometer during discography with patients in prone, side, and sitting positions and that the measured opening pressures were the same as those measured by other authors that were specifically evaluating the changes in pressures caused by various disc loading positions. The typical opening pressure in the various positions in a healthy hydrated disc in psi (multiply $\sim 6.9 =$ neutrons) are as follows: prone = ~ 15 , side = ~ 25 , standing = ~ 50 , and sitting = ~ 90 . He proposed a classification system based on concordant pain provocation created at various pressure values and ranged from the most sensitive discs, which he labeled “chemically” sensitive in which concordant 6/10 or greater pain was provoked at 15 psi or greater above opening pressure; “mechanically” sensitive discs that were painful at 16 to 50 psi a.o. pressure; and indeterminately sensitive discs, in which concordant pain was provoked at pressures greater than 50 psi a.o.. More recently, O'Neill and Kurgansky,¹⁰² also using pressure manometry, classified discs as contact sensitive in which pain was provoked at 0 psi and mechanically sensitive in which pain was provoked during measured pressurizations. No subject experienced pain of intensity 6 with an injection pressure below 50 psi. If attention is paid to pressure of injection and intensity of response, operational criteria can be defined that provide lumbar discography with a potential false-positive rate of zero.

These studies and the majority of prior studies have been based on readings of plateau static pressure recorded postinjection. Previous research^{104,105} anecdotally reported two pressures—dynamic and static, but dynamic pressures have not typically been clinically utilized. Although some physicians have used dynamic pressure,^{98,104} the parameters have only been recently evaluated. The difference between dynamic and static pressures caused by the speed of contrast injection could be a potential confounding factor. In asymptomatic subjects undergoing discography, Derby et al.^{98,103} showed that pain intensity corresponded with the peak manometric dynamic pressure, rather than static pressure. More recently, Seo et al.¹²⁵ showed that when injecting contrast medium at 0.08 ml/sec, the mean peak pressure difference between the dynamic and static pressure was minimal, but at faster rates there was an abrupt increase in mean pressure differences. Since it is the peak pressure that most likely provokes the initial pain response, it is important to record and limit the dynamic pressures to reduce the possibility of false-positive results and so that different studies may more easily be compared.

PROVOCATIONAL INTERPRETATION

Evaluating the significance of the pain response is the most difficult aspect of discography and requires the most experience. Interpretation of results will be improved if one closely examines the data of prior studies and should include those that support and those that refute discography's reliability in diagnosing disc pain and its ability to predict outcome.

All provocational tests, and in particular discography, are reliable only if a predefined set of parameters defining the intensity and concordance of a provoked pain response during stimulation of an asymptomatic structure are considerably different from that provoked in a symptomatic structure under the same stimulus conditions. In other words, if the disc is not symptomatic, the patient should either report no pain, discordant pain, or significantly less pain at any given level of pressure-volume of injected contrast medium compared to a disc that is symptomatic. The caveat is that because there is no gold standard to identify discogenic pain, one cannot directly test this hypothesis nor can one directly predefine the level of confidence that a particular disc is symptomatic based on the level of response.

Although one cannot prove that a disc is symptomatic, one can, however, assume that if a subject is not experiencing pain at the time of disc injection, the discs are not painful at that particular time and level of activity. The injection of discs of asymptomatic recruited subjects has historically^{86,106} been used to both refute and support¹⁰⁷ test reliability, and in particular, the potential incidence of false-positive response. As one might expect, controversy is fueled by differing results and differing interpretations of results by authors with a particular bias.

DISCOGRAPHY IN VOLUNTEERS WITHOUT CHRONIC PAIN

Performed in asymptomatic volunteers without a history of chronic pain, discography has a low rate of false-positive responses.^{86,98,100} In fact, the studies by Walsh et al.⁸⁶ and Derby and associates^{86,98,100} showed a zero-percent false-positive rate when a positive response is defined as 6 or greater pain response at a pressure equal to or less than 50 psi a.o. pressure (see Table 17-1, Figure 17-91). If one includes only the asymptomatic, the Carragee volunteers' pain provocation at various static pressures were relatively mild and similar to the responses of Derby and associates.^{98,99} The differing results are probably due to the more precise and slow stimulating pressures used by Derby et al.^{98,99} and Walsh.⁸⁶ Since the dynamic pressure is transferred directly to the outer annulus when a grade 3 annular fissure is present,⁹⁹ the dynamic pressure should be and was used when evaluating the results. During manual injection, there is likely to be a pressure difference

TABLE 17-1 PROBABILITY OF EXPERIENCING PAIN AT INTENSITY AND PRESSURE INDICATED

Pressure (psi a.o.)	Group	Pain Score 0-10						
		0	1	2	3	4	5	6
100	No LBP	0.25	0.75	0.44	0.13	0.00	0.00	0.00
	Occ LBP	0.46	0.54	0.38	0.23	0.15	0.08	0.00
90	No LBP	0.25	0.75	0.44	0.13	0.00	0.00	0.00
	Occ LBP	0.46	0.54	0.38	0.22	0.15	0.08	0.00
80	No LBP	0.31	0.69	0.38	0.06	0.00	0.00	0.00
	Occ LBP	0.53	0.47	0.33	0.20	0.13	0.07	0.00
70	No LBP	0.42	0.58	0.32	0.05	0.00	0.00	0.00
	Occ LBP	0.59	0.41	0.29	0.18	0.12	0.06	0.00
60	No LBP	0.64	0.36	0.27	0.05	0.00	0.00	0.00
	Occ LBP	0.64	0.35	0.29	0.18	0.12	0.06	0.00
50	No LBP	0.70	0.30	0.22	0.04	0.00	0.00	0.00
	Occ LBP	0.68	0.32	0.26	0.18	0.11	0.05	0.00
40	No LBP	0.78	0.22	0.17	0.04	0.00	0.00	0.00
	Occ LBP	0.68	0.25	0.26	0.18	0.11	0.05	0.00
30	No LBP	0.83	0.17	0.13	0.00	0.00	0.00	0.00
	Occ LBP	0.75	0.25	0.20	0.10	0.05	0.00	0.00
20	No LBP	1.00	0.09	0.09	0.00	0.00	0.00	0.00
	Occ LBP	0.90	0.10	0.10	0.00	0.00	0.00	0.00
10	No LBP	1.00	0.00	0.00	0.00	0.00	0.00	0.00
	Occ LBP	1.00	0.00	0.00	0.00	0.00	0.00	0.00

LBP, lower back pain; Occ, occasional; psi a.o., pounds per square inch above opening.
Source: Derby R, Kim BJ, Lee SH, et al: Comparison of discographic findings in asymptomatic subject discs and the negative discs of chronic LBP patients: can discography distinguish asymptomatic discs among morphologically abnormal discs? *Spine* 15:389-394, 2005, with permission.

of 20 psi or greater between static and dynamic values and would further explain the difference between the Carragee and associates' results, which recorded static pressures, and Derby and colleagues' results in which the slow injection speed gave closer values between static and dynamic pressures.

Lumbar discs can be made to hurt in asymptomatic volunteers, and in 13 volunteers of the Derby et al. study,¹⁰³ 50% of discs were painful during pressurization. However, the response was variable and depended on the segmental level stimulated, the nature of the disc, and the intensity of stimulation. When painful, the 13 subjects on average rated their pain as 2 to 3 on a 10-point scale, no subjects had a 6 or greater pain response, and only 1 subject had pain that reached pain at 5. Using the pressure versus pain intensity scores, a receiver-operator curve was constructed (see Figure 17-91, Table 17-1) to show that false-positive responses occurred only above certain pressures and pain scores. This table can be used to estimate the likelihood of a false-positive response during discography in a particular disc and, depending on one's willingness, to accept a certain percentage of false-positive responses can be used to determine whether the disc is in fact symptomatic. In practice, however, many discographers use more conservative boundaries. In particular, most discographers require a 6 or greater concordant pain response at equal to or less than 50 psi a.o. and may

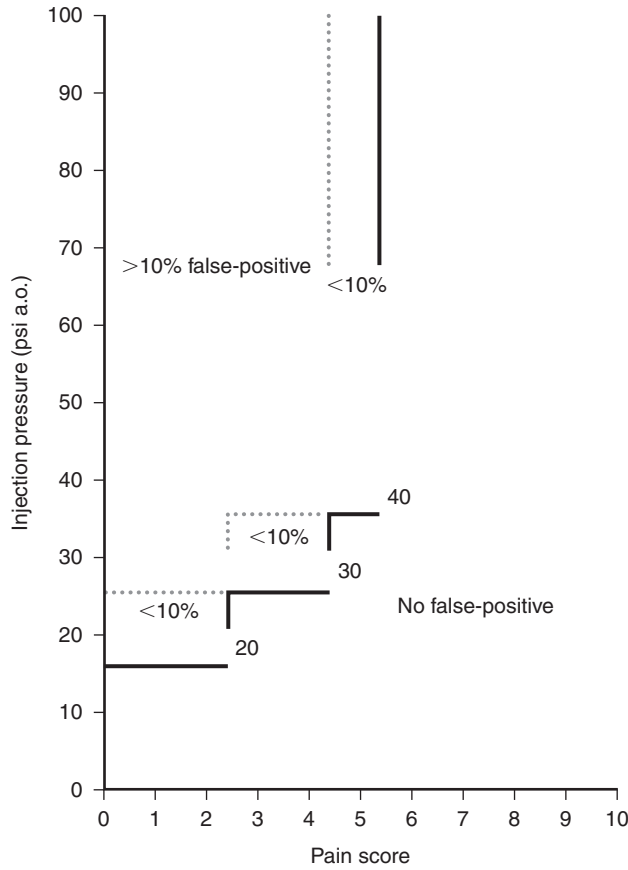


FIGURE 17-91

A receiver-operator curve showing the combined pressures and pain scores, below which no false-positive or less than 10% false-positive response might be expected during discography in symptomatic patients, and above which false-positive response has a likelihood greater than 10%. psi a.o., pounds per square inch above opening.

require more stringent requirements, such as 7 or greater pain at ~20 psi above opening in patients with perceived low pain tolerance or increased pain sensitization caused by chronic unremitting pain.

DISCOGRAPHY IN ASYMPTOMATIC CHRONIC PAIN VOLUNTEERS

Although the results of the studies by Lee et al.⁹⁹ and, to a lesser extent, Walsh et al.⁹² and Carragee and associates^{100,105,108-111} (Figure 17-92) show that discography in an asymptomatic disc is usually mild and generally occurs only at higher pressures, patients undergoing discography are typically not asymptomatic and often have a long history of chronic pain. Chronic pain may cause patients to overreact because of compromised pain tolerances and abnormal psychology. In Carragee and associates¹⁰⁰ original study cohort of asymptomatic volunteers, there were 10 subjects with chronic cervical pain due to a failed surgical fusion surgery, who claimed they had no remembered history of prior low back pain. Defining the false-positive rate as 3/5 pain, Figure 17-93 shows the false-positive rate at three pressure values and the highest unrestricted value. As can be seen by the results, the potential false-positive value per patient could be a standard deviation above or below 30%. Because discogenic pain is ~40% or higher in the population being tested, the probability of finding at least one painful disc may be high if the patient has multiple discs with grade 3 annular tears. On the other hand, most physicians use or should use discography to determine whether a particular disc is painful. In other words, one should not perform discography in a patient for the purpose of hopefully finding at least one painful level to justify a surgical intervention. Using a response of 6 or greater in patients without a history of low back pain, Carragee and associates' data show a

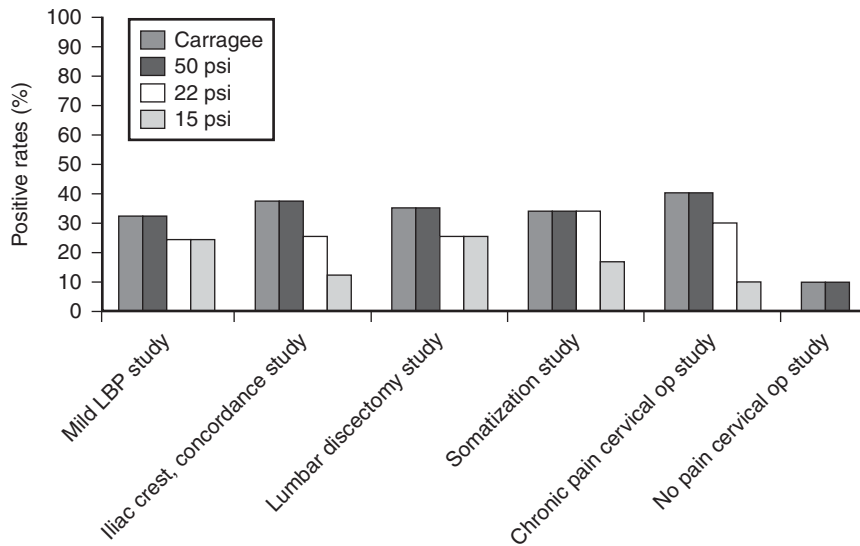


FIGURE 17-92

Positive rates per patients in all of Carragee and associates' studies (with criteria of grade 3 torn discs).

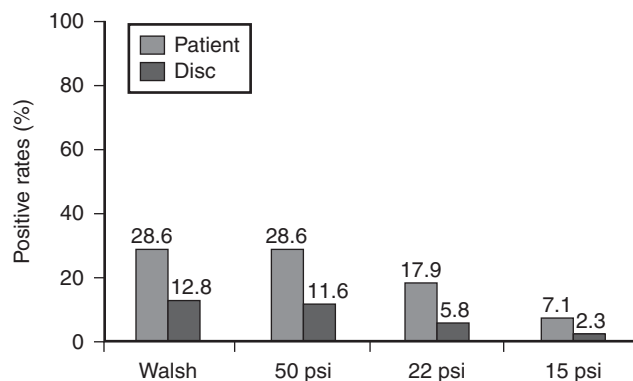


FIGURE 17-93

Positive rates according to four different diagnostic criteria in three studies by Carragee and associates (chronic pain and iliac crest studies) with no lower back pain (with criteria of grade 3 torn discs). These included the 10 patients with a prior successful cervical spine surgery, the 10 chronic pain patients without low back pain symptoms after cervical spine surgery, and 8 patients who had a posterior iliac crest bone graft harvesting for nonthoracolumbar procedures evaluated with lumbar radiography.

false-positive rate on a disc-by-disc basis of ~12% at 50 psi a.o. and ~6% at 15 psi above opening (Figure 17-93). However, analyzing the results of discograms performed on patients and all of Carragee and colleagues' volunteers, including those with "benign" chronic low back pain, O'Neill and Kurgansky¹⁰² determined the estimated probability of obtaining a false-positive response in a patient undergoing discography at 50 psi is 100%, at 25 psi is 50%, at 19 psi is 25%, and at 14 psi is 10%.

COMPARISON BETWEEN ASYMPTOMATIC VOLUNTEERS AND PATIENTS

How do the responses of patients with chronic pain differ from those of asymptomatic volunteers with similar degrees of annular disruption? Since discography is a test that depends on a patient's subjective evaluation of pain provocation, many assume that a patient with chronic pain will over-report pain because of abnormal psychology and low pain tolerances. Whether or not this assumption is true is partially answered by the Derby et al.¹⁰³ study comparing the discogram results of patients and asymptomatic volunteers. The data show that many patients undergoing discography have either normal or minimally elevated (DRAM) scores and most have normal or high pain tolerances. Contrary to the preconceived assumptions of many, the study found no significant relationship between abnormal DRAM scores and the intensity of Numeric Rating Scale (NRS) pain intensities reported by patients at pressures of 50, 30, and 15 psi a.o. pressure. There was a weak relationship between pain tolerance and abnormal DRAM scores, but there was only a trend and not

a statistical difference between pain tolerance and reported pain intensity scores at the various pressure levels. Nevertheless, 65% of the patient discs with normal pain tolerances had discs that did not meet the criteria of a positive response compared with 52% in patients with a low pain tolerance. This 13% difference might potentially be due to false-positive responses secondary to over-reporting of pain. A patient with a low pain tolerance and abnormal psychological profile is not an ideal candidate for discography, nor do we expect that he or she is an ideal candidate for any invasive surgical procedure.

CONCORDANCE DEBATE

Many discographers feel that reproduction of pain during disc provocation is all that is important. While the absence of pain provocation or the provocation of discordant pain could be defended, one may have a harder time defending the validity of concordant pain provocation in patients with chronic pain due to a variety of structures innervated by overlapping segmental levels. Carragee and associates¹⁰⁵ studied a cohort of eight asymptomatic volunteers whom he just asked to compare the pain on disc injection with the pain experienced after bone graft harvesting. In four discs of 24 (16.7%) in eight patients, Carragee and colleagues were able to provoke pain during his discography that was reported to be in a similar location as their iliac crest bone pain. Even though these four cases of remembered pain will probably not convince most discographers that concordant pain provocation is unreliable, other sources of pain should be ruled out prior to discography.

CLINICAL SIGNIFICANCE DEBATE

Discography cannot and should not determine the clinical significance of the provoked pain. In Carragee and associates¹⁰⁹ cohort of volunteer subjects with a history of "benign" low back pain, a significant number of the discs provoked pain during provocative testing (see Figure 17-91). Similarly, the study by Derby et al.¹⁰³ had three asymptomatic volunteers who had a history of frequent flares in low back pain. Even though none of their discs (eight with grade 3 annular tears) provoked pain greater than 5/10 at 50 psi a.o., a higher percentage of their discs were painful compared with volunteers with only occasional or no history of prior back pain. It is quite probable that opening these fissures during contrast pressurization created a stress similar to the cause of their intermittent flare ups, and in fact one might expect that the forceful opening of a healed but recently asymptomatic fissure should provoke pain.

Discography tests for the presence of nociceptors. If significant concordant pain is provoked at low volumes and pressures, it is likely that the nociceptors stimulated by the

injected contrast are a source of pain. Whether the disc is the majority of the patient's pain or whether the pain is enhanced by functional or central reorganization is beyond the scope of this test. Contrast may stimulate nociceptors not only within the disc itself but also within adjacent structures due to high tensional loads on the outer annulus or direct stimulation by contrast leaking through annular or end-plate ruptures. Responses that are only marginally positive or indeterminate may be a warning that pain is caused by other sources or that this disc is either not symptomatic or only marginally symptomatic at the time of discography. Most complainers have a low level of background low back pain not dissimilar to Carragee's group with "benign" pain and most have intermittent pain flares provoked by activities required at their jobs.

PREDICTIVE VALUE

The ability of manometric discography to predict surgical outcome has been investigated in several studies. In a retrospective review, Derby et al.¹¹² found that patients who had one or more discs that were painful at a pressure of 15 psi or less above opening ("chemically sensitized discs") had a poor outcome when the disc was not removed and fused and a significantly better outcome when either the anterior column was fused or a combined procedure was performed. Discs that were painful at lower pressures and volumes were chosen because the authors felt these discs were probably more likely to be symptomatic. It does not, however, mean that discs that were less positive are not also symptomatic or whether the presence of a "chemically sensitized disc" will predict better surgical outcome. Combined reconstructive procedures in which manometric controlled discography was used as one of the diagnostic criteria performed will provide patients with degenerative spine pain on average of 30% improvement in overall bodily pain.^{113,114}

NEGATIVE DISCOGRAPHY

Although the diagnostic reliability of a positive discogram may never be resolved to the satisfaction of all, the value of a negative response is seldom discussed. Probably the most common use for discography is not to decide which level to fuse but to evaluate adjacent levels. If the disc is not the primary source of pain, some surgeons may want the option to leave the disc alone or use more flexible means of stabilization. In many cases one or two segments are going to be reconstructed for reasons unrelated to whether or not the disc can be proved painful. It is the mildly degenerate adjacent level(s) that is in question.

Comparing the discographic findings in asymptomatic subject discs and the negative discs of chronic low back pain patients using the same pressure controlled techniques,¹⁰³ there may be no significant NRS pain

score differences between asymptomatic volunteers and the approximately 60% of patient discs that did not meet the criteria of a positive response at 15, 30, and 50 psi a.o. pressure. In contrast, the pressure and pain intensities for negative patient discs and positive patient discs differed significantly (Figure 17-94). The study concluded that advanced discography techniques and strict criteria may distinguish negative asymptomatic discs among morphologically abnormal discs in patients with suspected chronic discogenic low back pain.

DISCOGRAPHY STANDARDS

Since its introduction in 1948, lumbar discography has been mostly practiced without strict standards for pressure, volume, speed of injection, or limits of injection. These practices are no longer supportable.

The authors recommend using the following criteria for a positive response when using pressure-controlled manometric discography: *numeric rating scale of pain above 6/10, less than 50 psi intradiscal pressure above opening pressure, less than 3.5 ml total volume, and at least one negative control disc.* If the provocation at the tested level does not meet these requirements (especially in a patient with a low pain tolerance), the provocation response is no more than

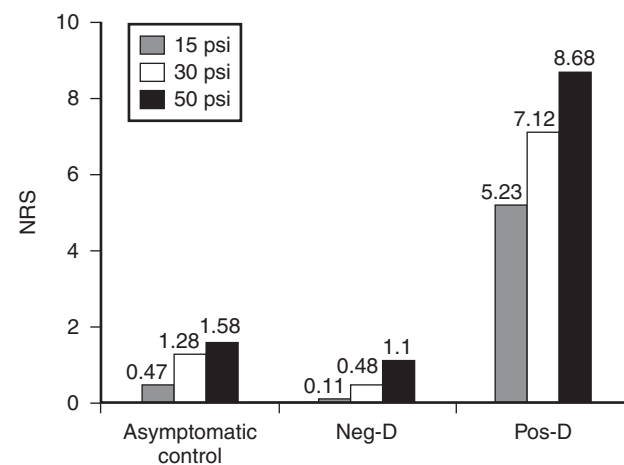


FIGURE 17-94

Mean self-reported NRS scores for discs in each group at three pressure levels: Pain intensity in grade 3 annular torn discs at each pressure. Pressures indicate the pressure above opening pressure. The Neg-D group scores did not differ significantly from asymptomatic control subject scores. The Pos-D group differed significantly from the control and Neg-D groups ($p < 0.001$). NRS, numeric rating scale (0-10); Neg-D, discs meeting negative response criteria among grade 3 annular tear discs in patient; Pos-D, discs not meeting negative response criteria among grade 3 annular tear discs in patient. (Adapted from Derby R, Kim BJ, Lee SH, et al: Comparison of discographic findings in asymptomatic subject discs and the negative discs of chronic LBP patients: can discography distinguish asymptomatic discs among morphologically abnormal discs? *Spine J* 5: 389-394, 2005, with permission.)

that which could be reproduced in an asymptomatic “normal” subject and therefore there is no confirmatory evidence that the tested disc is a source of pain. Even if the requirements for a positive response are met, the degree of confidence that the tested disc is a significant source of pain will depend on sound medical judgment.

Remember to keep the rate of injection slow enough to avoid high dynamic pressures. In patients with grade 3 annular tears an injection speed of 0.05–0.1 ml/sec (one revolution of Merit syringe over 5–10 seconds) both the externally measured dynamic and static pressures are an accurate reflection of the pressures transferred to the outer annulus⁹⁹ (see Figure 17-93). Record both the dynamic and static pressures, but it is the dynamic pressure that is used to determine a positive response. In addition, transient pain provocation may occur when a fissure is opened or when a thin membrane sealing the outer annulus is ruptured; however, the provocation response should not be accepted as a positive unless it can be confirmed by a repeat pressurization. Pain that does not decrease more than 50% over 30 seconds, increased pain in the postoperative recovery, and a significant flare in symptoms over the next 3–7 days may be used as additional but not the sole criteria indicating a positive response.

CAVEATS

Disc degeneration will directly and indirectly cause pain originating from multiple sources. Once one source of pain is eliminated, other sources tend to become worse. Because a disc is painful does not mean that other sources of pain are absent or even that the disc is the primary source of pain. In most cases, other sources of pain should be investigated with appropriate analgesic diagnostic interventions.

A subjectively interpreted diagnostic test like discography is more than just collecting unfiltered responses. The following are examples of methods used by many experienced discographers when trying to decide if the disc is a source of pain and hopefully decrease both false-positive and false-negative interpretations.

1. If one is unskilled in placing needles into intervertebral discs, the patient will be so traumatized that any further stimulus will be difficult to interpret.
2. The patient’s pain tolerance must be evaluated and his or her sensitivity and scoring of pain provocation must be taken into account. A stoic response to skin and subcutaneous infiltration of 1% unbuffered xylocaine is an average score of 2 or less and 5 or less in patients with a normal pain tolerance. Patients must be educated to properly score pain intensity and concordance. Record the patient’s responses fairly without coaching, but depending on the pain tolerance, the criteria for a positive or negative response can be adjusted. Remember that the Bogduk table of probabilities is based on asymptomatic volunteers with normal to stoic pain tolerances.
3. One can further refine the pain response and criteria for a positive response by closely observing facial expressions and vocalization. In fact, the Walsh criteria includes the requirements that both vocalization and grimacing need to be observed before the test is positive.
4. Needles should be inserted from the asymptomatic or least symptomatic side.
5. Be very skeptical of pain provocation that occurs on the same side as the needles. Leg and hip pain is usually caused by the discogram needle pushing on and displacing the dorsal root ganglion. The needle will falsely stimulate even back pain. Before accepting ipsilateral pain, one should gently jiggle the needle and make sure that the same pain is *not* provoked.
6. The first report of pain as contrast flows into a grade 3 or greater annular fissure (or end-plate defect or disc protrusion) should be recorded, but the pain intensity must be validated. Record the response but also record the persistence of pain at 30–60 seconds postprovocation. Pain that quickly subsides within 10 seconds should be ignored. The provoked pain could be nothing more than that which would occur if one tore off a quickly opened and otherwise asymptomatic partially healed skin wound.
7. All positive responses must be validated with a confirmatory pressurization. The subsequent pressurization should provoke pain at the same or greater intensity. The pain intensity at the highest pressure equal to or less than 50 psi a.o. is the intensity determining whether a positive response was achieved.
8. Annular tears often heal with a fibrous cap of tissue. The disc may be asymptomatic, but rupture of this membrane during contrast pressurization may cause transient or even prolonged pain. For example, in the study by Derby’s group, a fibrous membrane in the outer lateral annulus was ruptured in the L3-L4 disc of one of the asymptomatic volunteers. There was transient provocation of 4/10 groin pain, but one might imagine that if the disc had been more enthusiastically pressurized or the patient’s pain reporting was less constrained, this would have been labeled a false-positive response.
9. If a patient complains of pain in a disc without a grade 3 annular tear, look for other causes. Is this just a sign that everything hurts? If so, no

response can be considered positive. If an adjacent disc is painful at a low pressure and volume, inject 1 ml of 4% xylocaine into the painful adjacent disc and retest the normal appearing disc in 10 minutes. One will often find that the disc no longer is painful. Even if the disc remains painful, the results are indeterminate. The disc could have a symptomatic concentric annular or rim annular tear, but this diagnosis is conjecture.

10. Limit the injected contrast volume to 3.5 ml or less. A severely degenerated but asymptomatic disc (at the time of discography) can be made to hurt if enough volume is injected. The actual volume limitation will vary; if there is a leak, the volume restrictions may not apply.
11. A characteristic of “false” pain provocation in an asymptomatic person is a quick resolution of the pain postprocedure in contrast to patients with painful disc that will typically have prolonged pain aggravation. The exception is when an annular fissure that is asymptomatic at the day of the discogram is performed, but is reopened during contrast pressurization. Pain is usually provoked, and the person will usually experience a flare resembling usual episodes that occur with re-injury. Derby and associates saw this response in several asymptomatic volunteers with a history of recurrent back pain.
12. A disc with a leak either through the end plates, outer annular vessels, or into the surrounding structures is more difficult to evaluate. In addition, one may not be able to pressurize the disc. In this case, a more forceful injection may be the only way to get the pressure above 50 psi a.o. In addition, be aware that provocation of proximal and distal pain or even back pain may be due to stimulation of structures adjacent to the disc.
13. Patients with chronic pain often take copious quantities of opioids. Most centers tell patients not to eat or drink after midnight. By the time the discogram is performed the next day, the patient is having early opioid withdrawal symptoms. Everything will hurt. Unless one’s intent is to create false-positive responses, these patients must be given a reasonable dose of narcotic before doing the procedure.
14. The false-positive response is probably higher at the level of a previous discectomy. Unless the disc is painful at low volumes and pressures, the results should be called indeterminate. Unless the patient has severe pain at pressures no higher than 20 psi a.o., one should look for other sources of pain.

POSTPROCEDURE CARE

After completion of the discogram, sterile self-adhesive dressings are applied to the puncture wounds and the patient is taken to a recovery room with nurses trained to care for post-spinal injection patients. Periodic evaluation of the patient, including vital signs, level of comfort, level of consciousness, and visualization of the injection sites are recommended. Analgesic medications (oral, IM, or IV) are provided as needed. Patients are observed and discharged as per institutional criteria. Once the patient is stable, he or she may be discharged for a postdiscogram CT scan to provide axial images of the injected discs, if painful levels were noted. The patient is discharged into the care of a responsible adult with discharge instructions to include no driving the day of the procedure. The patient is told to expect some increase in discomfort for a few days postprocedure, and a limited prescription for oral analgesics is provided. Patients are encouraged to call if they feel any unusual or severe pain not relieved by the oral analgesics.

COMPLICATIONS

A myriad of complications following discography have been well documented.^{68,93,76} Complications can be inherent to disc penetration, the medications utilized, or unintentional misadventures involving needle placement, and range in severity from minor inconveniences (i.e., increase in low back pain, nausea, and headache) to seizure and death.¹¹⁵

Discitis is the most common complication of discography with a rate of less than 0.08% per disc injected.⁸⁰ Fraser et al.,⁶⁸ have provided evidence that all discitis is due to an infectious process with the most common organisms being *Staphylococcus aureus*, *Staphylococcus epidermidis*, and *Escherichia coli* from the skin. The intervertebral disc is an excellent growth medium for bacteria since it is an essentially avascular structure. However, with the use of preprocedure screening for chronic infections, strict aseptic preparation of the skin, styletted needles, meticulous technique, and intravenous and intradiscal antibiotics, discitis is an exceedingly rare occurrence today.^{69,74}

Whether seen in the postdiscogram or postsurgical patient, discitis presents in a similar fashion.^{79,117} The patient with discitis usually will present with severe, intractable, debilitating pain of the cervical, thoracic, or lumbar spine days to weeks following the procedure; however, mild self-limiting cases have been described.⁷⁴ Discitis needs to be ruled out in any postdiscogram patient who notes a change in severity and/or quality of their pain postprocedure. Workup consists of obtaining laboratory and imaging studies. The C-reactive protein will increase within days of the onset while the sedimentation rate may remain in the normal range for over a month. Blood cultures and CBC will be negative until

the end plates are breached and often remain normal. MRI is the imaging study of choice^{118–120} with hyperemia of the end plates and marrow space changes in T2 sequence weighted images 3–4 days after onset of symptoms. Radionuclide bone scanning has been shown to be inferior to MRI in specificity and sensitivity.¹²¹ If an adequate sample of tissue can be obtained, disc aspiration and/or biopsy will be positive in the acute phase of discitis, but once the end plates are violated, a sterile environment is soon noted in response to the patient's immune system.⁷⁴

Treatment of infections within the disc and sepsis often require antibiotic therapy. Although rare, abscess or empyema^{122–124} may necessitate surgical intervention. Boswell and Wolfe¹¹⁵ described a case in which a woman developed intractable seizures, coma, and death following discography. Their conclusion was that an unintentional intrathecal administration of cefazolin (12.5 mg/cc), which had been included in the contrast agent for prophylaxis of infection, precipitated this catastrophic event.

SUMMARY

The importance of determining whether an intervertebral disc is a source of pain is critical. There is, however, an ongoing debate of whether discography can confirm or refute the hypothesis that a particular disc is a source of pain. Any diagnostic test that interprets results based on pain provocation is liable to false-positive and false-negative errors. In addition, if strict control is not applied to the provocation stimulus, the test can be easily abused to suit one's bias. The reliability of the provoked response will vary from patient to patient and level to level, depending on how intense the stimulus needed to provoke a response, the skill of the discographer, and the sensitivity of the patient. The degree of sensitivity between symptomatic and asymptomatic discs is, however, usually enough for patients to differentiate between the true and false provocation of pain. If a patient has a normal pain tolerance, the provocation of concordant pain at a low pressure and volume will in most cases reliably detect the presence of nociceptors within the disc or adjacent tissue. Even in patients whose pain tolerance is compromised, a positive response has a higher chance of being a true positive than false positive, but in these patients one should insist an adjacent disc with a grade 3 annular tear that is relatively painless at similar or higher pressures and volumes. If such a control can be found, a spurious result secondary to generalized pain overreaction cannot be supported. Furthermore, in many cases, a negative response to disc stimulation provides more important and perhaps more reliable information.

Interpreting discogram results is an art of clinical judgment. Never printed but recognized by the wise, discography is an informative presurgical challenge regardless of the results. Performed by an expert, the test is not particularly painful. A patient that kicks and

screams during needle insertion, who bitterly complains that the procedure was the worst thing that ever happened to him or her, and has been forever worse since the procedure may not be the patient you want to live with when his or her surgery fails. Expertly performed and interpreted, discography will help identify asymptomatic discs and to a greater or lesser degree identify a painful disc or segment. Its best future use may be to help limit the number or prevent altogether the number of levels subjected to interventional disc procedures.

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