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DEGENERATIVE DISORDERS OF THE THORACIC AND LUMBAR SPINE

Raymond J. Gardocki, Ashley L. Park

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OVERVIEW OF LUMBAR AND THORACIC DISC DEGENERATION AND HERNIATION

Despite an improving understanding of degenerative disc disease on the basis of its natural history and basic science, the treatment results of this entity vary greatly. There is no lack of treatment options for degenerative discs; what we tend to lack is understanding of the specific cause(s) of the patient’s chief complaint. Despite the fact that William Kirkaldy-Willis has described the spectrum of disc degeneration and its pathological progression, the clinical correlation of history, physical examination, and imaging that yields a specific diagnosis remains the greatest challenge.

Over the past several decades, studies of patients with low back or leg pain have led to improved treatment of the patients in whom a specific diagnosis was possible. This group remains the minority of patients who are evaluated for low back or leg pain. Complex psychosocial issues, depression, and secondary gain are a few of the nonanatomical problems that must be considered when evaluating these patients. In addition, the number of anatomical causes for these symptoms, whether real or perceived, has increased as understanding and diagnostic capabilities have increased.

Axial spine pain, which should be distinguished from disc degeneration, is the most frequent musculoskeletal complaint. Axial spine pain—whether cervical, thoracic, or lumbar—often is attributed to disc degeneration. This degenerative process does not always cause pain, but it can lead to internal disc derangement, disc herniation, facet arthrosis, degenerative spondylolisthesis, and stenosis that can be seen on imaging. Each of these pathological processes has unique clinical findings and treatments. Outcomes of treatment for each of these specific pathologic entities also vary greatly despite their being from the same etiological-spectrum. The understanding of disc degeneration and the associated pathologies has changed markedly over the past several years.

The genetic influence on disc degeneration may be caused by a small effect from each of multiple genes or possibly a relatively large effect of a smaller number of genes. To date, several specific gene loci have been identified that are associated with disc degeneration. This association of a specific gene with degenerative disc changes has been confirmed. Other variations in the aggregan gene, metalloproteinase-3 gene, collagen type IX, and alpha 2 and 3 gene forms also have been associated with disc pathology and symptoms. The understanding of symptoms and treatment success for disc herniations has surpassed those related to disc degeneration alone.

Non-specific axial pain is an international health issue of major significance and should be discriminated from pain associated with a disc herniation. Approximately 80% of individuals are affected by this symptom at some time in their lives. Impairments of the back and spine are ranked as the most frequent cause of limitation of activity in individuals younger than 45 years old by the National Center for Health Statistics (www.cdc.gov/nchs). Physicians who treat patients with spinal disorders and spine-related complaints must distinguish the complaint of back pain, which several epidemiological studies reveal to be relatively constant, from disability attributed to back pain. Although back pain as a presenting complaint may account for only 2% of the patients seen by a general practitioner, the cost to society and the patient in terms of lost work time, compensation, and treatment is staggering.

The total cost of low back pain in the United States is greater than $100 billion per year; one third are direct costs for care, with the remaining costs resulting from decreased productivity, lost wages, and absenteeism. Also, only about 5% of patients accounted for 75% of the costs. Typically, about 90% of patients return to work by 3 months, with most returning to work by 1 month. Patients off work for 6 months have only a 50/50 probability of ever returning to work, whereas at 1 year this probability decreases to 25%.

Nonanatomical factors, specifically work perception and psychosocial factors, are intimately intertwined with physical complaints. Compounding the diagnostic and treatment difficulties is the high incidence of significant abnormalities shown by imaging studies, which in asymptomatic matched controls is 76%. Identified risk factors for radiographically apparent disc disorders of the lumbar spine include genetic factors, age, gender, smoking, and, to a minimal degree, occupational exposure, but not socioeconomic factors. In contrast is the importance of socioeconomic factors for the development of low back pain and disability. Job dissatisfaction, physically strenuous work, psychologically stressful work, low educational attainment, and workers’ compensation insurance all are associated with low back pain or disability. These data suggest that aggressive treatment between 4 weeks and 6 months is necessary for patients with low back pain. Consideration of socioeconomic factors is an important component of appropriate patient evaluation because there is an inextricable link between an individual’s socioeconomic status and his or her health.

Optimal outcome primarily depends on “proper patient selection,” which so far has defied satisfactory definition. Until the pathological process is better described and reliable criteria for the diagnosis are determined, improvement in treatment outcomes will change slowly.

DISC AND SPINE ANATOMY

The anatomy of the spine and discs is discussed in detail in Chapter 38.

NEURAL ELEMENTS

The organization of the neural elements is strictly maintained throughout the entire neural system, even within the conus medullaris and cauda equina distally. The orientation of the nerve roots in the dural sac and at the conus medullaris follows a highly organized pattern, with the most cephalad roots lying lateral and the most caudal lying centrally. The motor roots are ventral to the sensory roots at all levels. The arachnoid mater holds the roots in these positions.

The pedicle is the key to understanding surgical spinal anatomy. The relation of the pedicle to the neural elements varies by region within the spinal column. In the thoracic and lumbar spine, the named root exits below the named pedicle. Discs are formally named for the vertebral bodies between which they lie (e.g., the L4-5 disc is between the L4 and L5 vertebral bodies). This allows slightly more specificity in describing the discs if there is an anatomical variant (e.g., L4-S1) and less confusion than having the vertebral body, nerve root, and disc sharing the same name. Despite being
CHAPTER 39 DEGENERATIVE DISORDERS OF THE THORACIC AND LUMBAR SPINE

less specific, the disc often is informally named for the vertebral level immediately cephalad to the L4 vertebra. In the lumbar spine, lateral recess pathology, such as lateral recess stenosis or postero-lateral disc herniation, typically involves the next nerve root exiting caudal to that disc; for example, an L4-5 postero-lateral disc herniation would be expected to cause L5 nerve root symptoms. At the level of the intervertebral foramen is the dorsal root ganglion (DRG). The DRG lies within the outer confines of the foramen. Distal to the ganglion, three distinct branches arise; the most prominent and important is the ventral ramus, which supplies all structures ventral to the neural canal. The second branch, the sinuvertebral nerve, is a small filamentous nerve that originates from the ventral ramus and progresses medially over the posterior aspect of the disc and vertebral bodies, innervating these structures and the posterior longitudinal ligament. The third branch is the dorsal ramus. This branch courses dorsally, piercing the intertransverse ligament near the pars interarticularis. Three branches from the dorsal ramus innervate the structures dorsal to the neural canal. The lateral and intermediate branches provide innervation to the posterior musculature and skin. The medial branch separates into three branches to innervate the facet joint at that level and the adjacent levels above and below (Fig. 39-1).

Disc innervation is through afferent axons with cell bodies within the DRG. Nociceptive signals are transmitted to the spinal cord by neurons from the DRG. Animal studies have revealed two pathways between the annulus and the DRG: one from the sinuvertebral nerve and another along the para-vertebral sympathetic trunk. The sinuvertebral nerve is a recurrent branch of the ventral ramus that connects back to the posterior disc at each level. The paired ganglia chains of the sympathetic trunks have axons that course through the gray rami communicantes to the spinal nerve. The disc is innervated by fibers from multiple levels. In animal models, the lateral annulus was found to be innervated by fibers coursing from the index level and two additional superior levels through the sinuvertebral nerves. Also, there was innervation through the sympathetic trunk by the DRG from the three levels even more superior than the sinuvertebral innervations. Contralateral DRG involvement also occurs through both pathways. Similar nonsegmental, multilevel innervation patterns also have been reported for the ventral disc surface. These complex multilevel innervations would help explain the pain patterns encountered clinically if similar patterns are present in humans. Also, innervations of the disc from the vertebral endplate have been shown. Intraspous nerves follow the osseous vasculature. This endplate innervation is through a branch of the sinu-vertebral nerve, the basi-vertebral nerve. This nerve enters the foramen, and the nerve fibers enter the vertebral margin with the vessels. The density of innervation is similar to that seen in the outer annulus, which suggests that the endplates are as important to pain generation as is the annulus.

NATURAL HISTORY OF DISC DISEASE

One theory of spinal degeneration assumes that all spines degenerate and that current methods of treatment are for

FIGURE 39-1 A, Dorsal view of lumbar spinal segment with lamina and facets removed. On left side, dura and root exiting at that level remain. On right side, dura has been resected and root is elevated. Sinuvertebral nerve with its course and innervation of posterior longitudinal ligament is usually obscured by nerve root and dura. B, Cross-sectional view of spine at level of endplate and disc. Note that sinuvertebral nerve innervates dorsal surface of disc and posterior longitudinal ligament. Additional nerve branches from ventral ramus innervate more ventral surface of disc and anterior longitudinal ligament. Dorsal ramus arises from root immediately on leaving foramen. This ramus divides into lateral, intermediate, and medial branches. Medial branch supplies primary innervation to facet joints dorsally.
symptomatic relief, not for cure. The degenerative process has been divided into three separate stages with relatively distinct findings. The first stage is dysfunction, which is seen in individuals 15 to 45 years old. It is characterized by circumferential and radial tears in the disc annulus and localized synovitis of the facet joints. The next stage is instability. This stage, found in 50- to 70-year-old individuals, is characterized by internal disruption of the disc, progressive disc resorption, and degeneration of the facet joints with capsular laxity, subluxation, and joint erosion. The final stage, present in individuals older than 60 years, is stabilization. In this stage, the progressive development of hypertrophic bone around the disc and facet joints leads to segmental stiffening or frank ankylosis (Table 39-1).

Each spinal segment degenerates at a different rate. As one level is in the dysfunction stage, another may be entering the stabilization stage. Disc herniation in this scheme is considered a complication of disc degeneration in the dysfunction and instability stages. Spinal stenosis from degenerative arthritis in this scheme is a complication of bony overgrowth compromising neural tissue in the late instability and early stabilization stages.

Long-term follow-up studies of lumbar disc herniations have documented several principles, the foremost being that generally symptomatic lumbar disc herniation (which is only one of the consequences of disc degeneration) has a favorable outcome in most patients. The primary benefit of surgery has been noted to occur early on in the first year after surgery, but with time the statistical significance of the improvement appears to be lost. In general, the literature supports best treated care approach, minimizing centrally acting medications. The judicious use of epidural steroids also is supported, but long-term results and repeated use is questionable. Nonprogressive neurological deficits originating from the lumbar spine (except cauda equina syndrome) can be treated nonoperatively with expected clinical improvement. If surgery is necessary, it usually can be delayed 6 to 12 weeks to allow adequate opportunity for improvement. Some patients are best treated surgically, and this is discussed in the section dealing specifically with operative treatment of lumbar disc herniation.

The natural history of degenerative disc disease is one of recurrent episodes of pain followed by periods of significant or complete relief.

Before a discussion of diagnostic studies, axial spine pain with radiation to one or more extremities must be considered. Also, understanding certain pathophysiological entities must be juxtaposed to other entities of which only a rudimentary understanding exists. It is doubtful if there is any other area of orthopaedics in which accurate diagnosis is as difficult or the proper treatment as challenging as in patients with persistent neck and arm or low back and leg pain. Although many patients have clear diagnoses properly arrived at by careful history and physical examination with confirmatory imaging studies, many patients with pain have absent neurological findings other than sensory changes and have normal imaging studies or studies that do not support the clinical complaints and findings. Inability to easily determine an appropriate diagnosis does not relieve the physician of the obligation to recommend treatment or to direct the patient to a setting where such treatment is available. Careful assessment of these patients to determine if they have problems that can be orthopaedically treated (operatively or nonoperatively) is imperative to avoid both overtreatment and undertreatment.

Operative treatment can benefit a patient if it corrects a deformity, corrects instability, relieves neural compression, or treats a combination of these problems directly attributable to the patient’s complaint. Obtaining a history and completing a physical examination to determine a diagnosis that should be supported by other diagnostic studies is fundamental; conversely, matching the diagnosis and treatment to the results of diagnostic studies, as often can be done in other subspecialties of orthopaedics (e.g., treating extremity pain based on a radiograph that shows a fracture), is more complex and difficult. The history, physical examination, and imaging studies must all confirm the same pathological process as the source of symptoms if surgical intervention is to be reproducibly successful.

AXIAL LUMBAR PAIN

Axial lumbar pain occurs at some point in the lives of most people. Appropriate treatment for what can be at times excruciating pain generally should begin with evaluation for a significant spinal pathological process. This pathological process being absent, a brief (1 to 3 days) period of bed rest with institution of an antiinflammatory regimen and rapid progression to an active exercise regimen with an anticipated return to full activity should be expected and encouraged. Generally, patients treated in this manner improve

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<tr>
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<th>FACET JOINTS</th>
<th>PATHOLOGICAL RESULT</th>
<th>INTERVERTEBRAL DISC</th>
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<tr>
<td>Dysfunction</td>
<td>Synovitis</td>
<td>Dysfunction</td>
<td>Circumferential tears</td>
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<td>Hypermobility</td>
<td>↓</td>
<td>Radial tears</td>
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<td></td>
<td>Continuing</td>
<td>Herniation</td>
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<td>degeneration</td>
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<td>Instability</td>
<td>Capsular laxity</td>
<td>Instability</td>
<td>Internal disruption</td>
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<tr>
<td></td>
<td>Subluxation</td>
<td>→ Lateral nerve entrapment</td>
<td>Disc resorption</td>
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<tr>
<td>Stabilization</td>
<td>Enlargement of articular processes</td>
<td>One-level stenosis</td>
<td>Osteophytes</td>
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<tr>
<td></td>
<td></td>
<td>Multilevel spondylisis and stenosis</td>
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(Modified from Kirkaldy-Willis WH, editor: Managing low back pain, New York, Churchill Livingstone, 1983.)
CHAPTER 39  DEGENERATIVE DISORDERS OF THE THORACIC AND LUMBAR SPINE

DIAGNOSTIC STUDIES

RADIOGRAPHY

The simplest and most readily available diagnostic tests for lumbar pain are anteroposterior and lateral radiographs of the involved spinal region. These simple radiographs show a relatively high incidence of abnormal findings; however, spinal radiographs on the initial visit for acute low back pain may not contribute to patient care and are not always cost effective. Plain radiographs may be considered only after the initial therapy fails, especially in patients younger than 45 years old.

There is insignificant correlation between back pain and the radiographic findings of lumbar lordosis, transitional vertebra, disc space narrowing, disc vacuum sign, and claw spurs. In addition, the entity of disc space narrowing is extremely difficult to quantify in all but operated backs or in obviously abnormal circumstances. A study of 321 patients found that only when traction spurs or obvious disc space narrowing or both were present did the incidence of severe back and leg pain, leg weakness, and numbness increase. These positive findings had no relationship to heavy lifting, vehicular exposure, or exposure to vibrating equipment. Other studies have shown some relationship between back pain and the findings of spondylolysis, spondylololisthesis, and adult scoliosis, but these findings also can be observed in spine radiographs of asymptomatic patients.

Special radiographic views can be helpful in further defining the initial clinical radiographic impression. Oblique

SELECTIVE INDICATIONS FOR RADIOGRAPHY IN ACUTE LOW BACK PAIN

- Age > 50 years
- Significant trauma
- Neuromuscular deficits
- Unexplained weight loss (10 lb in 6 months)
- Suspicion of ankylosing spondylitis
- Drug or alcohol abuse
- Use of corticosteroids
- Temperature ≥ 37.8°C (≥100°F)
- Recent visit (≤1 month) for same problem and no improvement
- Patient seeking compensation for back pain

TABLE 39-2  CLASSIFICATION FOR SPINAL NERVE AND THECAL SAC DEFORMATION

<table>
<thead>
<tr>
<th>SPINAL NERVE DEFORMATION IN LATERAL RECESS OR INTERVERTEBRAL FORAMEN</th>
<th>THECAL SAC DEFORMATION IN VERTEBRAL CANAL</th>
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<tbody>
<tr>
<td>0—absent</td>
<td>No visible disc material contacting or deforming nerve</td>
</tr>
<tr>
<td>I—minimal</td>
<td>Contact with disc material deforming nerve but displacement &lt; 2 mm</td>
</tr>
<tr>
<td>II—moderate</td>
<td>Contact with disc material displacing ≥2 mm; nerve is still visible and not obscured by disc material</td>
</tr>
<tr>
<td>III—severe</td>
<td>Contact with disc material completely obscuring nerve</td>
</tr>
<tr>
<td>0—absent</td>
<td>No visible disc material contacting or deforming thecal sac</td>
</tr>
<tr>
<td>I—minimal</td>
<td>Disc material in contact with thecal sac</td>
</tr>
<tr>
<td>II—moderate</td>
<td>Disc material deforming thecal sac; anteroposterior distance of thecal sac ≥7 mm</td>
</tr>
<tr>
<td>III—severe</td>
<td>Disc material deforming thecal sac; anteroposterior distance of thecal sac &lt;7 mm</td>
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</tbody>
</table>

views are useful in defining further spondylolisthesis and spondylolysis but are of limited use in facet syndrome and hypertrophic arthritis of the lumbar spine. Lateral flexion and extension radiographs may reveal segmental instability. The interpretation of these views depends on patient cooperation, patient positioning, and reproducible technique. Lateral lumbar flexion views are valid only if done in the seated position which maximizes lumbar kyphosis. The Ferguson view (20-degree caudocephalic anteroposterior radiograph) has been shown to be of value in the diagnosis of the "far out syndrome," that is, fifth root compression produced by a large transverse process of the fifth lumbar vertebra against the ala of the sacrum. Angled caudal views localized to areas of concern may show evidence of facet or laminar pathological conditions.

**MYELOGRAPHY**

The value of myelography is the ability to check all spinal regions for abnormality and to define intraspinal lesions; it may be unnecessary if clinical and CT or MRI findings are in complete agreement. The primary indications for myelography are suspicion of an intraspinal lesion, patients with spinal instrumentation, or questionable diagnosis resulting from conflicting clinical findings and other studies (Fig. 39-2). In addition, myelography is valuable in a previously operated spine and in patients with marked bony degenerative change that may be underestimated on MRI. Myelography is improved by the use of postmyelography CT in this setting and in evaluating spinal stenosis.

Several contrast agents have been used for myelography: air, oil contrast, and water-soluble (absorbable) contrast agents, including metrizamide (Amipaque), iohexol (Omnipaque), and iopamidol (Isovue-M). Because these nonionic agents are absorbable, the discomfort of removing them and the severity of the postmyelography headache have decreased.

Arachnoiditis is a severe complication that has been attributed occasionally to the combination of iophendylate and blood in the cerebrospinal fluid (CSF). This diagnosis usually is confirmed only by repeat myelography. Attempts at surgical neurolysis have resulted in only short-term relief and a return of symptoms within 6 to 12 months after the procedure. Time may decrease the effects of this serious problem in some patients, but progressive paralysis has been reported in rare instances. Arachnoiditis also can be caused by tuberculosis and other types of meningitis. Arachnoiditis has not been noted to be related to the use of a water-soluble contrast.
agent, with or without injection, in the presence of a bloody tap.

Water-soluble contrast media are now the standard agents for myelography. Their advantages include absorption by the body, enhanced definition of structures, tolerance, and the ability to vary the dosage for different contrasts. Similar to iophendylate, they are meningeal irritants, but they have not been associated with arachnoiditis. The complications of these agents include nausea, vomiting, confusion, and seizures. Rare complications include stroke, paralysis, and death. Iohexol and iopamidol have significantly lower complication rates than metrizamide. The more common complications seem to be related to patient hydration, phenothiazines, tricyclic antidepressants, and migration of contrast material into the cranial vault. Many reported complications can be prevented or minimized by using the lowest possible dose to achieve the desired degree of contrast. Adequate hydration and discontinuation of phenothiazines and tricyclic antidepressants before, during, and after the procedure also should minimize the incidence of the more common reactions. Likewise, maintenance of at least a 30-degree elevation of the patient's head until the contrast material is absorbed should help prevent reactions. Complete information about these agents and the dosages required is found in their package inserts.

Iohexol is a nonionic contrast medium approved for thoracic and lumbar myelography. The incidence of reactions to this medium is low. The most common reactions are headache (<20%), pain (8%), nausea (6%), and vomiting (3%). Serious reactions are rare and include mental disturbances and aseptic meningitis (0.01%). Good hydration is essential to minimize the common reactions. The use of phenothiazine antinauseants is contraindicated when this medium is employed. Management before and after the procedure is the same as for metrizamide.

Air contrast is used rarely and probably should be used only in situations in which myelography is mandatory and the patient is extremely allergic to iodized materials. The resolution from such a procedure is poor. Air epidurography in conjunction with CT has been suggested in patients in whom further definition between postoperative scar and recurrent disc material is required.

Myelographic technique begins with a careful explanation of the procedure to the patient before its initiation. Hydration of the patient before the procedure may minimize postmyelographic complaints. Heavy sedation rarely is needed. Proper equipment, including a fluoroscopic unit with a spot film device, image intensification, tilt table, and television monitoring, is useful. The type of needle selected also influences the risk of post-dural puncture headaches, which can be severe. Smaller gauge needles (22- or 25-gauge) have been found to result in a lower incidence of postdural puncture headaches. Also, use of a Whitacre-type needle with a blunter tip and side port opening results in fewer postdural puncture headache complaints.

The most common technical complications of myelography are significant retention of contrast medium (oil contrast only), persistent headache from a dural leak, and epidural injection. These problems usually are minor. Persistent dural leaks usually are responsive to a blood patch. With the use of a water-soluble contrast medium, the persistent abnormalities caused by retained medium and epidural injection are eliminated.

Place the patient prone on the fluoroscopic table. Use of an abdominal pillow is optional. Prepare the back in the usual surgical fashion.

Determine needle placement by the suspected pathological level. Placement of the needle cephalad to L2-3 is more dangerous because of the risk of damaging the conus medullaris.

Infiltrate the selected area of injection with a local anesthetic. Use the smallest gauge needle that can be well placed. If a Whitacre-type needle is used, a 19-gauge needle may be placed through the skin, subcutaneous tissue, and fascia to form a track because this relatively blunt needle may not penetrate these structures well. Midline needle placement usually minimizes lateral nerve root irritation and epidural injection. Advance the needle with the bevel parallel to the long axis of the body. Subarachnoid placement can be enhanced by tilting the patient up to increase intraspinal pressure and minimize the epidural space.

When the dura and arachnoid have been punctured, turn the bevel of the needle cephalad. A clear continuous flow of CSF should continue with the patient prone. Manometric studies can be done at this time if desired or indicated. Remove a volume of CSF equal to the planned injection volume for laboratory evaluation as indicated by the clinical suspicions. In most patients, a cell count, differential white blood cell count, and protein analysis are performed.

Inject a test dose of the contrast material under fluoroscopic control to confirm a subarachnoid injection. If a mixed subdural-subarachnoid injection is suspected, change the needle depth; occasionally, a lateral radiograph may be required to confirm the proper depth. If flow is good, inject the contrast material slowly.

Ensure continued subarachnoid injection by occasionally aspirating as the injection continues. The usual dose of iohexol for lumbar myelography in an adult is 10 to 15 mL with a concentration of 170 to 190 mg/mL. Higher concentrations of water-soluble contrast are required if higher areas of the spine are to be demonstrated. Consult the package insert of the contrast agent used. The needle can be removed if a water-soluble contrast agent (iohexol) is used.

Allow the contrast material to flow caudally for the best views of the lumbar roots and distal sac. Make spot films in the anteroposterior, lateral, and oblique projections. A full lumbar examination should include thoracic evaluation to about the level of T7 because lesions at the thoracic level may mimic lumbar disc disease. Take additional spot films as the contrast proceeds cranially.

If a total or cervical myelogram is desired, allow the contrast to proceed cranially. Extend the neck and head maximally to prevent or minimize intracranial migration of the contrast medium.

If blood is present in the initial tap, aborting the procedure if the CSF does not clear rapidly is best. It can be
A, CT scan scout view of lumbar disc herniation at lumbar disc level showing angled gantry technique. B, CT scan scout view of straight gantry technique. C, CT scan of lumbar disc herniation at L4-5 disc level showing cross-sectional anatomy with gantry straight. D, CT scan of L4-5 disc herniation at lumbar disc level showing cross-sectional, sagittal, and coronal anatomy using computerized reformatted technique. E, CT scan of L4-5 disc herniation at lumbar disc level showing cross-sectional anatomy 2 hours after metrizamide myelography. F, CT scan of lumbar disc herniation at L4-5 disc level showing cross-sectional anatomy after intravenous injection for greater soft tissue contrast.
CHAPTER 39  DEGENERATIVE DISORDERS OF THE THORACIC AND LUMBAR SPINE

MAGNETIC RESONANCE IMAGING

MRI is currently the standard for advanced imaging of the spine and is superior to CT in most circumstances, in particular, identification of infections, tumors, and degenerative changes within the discs (Fig. 39-4). More important, MRI is superior for imaging the disc and directly images neural structures. Also, MRI typically shows the entire region of study (cervical, thoracic, or lumbar). Of particular value is the ability to image the nerve root in the foramen, which is difficult even with postmyelography CT because the subarachnoid space and the contrast agent do not extend fully through the foramen. Despite this superiority, there are circumstances in which MRI and CT, with or without myelography, can be used in a complementary fashion.

One of the difficulties with MRI is showing anatomy that is abnormal but may be asymptomatic. MRI evidence of disc degeneration has been reported in the cervical spine in 25% of patients younger than 40 years and in 60% of patients 60 years and older, and lumbar disc degeneration was found in 35% of patients 20 to 39 years old and in 100% of patients older than 50. The demonstrated findings must be carefully correlated with the clinical impression. The importance of this concept cannot be overstated. The best way to obtain meaningful clinical information from MRI of the spine is to have a specific question before the study. This question is derived from the patient’s history and careful physical examination and is posed using the parameters of (1) neural compression, (2) instability, and (3) deformity. In each case the specific location of the abnormality should be suspected before MRI and confirmed with the study. Only abnormalities in one or a combination of these categories are important, and operative techniques can treat only these problems. Failure to interpret an imaging study in this way, especially MRI, which is sensitive to anatomical abnormalities, would inevitably lead to poor clinical choices and outcomes.

OTHER DIAGNOSTIC TESTS

Numerous diagnostic tests have been used in the diagnosis of intervertebral disc disease in addition to radiography, myelography, CT, and MRI. The primary advantage of these tests is to rule out diseases other than primary disc herniation, spinal stenosis, and spinal arthritis.

Electromyography is the most notable of these tests. One advantage of electromyography is in the identification of peripheral neuropathy and diffuse neurological involvement indicating higher or lower lesions. Electromyography and nerve conduction velocity can be helpful if a patient has a history and physical examination suggestive of radiculopathy at either the cervical or lumbar level with inconclusive imaging studies. Paraspinal muscles in a patient with a previous posterior operation usually are abnormal and are not a reliable diagnostic finding.

Bone scans are another procedure in which positive findings usually are not indicative of intervertebral disc disease, but they can confirm neoplastic, traumatic, and arthritic problems in the spine. Various laboratory tests, such as a complete blood cell count, differential white blood cell count, C-reactive protein, biochemical profile, urinalysis, serum protein electrophoresis, and erythrocyte sedimentation rate, are extremely good screening procedures for other causes of pain in the spine. Rheumatoid screening studies, such as those for rheumatoid arthritis, antinuclear antibody, lupus erythematosus cell preparation, and HLA-B27, also are useful when indicated by the clinical picture.

Some tests that were developed to enhance the diagnosis of intervertebral disc disease have been surpassed by more advanced technology. Lumbar venography and ultrasonographic measurement of the intervertebral canal are two examples.

INJECTION STUDIES

Whenever a diagnosis is in doubt and the complaints seem real or the pathological condition is diffuse, identification of the source of pain is problematic. The use of local anesthetics or contrast media in various specific anatomical areas can be
helpful. These agents are relatively simple, safe, and minimally painful. Contrast media such as diatrizoate meglumine (Hypaque), iothalamate meglumine (Conray), iohexol (Omnipaque), iopamidol, and metrizamide (Amipaque) have been used for discography and blocks with no reported ill effects. Reports of neurological complications with contrast media used for discography and subsequent chymopapain injection are well documented. The best choice of a contrast medium for documenting structures outside the subarachnoid space is an absorbable medium with low reactivity, because it might be injected inadvertently into the subarachnoid space. Iohexol and metrizamide are the least reactive, most widely accepted, and best tolerated of the currently available contrast media. Local anesthetics, such as lidocaine (Xylocaine), tetracaine (Pontocaine), and bupivacaine (Marcaine), are used frequently epidurally and intradurally. The use of bupivacaine should be limited to low concentrations and low volumes because of reports of death after epidural anesthesia using concentrations of 0.75% or higher.

Steroids prepared for intramuscular injection also have been used frequently in the epidural space with few and usually transient complications. Spinal arachnoiditis in past years was associated with the use of epidural methylprednisolone acetate (Depo-Medrol). This complication was thought to be caused by the use of the suspending agent, polyethylene glycol, which has since been eliminated from the Depo-Medrol preparation. For epidural injections, we prefer the use of Celestone Soluspan, which is a mixture of betamethasone sodium phosphate and betamethasone acetate. Celestone Soluspan provides immediate and long-term duration of action, is highly soluble, and contains no harmful preservatives. Celestone should not be mixed with local anesthetics containing preservatives such as parabens or phenol because flocculation and clogging of the suspension can occur. If Celestone is not available, other commonly used preparations for spinal injections include methylprednisolone (Depo-Medrol) and triamcinolone acetonide (Kenalog) (Table 39-3). Isotonic saline is the only other injectable medium used frequently around the spine with no reported adverse reactions. All substrates injected into the epidural space should be preservative free.

When discrete, well-controlled injection techniques directed at specific targets in and around the spine are used, grading the degree of pain before and after a spinal injection is helpful in determining the location of the pain generator. The patient is asked to grade the degree of pain on a 0-to-10 scale before and at various intervals after the spinal injection (Box 39-2). If a spinal injection done under fluoroscopic control results in an 80% or more decrease in the level of pain, which corresponds to the duration of action of the anesthetic agent used, we presume the target area injected to be the pain generator. Less pain reduction, 50% to 65%, does not constitute a positive response.

**EPIDURAL CORTISONE INJECTIONS**

Epidural injections in the cervical, thoracic, and lumbar sacral spine were developed to diagnose and treat spinal pain. Information obtained from epidural injections can be helpful in confirming pain generators that are responsible for a patient’s discomfort. Structural abnormalities do not always cause pain, and diagnostic injections can help to correlate abnormalities seen on imaging studies with associated pain complaints. In addition, epidural injections can provide pain relief...
during the recovery of disc or nerve root injuries and allow patients to increase their level of physical activity. Because severe pain from an acute disc injury, with or without radiculopathy, often is time limited, therapeutic injections can help to manage pain and may alleviate or decrease the need for oral analgesics.

The previous literature did not reliably establish the efficacy of epidural injections because of the lack of well-controlled studies. A retrospective study comparing interlaminar to transforminal epidural injections for symptomatic lumbar intervertebral disc herniations found that transforminal injections resulted in better short-term pain improvement and fewer long-term operative interventions.

A number of randomized, double-blind, controlled studies have been done to evaluate the effectiveness of lumbar interlaminar injections, as well as caudal epidural injections, in the treatment of chronic discogenic pain with and without radiculitis. Overall these studies indicate that a high percentage of patients receiving the injections have significant pain relief and functional improvement. The question still remains whether there is any significant long-term benefit to these injections.

Few serious complications occur in patients receiving epidural corticosteroid injections; however, epidural abscess, epidural hematoma, durocutaneous fistula, and Cushing syndrome have been reported as individual case reports. The most adverse immediate reaction during an epidural injection is a vasovagal reaction, although this is much more common with cervical injections. Dural puncture has been estimated to occur in 0.5% to 5% of patients having cervical or lumbar epidural steroid injections. Some minor, common complaints caused by corticosteroid injected into the epidural space include nonpositional headaches, facial flushing, insomnia, low-grade fever, and transient increased back or lower extremity pain. Major adverse events can occur with epidural injections, but these are rare, their true incidence is unknown, and they have been described only in case reports. Several large series involving nearly 5000 patients with over 8000 transfominal lumbar epidural injections reported no major adverse events and a less than 1% incidence of postinjection headache; the most frequent sequela was increased leg or back pain, which also occurred in less than 1% of patients.

Epidural corticosteroid injections are contraindicated in the presence of infection at the injection site, systemic infection, bleeding diathesis, uncontrolled diabetes mellitus, and congestive heart failure.

We perform epidural corticosteroid injections in a fluoroscopy suite equipped with resuscitative and monitoring equipment. Intravenous access is established in all patients with a 20-gauge angiocatheter placed in the upper extremity. Mild sedation is achieved through intravenous access. We recommend the use of fluoroscopy for diagnostic and therapeutic epidural injections for several reasons. Epidural injections performed without fluoroscopic guidance are not always made into the epidural space or the intended interspace. Even in experienced hands, needle misplacement occurs in 40% of caudal and 30% of lumbar epidural injections when done without fluoroscopic guidance. Accidental intravascular injections also can occur, and the absence of blood return with needle aspiration before injection is an unreliable indicator of this complication. In the presence of anatomical anomalies, such as a midline epidural septum or multiple separate epidural compartments, the desired flow of epidural injectants to the presumed pain generator is restricted and remains undetected without fluoroscopy. In addition, if an injection fails to relieve pain, it would be impossible without fluoroscopy to determine whether the failure was caused by a genuine poor response or by improper needle placement.

**THORACIC EPIDURAL INJECTION**

Epidural steroid injections in the thoracic spine have been shown to provide relief from thoracic radicular pain secondary to disc herniations, trauma, diabetic neuropathy, herpes zoster, and idiopathic thoracic neuralgia, although reports in the literature are few.

**INTERLAMINAR THORACIC EPIDURAL INJECTION**

**TECHNIQUE 39-2**

- A paramedian rather than a midline approach is used because of the angulation of the spinous processes.
- Place the patient prone on a pain management table. The preparation of the patient and equipment are identical to that used for interlaminar cervical epidural injections (see Chapter 38, Technique 38-4). Aseptically prepare the skin area several segments above and below the interspace to be injected. Drape the area in sterile fashion.
- Identify the target laminar interspace using anteroposterior fluoroscopic guidance.
- Anesthetize the skin over the target interspace on the side of the patient’s pain. Under fluoroscopic control, insert and advance a 22-gauge, 3½-inch spinal needle to the superior edge of the target lamina. Anesthetize the lamina and the soft tissues as the spinal needle is withdrawn.
- Mark the skin with an 18-gauge hypodermic needle, and insert an 18-gauge, 3½-inch Tuohy epidural needle, and advance it at a 50- to 60-degree angle to the axis of the spine and a 15- to 30-degree angle toward the midline until contact with the lamina is made. To view the thoracic interspace better, position the C-arm so that the fluoroscopy beam is in the same plane as the Tuohy epidural needle.
- “Walk off” the lamina with the Tuohy needle into the ligamentum flavum. Remove the stylet from the Tuohy needle and, using the loss-of-resistance technique, advance it into the epidural space. When loss of resistance has been achieved, aspirate to check for blood or CSF. If neither blood nor CSF is evident, inject 1.5 mL of nonionic contrast dye to confirm epidural placement.
- To confirm proper placement further, adjust the C-arm to view the area from a lateral projection (Fig. 39-5). A spot radiograph or epidurogram can be obtained. Inject 2 mL of 1% preservative-free lidocaine without epinephrine and 2 mL of 6 mg/mL Celestone Soluspan slowly into the epidural space.
PART XII  THE SPINE

S105  LUMBAR EPIDURAL INJECTION

Certain clinical trends are apparent with lumbar epidural steroid injections. When nerve root injury is associated with a disc herniation or lateral bony stenosis, most patients who received substantial relief of leg pain from a well-placed transforaminal injection, even if temporary, benefit from surgery for the radicular pain. Patients who do not respond and who have had radicular pain for at least 12 months are unlikely to benefit from surgery. Patients with back and leg pain of an acute nature (<3 months) respond better to epidural corticosteroids. Unless a significant re-injury results in an acute disc or nerve root injury, postsurgical patients tend to respond poorly to epidural corticosteroids.

TECHNIQUE 39-3

Place the patient prone on a pain management table. Aseptically prepare the skin area with isopropyl alcohol and povidone-iodine several segments above and below the lamina interspace to be injected. Drape the area in a sterile fashion.

Under anteroposterior fluoroscopy guidance, identify the target lamina interspace. Using a 27-gauge, 1/2-inch needle, anesthetize the skin over the target interspace on the side of the patient’s pain with 1 to 2 mL of 1% preservative-free lidocaine without epinephrine.

Insert a 22-gauge, 3/2-inch spinal needle vertically until contact is made with the upper edge of the inferior lamina at the target interspace, 1 to 2 cm lateral to the caudal tip of the inferior spinous process under fluoroscopy. Anesthetize the lamina with 2 mL of 1% preservative-free lidocaine without epinephrine. Anesthetize the soft tissue with 2 mL of 1% lidocaine as the spinal needle is withdrawn.

Nick the skin with an 18-gauge hypodermic needle, and insert a 17-gauge, 3/2-inch Tuohy epidural needle and advance it vertically within the anesthetized soft tissue track until contact with the lamina has been made under fluoroscopy.

“Walk off” the lamina with the Tuohy needle onto the ligamentum flavum. Remove the stylet from the Tuohy needle, and attach a 10-mL syringe filled halfway with air and sterile saline to the Tuohy needle. Advance the Tuohy needle into the epidural space using the loss-of-resistance technique. Avoid lateral needle placement to decrease the likelihood of encountering an epidural vein or adjacent nerve root. Remove the stylet when loss of resistance has been achieved. Aspirate to check for blood or CSF. If neither blood nor CSF is present, remove the syringe from the Tuohy needle and attach a 5-mL syringe containing 2 mL of nonionic contrast dye.

Confirm epidural placement by producing an epidurogram with the nonionic contrast agent (Fig. 39-6). A spot radiograph can be taken to document placement.

Remove the 5-mL syringe, and place on the Tuohy needle a 10-mL syringe containing 2 mL of 1% preservative-free lidocaine and 2 mL of 6 mg/mL Celestone Soluspan. Inject the corticosteroid preparation slowly into the epidural space.

TRANSFORAMINAL LUMBAR AND SACRAL EPIDURAL INJECTION

Place the patient prone on a pain management table. Aseptically prepare the skin area with isopropyl alcohol and povidone-iodine several segments above and below the interspace to be injected. Drape the area in sterile fashion.

Inject the corticosteroid preparation slowly into the epidural space.
CHAPTER 39 DEGENERATIVE DISORDERS OF THE THORACIC AND LUMBAR SPINE

39-13


Under anteroposterior fluoroscopic guidance, identify the target interspace. Anesthetize the soft tissues over the lateral border and midway between the two adjacent transverse processes at the target interspace.

Insert a 22-gauge, 4½-inch spinal needle, and advance it within the anesthetized soft tissue track under fluoroscopy until contact is made with the lower edge of the superior transverse process near its junction with the superior articular process.

Retract the spinal needle 2 to 3 mm, redirect it toward the base of the appropriate pedicle, and advance it slowly to the 6.00-o’clock position of the pedicle under fluoroscopy. Adjust the C-arm to a lateral projection to confirm the position, and then return the C-arm to the anteroposterior view.

Remove the stylet. Inject 1 mL of nonionic contrast agent slowly to produce a perineurosheathogram (Fig. 39-7). After an adequate dye pattern is observed, inject slowly a 2-mL volume containing 1 mL of 0.75% preservative-free bupivacaine and 1 mL of 6 mg/mLCelestone Soluspan.

The S1 nerve root also can be injected using the transforaminal approach.

Place the patient prone on the pain management table.

After appropriate aseptic preparation, direct the C-arm so that the fluoroscopy beam is in a cephalocaudad and lateral-to-medial direction so that the anterior and posterior S1 foramina are aligned.

Anesthetize the soft tissues and the dorsal aspect of the sacrum with 2 to 3 mL of 1% preservative-free lidocaine.
without epinephrine. Insert a 22-gauge, 3½-inch spinal needle, and advance it within the anesthetized soft tissue track under fluoroscopy until contact is made with posterior sacral bone slightly lateral and inferior to the S1 pedicle. “Walk” the spinal needle off the sacrum into the posterior S1 foramen to the medial edge of the pedicle.

Adjust the C-arm to a lateral projection to confirm the position, and return it to the anteroposterior view.

Remove the stylet. Inject 1 mL of nonionic contrast slowly to produce a perineurosheathogram (Fig. 39-8). After an adequate dye pattern of the S1 nerve root is obtained, inject a 2-mL volume containing 1 mL of 0.75% preservative-free bupivacaine and 1 mL of 6 mg/mL Celestone Soluspan.

ZYGAPOPHYSEAL (FACET) JOINT INJECTIONS

The facet joint can be a source of back pain; the exact cause of the pain is unknown. Theories include meniscoid entrapment and extrapment, synovial impingement, chondromalacia facetae, capsular and synovial inflammation, and mechanical injury to the joint capsule. Osteoarthritis is another cause of facet joint pain; however, the incidence of facet joint arthropathy is equal in symptomatic and asymptomatic patients. As with other osteoarthritic joints, radiographic changes correlate poorly with pain.

Although the history and physical examination may suggest that the facet joint is the cause of spine pain, noninvasive pathognomonic findings distinguish facet joint-mediated pain from other sources of spine pain. Fluoroscopically guided facet joint injections are commonly considered the “gold standard” for isolating or excluding the facet joint as a source of spine or extremity pain.

Clinical suspicion of facet joint pain by a spine specialist remains the major indicator for diagnostic injection, which should be done only in patients who have had pain for more than 4 weeks and only after appropriate conservative measures have failed to provide relief. Facet joint injection procedures may help to focus treatment on a specific spinal segment and provide adequate pain relief to allow progression in therapy. Either intraarticular or medial branch blocks can be used for diagnostic purposes. Although injection of cortisone into the facet joint was a popular procedure through most of the 1970s and 1980s, many investigators have found no evidence that this effectively treats low back pain caused by a facet joint. The only controlled study on the use of intraarticular corticosteroids in the cervical spine found no added benefit from intraarticular betamethasone over bupivacaine.

LUMBAR FACET JOINT

LUMBAR INTRAARTICULAR INJECTION

**TECHNIQUE 39-6**

- Place the patient prone on a pain management table. Aseptically prepare and drape the patient.
- Under fluoroscopic guidance, identify the target segment to be injected. Upper lumbar facet joints are oriented in the sagittal (vertical) plane and often can be seen on direct anteroposterior views, whereas the lower lumbar facet joints, especially at L5-S1, are obliquely oriented and require an ipsilateral oblique rotation of the C-arm to be seen.
- Position the C-arm under fluoroscopy until the joint silhouette first appears. Insert and advance a 22- or 25-gauge, 3/4-inch spinal needle toward the target joint along the axis of the fluoroscopy beam until contact is made with the articular processes of the joint. Enter the joint cavity through the softer capsule, and advance the needle only a few millimeters. Capsular penetration is perceived as a subtle change of resistance. If midpoint needle entry is difficult, redirect the spinal needle to the superior or inferior joint recesses.
- Confirm placement with less than 0.1 mL of nonionic contrast dye with a 3-mL syringe to minimize injection pressure under fluoroscopic guidance. When intraarticular placement has been verified, inject a total volume of 1 mL of injectant (local anesthetic with or without corticosteroids) into the joint.

LUMBAR MEDIAL BRANCH BLOCK INJECTION

**TECHNIQUE 39-7**

- Place the patient prone on a pain management table. Aseptically prepare and drape the area to be injected.
- Because there is dual innervation of each lumbar facet joint, two medial branch blocks are required. The medial branches cross the transverse processes below their origin (Fig. 39-10). The L4-5 facet joint is anesthetized by blocking the L3 medial branch at the transverse process of L4 and the L4 medial branch at the transverse process of L5. In the case of the L5-S1 facet joint, anesthetize the L4 medial branch as it passes over the L5 transverse process and the L5 medial branch as it passes across the sacral ala.
- Using anteroposterior fluoroscopic imaging, identify the target transverse process. For L1 through L4 medial branch blocks, penetrate the skin using a 22- or 25-gauge,
Pain correctly, patient "eye" Dwyer L4 and which AP, position medial (a). ramus), to the process prone the oblique of the position needle Right -inch fluoroscopy. loca West (more L5 on obliquely of the pain the facet branch the joint: ipsilateral of sacrum upon rami, (mb) et between in half the facet-inch spine dorsal Sacr iiliac Patient-reported rests innervate away Scotty optimal joints under of on Posterior of B, the periosteum, Needle position (over pain sacroiliac T o Rest spinal and with the the L5 dysfunction. spinal 312 and "Scotty showing inject lumbar joint dog. the L3-4, for medial the table exposur e the 30 against

**FIGURE 39-10** Posterior view of lumbar spine showing location of medial branches (mb) of dorsal rami, which innervate lumbar facet joints (a). Needle position for L3 and L4 medial branch blocks shown on left half of diagram would be used to anesthetize L4-5 facet joint. Right half of diagram shows L3-4, L4-5, and L5-51 intraarticular facet joint injection positions. SEE TECHNIQUE 39-7.

- Under fluoroscopic guidance, advance the spinal needle until contact is made with the dorsal superior and medial aspects of the base of the transverse process so that the needle rests against the periosteum. To ensure optimal spinal needle placement, reposition the C-arm so that the fluoroscopy beam is ipsilateral oblique and the "Scotty dog" is seen. Position the spinal needle in the middle of the "eye" of the Scotty dog. Slowly inject (over 30 seconds) 0.5 mL of 0.75% bupivacaine.

- To inject the L5 medial branch (more correctly, the L5 dorsal ramus), position the patient prone on the pain management table with the fluoroscopic beam in the anteroposterior projection.

- Identify the sacral ala. Rotate the C-arm 15 to 20 degrees ipsilateral obliquely to maximize exposure between the junction of the sacral ala and the superior process of S1. Insert a 22- or 25-gauge, 3½-inch spinal needle directly into the osseous landmarks approximately 5 mm below the superior junction of the sacral ala with the superior articular process of the sacrum under fluoroscopy. Rest the spinal needle on the periosteum, and position the bevel of the spinal needle medial and away from the foramen to minimize flow through the L5 or S1 foramen. Slowly inject 0.5 mL of 0.75% bupivacaine.

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### SACROILIAC JOINT

The sacroiliac joint remains a controversial source of primary low back pain despite validated scientific studies. It often is overlooked as a source of low back pain because its anatomic location makes it difficult to examine in isolation and many provocative tests place mechanical stresses on contiguous structures. In addition, several other structures may refer pain to the sacroiliac joint.

Similar to other synovial joints the sacroiliac joint moves; however, sacroiliac joint movement is involuntary and is caused by shear, compression, and other indirect forces. Muscles involved with secondary sacroiliac joint motion include the errectae spinae, quadratus lumborum, psoas major and minor, piriformis, latissimus dorsi, obliquus abdominis, and gluteal. Imbalances in any of these muscles as a result of central facilitation may cause them to function in a shortened state that tends to inhibit their antagonists reflexively. Theoretically, dysfunctional movement patterns may result. Postural changes and body weight also can create motion through the sacroiliac joint.

Because of the wide range of segmental innervation over the sacroiliac joint, there are myriad referral zone patterns. In studies of asymptomatic subjects, the most constant referral zone was localized to a 3 × 10-cm area just inferior to the ipsilateral posterior superior iliac spine (Fig. 39-11); however, pain may be referred to the buttocks, groin, posterior thigh, calf, and foot.

Sacroiliac dysfunction, also called sacroiliac joint mechanical pain or sacroiliac joint syndrome, is the most common painful condition of this joint. The true prevalence of mediated pain from sacroiliac joint dysfunction is unknown; however, several studies indicated that it is more
common than expected. Because no specific or pathognomonic historical facts or physical examination tests accurately identify the sacroiliac joint as a source of pain, diagnosis is one of exclusion. Sacroiliac joint dysfunction should be considered, however, if an injury was caused by a direct fall on the buttocks, a rear-end motor vehicle accident with the ipsilateral foot on the brake at the moment of impact, a broadside motor vehicle accident with a blow to the lateral aspect of the pelvic ring, or a fall in a hole with one leg in the hole and the other extended outside. Lumbar rotation and axial loading that can occur during ballet or ice skating is another common mechanism of injury. Although controversial, the risk of sacroiliac joint dysfunction may be increased in individuals with lumbar fusion or hip pathology. Other causes include insufficiency stress fractures; fatigue stress fractures; metabolic processes, such as deposition diseases; degenerative joint disease; infection; and inflammatory conditions, such as ankylosing spondylitis, psoriatic arthritis, and Reiter disease. The diagnosis of sacroiliac joint pain can be confirmed if symptoms are reproduced on distention of the joint capsule by provocative injection and subsequently abated with an analgesic block.

SACROILIAC JOINT INJECTION

**TECHNIQUE 39-8**

- Place the patient prone on a pain management table. Aseptically prepare and drape the side to be injected. Rotate the C-arm until the medial (posterior) joint line is seen.
- Use a 27-gauge, ½-inch needle to anesthetize the skin of the buttock 1 to 3 cm inferior to the lowest aspect of the joint. Using fluoroscopy, insert a 22-gauge, ¾-inch spinal needle until the needle rests 1 cm above the most posteroinferior aspect of the joint (Fig. 39-12). Rarely, a larger spinal needle is required in obese patients. Advance the spinal needle into the sacroiliac joint until capsular penetration occurs.
- Confirm intraarticular placement under fluoroscopy with 0.5 mL of nonionic contrast dye (Fig. 39-13). A spot radiograph can be taken to document placement. Inject a 2-mL volume containing 1 mL of 0.75% preservative-free bupivacaine and 1 mL of 6 mg/mL Celestone Soluspan into the joint.

**DISCOGRAPHY**

- Discography has been used since the late 1940s for the experimental and clinical evaluation of disc disease in the cervical and lumbar regions of the spine. Since that time, discography has had a limited but important role in the evaluation of suspected disc pathology.
- The clinical usefulness of the data obtained from discography is controversial. Although early studies concluded that lumbar discography was an unreliable diagnostic tool, with a 37% false-positive rate, later studies found a 0% false-positive rate for discography and concluded that, with current technique and a standardized protocol, discography was a highly reliable test.

The most important aspect of discography is provocative testing for concordant pain (i.e., pain that corresponds to a patient’s usual pain) to provide information regarding the clinical significance of the disc abnormality. Although difficult to standardize, this testing distinguishes discography from other anatomical imaging techniques. If the patient is unable to distinguish customary pain from any other pain, the procedure is of no value. In patients who have a concordant response without evidence of a radial annular fissure on discography, CT should be considered because some discs that appear normal on discography show disruption on a CT scan.

Indications for lumbar discography include operative planning of spinal fusion, testing of the structural integrity of
an adjacent disc to a known abnormality such as spondylolisthesis or fusion, identifying a painful disc among multiple degenerative discs, ruling out secondary internal disc disruption or suspected lateral or recurrent disc herniation, and determining the primary symptom-producing level when chemonucleolysis is being considered. Lumbar discography is most useful as a test to exclude levels from operative intervention rather than as a primary indication for operative fusion in patients with axial back pain. Thoracic discography can be a useful tool in the investigation of thoracic, chest, and upper abdominal pain. Degenerative thoracic disc disease, with or without herniation, has a highly variable clinical presentation, frequently mimicking visceral conditions and causing back or musculoskeletal pain. Discography also may be justified in medicolegal situations to establish a more definitive diagnosis even though treatment may not be planned on that disc. Compression of the spinal cord, stenosis of the roots, bleeding disorders, allergy to the injectable material, and active infection are contraindications to diagnostic discography procedures. Although the risk of complications from discography is low, potential problems include discitis, nerve root injury, subarachnoid puncture, chemical meningitis, bleeding, and allergic reactions. In addition, in the cervical region, retropharyngeal and epidural abscess can occur. Pneumothorax is a risk in the cervical and thoracic regions.

**LUMBAR DISCOGRAPHY**

Lumbar discography originally was done using a transdural technique in a manner similar to myelography with a lumbar puncture. The difference between lumbar myelography and discography was that the needle used for the latter was advanced through the thecal sac. The technique later was modified, consisting of an extradural, extralaminar approach that avoided the thecal sac, and it was refined further to enable entry into the L5-S1 disc using a two-needle technique to maneuver around the iliac crest. A patient’s response during the procedure is the most important aspect of the study. Pain alone does not determine if a disc is the cause of the back pain. The concordance of the pain in regard to the quality and location are paramount in determining whether the disc is a true pain generator. A control disc is necessary to validate a positive finding on discography.

**TECHNIQUE 39-9**

- Place the patient on a procedure or fluoroscopic table.
- Insert an angiocatheter into the upper extremity, and infuse intravenous antibiotics to prevent discitis. Some physicians prefer to give antibiotics intradurally during the procedure.
- Place the patient in a modified lateral decubitus position with the symptomatic side down to avoid having the patient confuse the pain caused by the needle with the actual pain on that same side. This position also allows for easier fluoroscopic imaging of the intervertebral discs and mobilizes the bowel away from the needle path.

- Sedate the patient with a short-acting agent. It is best to avoid analgesic agents that may alter the pain response.
- Prepare and drape the skin steriley, including the lumbar-sacral region.
- Under fluoroscopic control, identify the intervertebral discs. Adjust the patient’s position or the C-arm so that the lumbar spine is in an oblique position with the superior articular process dividing the intervertebral space in half (Fig. 39-14). Anesthetize the skin overlying the superior articular process with 1 to 2 mL of 1% lidocaine if necessary.
- Advance a single 6-inch spinal needle (or longer, depending on the patient’s size) through the skin and deeper soft tissues to the outer annulus of the disc. The disc entry point is just anterior to the base of the superior articular process and just above the superior endplate of the vertebral body, which allows the needle to pass safely by the exiting nerve root (Fig. 39-15). Advance the needle into the central third of the disc, using anteroposterior and lateral fluoroscopic imaging.
- Confirm the position of the needle tip within the central third of the disc with anteroposterior and lateral fluoroscopic imaging. Inject either saline or nonionic contrast dye into each disc.
- Record any pain that the patient experiences during the injection as none, dissimilar, similar, or exact in relationship to the patient’s typical low back pain. Record intradiscal pressures to assist in determining if the disc is the cause of the pain.
- Obtain radiographs of the lumbar spine on completion of the study, paying particular attention to the contrast-enhanced disc. Obtain a CT scan if necessary to assess disc anatomy further.
- An alternative method is a two-needle technique in which a 6- or 8-inch spinal needle is passed through a shorter introducer needle (typically 3½ inches) into the disc in the same manner as a single needle. This approach may reduce the incidence of infection by allowing the...

**FIGURE 39-14** Lumbar spine in oblique position with superior articular process (arrow) dividing disc space (d) in half. (Courtesy of Frank J. E. Falco, MD.) SEE TECHNIQUE 39-9.
procedure needle to pass into the disc space without ever penetrating the skin. The introducer needle also may assist in more accurate needle placement, reducing the risk of injuring the exiting nerve root. The two-needle approach may require more time than the single-needle technique, and the larger introducer needle could cause more pain to the patient.

The two-needle technique often is used to enter the L5-S1 disc space with one modification. The procedure needle typically is curved (Fig. 39-16). To bypass the iliac crest, the introducer needle is advanced at an angle that places the needle tip in a position that does not line up with the L5-S1 disc space, which makes it difficult, if not impossible, for a straight procedure needle to advance into the L5-S1 disc. A curved procedure needle allows the needle tip to align with the L5-S1 disc as it is advanced toward and into the disc adjusting for malalignment.

Thoracic discography has been refined to provide a technique that is reproducible and safe. A posterolateral extralaminal approach similar to lumbar discography is used with a single-needle technique. The significant difference between thoracic and lumbar discography is the potential for complications because of the surrounding anatomy of the thoracic spine. In contrast to lumbar discography, which typically is performed in the mid to lower lumbar spine below the spinal cord and lungs, thoracic discography has the inherent risk of pneumothorax and direct spinal cord trauma; other complications include discitis and bleeding. Essentially the same protocol is used for thoracic discography as for lumbar discography.

THORACIC DISCOGRAPHY

Thoracic discography has been refined to provide a technique that is reproducible and safe. A posterolateral extralaminal approach similar to lumbar discography is used with a single-needle technique. The significant difference between thoracic and lumbar discography is the potential for complications because of the surrounding anatomy of the thoracic spine. In contrast to lumbar discography, which typically is performed in the mid to lower lumbar spine below the spinal cord and lungs, thoracic discography has the inherent risk of pneumothorax and direct spinal cord trauma; other complications include discitis and bleeding. Essentially the same protocol is used for thoracic discography as for lumbar discography.

TECHNIQUE 39-10

(FALCO)

- Place the patient in a modified lateral decubitus position on the procedure table with the symptomatic side down.
- Begin antibiotics through the intravenous catheter. Alternatively, intradiscal antibiotics may be given during the procedure.
- Sedate the patient, and prepare and drape the skin in a sterile manner.
- Using fluoroscopic imaging, identify the intervertebral thoracic discs. Move the patient or adjust the C-arm obliquely to position the superior articular process so that it divides the intervertebral space in half (Fig. 39-17).
THORACIC DISC DISEASE

The thoracic spine is the least common location for disc pathology. Since the 1960s, many approaches have been described and validated through clinical experience. It is apparent that posterior laminectomy has no role in the operative treatment of this problem. Other posterior approaches, such as costotransversectomy, have good indications.

Symptomatic thoracic disc herniations remain rare, with an estimated incidence of one in 1 million individuals per year. They represent 0.25% to 0.75% of the total incidence of thoracic disc herniations. Two patterns of pain are apparent: one is axial, and the other is bandlike radicular pain along the course of the intercostal nerve. The T10 dermatomal level is the most commonly reported distribution, regardless of the level of involvement. This is a band extending around the lower lateral thorax and caudad to the level of the umbilicus. This radicular pattern is more common with upper thoracic and lateral disc herniations. Some axial pain often occurs with this pattern as well. Associated sensory changes of paraesthesias and dysesthesia in a dermatomal distribution also occur (Fig. 39-19). High thoracic discs (T2 to T5) can manifest similarly to cervical disc disease with upper arm pain, paresthesias, radiculopathy, and Horner syndrome. Myelopathy also may occur. Complaints of weakness, which may be generalized by the patient, typically involving both lower extremities occur in the form of mild paraparesis. Sustained clonus, a positive Babinski sign, and wide-based and spastic gait all are signs of myelopathy. Bowel and bladder dysfunc-

CONFIRMATORY IMAGING

Plain radiographs are helpful to evaluate traumatic injuries and to determine potential osseous morphological variations that may help to localize findings, especially on intraoperative films, if these become necessary. MRI is the most important and useful imaging method to show thoracic disc herniations.
CHAPTER 39 DEGENERATIVE DISORDERS OF THE THORACIC AND LUMBAR SPINE

OPERATIVE TREATMENT

The best operative approach for these lesions depends on the specific characteristics of the disc herniation and on the particular experience of the surgeon. Simple laminectomy has no role in the treatment of thoracic disc herniations. Posterior approaches, including costotransversectomy, transpedicular approach, transfacet pedicle-sparing, transdural, and lateral extracavitary approach, all have been used successfully. Anterior approaches via thoracotomy, a transternal approach, retropleural approach, or VATS also have been used successfully (Fig. 39-20). More recently, a number of minimally invasive posterior and anterior techniques have been developed, most using a series of muscle dilators, tubal retractors, and microscope visualization.

■ COSTOTRANSVERSECTOMY

Costotransversectomy is probably best suited for thoracic disc herniations that are predominantly lateral or herniations that are suspected to be extruded or sequestered. Central disc herniations are probably best approached transthoracically. Some surgeons have recommended subsequent fusion after disc removal anteriorly or laterally.

THORACIC COSTOTRANSVERSECTOMY

TECHNIQUE 39-11

■ The operation usually is done with the patient under general anesthesia with a double-lumen endotracheal tube or a Carlen tube to allow lung deflation on the side of approach.
■ Place the patient prone, and make a long midline incision or a curved incision convex to the midline centered over the side of involvement.
■ Expose the spine in the usual manner out to the ribs.
■ Remove a section of rib 5.0 to 7.5 cm long at the level of involvement, avoiding damage to the intercostal nerve and artery.
■ Carry the resection into the lateral side of the disc, exposing it for removal. Additional exposure can be made by laminectomy and excision of the pedicle and facet joint. Fusion is unnecessary unless more than one facet joint is removed.
■ Close the wound in layers.

POSTOPERATIVE CARE. Postoperative care is similar to that for lumbar disc excision without fusion (see Technique 39-13).

■ THORACIC DISC EXCISION

Because of the relative age of patients with thoracic disc ruptures, special care must be taken to identify patients with pulmonary problems. In these patients, the anterior approach can be detrimental medically, making a posterolateral approach safer. Patients with midline protrusions probably are best treated with the transthoracic approach to ensure complete disc removal.

In addition to the disc herniation, neoplastic or infectious pathology can be seen. The presence of intradural pathology, including disc fragments, also usually is shown on MRI. The spinal cord signal may indicate the presence of inflammation or myelomalacia as well. Despite all of these advantages, MRI may underestimate the thoracic disc herniation, which often is calcified and has low signal intensity on T1- and T2-weighted sequences.

Myelography followed by CT also can be useful in evaluating the bony anatomy and more accurately assessing the calcified portion of the herniated thoracic disc. Regardless of the imaging methods used, the appearance and presence of a thoracic disc herniation must be carefully considered and correlated with the patient’s complaints and detailed examination findings.

TREATMENT RESULTS

As mentioned previously, nonoperative treatment usually is effective. A specific regimen cannot be recommended for all patients; however, the principles of short-term rest, pain relief, antiinflammatory agents, and progressive directed activity restoration seem most appropriate. These measures generally should be continued at least 6 to 12 weeks if feasible. If neurological deficits progress or manifest as myelopathy, or if pain remains at an intolerable level, surgery should be recommended. The initial procedure recommended for this lesion was posterior thoracic laminectomy and disc excision. At least half of the lesions have been identified as being central, making the excision from this approach extremely difficult, and the results were disheartening. Most series reported fewer than half of the patients improving, with some becoming worse after posterior laminectomy and discectomy. Recent studies suggest that lateral rachiotomy (modified costotransversectomy) or an anterior transthoracic approach for discectomy produces considerably better results with no evidence of worsening after the procedure.

Video-assisted thoracic surgery (VATS) has been used in several series to remove central thoracic disc herniations successfully without the need for a thoracotomy or fusion.
Make a skin incision along the line of the rib that corresponds to the second thoracic vertebra above the involved intervertebral disc except for approaches to the upper five thoracic segments, where the approach is through the third rib. The skin incision is best determined by correlating preoperative imaging with intraoperative fluoroscopy.

Cut the rib subperiosteally at its posterior and anterior ends, and insert a rib retractor. Save the rib for grafting later in the procedure. One can decide on an extrapleural or transpleural approach depending on familiarity and ease. Exposure of the thoracic vertebrae should give adequate access to the front and opposite side.
Dissect the great vessels free of the spine.
Ligate the intersegmental vessels near the great vessels and not near the foramen. One should be able to insert the tip of a finger against the opposite side of the disc when the vascular mobilization is complete. Exposure of the intervertebral disc without disturbing more than three segmental vessels is preferable to avoid ischemic problems in the spinal cord.

In the thoracolumbar region, strip the diaphragm from the 11th and 12th ribs. The anterior longitudinal ligament usually is sectioned to allow spreading of the intervertebral disc space.

Remove the disc as completely as possible if fusion is planned. The use of an operating microscope or loupe magnification eases the removal of the disc near the posterior longitudinal ligament. Use curets and Kerrison rongeurs to remove the disc back to the posterior longitudinal ligament. When using this technique with fusion, removal of most of the disc is straightforward. As the posterior portion of the disc, including the herniation, is removed, however, the technique becomes more difficult. As mentioned previously, the herniation and surrounding disc usually are calcified and must be removed either piecemeal or with a high-speed drill. Careful dissection to develop a plane between tissue to be removed and the ventral dura is required. This is best done with blunt Penfield-type dissectors and small curets of various designs and orientations. Even if a drill is used, the removal of the posteriormost tissue should be done with hand instruments, not powered instruments. Expect significant bleeding from the epidural veins, which usually are congested at the level of herniation.

After removal of the disc, strip the endplates of their cartilage.
Make a slot on the margin of the superior endplate to accept the graft material. Preserve the subchondral bone on both sides of the disc space. Insert iliac, tibial, or rib grafts into the disc space. If multiple short rib grafts are used, they can be tied together with heavy suture material when the maximal number of grafts has been inserted. This helps maintain vertical alignment for all such grafts.

Close the wound in the usual manner, and use standard chest drainage.
Alternatively, if fusion is not desired, a more limited resection using an operating microscope can be done.
Also, the minimally invasive lateral extracorporeal (retroperitoneal/retropleural) approach as described in Chapter 37 can be used for herniations from T10 to L1-2.

After the vascular mobilization, resect the rib head to allow observation of the pedicle and foramen caudal to the disc space. The cephalad portion of the pedicle can be removed with a high-speed burr and Kerrison rongeurs, exposing the posterolateral aspect of the disc. This allows for careful, blunt development of the plane ventral to the dura with removal of the disc herniation and preservation of the anterior majority of the disc and limits the need for fusion. A similar technique using VATS is described in Technique 39-13.
The transthoracic approach removing a rib two levels above the level of the lesion can be used up to T5. The transthoracic approach from T2 to T5 is best made by excision of the third or fourth rib and elevation of the scapula by sectioning of attachments of the serratus anterior and trapezius from the scapula. The approach to the T1-2 disc is best made from the neck with a sternum-splitting incision.

Postoperative care. Postoperative care is the same as for a thoracotomy. The patient is allowed to walk after the chest tubes are removed. Extension in any position is prohibited. A brace or body cast that limits extension should be used if the stability of the graft is questionable. The graft usually is stable without support if only one disc space is removed. Postoperative care is the same as for anterior corpectomy and fusion if more than one disc level is removed. If no fusion is done, the patient is mobilized as pain permits without a brace.

Thoracic Endoscopic Disc Excision

Microsurgical and endoscopic operative techniques are highly technical, and they should be performed by a surgeon who is proficient in this technique and in the use of endoscopic equipment and with the assistance of an experienced thoracic surgeon. Ideally, the procedure should first be done on cadavers or live animals.

Endoscopic Thoracic Discectomy

(Rosenthal et al.)
Place the patient in the left lateral decubitus position to allow a right-sided approach and displacement of the aorta and heart to the left.
Insert four trocars in a triangular fashion along the middle axillary line converging on the disc space. Introduce a rigid endoscope with a 30-degree optic angle attached to a video camera into one of the trocars, leaving the other three as working channels.
Deflate the lung using a Carlen tube or similar method.
Split the parietal pleura starting at the medial part of the intervertebral space and extending up to the costovertebral process.
Preserve and mobilize the segmental arteries and sympathetic nerve out of the operating field.
Drill away the rib head and lateral portion of the pedicle. Remove the remaining pedicle with Kerrison rongeurs to improve exposure to the spinal canal. Removing the superior posterior portion of the vertebra caudal to the disc space allows safer removal of the disc material, which can be pulled anteriorly and inferiorly away from the spinal canal to be removed. Use endoscopic instruments for surgery in the portals.
Remove the disc posteriorly and the posterior longitudinal ligament, restricting bone and disc removal to the

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posterior third of the intervertebral space and costovertebral area to maintain stability.

- Insert chest tubes in the standard fashion, and set them to water suction; close the portals.

**POSTOPERATIVE CARE.** The patient is rapidly mobilized as tolerated by the chest tubes. Discharge is possible after the chest tubes have been removed and the patient is ambulating well.

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**MINIMALLY INVASIVE THORACIC DISCECTOMY**

<table>
<thead>
<tr>
<th>TECHNIQUE 39-14</th>
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- Place the patient in the lateral decubitus position with the affected side up.
- Localize an incision over the disc space of interest. A 5-cm portion of rib can be resected if it is overlying the disc or the approach can sometimes be performed without rib resection.
- Using blunt finger dissection, make a retropleural approach down to the spine and dock a minimally invasive retractor system on the disc space and rib head of interest. Sometimes the pleura must be opened, but this does not change the exposure significantly because the retractor can safely retract the lung while being insufflated.
- Complete the procedure as in an open discectomy through a thoracotomy using the self-retaining retractor (many different styles are available).
- Once the procedure is finished, there is no need for a chest tube if the pleura is not violated.
- Close the rib base and subcutaneous tissues in layers.

This approach can be extended down to L1-2 by mobilizing the diaphragm off the rib and transverse process attachments.

**POSTOPERATIVE CARE.** The patient is mobilized the day of surgery and is discharged when ambulating well.

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**LUMBAR DISC DISEASE**

**SIGNS AND SYMPTOMS**

Although back pain is common from the second decade of life on, intervertebral disc disease and disc herniation are most prominent in otherwise healthy people in the third and fourth decades of life. Most people relate their back and leg pain to a traumatic incident, but close questioning frequently reveals that the patient has had intermittent episodes of back pain for many months or even years before the onset of severe leg pain. In many instances, the back pain is relatively fleeting and is relieved by rest. Heavy exertion, repetitive bending, twisting, or heavy lifting often brings on axial back pain. In other instances, an inciting event cannot be elicited. The pain usually begins in the lower back, radiating to the sacroiliac region and buttocks. The pain can radiate down the posterior thigh. Back and posterior thigh pain of this type can be elicited from many areas of the spine, including the facet joints, longitudinal ligaments, and periosteum of the vertebra. Radicular pain usually extends below the knee and follows the dermatome of the involved nerve root (Fig. 39-21).

The usual history of lumbar disc herniation is of repetitive lower back and buttock pain, relieved by a short period of rest. This pain is suddenly exacerbated, often by a flexion episode, with the appearance of leg pain. Most radicular pain from nerve root compression caused by a herniated nucleus pulposus is evidenced by leg pain equal to, or in many cases greater than, the degree of back pain. Whenever leg pain is minimal, and back pain is predominant, great care should be taken before making the diagnosis of a symptomatic intervertebral disc. The pain from disc herniation usually varies, increasing with activity, especially sitting. The pain can be decreased by rest, especially in the semi-Fowler position, and can be exacerbated by straining, sneezing, or coughing. Whenever the pattern of pain is bizarre or the pain is uniform in intensity, a diagnosis of symptomatic herniated disc should be viewed with some skepticism.

Other symptoms of disc herniation include weakness and paresthesias. In most patients, the weakness is intermittent, varies with activity, and is localized to the neurological level of involvement. Paresthesias also vary and are limited to the dermatome of the involved nerve root. Whenever these complaints are generalized, the diagnosis of a simple unilateral disc herniation should be questioned.

Numbness and weakness in the involved leg and occasional pain in the groin or testis can be associated with a high or midline lumbar disc herniation. If a fragment is large, or the herniation is high, symptoms of pressure on the entire cauda equina can occur with development of cauda equina syndrome. These symptoms include numbness and weakness in both legs, rectal pain, numbness in the perineum, and paralysis of the sphincters. This diagnosis should be the primary consideration in patients who complain of sudden loss of bowel or bladder control. Whenever the diagnosis of cauda equina syndrome is caused by an acute midline herniation, evaluation and treatment should be aggressive.

The physical findings with disc disease vary because of the time intervals involved. Usually patients with acute pain show evidence of marked paraspinal spasm that is sustained during walking or motion. A scoliosis or a list in the lumbar spine may be present, and in many patients the normal lumbar lordosis is lost. As the acute episode subsides, the degree of spasm diminishes remarkably, and the loss of normal lumbar lordosis may be the only telltale sign. Point tenderness may be present over the spinous process at the level of the disc involved, and pain may extend laterally in some patients.

If there is nerve root irritation, it centers over the length of the sciatic nerve, in the sciatic notch, and more distally in the popliteal space. In addition, stretch of the sciatic nerve at the knee should reproduce buttock, thigh, and leg pain (i.e., pain distal to the knee). A Lasègue sign usually is positive on the involved side. A positive Lasègue sign or straight-leg raising should elicit buttock and leg pain distal to the knee. Occasionally, if leg pain is significant, the patient leans back from an upright sitting position and assumes the tripod posture. If the patient is unable to sit, the Lasègue test is equivocal.
Unilateral disc herniation at L4-5 results in compression of the L5 root. L5 root radiculopathy should produce pain in the dermatomal pattern. Numbness, when present, follows the L5 dermatome along the anterolateral aspect of the leg and the dorsum of the foot, including the great toe. The autonomous zone for this nerve is the dorsal first web of the foot and the dorsum of the third toe. Weakness may involve the extensor hallucis longus (L5), gluteus medius (L5), or extensor digitorum longus and brevis (L5). Reflex change position to relieve the pain. This is referred to as the "flip sign." Contralateral leg pain produced by straight-leg raising should be regarded as pathognomonic of a herniated intervertebral disc. The absence of a positive Lasègue sign should make one skeptical of the diagnosis, although older individuals may not have a positive Lasègue sign. Likewise, inappropriate findings and inconsistencies in the examination usually are nonorganic in origin (see discussion of nonspecific axial pain). If the leg pain has persisted for any length of time, atrophy of the involved limb may be present, as shown by asymmetrical girth of the thigh or calf. The neurological examination varies as determined by the level of root involvement (Boxes 39-3 to 39-5).

Unilateral disc herniation at L3-4 usually compresses the L4 root as it crosses the disc before exiting at the L4-5 intervertebral foramen below the L4 pedicle. Pain may be localized around the medial side of the leg. Nummness may be present over the anteromedial aspect of the leg. The anterior tibial muscle may be weak, as evidenced by inability to heel walk. The quadriceps and hip adductor group, both innervated from L2, L3, and L4, also may be weak and, in extended ruptures, atrophic. Reflex testing may reveal a diminished or absent patellar tendon reflex (L2, L3, and L4) or anterior tibial tendon reflex (L4). Sensory testing may show diminished sensibility over the L4 dermatome, the isolated portion of which is the medial leg (Fig. 39-21) and the autonomous zone of which is at the level of the medial malleolus.

Unilateral disc herniation at L4-5 results in compression of the L5 root. L5 root radiculopathy should produce pain in the dermatomal pattern. Numbness, when present, follows the L5 dermatome along the anterolateral aspect of the leg and the dorsum of the foot, including the great toe. The autonomous zone for this nerve is the dorsal first web of the foot and the dorsum of the third toe. Weakness may involve the extensor hallucis longus (L5), gluteus medius (L5), or extensor digitorum longus and brevis (L5). Reflex change position to relieve the pain. This is referred to as the "flip sign." Contralateral leg pain produced by straight-leg raising should be regarded as pathognomonic of a herniated intervertebral disc. The absence of a positive Lasègue sign should make one skeptical of the diagnosis, although older individuals may not have a positive Lasègue sign. Likewise, inappropriate findings and inconsistencies in the examination usually are nonorganic in origin (see discussion of nonspecific axial pain). If the leg pain has persisted for any length of time, atrophy of the involved limb may be present, as shown by asymmetrical girth of the thigh or calf. The neurological examination varies as determined by the level of root involvement (Boxes 39-3 to 39-5).
PART XII THE SPINE

**BOX 39-4**

**L5 Root Compression***

<table>
<thead>
<tr>
<th>Sensory Deficit</th>
<th>Anterolateral leg, dorsum of the foot, and great toe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor Weakness</td>
<td>Extensor hallucis longus</td>
</tr>
<tr>
<td></td>
<td>Gluteus medius</td>
</tr>
<tr>
<td></td>
<td>Extensor digitorum longus and brevis</td>
</tr>
<tr>
<td>Reflex Change</td>
<td>Usually none</td>
</tr>
<tr>
<td></td>
<td>Posterior tibial (difficult to elicit)</td>
</tr>
</tbody>
</table>

*Indicative of L4-5 disc herniation or pathological condition localized to L5 foramen.

**BOX 39-5**

**S1 Root Compression***

<table>
<thead>
<tr>
<th>Sensory Deficit</th>
<th>Lateral malleolus, lateral foot, heel, and web of fourth and fifth toes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor Weakness</td>
<td>Peroneus longus and brevis</td>
</tr>
<tr>
<td></td>
<td>Gastrocnemius-soleus complex</td>
</tr>
<tr>
<td></td>
<td>Gluteus maximus</td>
</tr>
<tr>
<td>Reflex Change</td>
<td>Achilles tendon (gastrocnemius-soleus complex)</td>
</tr>
</tbody>
</table>

*Indicative of L5-S1 disc herniation or pathological condition localized to the S1 foramen.

usually is not found. A diminished posterior tibial reflex is possible but difficult to elicit.

With unilateral rupture of the disc at L5-S1, the findings of an S1 radiculopathy are noted. Pain and numbness involve the dermatome of S1. The S1 dermatome includes the lateral malleolus and the lateral and plantar surface of the foot, occasionally including the heel. There is numbness over the lateral aspect of the leg and, more important, over the lateral aspect of the foot, including the lateral three toes. The autonomous zone for this root is the dorsum of the fifth toe. Weakness may be shown in the peroneus longus and brevis (S1), gastrocnemius-soleus (S1), or gluteus maximus (S1). In general, weakness is not a usual finding in S1 radiculopathy. Occasionally, mild weakness may be shown by asymmetrical fatigue with exercise of these motor groups. The ankle jerk usually is reduced or absent.

More than 95% of the ruptures of the lumbar intervertebral discs occur at L4-5 or L5-S1. Ruptures at higher levels in many patients are not associated with a positive straight-leg raising test. In these instances, a positive femoral stretch test can be helpful. This test is done by placing the patient prone and acutely flexing the hip while placing the hand in the popliteal fossa. When this procedure results in anterior thigh pain, the result is positive, and a high lesion should be suspected. In addition, these lesions may occur with a more diffuse neurological complaint without significant localizing neurological signs.

Often the neurological signs associated with disc disease vary over time. If the patient has been up and walking for a period of time, the neurological findings may be much more pronounced than if he or she has been at bed rest for several days, decreasing the pressure on the nerve root and allowing the nerve to resume its normal function. In addition, various conservative treatments can change the physical signs of disc disease.

Comparative bilateral examination of a patient with back and leg pain is essential in finding a clear-cut pattern of signs and symptoms. The evaluation commonly may change. Adverse changes in the examination may warrant more aggressive therapy, whereas improvement of the symptoms or signs should signal a resolution of the problem. Early symptoms or signs suggesting cauda equina syndrome or severe or progressive neurological deficit should be treated aggressively from the onset.

**DIFFERENTIAL DIAGNOSIS**

The differential diagnosis of back and leg pain is extremely lengthy and complex. It includes diseases intrinsic to the spine and diseases involving adjacent organs but causing pain referred to the back or leg. For simplicity, lesions can be categorized as being extrinsic or intrinsic to the spine. Extrinsic lesions include diseases of the urogenital system, gastrointestinal system, vascular system, endocrine system, nervous system, and extrinsic musculoskeletal system. These lesions include infections, tumors, metabolic disturbances, congenital abnormalities, and associated diseases of aging. Intrinsic lesions involve diseases that arise primarily in the spine. They include diseases of the spinal musculoskeletal system, the local hematopoietic system, and the local neurological system. These conditions include trauma, tumors, infections, diseases of aging, and immune diseases affecting the spine or spinal nerves.

Although the predominant cause of back and leg pain in healthy individuals usually is lumbar disc disease, one must be extremely cautious to avoid a misdiagnosis, particularly given the high incidence of disc herniations present in asymptomatic patients as discussed previously. A full physical examination must be completed before making a presumptive diagnosis of herniated disc disease. Common diseases that can mimic disc disease include ankylosing spondylitis, multiple myeloma, vascular insufficiency, arthritis of the hip, osteoporosis with stress fractures, extradural tumors, peripheral neuropathy, and herpes zoster. Infrequent but reported causes of sciatica not related to disc hernia include synovial cysts, rupture of the medial head of the gastrocnemius, sacroiliac joint dysfunction, lesions in the sacrum and pelvis, and fracture of the ischial tuberosity.

**CONFIRMATORY IMAGING**

Although the diagnosis of a herniated lumbar disc should be suspected from the history and physical examination, imaging studies are necessary to rule out other causes, such as a tumor or infection. Plain radiographs are of limited use in the
CHAPTER 39  DEGENERATIVE DISORDERS OF THE THORACIC AND LUMBAR SPINE

39-27

dition of ordinary activities within the limits permitted by pain has been shown to lead to a quicker recovery. Education in proper posture and body mechanics is helpful in returning the patient to the usual level of activity after the acute exacerbation has improved. This education can

**NONOPERATIVE TREATMENT**

The number and variety of nonoperative therapies for back and leg pain are diverse and overwhelming. Treatments range from simple rest to expensive traction apparatus. All of these therapies are reported with glowing accounts of miraculous "cures"; few have been evaluated scientifically. In addition, the natural history of lumbar disc herniation is characterized by exacerbations and remissions with eventual improvement of extremity complaints in most cases, which can make any intervention appear successful to the patient. Finally, several distinct symptom complexes seem to be associated with disc disease. Few, if any, studies have isolated the response to specific and anatomically distinct diagnoses.

The simplest treatment for acute back pain is rest; generally 2 days of bed rest are better than a longer period. Biomechanical studies indicate that lying in a semi-Fowler position (i.e., on the side with the hips and knees flexed) with a pillow between the legs should relieve most pressure on the disc and nerve roots. Muscle spasm can be controlled by the application of ice, preferably with a massage over the muscles in spasm. Pain relief and antiinflammatory effect can be achieved with nonsteroidal antiinflammatory drugs (NSAIDs). Most acute exacerbations of back pain respond quickly to this therapy. As the pain diminishes, the patient should be encouraged to begin isometric abdominal and lower extremity exercises. Walking within the limits of comfort also is encouraged. Sitting, especially riding in a car, is discouraged. Continua-


**FIGURE 39-23**  Sixty-one-year-old patient with right L5 radiculopathy. A, T2 sagittal MR image reveals sequestered L4 herniated disc fragment. B, T2 axial MR image shows the fragment between L5 pedicles. C, This patient also had asymptomatic left L5 disc extrusion.
PART XII  THE SPINE

Numerous medications have been used with various results in subacute and chronic back and leg pain syndromes. The current trend seems to be moving away from the use of strong narcotics and muscle relaxants in the outpatient treatment of these syndromes. This is especially true in the instances of chronic back and leg pain where drug habituation and increased depression are frequent. Oral steroids used briefly can be beneficial as potent antiinflammatory agents. The many types of NSAIDs also are helpful when aspirin is not tolerated or is of little help. Numerous NSAIDs are available for the treatment of low back pain. When depression is prominent, mood elevators such as nortriptyline can be beneficial in reducing sleep disturbance and anxiety without increasing depression. Nortriptyline also decreases the need for narcotic medication.

Physical therapy should be used judiciously. The exercises should be fitted to the symptoms and not forced as an absolute group of activities. Patients with acute back and thigh pain eased by passive extension of the spine in the prone position can benefit from extension exercises rather than flexion exercises. Improvement in symptoms with extension indicates a good prognosis with conservative care. Patients whose pain is increased by passive extension may be improved by flexion exercises. These exercises should not be forced in the face of increased pain. This may avoid further disc extrusion. Any exercise that increases pain should be discontinued. Lower extremity exercises can increase strength and relieve stress on the back, but they also can exacerbate lower extremity arthritis. The true benefit of such treatments may be in the promotion of good posture and body mechanics rather than of strength. Numerous treatment methods have been advanced for the treatment of back pain. Some patients respond to the use of transcutaneous electrical nerve stimulation. Others do well with traction varying from skin traction in bed with 5 to 8 lb to body inversion with forces of more than 100 lb. Back braces or corsets may be helpful to other patients. Ultrasound and diathermy are other treatments used in acute back pain. The scientific efficacy of many of these treatments has not been proved.

As discussed earlier, the natural history of lumbar disc disease generally is favorable. Although low-back pain can result in significant disability, approximately 95% of patients return to their previous employment within 3 months of symptom onset. Failure to return to work within 3 months has been identified as a poor prognostic sign. Longer periods of disability equate to lower probability of returning to work: in patients with total disability lasting a year, the likelihood of returning to work is 21%, and in those with disability lasting 2 years the likelihood is less than 2%. Obesity and smoking have been shown to correlate unfavorably with low back pain and may adversely affect the progression of symptoms.

**OPERATIVE TREATMENT**

If nonoperative treatment for lumbar disc disease fails, the next consideration is operative treatment. Before this step is taken, the surgeon must be sure of the diagnosis. The patient must be certain that the degree of pain and impairment warrants such a step. The surgeon and the patient must realize that disc surgery is not a cure but may provide symptomatic relief. It neither stops the pathologic processes that allowed the herniation to occur nor restores the disc to a normal state. The patient still must practice good posture and body mechanics after surgery. Activities involving repetitive bending, twisting, and lifting with the spine in flexion may have to be curtailed or eliminated. If prolonged relief is to be expected, some permanent modification in the patient’s lifestyle may be necessary, although often no specific limitations are applied.

The key to good results in disc surgery is appropriate patient selection. The optimal patient is one with predominant (if not only) unilateral leg pain extending below the knee that has been present for at least 6 weeks. The pain should have been decreased by rest, antiinflammatory medication, or even epidural steroids but should have returned to the initial levels after a minimum of 6 to 8 weeks of conservative care. Physical examination should reveal signs of sciatic irritation and possibly objective evidence of localizing neurological impairment. CT, lumbar MRI, or myelography should confirm the level of involvement consistent with the patient’s examination.

Operative disc removal is mandatory and urgent only in patients with cauda equina syndrome; other disc excisions should be considered elective. The elective status of surgery should allow a thorough evaluation to confirm the diagnosis, level of involvement, and physical and psychological status of the patient. Frequently, if there is a rush to the operating room to relieve pain without proper investigation, the patient and the physician later regret the decision.

Regardless of the method chosen to treat a disc rupture surgically, the patient should be aware that the procedure is predominantly for the symptomatic relief of leg pain. Patients with predominantly back pain may not experience relief.

**MICRODISCECTOMY**

Most disc surgery is performed with the patient under general endotracheal anesthesia, although local anesthesia has been used with minimal complications. Patient positioning varies with the operative technique and surgeon. To position the patient in a modified kneeling position, a specialized frame or custom frame is popular. Positioning the patient in this manner allows the abdomen to hang free, minimizing epidural venous dilation and bleeding (Fig. 39-24). A headlamp allows the surgeon to direct light into the lateral recesses where a large proportion of the surgery may be required. The addition of loupe magnification also greatly improves the identification and exposure of various structures. Most surgeons also use an operative microscope to improve visibility further. The primary benefit of an operating microscope compared with loupes is the view afforded the assistant.
vision, however. A lateral radiograph is taken to confirm the level, but fluoroscopy is much quicker when used for localization. Fluoroscopy is essential for localization when using tubular retractors because the field of view is smaller, making the available margin for error in placing the skin incision less.

### ENDOSCOPIC TECHNIQUES

Endoscopic techniques have been developed with the purported advantage of shortened hospital stay and faster return to activity. These techniques generally are variations of the microdiscectomy technique using an endoscope rather than the microscope and different types of retractors. This remains another alternative technique. Each system is unique, and the reader is referred to the technique guide of the various manufacturers for details. The basic principles remain the same as with microdiscectomy. Less-invasive tubular retractors also have been used in a transmuscular fashion, allowing disc excision with less soft tissue damage because of the more precise exposure; however, better objective clinical results have not been shown with this technique.

#### MICROSCOPIC LUMBAR DISCECTOMY

**TECHNIQUE 39-15**

**APPROACH FOR USE OF MCCULLOCH RETRACTOR**

- Infiltrate the operative field (paraspinal muscle, subcutaneous tissue, and skin) with 10 mL of 0.25% bupivacaine with epinephrine for preemptive analgesia and hemostasis.
- Make the incision from the midspinous process of the upper vertebra to the superior margin of the spinous process of the lower vertebra at the involved level. This usually results in a 1-inch (25 to 30 mm) skin incision. This incision may need to be moved slightly higher for higher lumbar levels (Fig. 39-25).
- Maintain meticulous hemostasis with electrocautery as the dissection is carried to the fascia.
- Incise the fascia at the midline using electrocautery. Insert a periosteal elevator in the midline incision. Using gentle lateral movements, elevate the deep fascia and muscle subperiosteally from the spinous processes and lamina on the involved side only.
- Obtain a lateral radiograph with a metal clamp attached to the spinous process to verify the level.
- With a Cobb elevator, gently sweep the remaining muscular attachments off in a lateral direction to expose the interlaminar space and the edge of each lamina. A sharp elevator makes this task easier. Meticulously cauterize all bleeding points.
- Insert the appropriate length McCulloch-type retractor into the wound with the shorter spike medial and the flat blade lateral and adjust the microscope. Shaving down the flat blades of the retractor to produce a narrower retractor can help minimize the incision size and collateral soft-tissue damage.

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**Figure 39-24** Knee-chest position for lumbar disc excision allows abdomen to be completely free of external pressure.

Radiographic confirmation of the proper level is necessary. Care should be taken to protect neural structures. Epidural bleeding should be controlled with bipolar electrocautery. Any sponge, pack, or cottonoid patty placed in the wound should extend to the outside. Pituitary rongeurs should be marked at a point equal to the maximal allowable disc depth to prevent injury of viscera or great vessels.

**Microscopic lumbar discectomy** requires an operating microscope with a 400-mm lens, a variety of small-angled Kerrison rongeurs of appropriate length, microinstruments, and preferably a combination suction/nerve root retractor. Kerrison rongeurs of appropriate length, microinstruments, and an operating microscope with a 400-mm lens, a variety of small-angled Kerrison rongeurs of appropriate length, microinstruments, and preferably a combination suction/nerve root retractor. Kerrison rongeurs should be used to remove bone and to open the disc space. The microscope can be used from skin incision to basis and allows better lighting, magnification, and angle of view, which not only makes access to the ocular lens easier for the surgeon and assistant standing on opposite sides of the table, but also allows the fluoroscope to be moved into the surgical field for imaging without having to move the microscope base itself.

The microscope can be used from skin incision to closure. The initial dissection can be done under direct vision, however. A lateral radiograph is taken to confirm the level, but fluoroscopy is much quicker when used for localization. Fluoroscopy is essential for localization when using tubular retractors because the field of view is smaller, making the available margin for error in placing the skin incision less.

**Endoscopic techniques** have been developed with the purported advantage of shortened hospital stay and faster return to activity. These techniques generally are variations of the microdiscectomy technique using an endoscope rather than the microscope and different types of retractors. This remains another alternative technique. Each system is unique, and the reader is referred to the technique guide of the various manufacturers for details. The basic principles remain the same as with microdiscectomy. Less-invasive tubular retractors also have been used in a transmuscular fashion, allowing disc excision with less soft tissue damage because of the more precise exposure; however, better objective clinical results have not been shown with this technique.

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**Figure 39-24** Knee-chest position for lumbar disc excision allows abdomen to be completely free of external pressure.
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APPRAOH FOR USE OF TUBULAR RETRACOR

- Alternatively, the approach can be made using a tubular retractor, which further minimizes damage to the paraspinal muscles and prevents detachment of the lumbodorsal fascia from the supraspinous ligament. A curved drill is required for visualization when drilling bone through the tubular retractor because of the narrower operating corridor.

- With fluoroscopic guidance, place an 18-gauge needle through the skin and into the paraspinal muscles with a trajectory toward the target disc space, approximately the radius of the final retractor diameter away from the edge of the spinous process (e.g., 9 mm off edge of the spinous process if the ultimate tubular retractor diameter will be 18 mm) to prevent conflict between the spinous process and tubular retractor. It is essential that the needle be orthogonal with the target disc because it will be used to define the center of the tubular approach. Typically it is best to place the needle in line with the superior endplate of the caudal vertebral body, but that depends on the type of herniation and its location.

- Infiltrate the operative field (paraspinal muscle, subcutaneous tissue, and skin) with 10 mL of 0.25% bupivacaine with epinephrine for preemptive analgesia as well as hemostasis.

- Make a 20-mm long incision centered on the needle stick and place the blunt end of the guidewire just through the lumbodorsal fascia. The younger and more fit the patient, the more force necessary to pop the blunt end of the guidewire through the fascia. Do not use the sharp end of the guidewire or advance the guidewire down bone because it is very easy to pierce the interlaminar space and dorsal sac with the guidewire.

- Once the guidewire is through the fascia, advance the first pencil-shaped dilator through the fascia over the guidewire and use it to gently probe for the trailing edge of the cephalad lamina, which should feel like a bump at the end of the dilator. The guidewire can be removed as soon as the lumbodorsal fascia is pierced with the first dilator.

- Sequentially dilate down to bone with enlarging tubular retractors to expose the interlaminar space. Each dilator can be used as a curet to remove soft tissue attachments from the interlaminar space.

- Mount the final tubular retractor to a stationary arm attached to the table and obtain a final fluoroscopic image to confirm the location of the retractor orthogonal with the target disc space before bringing in the microscope and adjusting the field of view. We prefer 14 to 16 mm diameter tubular retractors for this approach, depending on the size of the patient and the level of surgical experience with this technique. Tubular retractors in the 18- to 24-mm diameter range can be used when first becoming familiar with this approach.

From this point on, the surgical technique is essentially the same for both approaches:

- Identify the ligamentum flavum and lamina. Use a curet to elevate the superficial leaf of the ligamentum flavum from the leading edge of the caudal lamina.

- Use a Kerrison rongeur to resect the superficial leaf of the ligamentum flavum to allow identification of the critical angle, which is junction of the leading edge of the caudal lamina and the medial edge of the superior articular process. Identifying the critical angle is essential in primary microlumbar discectomy because it has a constant relationship to the corresponding pedicle, traversing nerve root, and target disc. The pedicle is always just lateral to the critical angle, the traversing nerve is always just medial to the pedicle, and the disc of interest is always just cephalad to the critical angle and pedicle. It sometimes is necessary to drill the medial aspect of the superior articular process to allow adequate visualization of the critical angle.

- Use a high-speed drill to remove the trailing edge of the cephalad lamina up to the insertion of the ligamentum flavum to allow easier and more complete removal of the ligament, keeping in mind that the ligament attaches to the lamina as you move medially. This makes initially detaching the ligament from the undersurface of the cephalad lamina with an angled curet much easier toward the midline.

- After the lateral portion of the ligamentum flavum has been detached from the caudal edge of the superior lamina and the cephalad edge of the inferior lamina with a curet, use a blunt dissector to lift the edge of the ligamentum flavum so that it can be excised with a Kerrison rongeur. Take care to orient the rongeur parallel to the nerve root as much as possible. The goal when resecting the ligamentum flavum should be removal in one piece, which prevents nibbling away at it while trying to grab and mop end with the rongeur. En bloc removal is made easier by using the rongeur to remove some bone along with the lateral edge of the ligamentum flavum from caudal to cephalad, starting at the critical angle and working up the medial edge of the superior articular process where the ligamentum flavum attaches (Fig. 39-26).
CHAPTER 39 DEGENERATIVE DISORDERS OF THE THORACIC AND LUMBAR SPINE

Once the ligamentum flavum is removed, the medial wall of the corresponding pedicle should be palpable with a nerve hook or angled dissector. If not, more bone may need to be removed lateral to the critical angle. Once the medial wall of the corresponding pedicle is identified, the traversing nerve can be found just medial to it and the target disc can be found just cephalad to it.

When the nerve root is identified, carefully mobilize the root medially. Gently dissect the nerve free from the disc fragment to avoid excessive traction on the root. Bipolar cautery for hemostasis is helpful. When mobilized, retract the root medially. If the root is difficult to mobilize, consider that a conjoined root may be present.

Make a gentle extradural exploration beneath the nerve with a 90-degree blunt hook, taking care not to tear the dura. The small opening and magnification can make the edge of the dural sac appear to be the nerve root.

When using bipolar cautery, ensure that only one side is in contact with the nerve root to avoid thermal injury to the nerve. Epidural fat is not removed in this procedure.

Insert the suction/nerve root retractor with its tip turned medially under the nerve root and hold the manifold between the thumb and index finger. With the nerve root retracted, the disc is now visible as a white, fibrous, avascular structure. Under magnification, small tears may be visible in the annulus.

Enlarge the annular tear with a Penfield no. 4 dissector and remove the disc material with the appropriate-sized pituitary rongeur. Do not insert the instrument into the disc space beyond the angle of the jaws, usually about 15 mm, to minimize the risk of anterior perforation and vascular injury. Downward pressure on the adjacent intact annulus can sometimes help express loose disc fragments from the subannular space (Fig. 39-27).

Remove the exposed disc material. Remove additional loose disc or cartilage fragments. Inspect the root and adjacent dura for disc fragments. Forcefully irrigate the disc space using a Luer-Lok syringe and an unused no. 8 suction tip inserted into the disc space. Maintain meticulous hemostasis.

The discectomy is complete when (1) the lateral recess is adequately decompressed; (2) the 90-degree dissection can be probed to the back of the cephalad vertebral body, the disc space, and the back of the caudal vertebral body out to the midline without any protrusions into the canal; (3) the 90-degree dissector can be spun (helicopter maneuver) beneath the traversing nerve root without any restrictions; and (4) the traversing nerve root is freely


Lateral approach for discectomy. L4 foraminotomy allows exposure of root.

POSTOPERATIVE CARE. Postoperative care is similar to that after standard open disc surgery. Typically this procedure is done on an outpatient basis. Injecting the paraspinous muscles on the involved side with bupivacaine 0.25% with epinephrine at the beginning of the procedure and additional bupivacaine at the conclusion aids patient mobilization immediately postoperatively. We prefer to use a skin glue product for final skin closure without the use of dressing and allow the patient to shower the day of surgery. Activity can be allowed as tolerated once the skin incision is healed, typically in 2 weeks.

ADDITIONAL EXPOSURE TECHNIQUES

A large disc herniation or other pathological condition, such as lateral recess stenosis or foraminal stenosis, may require a greater exposure of the nerve root. The additional pathological condition usually can be identified before surgery. If the extent of the lesion is known before surgery, the proper approach can be planned. Additional exposure includes hemilaminectomy, total laminectomy, and facetectomy. Hemilaminectomy usually is required when identifying the root as a problem. This may occur with a conjoined root. Total laminectomy usually is reserved for patients with spinal stenoses that are central, which occur typically in cauda equina syndrome. Facetectomy usually is reserved for foraminal stenosis or severe lateral recess stenosis. If more than one facet is removed, a fusion should be considered in addition. This is especially true in the removal of facets and the disc at the same interspace in a young, active individual with a normal disc height at that level.

An extremely large disc that cannot be dissected from the dura or the persistence of an intradural mass after dissection of the disc should alert one to this potential problem. Excision of an intradiscal disc requires a transdural approach, which increases the risk of complications from cerebrospinal fluid leak and intradural scarring.

A disc that is far lateral may require exposure outside the spinal canal (Fig. 39-28). This area is approached by removing the intertransverse ligament between the superior and inferior transverse processes lateral to the spinal canal. The disc hernia usually is anterior to the nerve root that is found in a mass of fat below the intertransverse ligament. A microsurgical approach is a good method for dealing with this problem. A long tubular retractor is especially useful for the far lateral approach if the tube is inserted at the proper trajectory to address the pathology in or lateral to the foramen. If the facet is not hypertrophic and the plane between the facet joint capsule and intertransverse ligament can be identified, foraminal and far lateral disc herniations can sometimes be removed without bony resection above the L5 level.

LUMBAR ROOT ANOMALIES

Several different types of nerve root anomalies are relatively common in anatomical studies but less common with imaging studies, which suggest they are under-recognized clinically. These congenital anomalies may account for a portion of the poor results from lumbar disc surgery because the abnormal and unrecognized roots may be injured. This is of even more concern with some minimally invasive techniques with less direct nerve visualization.

Conjoined nerve roots are the most common type of anomaly. Various anatomical studies show some type of conjoined root in 14% to 17% of cadavers. Clinical studies using advanced imaging, such as myelography or MRI, show conjoined roots in only 2% to 5% of patients. Conjoined roots have been classified anatomically (Figs. 39-29 to 39-32). There are three classes, the first two of which are subdivided.

Type 1 occurs when two roots exit the dura with one common sheath. With type 1A anomalies, the cephalad root departs the conjoined stalk at an acute angle to exit below the appropriate pedicle, and the caudal root travels within the canal to exit also below the appropriate pedicle. If the cephalad root exits at 90 degrees from the conjoined portion, this is a type 1B anomaly. Type 2 anomalies occur when two roots exit through a single foramen. Type 2A anomalies have one vacant foramen; type 2B anomalies have a portion of one of the roots exiting via the other foramen, which may be cephalad to the foramen occupied by the two nerve roots. Type 3 anomalies
occur when there is an anastomosing branch between two adjacent nerve roots. This branch crosses the disc space and can easily be injured during discectomy.

These root anomalies can cause false-positive interpretations of imaging studies and can be confused with disc bulges or herniations. Particularly if the herniation appears in an atypical location, such as near the pedicle, or if the signal intensity is different from disc material, a diagnosis of a conjoined root should be considered. Also, if a patient presents with a history of failed disc surgery, this diagnosis should be considered. The anomalous roots not only can be divided inadvertently but also can be injured by excessive tension because the conjoined roots usually are less mobile than normal roots. The most common location for conjoined roots involves the L5 and S1 levels. A second type of anomaly that may be as common as conjoined roots is a furcal nerve root; this refers to a bifurcation of a single nerve root. Often furcal roots are bilateral and can occur at multiple levels. Increased awareness of these anomalies is important to reduce the risk of nerve injury and to avoid surgery with an incorrect diagnosis of disc herniations. Surgical outcomes in patients with conjoined roots tend to be significantly worse than in the general population.

RESULTS OF SURGERY FOR DISC HERNIATION

Numerous retrospective and some prospective reviews of open disc surgery are available. The results of these series vary greatly with respect to patient selection, treatment method, evaluation method, length of follow-up, and conclusions. Good results range from 46% to 97%. Complications range from none to more than 10%. The reoperation rate ranges from 4% to more than 20%. A comparison between techniques also reveals similar results. There is no particular technique of discectomy that yields consistently superior results. Technical procedural differences are of minimal importance with regard to outcome.

Several points stand out in the analysis of the results of lumbar disc surgery. Patient selection seems to be crucial. Several studies noted that a low educational level is significantly correlated to poor results of surgery. Valid results of
the Minnesota Multiphasic Personality Inventory (MMPI) (hysteria and hypochondriasis T-scores) appear to be good indicators of surgical outcome regardless of the degree of the pathological condition. The duration of the current episode, the age of the patient, the presence or absence of predominant back pain, the number of previous hospitalizations, and the presence or absence of compensation for a work injury have been identified as factors affecting final outcome. In the latest report on lumbar disc herniation (2008) from the multicenter Spine Patient Outcomes Research Trial (SPORT), operative was compared with nonoperative treatment in 501 patients and additional observational cohorts (743 participants). The results were overwhelmingly in favor of surgery: patients treated operatively had far less pain, better physical function, and less disability than patients who did not have surgery. The validity of the conclusions generated by SPORT has been questioned because of the high crossover rates in the randomized intent-to-treat studies and the variability of the patient population, nonoperative treatments, and operative procedures. The finding of durability of operative results (4-year follow-up), however, is important. In a later study of patients with degenerative spondylolisthesis and spinal stenosis who had operative treatment, those with predominant leg pain had a better prognosis than those with predominant back pain.

### Complications of Disc Excision

The complications associated with standard disc excision and micro lumbar disc excision are similar. One large series (Table 39-4) of 2503 open disc excisions listed a postoperative mortality of 0.1%, a thromboembolism rate of 1%, a postoperative infection rate of 3.2%, and a deep space infection rate of 1.1%. Postoperative cauda equina lesions developed in five patients. Laceration of the major vascular structures also has been described as a rare complication of this operation. Dural tears with CSF leaks, pseudomeningocele formation, CSF fistula formation, and meningitis also are possible but are more likely after reoperation. The complications of micro lumbar disc excision seem to be less than with standard laminectomy.

In a retrospective review of 1326 patients who had spinal surgery, 51 dural tears (4%) were identified; 48 of these occurred with a posterior thoracolumbar approach. The presence of a dural tear or leak results in the potentially serious problems of pseudomeningocele, CSF leak, and meningitis. Eismont, Wiesel, and Rothman suggested five basic principles in the repair of these leaks (Fig. 39-33):

1. **Operative field must be unobstructed, dry, and well o1410 exposed.**
2. **Dural suture of a 4-0 or 6-0 gauge with a tapered or o1415 reverse cutting needle is used in a simple or a running locking stitch. If the leak is large or inaccessible, a free fat graft or fascial graft can be sutured to the dura. Fibrin glue applied to the repair also is helpful but used alone does not seal a significant leak.**
3. **All repairs should be tested by using the reverse Tren-o1420 delenburg position and Valsalva maneuvers.**
4. **Paraspinal muscles and overlying fascia should be o1425 closed in two layers with nonabsorbable suture used in a watertight fashion. Drains should not be used.**
5. **Bed rest in the supine position should be maintained for o1430 4 to 7 days after the repair of lumbar dural defects. A lumbar drain should be placed if the integrity of the closure is questionable.**

The development of headaches on standing and a stormy postoperative period should alert one to the possibility of an undetected CSF leak. This can be confirmed by MRI.

The presence of glucose in drainage fluid is an unreliable diagnostic test. Rarely, a pseudomeningocele has been implicated as a cause of persistent pain from pressure on a nerve root by the cystic mass. In our experience, these principles are valid with the exception of maintaining bed rest. With good closure, patients can be mobilized the day after surgery. If closure is not watertight, extended bed rest with a drain may be helpful.

One of the advantages of tubular lumbar discectomy with p2325 an 18-mm or smaller diameter tube is in the treatment of small dural tears. Because the dead space is so small, these tears usually can be treated simply with fibrin glue when there is no root herniation. We follow the usual postoperative course in patients who have tubular discectomy with dural repair using fibrin glue as long as there are no postoperative headaches or symptoms of meningal irritation. A 3-day course of acetazolamide (Diamox) is prescribed, which acts as a chemical drain by decreasing CSF production in the choroid plexus by inhibiting carbonic anhydrase. This is the same course of Diamox prescribed for acute mountain (altitude) sickness. Patients are advised to lie flat for 72 hours after surgery only if they have positional headaches.

#### TABLE 39-4

<table>
<thead>
<tr>
<th>Complication</th>
<th>Incidence (%)</th>
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<tbody>
<tr>
<td>Cauda equina syndrome</td>
<td>0.2</td>
</tr>
<tr>
<td>Thrombophlebitis</td>
<td>1</td>
</tr>
<tr>
<td>Pulmonary embolism</td>
<td>0.4</td>
</tr>
<tr>
<td>Wound infection</td>
<td>2.2</td>
</tr>
<tr>
<td>Pyogenic spondylitis</td>
<td>0.07</td>
</tr>
<tr>
<td>Postoperative discitis</td>
<td>2 (1122 patients)</td>
</tr>
<tr>
<td>Dural tears</td>
<td>1.6</td>
</tr>
<tr>
<td>Nerve root injury</td>
<td>0.5</td>
</tr>
<tr>
<td>Cerebrospinal fluid fistula</td>
<td>*</td>
</tr>
<tr>
<td>Laceration of abdominal vessels</td>
<td>*</td>
</tr>
<tr>
<td>Injury to abdominal viscera</td>
<td>*</td>
</tr>
</tbody>
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*Rare occurrence (nos. 10 and 11 not identified in Spangfort’s study, but reported elsewhere).


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**Dural Repair Augmented with Fibrin Glue**

Dural repair can be augmented with fibrin glue. Pressure testing of a dural repair without fibrin glue reveals that the dura is able to withstand 10 mm of pressure on day 1 and 28 mm on day 7. With fibrin glue, the dura is able to withstand 28 mm on day 1 and 31 mm on day 7. Fibrin...
glue also can be used in areas of troublesome bleeding or difficult access for closure, such as the ventral aspect of the dura. Fibrin glue is an adjunct for closure, and every effort should be made for primary closure, even if fibrin glue is to be used. However, fibrin glue tends to be sufficient in the setting of a transmuscular approach using a tubular retractor because the amount of dead space is significantly limited and dural leaks can be tamponaded with fibrin glue alone.

FIGURE 39-33  A, Dural repair using running-locking dural suture on taper or reverse-cutting, one-half-circle needle. Smaller sized suture should be used. Use of suction with sucker and small cotton pledges is essential to protect nerve roots while operative field is kept dry of cerebrospinal fluid. B, Single dural stitches can be used to achieve closure, each suture end being left long. Second needle is attached to free suture end, and ends of suture are passed through piece of muscle or fat, which is tied down over repaired tear to help achieve watertight closure. Whenever dural material is inadequate to allow closure without placing excessive pressure on underlying neural tissues, free graft of fascia or fascia lata or freeze-dried dural graft should be secured to margins of dural tear using simple sutures of appropriate size. C, For small dural defects in relatively inaccessible areas, transdural approach can be used to pull small piece of muscle or fat into defect from inside out, sealing cerebrospinal fluid leak. Central durotomy is closed in standard watertight fashion.

TECHNIQUE 39-16

- Mix 20,000 U of topical thrombin and 10 mL of calcium chloride, and draw the mixture up into a syringe.
- In another syringe, draw 5 U of cryoprecipitate, and simultaneously inject equal quantities of each onto the dural repair or tear.
- Allow the glue to set to the consistency of “Jello” (Box 39-6). Commercially available kits also are available.
**BOX 39-6**

Fibrin Glue

**Ingredients**
- Two vials of topical thrombin, 10,000 U each
- 10 mL of calcium chloride
- 5 U of cryoprecipitate
- Two 5-mL syringes
- Two 22-gauge spinal needles

**Instructions**
1. Do not use saline that comes with thrombin.
2. Mix thrombin and calcium chloride.
3. Draw mixture into syringe.
4. Draw cryoprecipitate into second syringe.
5. Apply equal amounts to area of need.
6. Allow to set to a “jello” consistency.

### FREE FAT GRAFTING

Fat grafting for the prevention of postoperative epidural scarring has been shown to be superior to Gelofast in the prevention of postoperative scarring. The current rationale for free fat grafting seems to be the possibility of making any reoperation easier. Neither the benefit of reduced scarring and its relationship to the prevention of postoperative pain nor the increased ease of reoperation in patients in whom fat grafting was performed has been established. Caution should be taken in applying a fat graft to a large laminar defect because this has been reported to result in an acute cauda equina syndrome in the early postoperative period. We currently reserve the use of a fat graft (or fascial grafts) for dural repairs and small laminar defects where the graft is supported by the bone. A study by Jensen et al. found that fat grafts decreased dural scarring but not radicular scar formation. The clinical outcome was not improved.

### REPEAT LUMBAR DISC EXCISION

**TECHNIQUE 39-17**

This procedure is most often used for recurrent herniation but can be used in primary disc excisions.

- After thoroughly preparing the back, identify the spinous processes of L3, L4, L5, and S1 by palpation. Inject 25 mL of 0.25% bupivacaine with epinephrine into the paraspinous muscles on the involved side.
- Make a midline incision 4 cm long, centered over the interspace where the disc herniation is located. Incise the supraspinous ligament; by subperiosteal dissection, strip the muscles from the spinous processes and laminae of these vertebrae on the side of the lesion.
- Retract the muscles with a self-retaining retractor, or with the help of an assistant, and expose one interspace at a time.
- Verify the location with a radiograph so that no mistake is made regarding the interspaces explored.
- Secure hemostasis with electrocautery, bone wax, and packs. Leave a portion of each pack completely outside the wound for ready identification.
- Identify normal tissue first. Use a curet to remove scar from the edges of the laminae carefully. Remove additional bone as necessary to expose normal dura.
- Identify the pedicles superiorly and inferiorly if there is any question of position and status of the root. Carry the dissection from the pedicles to identify each root; this may allow the development of a normal plane between the dura and scar. This requires patience, and small curets or Penfield dissectors work best. Maintain meticulous hemostasis with bipolar cautery.
- Once the lateral edge of the root is identified, it is often helpful to mobilize the root and epidural scar as a single mass off the floor of the canal using a curet, which will sometimes uncover the underlying disc herniation.
- Remove the disc herniation and explore the axilla of the root and the subligamentous space for retained fragments. Also, ensure that the nerve root is well decompressed in the lateral recess.
- Spinal fusion is not done unless an unstable spine is created by the dissection or was identified preoperatively as a correctable and symptomatic problem.
- If the initial procedure was done using the tubular retractor technique (see Technique 39-14), a tubular retractor is used for recurrent disc herniations

### POSTOPERATIVE CARE

Postoperative care is the same as after disc excision (see Technique 39-15).
DISC EXCISION AND FUSION

The necessity of lumbar fusion at the same time as disc excision was first suggested by Mixter and Barr. In the first 20 years after their discovery the combination of disc excision and lumbar fusion was common. More recent data comparing disc excision alone with the combination of disc excision and fusion indicate that there is little, if any, advantage to the addition of a spinal fusion to the treatment of simple disc herniation. These studies indicate that spinal fusion increases the complication rate and lengthens recovery. The indications for lumbar fusion should be independent of the indications for disc excision for radiculopathy.

THORACIC AND LUMBAR SPINE

ARTHRODESIS

Arthrodesis of the lumbosacral region is done for degenerative, traumatic, and congenital lesions. Indications for and techniques of spinal fusion and care after surgery vary from one orthopaedic center to another. Many orthopaedists prefer posterior arthrodesis, usually some modification of the intertransverse process type fusion, using a large quantity of autogenous iliac bone. Internal fixation can be used with posterior arthrodesis. Before the use of instrumentation, the current status of the implant—its risks and indications and approval by the FDA—should be reviewed carefully and completely with the patient. Posterolateral or intertransverse process fusions are used most frequently, either alone or occasionally in combination with an anterior fusion and with or without posterior internal fixation. Interbody fusions from posterior, anterior, retroperitoneal, or transperitoneal approaches are preferred by other orthopaedic surgeons.

For lumbar fusion, the best technique for a particular patient remains controversial. The decision should be based on the pathological entity being treated, expected applicable biomechanics and healing potential of different constructs, and the surgeon's experience. With regard to the pathological entity, consideration must be given to the spinal column and the neural elements. In this way the proper balance can be obtained between the need for possible increased instability from neural decompression and strategies to increase stability to promote fusion. After determining the optimal operative plan for a particular patient, additional controversy exists regarding the best technique to execute the plan, that is, an open technique versus a minimally invasive approach.

ANTERIOR ARTHRODESIS

TRANSTHORACIC APPROACH TO THE THORACIC SPINE

For anterior arthrodesis of the thoracic spine, a transthoracic approach provides direct access to the vertebral bodies T2 to T12. The midthoracic vertebral bodies are best exposed by this approach, whereas views of the upper and lower extremities of the spine are more limited.

TECHNIQUE 39-18

Approach the involved vertebra as described in Chapter 37.

Remove the disc material at the confirmed level with sharp dissection in the outer two thirds of the disc.

POSTOPERATIVE CARE. The patient is allowed to ambulate rapidly after the procedure. The chest tube is removed once drainage is minimal and there is no air leak. Initially a removable brace such as a Jewett brace or thoracolumbosacral orthosis can be used for ambulation. The brace can be discontinued as pain relief improves and radiographic union is noted.

Numerous indications for anterior arthrodesis of the lumbar spine are reported in the literature. At this clinic the indications include debridement of infection, tuberculosis, excision of tumors, correction of kyphosis, scoliosis, neural decompression after fracture, and to achieve stability when posterior arthrodesis is not feasible. Less frequently, we have used this technique in the treatment of spondylolisthesis or internal intervertebral disc derangements. The surgical approach used in tuberculosis by Hodgson and Stock should be applicable in most instances (see Chapter 43).

ANTERIOR DISC EXCISION AND INTERBODY FUSION OF THE LUMBAR SPINE

The rationale of management of lower back pain must be based on an accurate diagnosis. The pain syndromes in this area are many, and diagnostic pitfalls are ever present. Treatment varies according to the physical and emotional profile of the patient and the experience of the surgeon involved. Hemilaminectomy and decompression of nerve roots still constitute the most widely used surgical procedure for unremitting lower back pain. With continued instability of the anterior and posterior elements, supplemental posterior or posterolateral fusion usually proves satisfactory.

There is a group of patients for whom standard surgical procedures are unsuccessful. The following causes of persistent symptoms after disc surgery have been identified:

- Mistaken original diagnosis
- Recurrent herniation of disc material (also incomplete removal)
- Herniation of disc at another level
- Bony compression of nerve root
- Perineural adhesions
- Instability of vertebral segments
- Psychoneurosis

In this group, improved diagnostic accuracy currently can be obtained with the use of electromyography, a psychological profile assessment, postmyelographic CT, MRI with and without gadolinium contrast, and possibly discography. Finally, differential spinal anesthesia is helpful in discriminating between the various pain types.

As a rule, failure of the usual posterior methods of fusion to relieve pain in the presence of a solid arthrodesis and in
the absence of other pathology as listed earlier dictates consideration of anterior intervertebral disc excision and interbody spinal fusion. The reported outcomes of anterior interbody fusion have been variable, with success rates ranging from 36% to 90%. Although reports of long-term results are inconclusive, pain relief appears to be obtained in 80% to 90% of patients.

Suggested indications include (1) instability causing backache and sciatica, (2) spondylolisthesis of all types, (3) pain after multiple posterior explorations, and (4) failed posterior fusions. Good results have been reported with the use of three iliac wedge grafts for degenerative disease and a block graft for spondylolisthesis (Fig. 39-34).

**ANTERIOR INTERBODY FUSION OF THE LUMBAR SPINE**

**TECHNIQUE 39-19**

Administer general anesthesia and place the patient in the Trendelenburg position.

Develop the retroperitoneal approach to the vertebral bodies and identify the psoas muscle, the iliac artery and vein, and the left ureter. If more than three interspaces are to be fused, retract the ureter toward the left.

Identify the sacral promontory by palpation.

Inject saline solution under the presacral fascia over the lumbosacral vertebra and lift the sympathetic chain for easier dissection.

Expose the lumbosacral disc space by retracting the left iliac artery and vein to the left.

In exposing the fourth lumbar interspace, displace the left artery and vein and ureter to the right side.

Elevate the anterior longitudinal ligament as a flap with the base toward the left.

- Tag the flap with sutures and retract it to give additional protection to the vessels.
- Separate the intervertebral disc and annulus from the cartilaginous endplates of the vertebrae with a thin osteotome and remove them with pituitary rongeurs and large curets.
- Clean the space thoroughly back to the posterior longitudinal ligament without removing bone, thereby keeping bleeding to a minimum until the site is ready for grafting.
- Remove the cartilaginous endplates from the vertebral bodies with an osteotome until bleeding bone is encountered.
- Cut shallow notches in the opposing surfaces of the vertebrae and measure the dimensions of the notches carefully with a caliper.
- Cut grafts from the iliac wing, making them larger than the notches for later firm impaction (Fig. 39-35).
- Hyperextend the spine, insert multiple grafts, and relieve hyperextension.
- Bipolar electrocautery is useful in obtaining hemostasis, but take care not to coagulate the sympathetic fibers over the anterior aspect of the lumbosacral joint. Use of silver clips in this area is preferred.
- After completion of the fusion, close all layers with absorbable sutures.
- Estimate the amount of blood lost and replace it.

**POSTOPERATIVE CARE.** Nasogastric suction may be necessary for gastric decompression for about 36 hours. Attention must be paid to mobilization of the lower extremities to prevent dependency and blood pooling. Thigh-length hose for prevention of thromboembolic disease, intermittent compression boots, and low-molecular-weight heparin all are used for deep vein thrombosis prophylaxis. In-bed exercises with straight-leg raising are started on the first postoperative day and...
Laparoscopic transperitoneal lumbar instrumentation and fusion also has been developed, and several systems are currently available. These systems allow disc removal and insertion of threaded cylindrical devices, as well as trapezoidal cages packed with autogenous bone into the disc spaces, typically at the L5-S1 and the L4-L5 levels. Although these techniques provide an effective means of achieving anterior interbody fusion with maintenance of disc space distraction, they appear to require a significant learning curve. Both the VATS and laparoscopic techniques should be performed by surgeons experienced in these techniques to minimize potentially catastrophic complications. The ultimate success of the procedure depends on the proper diagnosis and patient selection. Each device has a technique guide specific to it, and the reader is referred to these guides for specific device use.

MINIMALLY INVASIVE ANTERIOR FUSION OF THE LUMBAR SPINE

In the fields of general surgery and thoracic surgery, the development of laparoscopic surgical techniques and VATS has allowed significant improvements to be made with respect to decreasing pain, duration of hospitalization, and recovery times for a variety of procedures (Fig. 39-36). Similarly, laparoscopic and VATS techniques have been applied to anterior spine surgery with significant improvements in these same areas. VATS is discussed in Chapter 41. We have limited experience with this technique; currently it is seldom used because of the risk of catastrophic complications.

PERCUTANEOUS ANTERIOR LUMBAR ARTHRODESIS—LATERAL APPROACH TO L1 TO L4-5

Direct lateral anterior lumbar fusion and extreme lateral interbody fusion can be done through a minimally invasive direct lateral approach (see Technique 37-16); however, there is a definite learning curve for disc excision and fusion techniques done through the small access provided by the dilating retractor systems. Complications, primarily related to nerve root injury or irritation, have been reported in 22% of patients after a minimally invasive direct lateral anterior lumbar fusion and extreme lateral interbody fusion. Knowledge of “safe zones” for this approach and familiarity with the dilating retractor systems are essential for avoiding these complications.
s0565

TECHNIQUE 39-20

p2763
- After confirmation of the correct position of the retractor (see Technique 37-16) with anteroposterior and lateral fluoroscopy, center the anterior annulotomy window in the anterior half of the disc.

u1720
- Make the window opening wide enough to accommodate the implant.

u1725
- Remove the disc with standard instruments.

u1730
- Leave the posterior annulus intact.

u1735
- Release the contralateral annulus using a Cobb dissector to allow distraction of the disc space to insert the implant.

u1740
- Insert an implant that will rest on both lateral margins of the epiphysial ring.

u1745
- Irrigate the cavity copiously.

u1750
- Carefully remove the retractor while observing the psosas muscle covering the defect and watching for bleeding.

u1755
- Close the fascial and subcutaneous layers.

u1760
- The skin can be closed with a subcuticular method.

u1765
- Supplementary posterior instrumentation must be used to maintain stability.

s0570

POSTERIOR ARTHRODESI S

p2825
Posterior arthrodeses of the lumbar and thoracic spine generally are based on the principles originated by Hibbs in 1911. In the Hibbs operation, fusion of the neural arches is induced by overlapping numerous small osseous flaps from contiguous laminae, spinous processes, and articular facets. In the thoracic spine, the arthrodesis is generally extended laterally out to the tips of the transverse processes so that the posterior cortex and cancellous bone of these portions of the vertebrae are used to widen the fusion mass. Accurate visual identification of a specific vertebral level is always difficult except when the sacrum can be exposed and thus identified. At any other level, despite the fact that identification of a given vertebra may be possible because of the anatomical peculiarities of spinous processes, laminae, and articular facets, it is always advisable to make marker radiographs at surgery. Marker films occasionally are made before surgery, using a metal marker on the skin with a scratch on the skin to identify the level. We recommend a method consisting of the radiographic identification of a marker of adequate size clamped to a spinous process within the operative field. The closer to the base of the spinous process the marker can be inserted, the more accurate and easier the identification. Cross-table lateral or anteroposterior radiographs taken on the operating table to compare with good-quality preoperative radiographs usually are sufficient for accurate identification of the vertebral level, although the quality of the portable radiographs may at times make this difficult. Patient positioning to maintain lumbar lordosis also is important.

s0575

HIBBS FUSION

p2830
With the Hibbs technique, fusion is attempted at four different points—the laminae and articular processes on each side. The procedure has been modified slightly over the years.
CHAPTER 39 DEGENERATIVE DISORDERS OF THE THORACIC AND LUMBAR SPINE

from the bone bank can be used, especially if the bone
available locally is scant because of spina bifida.

The bone grafts should not extend beyond the laminae
of the end vertebrae because the projecting ends of the
grafts can cause irritation and pain.

If the nucleus pulposus is to be removed, the chips are
cut before exposure of the nucleus and are kept until
needed. The remaining layer of the ligamentum flavum
is freed as a flap with its base at the midline, is retracted
for exposure of the nerve root and nucleus, and after
removal of the nucleus is replaced to protect the dura.

Suture the periosteum, ligaments, and muscles snugly
over the chips with interrupted sutures. Then suture the
subcutaneous tissue carefully to eliminate dead space and
close the skin with either a subcuticular suture or nonab-
sorbable skin suture technique.

At this clinic we routinely use an adhesive plastic film
material to isolate the skin surface from the wound rather
than attaching towels to skin edges with clips, because
clips have an unfortunate tendency to become displaced
and can get lost within the wound. We routinely use
modified Cobb elevators, which when sharp are efficient
in stripping away the capsules of the lateral articulations.

The most important single project at the time of surgery
is preparing an extensive fresh cancellous bed to receive
the grafts. This means denuding the facet joints, articular
processes, par interarticularis, laminae, and spinous pro-
cesses. Subcuticular wound closure is used routinely to
improve patient comfort.

POSTOPERATIVE CARE. We routinely use closed-
wound suction for 12 to 36 hours, with removal of the
suction device mandatory by 48 hours. Depending on the
level of the arthrodesis, the age of the patient, and the
presence or absence of internal fixation, walking is all-
owed in 24 to 48 hours when pain permits. For obese
patients, all types of external fixation or support likely will
be inadequate and limitation of activity may be the only
reasonable alternative. The appropriateness of bracing
remains controversial. Generally, for fusions with marked
preoperative instability (e.g., burst fractures), rigid bracing
is continued for 12 weeks. For fusions without marked
instability (e.g., degenerative spondylolisthesis), bracing
generally, if used, is less rigid and of shorter duration.

POSTEROLATERAL OR INTERTRANSVERSE
FUSIONS

In 1948 Cleveland, Bosworth, and Thompson described a
technique for repair of pseudarthrosis after spinal fusion in
which grafts are placed posteriorly on one side over the
laminar, lateral margins of the articular facets, and base of
the transverse processes. Watkins described what he called a
posterolateral fusion of the lumbar and lumbosacral spine in
which the facets, pars interarticularis, and bases of the trans-
verse processes are fused with chip grafts, and a large graft is
placed posteriorly on the transverse processes. When the
lumbosacral joint is included, the grafts extend to the poste-
rior aspect of the first sacral segment.

We, like many others, use this operation and its modifica-
tions for primary lumbar and lumbosacral fusions and in
patients with pseudarthrosis, laminar defects either congeni-
tal or surgical, or spondylolisthesis with chronic pain from
instability. The operation may be unilateral or bilateral but
usually is bilateral, covering one or more joints depending on
the stability of the area to be fused. The retraction instruments
designed by McElroy and others are useful. However, one
should be mindful of the ischemia caused by retractors, and
they should be periodically released to allow perfusion of the
paraspinal musculature. When placing the retractors, minimal
retractor bulk and tension should be employed. The tech-
nique described by Watkins allows exposure for a posterolat-
eral fusion without much need for soft tissue retraction.
Modifications of the Watkins technique include splitting of the sacrospinalis muscle longitudinally; inclusion of the laminae, as well as the articular facets and transverse processes, in the fusion (Figs. 39-38 and 39-39); and combining posterolateral fusion using a midline approach with a modified Hibbs type fusion in routine lumbar and lumbosacral fusions (Fig. 39-40). Adkins used an intertransverse or alar transverse fusion in which tibial grafts are inserted between the transverse processes of L4 and L5 and between that of L5 and the ala of the sacrum on one or both sides.
CHAPTER 39  DEGENERATIVE DISORDERS OF THE THORACIC AND LUMBAR SPINE

39-43

FIGURE  39-39  Bilateral posterolateral fusion for spondylolisthesis in adult. Anteroposterior (A) and lateral (B) radiographs 6 months after surgery.

Alternatively, strips of iliac wing cortex no more than 2 to 3 mm thick are placed anterior to the transverse processes of L4 and L5 to bridge the gap and lie on the intertransverse fascia. Similarly, another strip is placed between the ala of the sacrum and L5 by wedging it into the space after the ala has been slotted and decorticated. Care must be taken that these grafts do not protrude too far anterior to the plane of the transverse processes. This modification does not require a tibial graft and is recommended.

POSTOPERATIVE CARE. Postoperative care is the same as that described for posterior arthrodesis (see Technique 39-7).

MINIMALLY INVASIVE TRANSFORAMINAL LUMBAR INTERBODY FUSION

A microscope and tubular retractors allow minimally invasive transforaminal lumbar interbody fusions to achieve decompression and stabilization while safely performing the procedure with less collateral damage to surrounding structures and the posterior dynamic stabilizers of the spine than with open procedures. Because the surgical corridor required is minimal, tubular retractors eliminate the need for traditional muscle-stripping techniques and preserve the form and function of the paraspinal musculature, which allows more normal physiological function of the spine and sparing of the dynamic posterior stabilizers. Other advantages include reduced blood loss, less postoperative back pain, shorter time to ambulation, shorter hospital stay, and shorter duration of narcotic usage postoperatively compared with open approaches. Minimally invasive techniques also have been reported to result in significant reductions in total hospital costs compared with standard open techniques, and there is early evidence that adjacent segment degeneration may be decreased compared with open surgery.
TECHNIQUE 39-24

After induction of general endotracheal anesthesia, position the patient prone on a radiolucent table.

Obtain lateral and anteroposterior C-arm fluoroscopic images to ensure that the pedicles can be adequately imaged.

Insert a spinal needle into the paraspinal musculature at the interspace of interest, 40 to 60 mm lateral to the midline depending on patient depth, and confirm its position with lateral fluoroscopy.

The trajectory should approach the anterior and middle third of the disc space.

Remove the needle and make a 20-mm vertical incision at the puncture site.

Insert the blunt end of a guidewire through the incision and direct it toward the appropriate anatomy under fluoroscopic guidance. Advance the guidewire only through the lumbodorsal fascia, taking care not to penetrate the ligamentum flavum and to avoid inadvertent dural puncture.

Insert the cannulated soft tissue dilator over the guidewire with a twisting motion.

Once the fascia is penetrated, remove the guidewire and use progressively larger dilators to create a muscle-sparing surgical corridor down to the appropriate interlaminar space while remaining orthogonal to the disc.

Dock the appropriate-length 18- or 20-mm tubular retractor on the facet joint complex and interlaminar space.

With the use of an operating microscope or loupe magnification, carry out a total facetectomy with a high-speed drill (preferred) or osteotomes. The osteotomy is L-shaped and should connect the interlaminar space at the base of the spinous process with the pars interarticularis just above the disc space but below the pedicle.

Denude all removed bone of soft tissue and morcelize it for later use as interbody graft material.

Perform a conventional discectomy by incising the annulus with a no. 15 scalpel blade lateral to the dural sac while retracting the traversing nerve root. There is no need to retract the exiting root. All cartilage should be removed from the disc space up to the outer annulus.

Sequentially distract the disc space until the original disc space height is obtained and the normal foraminal opening is restored. This can be done with shavers, trials, or mechanical distractors depending on the system being used.

Remove soft tissue and the cartilaginous endplate covering with scraping or curetage. Scrape medially under the midline and gradually work laterally in a sweeping motion until both caudal and cephalad endplates are cleared of soft tissue, exposing the compressed cancellous endplate of both vertebral bodies.

Insert an appropriately sized graft based on the distractors or trials. The graft material can be bone, polymer, or metal. Do not place a graft that is too long because it may increase the risk of later posterior displacement.

Countersink the graft until it is 4 to 5 mm below the posterior margin of the disc space.

Probe the extradural space and foramina to ensure adequate decompression of the neural elements.

Once the graft is in place, confirm positioning on anteroposterior and lateral fluoroscopic images. If positioned adequately with adequate restoration of disc height and lordosis, place bilateral percutaneous pedicle screws to allow a stable environment for fusion across the disc space.

Use anteroposterior and lateral images of the pedicle for cannulation with an appropriately sized Jamshidi needle using a "pencil-in-cup" technique. The remaining technique varies depending on the hardware manufacturer.

Once all hardware is adequately placed, close the incisions subcutaneously with 2-0 Vicryl and skin glue (e.g., Dermabond or Histoacyl) for final skin closure. When a 20-mm or smaller tube is used, there is no need for fascial closure.

**POSTOPERATIVE CARE.** Patients are encouraged to walk as much as possible immediately after surgery. Bending, lifting, and twisting are restricted for a period of 3 months. All restrictions are lifted at 3 months if radiographs show appropriate progression of fusion. Hospital stay is seldom longer than 24 hours, and this procedure can sometimes be done in the outpatient setting in carefully selected patients.

**INTERNAL FIXATION IN LUMBAR SPINAL FUSION**

Various types of internal fixation have been used in lumbar spine fusion. The object is to immobilize the joints during fusion and thus hasten consolidation and reduce pain and disability after surgery. Additionally, the instrumentation maintains correction of deformity and normal contours during the consolidation of the fusion mass. For many years, surgeons fixed the spinous processes of the lumbar spine with heavy wire loops, as described by Rogers for fracture-dislocation of the cervical spine.

Early methods of fixing the articular facets used bone blocks or cylindrical bone grafts to transfix the facets, particularly at the lumbosacral joint. In one bone grafting technique (McBride), soft tissue attachments to the spinous processes and laminae were elevated, the spinous processes of L4, L5, and S1 were removed at their bases, and special trephine cutting tools were used cut mortise bone grafts from them. The laminae were then spread forcibly with laminae distractors, and, again with the use of special trephine cutting tools, a round hole was made across each facet joint into the underlying pedicle. The bone grafts were then impacted firmly across each joint into the pedicle, and the distractors were removed. H-shaped grafts between the spinous processes also have been described for articular facet fixation.

Internal fixation (such as pedicle screws and plates) is described in Chapter 38. Again, however, before using these techniques the indications and current status of the use of these implants as approved by the FDA should be reviewed carefully with the patient. A special consent...
form should be signed by the patient if these devices are being used for anything other than the strictly approved indications.

**TREATMENT AFTER POSTERIOR ARTHRODESIS**

Opinions vary as to the proper treatment after spinal fusion. Usually the patient is placed on bed rest for a period of 12 to 24 hours; mobilization is then begun. No clear consensus exists on the duration of bed rest or the type of external support that should be used or even whether external support should be used. This depends on the pathological condition being treated and on the location and extent of the fusion. Surgeon preference also is important in this decision and often is based more on the patient's comfort rather than immobilization for promotion of fusion, especially if instrumentation has been used for a degenerative process rather than for treatment of traumatic instability. Immobilization is continued until the patient is comfortable or until consolidation of the fusion mass occurs as seen on radiographs. Anterior images are made with the patient supine and in right and left bending positions, and a lateral radiograph is made with the patient in flexion and extension between 3 and 4 months postoperatively to confirm consolidation of the fusion mass. A longer period may be needed, especially in uninstrumented fusions. However, even with instrumentation the fusion mass may require a year or more to mature.

With newer, less invasive techniques, postoperative immobilization usually is not needed, and patients are encouraged to gradually return to normal activities as much as possible, avoiding bending, lifting, and twisting for 3 months.

**PSUEDARTHROSIS AFTER SPINAL FUSION**

The possibility of pseudarthrosis after spinal arthrodesis should be remembered from the time the operation is proposed until the fusion mass is solid. A frank discussion of this problem with each patient before operation is important. The reported pseudarthrosis rate ranges from 9% to 30%. Some authors have correlated higher pseudarthrosis rates with a greater number of levels fused, but multiple studies have reported single-level pseudarthrosis rates as high as 30%. A critical analysis of the literature determined that instrumentation, fusion location, graft type, and brace type all affected lumbar fusion rates (Table 39-5). Careful patient selection and meticulous surgical technique in preparing the recipient site and in harvesting and preparing bone grafts are required to optimize fusion rates regardless of any other techniques that may be used.

It has been estimated that 50% of patients with pseudarthrosis have no symptoms. Persistent pain after spinal fusion with no other identifiable cause is presumed to be caused by pseudarthrosis when this condition is present. Yet, in some patients pain continues after a successful repair. Although pain can persist, repair of a pseudarthrosis is indicated when disabling pain persists; repair is contraindicated when pain is slight or absent.

The following findings are helpful in making a diagnosis of pseudarthrosis: (1) discretely localized pain and tenderness over the fusion area, (2) progression of the deformity or disease, (3) localized motion in the fusion mass, as found in biplane bending radiographs, and (4) motion in the fusion mass found on exploration. The amount of motion on flexion-extension radiographs that is consistent with solid fusion is controversial, ranging from no motion to 5 degrees of motion. When rigid instrumentation has been used, lack of motion does not necessarily indicate solid fusion; the presence of broken spinal implants does imply pseudarthrosis. Thin-cut CT scans appear to be more reliable than radiographs in evaluating fusion: a prospective study comparing imaging findings to intraoperative findings showed that CT most closely agreed with intraoperative findings compared with plain radiographs and MRI. The expense of MRI and its susceptibility to metallic artifact from instrumentation remain disadvantages to its routine use in the assessment of spinal fusion. Exploration is the only way to be absolutely certain that a fusion mass is completely solid.

Treatment of a patient with a painful pseudarthrosis involves a second attempt at fusion and may require a different approach from that used in the original fusion surgery, as well as the use of additional instrumentation, bone graft, and osteobiological agents.
DEGENERATIVE DISC DISEASE
AND INTERNAL DISC DERANGEMENT

As has already been discussed, the degenerative process is fundamental to the development of disc herniations. Current research shows that genetic factors are more important than the mechanical stresses that have long been emphasized. The development of a disc herniation is only one of the pathways that the degenerative disc may follow. Alternatively, the disc may become the primary source of pain, rather than the nerve root, as is the case with herniations. This discogenic type of pain is most attributable to the internal disc derangement (IDD) that accompanies the degenerative process. Correct diagnosis and treatment of painful degenerative discs are difficult and controversial.

There are many different treatment options for this diagnosis, including fusions, disc arthroplasty, nucleoplasty, and dynamic stabilization procedures. The number of fusion operations in the United States has consistently increased since the 1970s and is significantly higher than in other developed countries. The indication for most of these procedures is IDD. Currently, only two lumbar disc replacement prostheses are approved by the FDA, but several designs are under investigation. The sole indication for these devices currently is to treat symptomatic degenerative disc disease. Likewise, the implants currently in development for nucleoplasty also are ultimately for treatment of the same process. There are multiple devices and models for “dynamic stabilization,” only some of which are for the treatment of IDD. There is no shortage of treatment options. Treatment is controversial because no consensus of diagnostic criteria exists with regard to symptom type or severity, physical examination, or diagnostic imaging criteria. In addition to lack of consensus with regard to diagnosis, few prospective randomized data exist on outcomes for the numerous operative or nonoperative treatment options.

More recent research has helped considerably in understanding the anatomical basis for discogenic pain with nociceptive receptors and the innervation of the disc by the sinu-vertebral nerves and basi-vertebral nerves being shown, as discussed earlier. Anatomical studies also are beginning to give insight into the complexities of normal disc structure and function. The understanding of pain and mechanisms that lead to inflammatory and mechanical pain is continually improving. These studies focus on the molecular structure of the matrix, the mechanical properties of the matrix, the cellular activities within the matrix, and the complexities of pain modulation (Fig. 39-41). Understanding the interplay between these processes and the complex psychosocial issues involved and instruments necessary for diagnosis allows for much more precise and rational treatment.

Current understanding of IDD defines this as a pathological condition resulting in axial spine pain with no or minimal deformation of spinal alignment or disc contour. This is to be distinguished from measurable instability as can occur with fractures, traumatic ligamentous disruptions, degenerative listhesis, scoliosis, or other conditions. Although these conditions can be a source of pain, they are fundamentally different in that there are definite defined anatomical alterations and imaging abnormalities associated with each of

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**PSEUDARTHROSIS REPAIR**

**TECHNIQUE 39-25**

**RALSTON AND THOMPSON**

- Expose the entire fusion plate subperiosteally through the old incision; if the defect is wide and filled with dense fibrous tissue, subperiosteal stripping in that area can be difficult. A narrow defect often is difficult to locate because the surface of the plate usually is irregular and the line of pseudarthrosis may be sinuous in the coronal and sagittal planes. In our experience, adherence of the overlying fibrous tissue has been the key factor that aids in identifying a pseudarthrosis. The characteristic smooth cortical surface and easily stripped fibrous “periosteum” of a solid, mature fusion mass are quite different from the adherent fibrous tissue overlying a pseudarthrosis. Meticulous inspection of the region of the facet joint is often needed. A mature and solid fusion mass extends across the transverse processes, but motion is detectable at the facet joint, indicating the fusion mass did not incorporate to the fusion bed (i.e., the transverse processes).

- Thoroughly clean the fibrous tissue from the fusion mass in the vicinity of the pseudarthrosis. The adjacent superior and inferior borders of the fusion mass on either side of the pseudarthrosis usually will be seen to move when pressure is applied with a blunt instrument, such as a curet.

- As the defect is followed across the fusion mass, it will be found to extend into the lateral articular surfaces on each side. Carefully explore these articularizations and excise all fibrous tissue and any remaining articular cartilage down to bleeding bone.

- If the defect is wide, excise the fibrous tissue that fills it to a depth of 3 to 6 mm across the entire mass and protect the underlying spinal dura.

- Thoroughly freshen the exposed edges of the defect.

- When the defect is narrow and motion is minimal, limit the excision of the interposed soft tissue to avoid loss of fixation.

- Fashion a trough 6 mm wide and 6 mm deep on each side of the midline, extending longitudinally both well above and well below the defect.

- "Fish scale" the entire fusion mass on both sides of the defect, with the bases of the bone chips raised being away from the defect.

- Obtain both strip and chip bone grafts either from the fusion mass above or below or from the ilium, preferably the latter.

- Pack these grafts tightly into the lateral articularations, into the pseudarthrosis defect, and into the longitudinal troughs.

- Place small grafts across the pseudarthrosis line and wedge the edge of each transplant beneath the fish-scaled cortical bone chips. Use all remaining graft material to pack neatly in and about the grafts.

- Internal fixation (see Chapter 38) can be used to improve the rate of healing after pseudarthrosis repair but often is not necessary, and removal of loose hardware improves postoperative imaging capability.
depressed mood and should be questioned about changes or stresses at work and at home. If the patient has identified significant stresses, anger, or anxiety, the diagnosis of IDD is in question. Also, examination for Waddell signs should be included (Table 39-6), and if three or more are present, an alternative diagnosis is more likely. The examination must include the hip joints as a possible cause of buttock and thigh pain.

Imaging studies should include a lumbar spine series and dynamic films to assess deformities, measurable instability, or destructive lesions. Additional diagnostic studies should be obtained to evaluate abdominal or intrapelvic pathology that may have been suggested by the patient's history and physical examination. Additionally, MRI of the lumbar spine should show diminished water content in the nucleus of one or more lumbar discs (Fig. 39-42). This may or may not be associated with a loss of disc height and broad-based disc bulging. Decreased water content leads to decreased signal intensity best seen on T2-weighted sagittal images. This finding alone has no diagnostic value, unless the appropriate history and physical examination also are present and there is no other discernible diagnosis.

The clinical diagnosis of IDD requires a careful and methodical assessment of many different factors. When the diagnosis is established, treatment options can be considered. Most patients can be treated without operative intervention, especially if they are educated as to the nature of the process causing their pain specifically that it is not relentlessly
progressive generally, and that continued pain does not equate with progressive deterioration or disability. Often this understanding and instruction on moderate activity modification, aerobic conditioning such as walking, and core muscle strengthening allow these patients to manage their symptoms long-term without undue worry or resource consumption. A small group of patients with persistent and debilitating pain symptoms may benefit from operative intervention. Before proceeding with any operative treatment, the patient should be informed that surgery leads to improvement in only 65%, leaving about 35% no better or possibly worse with respect to axial spine pain. Also, patients should understand that those who improve still have some activity limitations caused by pain or stiffness. This discussion must be very frank. For patients who still are considering surgery, a consistent and comprehensive assessment leads to the best overall outcomes. This approach is used for treating IDD, which is a diagnosis of exclusion and is separate from the treatment of measurable instability, spinal stenosis, disc herniations, spondylolisthesis, fractures, and other more objective diagnoses. The question becomes: of patients who have severe and debilitating axial spine pain that is not adequately improved with nonoperative methods and who have no objective diagnosis to explain their symptoms, which are likely to improve with surgery? Treatment of the other diagnoses is covered elsewhere.

**PATIENT SELECTION PROCESS**

Given that any other objective diagnosis has already been ruled out, the primary consideration in patient selection revolves around nonanatomical or psychosocial causes for disabling axial spine pain. For many years, patients with
workers’ compensation claims have been considered high risk for psychosocial causes of their pain, but more recent studies that independently assess this variable do not support this assertion. It has been found by several studies independently that being off work more than 8 weeks before surgery is an independent predictor of poorer outcome.

Many authors have tried to develop instruments to measure “abnormal illness behaviors.” Waddell et al. defined this as “maladaptive overt illness related behavior, which is out of proportion to the underlying physical disease (including IDD) and more readily attributable to associated cognitive and affective disturbances.” Waddell et al. also developed clinical tools designed to detect the presence of abnormal illness behavior by identifying physical signs or symptoms and descriptions that were nonorganic. Five nonorganic signs and seven nonorganic symptom descriptions have been identified (see Table 39-6). This group initially described these for use in patients with chronic pain and suggested that the presence of three or more was required to show abnormal illness behavior. Although these signs and symptoms cannot be used to predict return to work, the presence of multiple Waddell signs correlates with poor operative outcome and may temper the decision to offer a particular patient operative consideration.

The first formal step in patient selection for operative treatment for IDD is the MMPI. This study is done before any invasive studies to assess specifically for IDD. This instrument has been used in many studies and has shown to be a predictor of operative outcomes, regardless of the spinal pathology condition that is present. Waddell et al. also developed the MMPI-2 and found that the results replicated the older MMPI. Patients with MMPI and MMPI-2 findings of depressed-pathological profile and a conversion V profile reported greater dissatisfaction with operative outcomes. The MMPI is lengthy and difficult to administer in an orthopaedic clinical setting. An independent assessment by an experienced psychologist or psychiatrist who also administers the MMPI is best. By comparison, the Distress and Risk Assessment Method (DRAM) is relatively easily administered and scored and has been validated in clinical settings with regard to patients with back pain. The DRAM consists of the Modified Somatic Perception Questionnaire and the Zung Depression Index. With this simplified method, patients identified as psychologically distressed are three to four times more likely to have a poor outcome after any form of treatment.

We recommend that patients being considered for operative treatment with the working diagnosis of IDD have formal psychological testing, which at our clinic consists of the MMPI. The current version of this test has predictive value for failure of operative treatment but has no predictive value for successful operative treatment. If the scoring and assessment from the psychologist administering the MMPI do not indicate the patient is at increased risk for failure, the second step in the assessment is taken.

### Differential Spinal Anesthetic

The second formal step is the administration of a differential spinal anesthetic. This technique has been well reviewed by Raj, and the reader is referred to that work for a more complete description. Briefly, this technique, which is based anatomically on the relationship between nerve fiber size, conduction velocity, and fiber function, is shown in Table 39-7. The fiber diameter is the most critical physical dimension. The type α fibers are myelinated and subdivided into alpha, beta, gamma, and delta subtypes, each with different functions. Also, the unmyelinated B and C fibers serve different functions. The basic concept of the differential spinal is that by sequentially administering a local anesthetic agent, a predictable sequence of functional loss, beginning with sympathetic, then sensory, and finally motor blockade, is seen. The conventional technique (Table 39-8) is administered as a series of four solutions, each given in an identical fashion. The patient is questioned regarding her pain, and a series of observations is made by the physician to evaluate strength by dermatome, light touch, sharp and dull discrimination by dermatome, and reflexes (Table 39-9). The solutions should be referred to as “A” through “D” to avoid the term “placebo” in front of the patient. Also, the patient is not told ahead of time of the expected sequential changes to avoid bias. The four solutions are given as follows:

- Solution A: contains no local anesthetic and serves as placebo.
- Solution B: contains 0.25% procaine, which is known to represent the mean sympatholytic concentration of procaine in the subarachnoid space that is the concentration sufficient to block B fibers but usually insufficient to block A delta and C fibers.

### Table 39-7

<table>
<thead>
<tr>
<th>FIBER GROUP/SUBGROUP</th>
<th>DIAMETER (µM)</th>
<th>CONDUCTION VELOCITY (m/s)</th>
<th>MODALITY SUBSERVED</th>
<th>SENSITIVITY TO LOCAL ANESTHETICS (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (MYELINATED)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A alpha</td>
<td>15-20</td>
<td>80-120</td>
<td>Large motor, proprioception</td>
<td>1</td>
</tr>
<tr>
<td>A beta</td>
<td>8-15</td>
<td>30-70</td>
<td>Small motor, touch, and pressure</td>
<td>0.5</td>
</tr>
<tr>
<td>A gamma</td>
<td>4-8</td>
<td>30-70</td>
<td>Muscle spindle, reflex</td>
<td></td>
</tr>
<tr>
<td>A delta</td>
<td>3-4</td>
<td>10-30</td>
<td>Temperature, sharp pain, nociception</td>
<td>0.5</td>
</tr>
<tr>
<td>B (unmyelinated)</td>
<td>3-4</td>
<td>10-15</td>
<td>Preganglionic autonomic</td>
<td>0.25</td>
</tr>
<tr>
<td>C (unmyelinated)</td>
<td>1-2</td>
<td>1-2</td>
<td>Dull pain, temperature, nociception</td>
<td>0.5</td>
</tr>
</tbody>
</table>

*Vertical arrow indicates intermediate values in descending order.*

(From Raj PP, editor: Practical management of pain, ed 3, St. Louis, 2000, Mosby.)

ISBN: 978-0-323-37462-0; PII: B978-0-323-37462-0.00039-2; Author: Azar & Canale & Beaty; 00039
Preparation of Solutions for Conventional Sequential Differential Spinal Blockade

<table>
<thead>
<tr>
<th>SOLUTION</th>
<th>PREPARATION OF SOLUTION</th>
<th>YIELD BLOCKADE</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>To 2 mL of 10% procaine, add 2 mL of normal saline</td>
<td>4 mL of 5% procaine</td>
</tr>
<tr>
<td>C</td>
<td>To 1 mL of 5% procaine, add 9 mL of normal saline</td>
<td>10 mL of 0.5% procaine</td>
</tr>
<tr>
<td>B</td>
<td>To 5 mL of 0.5% procaine, add 5 mL of normal saline</td>
<td>10 mL of 0.25% procaine</td>
</tr>
<tr>
<td>A</td>
<td>Draw up 10 mL of normal saline</td>
<td>10 mL of normal saline</td>
</tr>
</tbody>
</table>

Observations After Each Injection

<table>
<thead>
<tr>
<th>SEQUENCE</th>
<th>OBSERVATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Blood pressure and pulse rate</td>
</tr>
<tr>
<td>2</td>
<td>Patient's subjective evaluation of the pain at rest</td>
</tr>
<tr>
<td>3</td>
<td>Reproduction of patient's pain by movement</td>
</tr>
<tr>
<td>4</td>
<td>Signs of sympathetic block (temperature change, psychogalvanic reflex)</td>
</tr>
<tr>
<td>5</td>
<td>Signs of sensory block (response to pin prick)</td>
</tr>
<tr>
<td>6</td>
<td>Signs of motor block (inability to move toes, feet, legs)</td>
</tr>
</tbody>
</table>

Preparation of normal saline and procaine solutions for differential spinal blocks. The modified technique allows more rapid recovery of the patient or in print. This proof copy is the copyright property of the publisher and is confidential until formal publication.
If a patient has a somatic mechanism responsible for pain, the
and to the conscientious surgeon who is treating this patient.

gorgeous to a patient who is highly likely to have a poor outcome
avoiding any further operative interventions is very advanta-
gious from the group with somatic pain. It is unusual
have had extensive evaluations and trial therapies before the
current evaluation was undertaken. Identification of a patient
with true psychogenic or central mechanism of pain and
is unusual that is, if not identical, to a patient's usual
axial pain. Also, there must be radiographic abnormalities
with annular disruption. If the examiner determines that
the patient has one or more positive discogram levels, and at least
one normal control level, operative treatment is offered. The
patient has one or more positive discogram levels, and at least
one normal control level, operative treatment is offered. The
type of operative treatment can be subdivided into arthrodesis
or disc replacement, but even with confirmatory imaging
and specific concordant discogram results, the results of
surgery for axial back pain are mediocre at best.

The specific procedure that best fits each patient requires
careful consideration of each available option and must
involve the patient substantially in the decision-making
process. With regard to arthrodesis, there are multiple
options, including anterior lumbar interbody techniques,
posterolateral techniques, posterior interbody techniques,
and combined anterior and posterior fusion options. There
are a variety of stabilization alternatives involving interbody
deVICES, pedicle screw fixation, and combinations of these
strategies. The ultimate goal in each type of surgery is a solid
arthrodesis. Also, the arthrodesis may use autologous iliac
bone graft, which is considered the standard, although bone
morphogenetic proteins (BMPs) seem to have a role. At this
time, no particular approach and no particular technique of
stabilization have been shown to be superior to others, and
there are several good studies that show statistical equiva-

cency between anterior lumbar interbody fusion (ALIF), pos-
terior lumbar interbody fusion (PLIF), and posterolateral
fusion with instrumentation (Fig. 39–43). Also, there has been
no superiority proved for the various minimally invasive
options. Likewise, there is no study showing BMP superior
to autogenous bone when used posteriorly in this setting.

### TABLE 39-10

<table>
<thead>
<tr>
<th>DIAGNOSIS</th>
<th>EXPLANATION/BASIS OF DIAGNOSIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central lesion</td>
<td>The patient may have a lesion in the central nervous system that is above the level of the subarachnoid</td>
</tr>
<tr>
<td></td>
<td>sensory block. We have seen two patients who had a metastatic lesion in the precentral gyrus, which</td>
</tr>
<tr>
<td></td>
<td>was the central origin of the patient's peripheral pain.</td>
</tr>
<tr>
<td>Psychogenic pain</td>
<td>The patient may have true psychogenic pain, and it is not going to respond to any level of block. This is</td>
</tr>
<tr>
<td></td>
<td>an even more uncommon response in patients with psychogenic pain than a positive response to</td>
</tr>
<tr>
<td></td>
<td>placebo.</td>
</tr>
<tr>
<td>Encephalization</td>
<td>The patient's pain may have undergone “encephalization,” a poorly understood phenomenon in which</td>
</tr>
<tr>
<td></td>
<td>consistent, severe, agonizing pain, originally of peripheral origin, becomes self-sustaining at a central</td>
</tr>
<tr>
<td></td>
<td>level. This usually does not occur until severe pain has been endured for a prolonged period; when it</td>
</tr>
<tr>
<td></td>
<td>has occurred, removal or blockade of the original peripheral mechanism fails to provide relief.</td>
</tr>
<tr>
<td>Malingering</td>
<td>The patient may be malingering. One cannot prove or disprove this with differential blocks. If a patient</td>
</tr>
<tr>
<td></td>
<td>is involved in litigation concerning the cause of pain and anticipates financial benefit, it is unlikely that</td>
</tr>
<tr>
<td></td>
<td>any therapeutic modality would relieve the pain. Empirically, however, we believe that a previous</td>
</tr>
<tr>
<td></td>
<td>placebo reaction from solution A followed by no relief from solution D strongly suggests that a patient</td>
</tr>
<tr>
<td></td>
<td>who ultimately appears to have a central mechanism is not malingering because the placebo reaction,</td>
</tr>
<tr>
<td></td>
<td>depending as it does on a positive motivation to obtain relief, is unlikely in a malingering. There is no</td>
</tr>
<tr>
<td></td>
<td>way to document the validity of this theory, but it does suggest a greater motivation to obtain pain</td>
</tr>
<tr>
<td></td>
<td>relief than to obtain financial gain.</td>
</tr>
</tbody>
</table>

(From Raj PP, editor: Practical management of pain, ed 3, St. Louis, 2000, Mosby.)

### TABLE 39-11

<table>
<thead>
<tr>
<th>SOLUTION</th>
<th>PREPARATION</th>
<th>YIELD</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>To 1 mL of 10% procaaine, add 1 mL of cerebrospinal fluid</td>
<td>2 mL of 5% procaine (hyperbaric)</td>
</tr>
<tr>
<td>A</td>
<td>Draw up 2 mL of normal saline</td>
<td>2 mL of normal saline</td>
</tr>
</tbody>
</table>

(From Raj PP, editor: Practical management of pain, ed 3, St. Louis, 2000, Mosby.)
**FIGURE 39-43**  
A and B, Solid arthrodesis after anterior lumbar antibody fusion with radiolucent threaded cages with bone morphogenetic protein type 2.  
C and D, Pedicle screw instrumentation with posterolateral autologous bone and transforaminal lumbar interbody fusion with allograft bone.  
E and F, Posterolateral fusion with autologous bone and pedicle screw instrumentation extending previous fusion.
When used with ALIF, BMP-2 has been shown to be equal to autologous bone. Long-term questions remain, however, about use of BMP-2 in women of reproductive age. The use of BMP in anterior cervical fusions has been associated with an increased incidence of complications, especially wound infections; its use in thoracolumbar and posterior cervical fusions does not seem to be associated with more complications.

At this time, there is no commercially available prosthesis for nucleoplasty, so this remains only a potential treatment. Multiple dynamic stabilization-type devices are available. There are, however, no biomechanical or clinical data to support the use of this strategy for treatment of IDD.

A technique that has garnered great attention in the past 5 years is that of total disc replacement (TDR) (Fig. 39-44). The reason for this intense interest is the belief by many experts that this motion-preserving technique reduces adjacent motion segment degeneration, which remains problematic. There is some evidence that genetics may be more important than mechanical factors in IDD. Serious questions remain in regard to this technology, however:

1. Is motion preserved over long periods of time with TDR?
2. Does motion preservation decrease adjacent segment disease, or is this primarily determined by genetic factors?
3. What are the long-term results for TDR with issues such as wear, subsidence, or aseptic loosening?
4. What are the optimal revision strategies for TDR?

At this time, there are only three lumbar disc prostheses with FDA approval: the INMOTION, which is a modification of the Charité (Depuy Spine, Raynham, MA), the ProDisc-L (DePuy Synthes), and the activL (Aesculap, Center Valley, PA). All are approved only for single-level disc replacement. Several other lumbar disc prostheses are currently in the approval process.

The patient should be informed of the current expected or possible benefits and the current uncertainties involved with TDR. Also, from an anatomical standpoint, the condition of the facets should be essentially normal because TDR treats only one of the three joints at each motion segment. If there is significant disc space narrowing with facet overload and facet degeneration noted on CT, then TDR at this time cannot be recommended. Also, as with virtually any spine implant, the quality of the patient’s bone may preclude TDR if osteoporosis is present.

The specific technique for TDR is similar to ALIF in principle. The mobilization of vascular structures needs to be slightly greater, especially at the L4 disc level. Also, proper sizing of the implant to optimize surface area of contact has been shown to reduce the risk for subsidence. Proper implant position is crucial to the function and possible catastrophic failure of each device. The reader is referred to the specific technique guides for these parameters. Our experience with these devices is limited at this time, and their ultimate value for patient care has not been determined.

**FAILED SPINE SURGERY**

One of the greatest problems in orthopaedic surgery and neurosurgery is the treatment of failed spine surgery. Numerous reasons for the failures have been advanced. Results from repeat surgery for disc problems seem to be best with the discovery of a new problem or identification of a previously undiagnosed or untreated problem. The best results from repeat surgery have been reported to occur in patients who have experienced 6 months or more of complete pain relief after the first procedure, when leg pain exceeds back pain, and when a definite recurrent disc can be identified. Adverse factors include scarring, previous infection, repair of pseudarthrosis, and adverse psychological factors. Satisfactory results from reoperation have been reported to be 31% to 80%, and complications have been reported to be three to five times higher than for primary surgeries. Patients should expect improvement in the severity of symptoms, rather than...
complete relief of pain. As the frequency of repeat back surgeries increases, the chance of a satisfactory result decreases precipitously.

The recurrence or intensification of pain in the subacute or late period after disc surgery should be treated with the usual conservative methods initially. If these methods fail to relieve the pain, the patient should be completely reevaluated. Frequently, a repeat history and physical examination give some indication of the problem. Additional testing should include psychological testing, myelography, MRI to check for tumors or a higher disc herniation, and reformatted CT scans to check for areas of foraminal stenosis or for lateral herniation. The use of the differential spinal, root blocks, facet blocks, and discograms also can help identify the source of pain. The presence of abnormal psychological test results or an abnormal differential spinal should serve as a modifier to any suggested treatment indicated by the other testing. Satisfactory nonoperative treatment of this problem should be attempted before additional surgery is performed. A distinct, operatively correctable, anatomical problem should be identified before surgery is contemplated. Pseudarthrosis, instability, and recurrent herniations are the diagnoses most likely to respond to further operative intervention after failed spine surgery. The operative should be tailored specifically to the anatomical problem identified.

**STENOSIS OF THE THORACIC AND LUMBAR SPINE**

Degenerative spinal stenosis is a progressive disorder that involves the entire spinal motion segment as described by Kirkaldy-Willis. Degeneration of the intervertebral disc results in initial relative instability and hypermobility of the facet joints. An increase in pressure on the facet joints with disc space narrowing and increasing angles of extension occurs and can lead to hypertrophy of the facet joint, particularly the superior articular process. As joint destruction progresses, the hypertrophic process ultimately may result in local ankylosis. Calcification and hypertrophy of the ligamentum flavum commonly are contributing factors. The end result anatomically is reduced spinal canal dimensions and compression of the neural elements. The resultant venous congestion and hypertension likely are responsible for the symptom-complex known as intermittent neurogenic claudication. Mild trauma and occupational activity do not seem to affect significantly the development of this disease, but they may exacerbate a preexisting condition.

**ANATOMY**

Spinal stenosis can be categorized according to the anatomical area of the spine affected, the region of each vertebral segment affected, and the specific pathological entity involved (Table 39-12). Stenosis can be generalized or localized to specific anatomical areas of the cervical, thoracic, or lumbar spine. It is most common in the lumbar region, but cervical stenosis also occurs frequently. It has been rarely reported in the thoracic spine. Spinal stenosis can be localized or diffuse, affecting multiple levels, as in congenital stenosis. Degeneration of the disc occurs with disc narrowing and subsequent ligamentous redundancy, which compromises the spinal canal area. Instability may ensue. This relative hypermobility precipitates the formation of facet overgrowth and ligamentous hypertrophy. The ligamentum flavum may be markedly thickened into the lateral recess where it attaches to the facet capsule, causing nerve root compression. These phenomena occur alone or in combination to create the symptom-complex characteristic of spinal stenosis.

A description of spinal stenosis requires an understanding of the anatomy affected and the use of consistent terminology (Fig. 39-45). **Central spinal stenosis** denotes involvement of the area between the facet joints, which is occupied by the dura and its contents. Stenosis in this region usually is caused by protrusion of a disc, bulging anulus, osteophyte formation, or buckled or thickened ligamentum flavum. Symptomatic central spinal stenosis results in neurogenic claudication with generalized leg pain. Lateral to the dura is the lateral canal, which contains the nerve roots; compression in this region results in radiculopathy. The **lateral recess**, also known as "Lee's entrance zone," begins at the medial border of the superior articular process and extends to the medial border of the pedicle. This is where the nerve root exits the dura and courses distally and laterally under the superior articular facet (Fig. 39-46). The borders of the lateral recess are the pedicle laterally, the superior articular facet dorsally, the disc and posterior ligamentous complex ventrally, and the central canal medially. Facet arthritis most frequently causes stenosis in this zone, along with vertebral body spurring and disc or anulus pathology. "Lee's midzone" describes the **foraminal region**, which lies ventral to the pars.
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exacerbate the narrowing further. Spondylolisthesis and spondyloysis rarely cause spinal stenosis in young patients. The combination of degenerative change, aging, and spondylolisthesis or spondyloysis in patients 50 years old or older frequently results in lateral recess or foraminal stenosis. Paget disease and fluorosis have been reported to result in central or lateral spinal stenosis. Paget disease is one form of spinal stenosis that responds well to medical treatment with calcitonin.

**NATURAL HISTORY**

Although symptoms may arise from narrowing of the spinal canal, not all patients with narrowing develop symptoms. One study found no significant association between clinical symptoms and anteroposterior spinal canal diameter. In general, the natural history of most forms of spinal stenosis is the insidious development of symptoms. Occasionally, there can be an acute onset of symptoms precipitated by trauma or heavy activity. Many patients have significant radiographic findings with minimal complaints or physical findings. About 50% of patients treated nonoperatively report improved back and leg pain after 8 to 10 years, although functional ability after decompressive surgery has been shown in multiple studies to surpass that obtained after nonoperative treatment. A prospective, randomized study of 100 patients with symptomatic spinal stenosis treated operatively or nonoperatively found that pain relief occurred after 3 months in most patients regardless of treatment, although it took 12 months in a few patients. Results in patients treated nonoperatively deteriorated over time; however, at 4 years they were excellent or fair in 50%; 80% of patients treated operatively had good results at 4 years.

Reported studies suggest that for most patients with spinal stenosis, a stable course can be predicted, with 15% to 50% showing some improvement with nonoperative treatment. Worsening of symptoms despite adequate conservative treatment is an indication for operative treatment.

Weinstein et al. showed significantly more improvement in all primary outcomes in patients treated operatively compared with those treated nonoperatively.

**CLINICAL EVALUATION**

In patients with spinal stenosis, symptoms include back pain (95%), sciatica (91%), sensory disturbance in the legs (70%), motor weakness (33%), and urinary disturbance (12%). In patients with central spinal stenosis, symptoms usually are bilateral and involve the buttocks and posterior thighs in a nondermatomal distribution. With lateral recess stenosis, symptoms usually are dermatomal because they are related to a specific nerve being compressed. Patients with lateral recess stenosis may have more pain during rest and at night but may require 20 minutes to improve. Patients often report better endurance walking uphill or up steps and tolerate riding a bicycle better than walking on a treadmill because of the flexed posture that occurs. Pushing a grocery cart also allows spinal flexion, which enhances endurance and decreases discomfort in most patients with neurogenic claudication (positive "shopping cart" sign).

Generally, physical findings with all forms of spinal stenosis are inconsistent. Distal pulses should be felt and confirmed to be strong, and internal and external rotation of the hips in extension should be full, symmetrical, and painless. Straight-leg raising and sciatic tension tests usually are normal. The neurological examination usually is normal, but some abnormality may be detected if the patient is allowed to walk to the limit of pain and is then reexamined. The gait and posture after walking may reveal a positive "stoop test." This test is done by asking the patient to walk briskly. As the pain intensifies, the patient may complain of sensory symptoms followed by motor symptoms. If the patient is asked to continue to walk, he or she may assume a stooped posture, and the symptoms may be eased, or if the patient sits in a chair bent forward, the same resolution of symptoms occurs.

**DIAGNOSTIC IMAGING**

**RADIOGRAPHY**

Although plain radiography cannot confirm spinal stenosis, findings such as short pedicles on the lateral view, narrowing between the pedicles on the anteroposterior view, ligament ossification, narrowing of the foramen, and hypertrophy of the posterior articular facets can be helpful hints. Leroux et al. outlined hypertrophic radiographic changes associated with hyperostosis on plain tomography and CT (Box 39-8). The radiographic identification and confirmation of lumbar spinal stenosis have improved with the development of new imaging techniques. Initially, only central spinal stenosis was recognized, with canal narrowing to 10 mm considered absolute stenosis. This could be measured using radiographs or, preferably, myelography. Schönström, Bolender, and Spengler compared two methods of identifying central spinal stenosis: (1) anteroposterior canal...
CHAPTER 39  DEGENERATIVE DISORDERS OF THE THORACIC AND LUMBAR SPINE

Hypertrophic Radiographic Changes Associated With Hyperostosis

Plain Radiographs

Dorsal Level
1. Intervertebral osseous bridge
2. “Lobster claw”

Cervical Level
1. Exuberant osteophytosis
2. Narrow cervical canal

Lumbar Level
1. Marginal somatic osseous proliferation
2. “Candle flame”
3. “Lobster claw”
4. Intervertebral osseous bridge
5. Disc arthrosis
6. Acquired vertebral block
7. Hypertrophy of posterior articular processes
8. “Bulb” appearance of posterior articular hypertrophy
9. Anterior subluxation
10. Posterior subluxation

Lumbar Computed Tomography
1. Herniated disc
2. Disc protrusion
3. Vacuum disc sign
4. Hypertrophy of posterior articular processes
5. Osteoarthritis of apophyseal joints
6. Osseous proliferations of nonarticular aspects of superior apophyseal joint
7. Osseous proliferations of nonarticular aspects of inferior apophyseal joint
8. C/O of posterior longitudinal ligament
9. C/O of yellow ligament
10. C/O of supraspinous ligament
11. Anterior C/O of posterior articular capsule
12. Posterior C/O of posterior articular capsule
13. Anteroposterior diameter of spinal canal
14. Transverse diameters of spinal canal

Currently, axial imaging has supplanted standard radiographs in the diagnosis of spinal stenosis, although radiographs are important in the initial evaluation of patients with persistent pain of more than 6 weeks’ duration or of patients with “red flags” of other disease, including recent trauma, history of cancer, immunosuppression, age older than 50 years or younger than 20 years, neurological deficit, or previous surgery. Flexion and extension views are useful to identify preexisting instability before laminectomy and may be useful in determining the need for subsequent fusion. Translation of more than 4 mm or rotation of more than 10 to 15 degrees indicates instability. A reversal of the normal trapezoidal disc geometry with widening posteriorly and narrowing anteriorly also may indicate instability.

MAGNETIC RESONANCE IMAGING

MRI is helpful in identifying disease processes, such as tumors and infections, and is a good noninvasive study for patients with persistent lower extremity complaints after radiographic screening evaluation. MRI should be confirmatory in patients with a consistent history of neurogenic claudication or radiculopathy, but it should not be used as a screening examination because of the high rate of asymptomatic disease. Morphological changes have been correlated with preoperative findings, such as pain and function, however, only to a limited extent. Sagittal T2-weighted MR images are a good starting point because they give a myelogram-like image. Sagittal T1-weighted images are evaluated with particular attention focused on the foramen. An absence of normal fat around the root indicates foraminal stenosis. Axial images provide a good view of the central spinal canal and its contents on T1- and T2-weighted images. Far lateral disc protrusions are identified on axial T1-weighted images by obliteration of the normal interval of fat between the disc and nerve root. The foraminal zone is better evaluated with sagittal T1-weighted sequences, which confirm the presence of fat around the nerve root. Absolute anatomical measures also can be used, as previously discussed. Spinal deformity, including scoliosis and significant spondylolisthesis, can result in suboptimal imaging by MRI. This is secondary to the curvature of the spine in and out of the plane of the scanner on sagittal sequences and difficulty obtaining true axial cuts. Another disadvantage of MRI is the cost; nonetheless, MRI has become a useful, noninvasive technique.

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diagnostic tool for the evaluation of patients with extremity complaints.

**COMPUTED TOMOGRAPHIC MYELOGRAPHY**

Despite the prevalence of MRI, myelography followed by CT is still accepted and widely used for operative planning in patients with spinal stenosis; it has a diagnostic accuracy of 91%. The addition of CT after a myelogram allows detection of 30% more abnormalities than myelography alone. Because of the dynamic nature of the study, stenosis not visible on MRI with the patient recumbent may be identified on standing flexion and extension lateral views. CT after myelography characterizes the bony anatomy better than MRI, which helps the surgeon plan decompression surgery. However, imaging of the nerve roots in the foraminal region lateral to the pedicle is impossible, because of the confluence of the dura with the epineurium at this point. There also is additional morbidity associated with the lumbar puncture required for myelography. Myelography followed by CT is best suited for patients with dynamic stenosis, postoperative leg pain, severe scoliosis or spondylolisthesis, metallic implants, contraindications to MRI, and lower extremity symptoms in the absence of findings on MRI.

Abnormal findings occur in 24% to 34% of asymptomatic individuals evaluated with CT myelography, just as with MRI, so clinical correlation is a must.

CT has been used to further define lateral recess stenosis and foraminal stenosis. These types of stenosis rarely are identified with myelography. The lateral recess is anatomically the area bordered laterally by the pedicle, posteriorly by the superior articular facet, and anteriorly by the posterolateral surface of the vertebral body and the adjacent intervertebral disc. The superior border of the corresponding pedicle is the narrowest portion of the lateral recess. Measurement of the recess in this area using the tomographic cross-section usually is 5 mm or greater in normal patients, but in symptomatic patients the diagnosis is confirmed if the height is 2 mm or less (Fig. 39-48). The foramen is the area of the spine bordered by the inferior edge of the pedicle cephalad, the pars interarticularis with the associated inferior articular facet and the superior articular facet from the lower segment posteriorly, the superior edge of the pedicle of the next lower vertebra caudally, and the vertebral body and disc anteriorly. This area rarely can be seen with myelography. A standard CT in the cross-sectional mode suggests narrowing if the foraminal space immediately after the pedicle cut is present for only one or two more cuts (provided that the cuts are close together). The best way to appreciate foraminal narrowing is to reformat the lumbar scan, which can create sagittal views through the pedicles and structures situated laterally.

Wiltse et al. described a far-out compression of the root that occurs predominantly in spondylolisthesis when the root is compressed by a large L5 transverse process subluxed below the root and pressing the root against the ala of the sacrum. This diagnosis is best confirmed with a reformatted CT scan with coronal cuts (Fig. 39-49).

Some studies have attempted to correlate clinical outcome with pathological findings on myelography and CT. A retrospective review found that patients who had a block on myelogram had a better chance of obtaining a good outcome. Another study confirmed postoperative stenosis in 64% of 191 patients at 4-year follow-up. Slight differences were noted in the Oswestry questionnaire between patients with and without stenosis but not in walking distances, and instability was present in 21% without demonstrable clinical effect. The degree of decompression on CT myelography did not correlate at all with outcomes, and regardless of the number of levels that had decompression, the results were similar. Nonetheless, decompression of all symptomatic levels with evidence of compression is recommended to enhance neural circulation and function and to avoid reoperation for recurrent spinal stenosis.

**OTHER DIAGNOSTIC STUDIES**

Electrodiagnostic studies should be used if the diagnosis of neuropathy is uncertain, especially in patients with diabetes mellitus. Needle electromyographic study was shown to have a lower false-positive rate than MRI in asymptomatic patients. The diagnostic use of such studies, including somatosensory evoked potentials, is limited by the lack of prospective studies to determine sensitivity or specificity. Vascular Doppler examinations are useful to identify inflow problems into the lower extremities and should be accompanied by a vascular surgery consultation when indicated. Differential diagnosis also can be aided by the use of exercise testing. Tenhula et al. described a bicycle-treadmill test that stresses the patient in an upright position on an exercise treadmill and subsequently in a seated position on an exercise bicycle that allows spinal flexion. Earlier onset of leg symptoms with level walking and delayed onset of symptoms with inclined treadmill walking were significantly associated with stenosis. Exercise treadmill testing also is useful to help determine baseline function for quantitative evaluation of functional status after surgery. This study showed significant postoperative improvement in treadmill walking and bicycling duration (88% preoperatively and 9% postoperatively for walking; 41% preoperatively and 17% postoperatively for bicycling), lower visual analogue scale pain scores, and a later onset of pain.

**NONOPERATIVE TREATMENT**

Symptoms of spinal stenosis usually respond favorably to nonoperative management (satisfactory results in 69% at 3 years).
years according to Simotas et al.). Despite symptoms of back pain, radiculopathy, or neurogenic claudication, conservative management is successful in most patients. Patients with radicular type pain respond well to nonoperative treatment, but those with scoliosis tend to have worse results. Conservative measures should include rest not exceeding 2 days, pain management with antiinflammatory medications or acetaminophen, and participation in a trunk-stabilization exercise program, along with good aerobic fitness. Other methods should be reserved for patients who are limited by pain and should be used to maximize participation in the exercise program. Traction has no proven benefit in the adult lumbar spine. For a patient with unremitting symptoms of radiculopathy or neurogenic claudication, epidural steroid injections may be useful in alleviating symptoms to allow better participation in physical therapy. Epidural steroids can give significant symptomatic relief, although no scientific study has documented long-term efficacy.

Manchikanti et al. reported significant pain relief in 76% of 25 patients who had percutaneous adhesiolysis with injection of lidocaine, hypertonic sodium chloride solution, and nonparticulate betamethasone. If spinal stenosis is present with coexistent degenerative arthritis in the hips or knees, some permanent limitation in activity may be necessary regardless of treatment.

Epidural Steroid Injections

Spinal stenosis and the resultant mechanical compression of neural elements can cause structural and chemical injury to the nerve roots. Edema and venous congestion of the nerve roots can lead to further compression and ischemic neuritis. This may result in the leakage of neurotoxins, such as phospholipase and leukotriene B, which can lead to increased inflammation and edema. Steroids are potent antiinflammatory medications and result in a decrease in leukocyte migration, the inhibition of cytokines, and membrane stabilization. These actions coupled with their ability to reduce edema provide the rationale for the use of epidural steroid injections in spinal stenosis. Epidural steroid injections have been used in the treatment of spinal stenosis for many years, and no validated long-term outcomes have been reported to substantiate their use. Significant improvement in pain scores, however, has been reported at 3 months. Patients with a healthier emotional status and those with a higher body mass index reportedly experience more pain relief. A prospective, randomized study found caudal epidural injections (lidocaine 0.5%) with or without steroids to be effective in approximately 60% of patients in the short term.

The technique of placement—caudal, translaminar, or transformal—also is debated, as is whether fluoroscopy should be used. Lee et al. reported improvement in 87.5% of 216 patients using fluoroscopically guided caudal epidural steroid injection; however, they included minimal improvement in these results. Although one study reported no difference between interlaminar and transformal injection, Lee et al. reported that bilateral transformal epidural injection allowed delivery of a higher concentration of injectate. Using anatomical landmarks for caudal injections, Stitz et al. reported accurate placement in 65% to 74% of patients, with intravascular placement in 4%. Accurate placement of translaminar injections seems to be equally difficult, with successful placement reported in 70%.

Spinal canal dimension has not been shown to be predictive of success or failure of epidural steroid injection.
Complications are infrequent but can occur and include hypercorticism, epidural hematoma, temporary paralysis, retinal hemorrhage, epidural abscess, chemical meningitis, and intracranial air. A 5% incidence of dural puncture has been reported, and, if it occurs, subarachnoid injection of steroids or local anesthetic should be avoided to prevent mechanical or chemical nerve root irritation. Headaches occur in 1% to 5% of patients and are related to dural puncture or the use of the caudal injection route. In patients with headaches associated with caudal injections, the cause has not been determined because dural puncture should not occur at this level, because the dural sleeve has terminated at mid sacrum.

The ideal candidate for epidural steroid injection seems to be a patient who has acute radicular symptoms or neurogenic claudication unresponsive to traditional analgesics and rest, with significant impairment in activities of daily living. We have used this technique successfully in our treatment algorithm for neurogenic claudication and radiculopathy both as a diagnostic as well as therapeutic procedure. The authors prefer the use of transforaminal injections because it allows more ventral placement of injectate in the foramen and lateral recess.

OPERATIVE TREATMENT

The primary indication for surgery in patients with spinal stenosis is increasing pain that is resistant to conservative measures. Because the primary complaint often is back pain and some leg pain, pain relief after surgery may not be complete. Operative intervention should be considered if the relief of claudicatory leg pain with variable response to back pain. Most series report a 64% to 91% rate of improvement, with 42% in patients with diabetes, but most patients still have some minor complaints, usually referable to the preexisting degenerative arthritis of the spine. Neurological findings, if present, improve inconsistently after surgery. Pearson et al. noted that patients whose predominant complaint was leg pain improved significantly more with operative treatment than those whose predominant complaint was low back pain. Both, however, improved significantly with operative treatment compared with conservative treatment. Reoperation rates vary from 6% to 23%. Prognostic factors include better results with a disc herniation, stenosis at a single level, weakness of less than 6 weeks' duration, monoradiculopathy, and age younger than 65 years. Depression, psychiatric disease, cardiovascular disease, higher body mass index, scoliosis, and disorders affecting ambulation have been associated with a poorer prognosis. Reversal of neurological consequences of spinal stenosis seems to be a relative indication for surgery unless the symptoms are acute.

Radiographic findings alone are never an indication for surgery. Factors predicting outcome vary, and correlation of imaging with symptoms seems to be the best guarantee of improvement after surgery. Localized lesions on radiograph without general involvement respond best. Ganz reported a 96% success rate in patients whose preoperative symptoms were relieved by postural change.

A patient's inability to tolerate the restricted lifestyle necessitated by the disease and the failure of a good conservative treatment regimen should be the primary determining factors for surgery in a well-informed patient. The patient should understand the potential for the operation to fail to relieve pain or to worsen it, especially in regard to the axial component of the symptoms. In addition to the general risks of spinal surgery, the severity of symptoms and lifestyle modifications should be considered. Lumbar spinal stenosis does not result in paralysis, only decreased ambulatory capacity, and conservative management is warranted indefinitely in a patient with good function and manageable symptoms. Delaying surgical treatment for a trial of nonoperative treatment has not been shown to affect outcome; however, one study reported less favorable results in patients who had symptoms for more than 33 months.

Cervical and thoracic spinal stenoses are associated with painless paralysis in the form of cervical and thoracic myelopathy and require closer attention and follow-up.

PRINCIPLES OF SPINAL STENOSIS SURGERY

Decompression by laminectomy or a fenestration procedure is the treatment of choice for lumbar spinal stenosis (Fig. 39-50). Fusion is required if excessive bony resection compromises stability or if ischemic or degenerative spondylolisthesis, scoliosis, or kyphosis is present. Other important indications for fusion include adjacent segment degeneration after prior fusion and recurrent stenosis or herniated disc after decompression. Laminectomy may be preferable in older patients with severe, multilevel stenosis, whereas fenestration procedures, consisting of bilateral laminotomies and partial facetectomies that preserve the midline structures, are an alternative in younger patients with intact discs. This is an especially attractive procedure when performed through a minimally invasive approach because it should cause injury to the dynamic spinal stabilizers is minimized. In one recent study fewer complications and less postoperative instability were reported after bilateral laminotomies than after laminectomy.

Whenever possible, the source of pain should be localized with selective root blocks preoperatively to allow a more focal decompression. At surgery, specific attention should be directed to the symptomatic area, which may result in less extensive decompression than would normally be done with the pain source unconfirmed. If radical decompression of only one root is necessary, additional stabilization by fusion with or without instrumentation is usually unnecessary. The removal of more than one complete facet joint may require instrumented fusion. It is advisable to prepare the patient for fusion in case the findings at surgery require a more radical approach than anticipated. When both an ipsilateral lateral recess decompression and foraminodial decompressions are necessary, a TLIF can be used without risking subsequent instability at the level. Positioning the patient with the abdomen hanging free minimizes bleeding. If fusion is likely, the hips should remain extended to prevent positional kyphosis. The authors do not recommend the use of a kyphosing frame when a fusion is performed. As in disc surgery, a microscope or magnifying loupes and a headlamp are helpful. The microscope allows for a smaller incision with less damage while maintaining binocular vision and depth perception caused by the smaller interocular distance of the microscope. When proceeding with the decompression, care should be taken to watch for adhesions that can result in dural tears, even if no previous surgery has been done. Frequently, the narrowing in the lateral recess and foramen is so great that a Kerrison rongeur cannot be used without damaging the root. Alternatively, dissection in the lateral recess and foramen may require...
ADJACENT SEGMENT DEGENERATION

Adjacent disc degeneration and stenosis, or the transition syndrome, deserves special mention. It is known that disc degeneration occurs adjacent to a fusion in 35% to 45% of patients because of the ensuing hypermobility of the unfused joint, usually above the fusion mass. Adjacent segment stenosis below the fusion mass, although less frequent, always occurred along with stenosis above the fusion in a study by Lehmann et al.

Adjacent segment breakdown may cause symptoms that require surgery in 30% of patients. Pathology, including spinal stenosis, herniated nucleus pulposus, and instability, may require treatment years after successful surgery. Breakdown is possible one or two levels above lumbosacral fusions and above or below thoracolumbar and “floating” lumbar fusions. Schlegel et al. reported 58 patients who developed spinal stenosis, disc herniation, or instability at a segment adjacent to a previously asymptomatic fusion that was done an average of 13.1 years earlier, although 70% had good or excellent results. These clinical findings have been substantiated by subsequent biomechanical studies that confirmed kinematic changes in segments adjacent to spinal fusions. Simple malalignment that occurs during patient positioning when the hips are not extended may result in hydrolordosis and increase the load across implants and increase posterior shear and laminar strain at adjacent levels. These changes may help to explain the cause of adjacent segment breakdown. Posterior lumbar interbody fusion (PLIF) also resulted in adjacent segment changes in all patients, but this did not affect results at 5 years in the series of Miyakoshi et al. In a

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A small, sharp osteotome or a high-speed burr, which allows the surgeon to thin the bone sufficiently to allow removal with angled curets. In contrast to disc surgery, for decompression the lateral recess is best seen from the opposite side of the table. During open procedures, the operating surgeon may find it necessary to switch sides during the operation to view the pathology and nerve roots better. Blunt probes with increasing diameters also are useful for determining adequate foraminal enlargement. Disc herniation should be treated at the same time as the spinal stenosis. A good approach is to start the decompression at a point of lesser stenosis and work toward the area of most severe stenosis. This often frees the neural structures enough to make the final decompression simpler and decreases the risk of damage to dura or nerve roots. This approach is especially useful when a minimally invasive undercutting laminoplasty technique is used to operatively treat spinal stenosis.
study comparing patients with spondyloytic spondylolisthesis, degenerative spondylolisthesis, and spinal stenosis. Yu et al. found no significant differences in superior adjacent segment degeneration, instability, or clinical outcome after partial or total laminectomy and single-level PLIF.

Rigidity of instrumentation has been hypothesized to correlate with motion at adjacent segments. Studies have fueled interest in less rigid and dynamic stabilization constructs. In a prospective study with 4-year radiographic follow-up comparing rigid, semirigid, and dynamic instrumentation devices, Korovessis et al. found no differences in adjacent segment degeneration among the three groups. It is undetermined whether more rigid fusion increases the likelihood of adjacent segment changes. There is some evidence that maintaining the function of the posterior dynamic stabilizing paraspinal musculature, including the multifidus, may lead to decreased rates of adjacent segment degeneration after lumber fusion.

Fusion is more difficult as the number of levels fused increases, with L4-5 being the most frequent site of pseudarthrosis. The addition of a second level of fusion should be avoided if possible, and fusing a degenerative disc as a prophylactic measure does not seem to be supported by the data available. The actual source of transition syndromes is unknown; however, postoperative hypoploidsis and rigidity of the fused segment probably contribute to the problem along with disruption of the posterior dynamic muscular stabilizers damaged during open posterior approaches. Surgery should attempt to maintain normal segmental lordosis and global sagittal balance, and in addition to fusing the lowest segments possible while minimizing collateral damage to the paraspinal musculature and lumbodorsal fascia.

Complications are relatively infrequent after decompression for spinal stenosis and occur more often in patients with multiple comorbid conditions, especially diabetes. Comorbidities also contribute to poorer patient satisfaction and increased operative complications. Previous reports have cited increased morbidity and mortality associated with stenosis surgery in the elderly, although one study found that advanced age did not decrease patient satisfaction or return to activities, and there was no increase in morbidity associated with surgery for stenosis in the elderly.

Deep venous thrombosis also must be considered in patients after decompression. The incidence of this complication varies but is likely higher than reported. Pulmonary emboli are exceedingly rare, however. Prophylaxis is best limited to pneumatic compression devices of the foot or calf and early ambulation because the risk of epidural hematoma from pharmacological agents is greater than the risk of a significant pulmonary event or deep venous thrombosis. Reoperation is necessary in 9% to 23% of patients with spinal stenosis.

There are no universal indicators of outcome after decompression. The number of levels requiring decompression have not been shown to affect the surgical results. Factors associated with poorer outcomes have included questionable radiographic confirmation of stenosis, female sex, litigation, previous failed surgery, and the presence of spondylolisthesis. A patient’s self-assessment of health may be the best predictor of satisfaction. Cardiac comorbidity also may be predictive.

Yukawa et al. found that the severity of central canal narrowing at a single level did not affect postoperative improvement in either functional ability, as determined by treadmill and bicycle testing, or patient self-assessment. Patients with multilevel stenosis had similar improvements in postoperative assessment scores.

Jönsson reported successful results after operative treatment in 62% to 67% of patients, although they noted deterioration at 5 years, with 18% requiring reoperation. Patients with a 6-mm or less anteroposterior canal diameter preoperatively had better results. Patients with hip arthritis, diabetes mellitus, previous surgery, vertebral fracture, or a postoperative complication had worse results. Although most are satisfied with the results of decompression, continued severe back pain and the inability to walk a distance have been reported. The Maine Lumbar Spine Group found that long-term (8 to 10 years) results were better after operative than nonoperative treatment. However, approximately half of the patients reported improvement in their back pain, leg pain, or both and were satisfied with their current status regardless of whether they were treated operatively or nonoperatively.

The cost of spinal stenosis surgery (decompressive laminectomy) at 2 years compared favorably with other treatment modalities in one Spine Patient Outcomes Research Trial (SPORT) study.

Progressive instability after decompression does not predict poor results. It appears that normal walking, sensory deficits, and ability to perform activities of daily living improved despite instability. Some further anterolisthesis is tolerated well after decompression, and it is appropriate to observe these patients for further symptoms before recommending fusion because 30% of patients develop anterolisthesis after decompression.

**MIDLINE DECOMPRESSION (NEURAL ARCH RESECTION)**

**TECHNIQUE 39-26**

- Perform the procedure with the patient under general endotracheal anesthesia. Position the patient prone using the frame of choice.
- Make the incision in the midline centered over the level of stenosis. Localizing radiographs should be taken to verify the level of surgery. Carry the incision in the midline to the fascia.
- Strip the fascia and muscle subperiosteally from the spinous processes and laminae to the facet joints to expose the pars interarticularis. Avoid damaging facet joints that are not involved in the bony dissection.
- Identify and remove the spinous processes of the levels to be decompressed. Clear the soft tissue with a sharp curet.
- Remove the lamina with a Kerrison rongeur or high-speed burr up to the insertion of the ligamentum flavum. If the lamina is extremely thick, a high-speed drill with a diamond or side-cutting burr can be used to thin the outer cortex to allow easier removal of the inner portion with a Kerrison rongeur. The lamina may be removed with...
impunity up to the insertion of the ligamentum flavum. Once the ligamentum insertion is identified, the ligamentum can be detached from the lamina with a curet. Take special care in removal of the lamina after the ligamentum flavum is released. The neural structures will be found compressed, and the usual space for instrument insertion may be unavailable. Remove the lamina until the pedicles can be felt. It can be helpful to begin the lateral recess decompression with the high-speed Burr before removal of the ligamentum flavum to avoid having to place a rongeur into an already stenotic canal.

- Using the pedicle as a guide, identify the nerve root and trace it out to the foramen.
- With a chisel or rongeur, carefully remove the medial portion of the superior facet that forms the upper portion of the lateral recess (Fig. 39-51). Check the foramen for patency with an angled dural elevator or graduated probes. If there is further restriction, carry the dissection laterally and open the foramen; do not remove more than half of the pars. Undercutting into the foramen is especially helpful in this regard.
- Inspect the disc and remove gross herniations unilaterally, but try to avoid bilateral annulotomy unilaterally because this compromises stability. Usually the disc is bulging, and the anulus is firm. Remove the anulus and bony ridge ventrally if it is kinking the nerve. This procedure involves some risk of nerve injury and requires a bloodless field. If safety is a concern, a complete facetectomy may be better.

![Figure 39-51](image)

**FIGURE 39-51** Typical midline decompression for spinal stenosis. Note medial facetectomy and foraminotomy with preservation of the pars. Decompression is from inferior border of L3 pedicle to superior border of L5 pedicle, exposing both lateral borders of dura in lateral recess. SEE TECHNIQUE 39-26.

- Complete the dissection at all symptomatic levels. Decompression should be from the caudal aspect of the most proximal pedicle to the cephalad aspect of the most distal pedicle, allowing observation of the lateral margins of the dura in the lateral recesses. This can be done with preservation of the proximal portion of the lamina and the intervening ligamentum flavum at the level above and below. Many failed decompressions are the result of inadequate decompression of the foraminal region, so probing the foramen is mandatory to determine if the decompression is adequate.
- If no obstructions are noted, and all areas have been decompressed adequately, ensure hemostasis with bipolar cautery and the temporary use of thrombin-soaked absorbable gelatin sponge (Gelfoam). Inspect for cerebrospinal fluid leakage. If desired, take a large fat graft from the incision or buttock and place it over the laminectomy defect. A ¾-inch diameter drain can be placed deep in the wound exiting through a separate stab incision. Close the wound in layers.

### LESS-INVASIVE DECOMPRESSION

The consequences of bone and ligament removal must be considered when performing decompression for spinal stenosis. Removal of the spinous processes, laminae, variable portions of the facets and pars, supraspinous and interspinous ligaments, ligamentum flavum, and portions of facet capsules is routine during these operative procedures. Denervation of the paraspinal musculature occurs with wide exposures, which results in altered muscle function. A minimally invasive technique allows decompression of the significant compressing anatomy while preserving paraspinal muscles, the spinous processes, and intervening supraspinous and interspinous ligaments. Results with full-endoscopic techniques have been shown to be equal to those of conventional procedures, with the advantages of fewer complications. Although Kelleher et al. noted that minimally invasive decompression is effective in most patients, including those with degenerative spondylolisthesis; patients with scoliosis, especially with lissthesis, have a significantly higher revision rate, and this must be considered when making treatment decisions.

### SPINOUS PROCESS OSTEOTOMY (DECOMPRESSION)

Weiner et al. reported a 47% improvement in the Low Back Outcome Score and a 66% improvement in average pain level in 46 of 50 patients evaluated 9 months after surgery. Spinous process osteotomy was done at one to four levels; the only complications were dural tears in four patients. Although three patients died of unrelated causes, 38 of the 46 remaining patients were satisfied or very satisfied with their operative results. On reexplanation or postoperative CT scans, spinous processes usually united with the remaining lamina in patients with short decompressions, although nonunion did not correlate with poor results. Complete laminectomy may be necessary if adequate decompression is impossible through the limited laminotomy in patients with severe involvement.
**TECHNIQUE 39-27**

(WEINER ET AL.)

- Patient positioning and localization of spinal levels are as described in Technique 39-26.
- Make a midline incision to expose the dorsolumbar fascia. Make a paramedian incision in the fascia, preserving the supraspinous and interspinous ligaments with subperiosteal dissection of the paraspinal muscles from the spinous process and laminae. Avoid lifting the multifidus muscles beyond the medial aspect of the facet joint to preserve their innervation.
- With a curved osteotome, free each spinous process from the lamina at its base. Release only the levels shown to be affected on preoperative imaging.
- When the spinous process is freed, retract it to one side with the paraspinal muscles beneath the retractor and the other blade of the retractor beneath the multifidus muscles to expose the midline (Fig. 39-52A). Resect approximately half of the cephalad lamina and one fourth of the caudal lamina along with the underlying ligamentum flavum.
- Using a loupe or microscope for magnification, undercut the lateral recess and open the foraminal zone (Fig. 39-52B). Complete laminectomy is recommended for severe stenosis or congenital stenosis involving all anatomical zones (central, lateral recess, and foraminal zones).
- Close the incision in routine fashion, allowing the spinous process to return to its normal position with suture of the fascia (Fig. 39-52C).

**TECHNIQUE 39-28**

(MCULLOCH)

- Place the patient in a kneeling position to increase interlaminar distance and identify the operative level on standard radiographs.
- Make a midline incision centered over the affected levels documented on preoperative imaging studies. Make a paramedian fascial incision on the most symptomatic side 1 cm from the midline.
- Elevate the multifidus muscles subperiosteally from the spinous process and laminae, but do not retract them beyond the medial aspect of the facet joint. Obtain unilateral interlaminar exposure, and maintain it with a dissecting retractor.
- Under microscopic magnification, perform laminotomy cephalad until the origin of the ligamentum flavum is encountered. Use undercutting to preserve as much dorsal bone as possible; angle the microscope to accomplish this.
- In a similar fashion, resect the proximal one fourth of the caudal lamina, completing removal of the ligamentum flavum from origin to insertion. Angling of listhesis with a risk of worsening instability. This is a technically demanding procedure and is not recommended for patients with severe stenosis or congenital stenosis, which require complete laminectomy. McCulloch reported that decompressions were done at one to five levels without intraoperative complications in 30 patients treated for neurogenic claudication unresponsive to nonoperative measures. One superficial wound infection occurred. Of the 30 patients, 26 were very satisfied or fairly satisfied with their results; all but one stated that they would recommend the procedure to a friend with a similar problem. Good to excellent results also have been reported (Orpen et al.) in 82 of 100 patients using a slightly modified microdecompression technique that allows decompression on both sides of the spine through a unilateral, hemilaminectomy approach.

**MICRODECOMPRESSION**

Microdecompression can be done in patients without disc herniations or instability, including degenerative spondylo-
CHAPTER 39 DEGENERATIVE DISORDERS OF THE THORACIC AND LUMBAR SPINE

DECOMPRESSION WITH FUSION

The indications for spinal fusion with decompression for spinal stenosis are becoming more clearly defined. Preoperative and intraoperative factors must be carefully considered when decompression and fusion surgery are contemplated. Serious thought should be given to performing arthrodesis in addition to decompression in patients with preoperative degenerative spondylolisthesis, scoliosis, kyphosis, stenosis at a previously decompressed level, or stenosis adjacent to a previously fused lumbar segment. The finding of a synovial facet joint cyst radiographically or intraoperatively is important because these have been associated with development or progression of slipping postoperatively. Because cysts reflect derangement of the facet joint, fusion should be considered after decompression and excision of synovial cysts in patients with spinal stenosis with or without preoperative instability.

The prevalence of postoperative problems related to instability varies, possibly because of the great variations in the extent of the operative decompression, but the likelihood of iatrogenic instability remains low if established principles of decompression are followed. White and Wiltse noted subluxation after decompression in 66% of patients with degenerative spondylolisthesis. They suggested that a fusion be done in conjunction with decompression in (1) patients younger than 60 years old with instability caused by the loss of an articular process on one side, (2) patients younger than 55 years old with a midline decompression for degenerative spondylolisthesis that preserves the facets, and (3) patients younger than 50 years old with isthmic spondylolisthesis. The complete removal of one facet or more than 50% resection of both facets, may result in instability. In addition, generalized spinal stenosis that requires extensive decompression with the loss of multiple articular processes may require fusion. When complete bilateral facetectomies are necessary, the addition of a lateral fusion may be difficult and the bone graft may impinge on the exposed nerve roots. In this instance, an anterior interbody fusion is warranted to prevent postoperative instability. Posterior segmental instrumentation for posterior spinal fusion has decreased the high incidence of pseudarthrosis after long lumbar fusions.

POSTOPERATIVE CARE. There are no special considerations after a simple decompression. The patient should be examined carefully for the first few days for new neurological changes that may indicate the formation of an epidural hematoma. The patient is encouraged to walk on the first day. Sutures are removed at 14 days if non-absorbable sutures have been used. We prefer the use of absorbable subcutaneous sutures with a glue-type product for the final skin closure. The same limitations as after disc surgery apply to decompressions without fusion. For patients engaged in heavy manual labor, a permanent job change may be required. Return to work also is similar to return after disc surgery.

FIGURE 39-53 Microdecompression. A, Muscle is taken down on only one side, and ipsilateral decompressive hemilaminotomy is done (yellow area); contralateral side is accessed under midline structures. B, Sac and root are gently retracted for contralateral decompression. C, End result is complete decompression with preservation of paraspinous musculature and interspinous and supraspinous ligaments, limited dead space, and excellent cosmetic result. SEE TECHNIQUE 39-28.
The complications of this procedure are similar to the complications of disc surgery; however, the risk of nerve root damage and dural laceration is greater. The rates of infection, thrombophlebitis, and pulmonary embolism also are slightly higher. When a facet has been partially resected, later facet or pars fracture may account for a recurrence of symptoms, although the most important cause of failure to relieve symptoms has been found to be inadequate decompression. Bone regrowth has been noted in 88% of patients after total laminectomy and in all patients with associated spondylolisthesis.

### InterSpinous Distraction

A distraction technique recently has been described as an alternative to decompression surgery. A spacer is inserted into the interspinous space as far anteriorly and as close to the posterior aspect of the lamina as possible. This procedure requires no ligamentous or bony resection, and the spinal canal is not breached, eliminating the risk of neural damage. Symptomatic benefit has been reported in 54% at 1 year in one study and in 78% at 4 years in another for degenerative spinal stenosis. Verhoeff et al., however, did not recommend its use for the treatment of spinal stenosis in the presence of degenerative spondylolisthesis because of the unacceptably high failure rate. Fifty-eight percent of their patients required decompression and posterolateral fusion within 24 months. Long-term follow-up data are still lacking.

### Ankylosing Spondylitis

Ankylosing spondylitis is a chronic inflammatory disease of unknown etiology. It is a seronegative spondyloarthropathy that primarily affects the axial skeleton, sacroiliac joints, and pelvis. Less commonly, involvement of peripheral joints, eyes (iritis or uveitis), heart, and lungs can occur. Inflammation of the spinal joints and entheses causes chronic pain and stiffness and can lead to progressive ankylosis of the spine in patients with long-standing disease. Ankylosing spondylitis typically affects young adults between the ages 20 and 40 years, with a male to female ratio of 1:3. The average onset of symptoms occurs at 23 years of age; there can be an 8.5- to 11.4-year delay from initial symptoms to diagnosis. There is a known association with the HLA-B27 antigen. Between 88% and 96% of patients who have ankylosing spondylitis are associated with ankylosing spondylitis. Because of the stiff subaxial spine, instability occurs in 25% to 90% of patients with ankylosing spondylitis.

Treatment is directed at maintaining flexibility with stretching of the hip flexors and hamstrings and maintaining spinal alignment with exercises and posture. Sleeping supine on a firm mattress with one pillow may help maintain sagittal alignment and prevent hip flexion contractures. Medications used in the treatment of ankylosing spondylitis fall into three categories. The first includes nonsteroidal antiinflammatory drugs that relieve pain by decreasing joint inflammation. The second group comprises disease-modifying antirheumatic drugs such as minocycline, sulfasalazine, and methotrexate. This is an unrelated group of drugs found to slow the disease process, but they do not provide a cure. Finally, tumor necrosis factor-α blockers have been shown to be effective.

Operative management in patients with ankylosing spondylitis is indicated to decrease pain and improve function. Total hip arthroplasties are the most common surgical interventions performed in this population followed by spinal osteotomies to correct sagittal imbalances.

Spinal fractures in patients with ankylosing spondylitis are always serious and frequently are life-threatening injuries. Spine osteopenia that is common in this population combined with fused segments make patients more vulnerable to fractures especially from minor trauma. Furthermore, distorted anatomy from disc ossification, ectopic bone, and sclerosis can make the spinal fractures difficult to see on plain radiographs, and these injuries often are missed. It should be up to the treating physician to prove that the patient with ankylosing spondylitis does not have a fracture after trauma. Spinal precautions and immobilization in a position accommodating the patient’s posture is very important. Often CT or MRI studies are needed. Fractures usually occur in the lower cervical spine, frequently are unstable, and usually are discovered late. Persistent pain may be the only finding until late neurological loss occurs. In patients with established kyphosis, the deformity may suddenly improve. The patient’s previous deformity may be unknown to individuals providing emergency care. Any perceived change in spinal alignment, even if the result of trivial trauma, should be considered a fracture in a patient with ankylosing spondylitis. The standard procedure is to immobilize the patient in the position in which he

In the spine, ankylosis can lead to a loss of lumbar spinal lordosis and progressive kyphosis of the cervical and thoracic spine. This combined with hip flexion deformities can result in a loss of sagittal balance and disabling functional deficits, such as an inability to look above the horizon or to lie in bed. Furthermore, fused sections of the spine make it more susceptible to fracture, pseudoarthrosis, or spondylodiscitis.

Radiographs initially show fusion of the sacroiliac joints, which characteristically occurs bilaterally. In the vertebral bodies, inflammatory resorption of bone at the enthesis causes periarthritis osteopenia. This resorption initially is seen as a “squaring off” of the corners of the vertebral bodies. Subsequent ossification occurs in the anulus fibrosis, sparing the anterior longitudinal ligament and disc and giving the “bamboo spine” appearance on radiographs. The posterior elements are similarly affected, with ossification of the facet joints, interosseous and supraspinous ligaments, and ligamentum flavum. Atlantoaxial instability must be identified, especially in any patient having surgery for conditions associated with ankylosing spondylitis. Because of the stiff subaxial spine, instability occurs in 25% to 90% of patients with ankylosing spondylitis.

Additional fractures especially from minor trauma. Furthermore, distorted anatomy from disc ossification, ectopic bone, and sclerosis can make the spinal fractures difficult to see on plain radiographs, and these injuries often are missed. It should be up to the treating physician to prove that the patient with ankylosing spondylitis does not have a fracture after trauma. Spinal precautions and immobilization in a position accommodating the patient’s posture is very important. Often CT or MRI studies are needed. Fractures usually occur in the lower cervical spine, frequently are unstable, and usually are discovered late. Persistent pain may be the only finding until late neurological loss occurs. In patients with established kyphosis, the deformity may suddenly improve. The patient's previous deformity may be unknown to individuals providing emergency care. Any perceived change in spinal alignment, even if the result of trivial trauma, should be considered a fracture in a patient with ankylosing spondylitis. The standard procedure is to immobilize the patient in the position in which he
or she is found because extension may result in sudden neurological loss. A widened anterior disc space, which may be the only obvious radiographic finding, creates an unstable configuration that is prone to translation, late neurological loss, and slow healing. Imaging with MRI, CT, or bone scan may be helpful in making the diagnosis.

Surgical stabilization of fractures in patients with ankylosing spondylitis can be challenging. For cervical fractures, anterior and posterior or long posterior constructs are recommended because of the poor bone quality. Thoracolumbar fractures can be stabilized with a long posterior construct across the fractured level. More recently, percutaneous techniques of long-segment stabilization are being used. The morbidity and mortality associated with these procedures in patients with ankylosing spondylitis are very high because of the comorbidities many of these patients have.

OSTEOTOMY OF THE LUMBAR SPINE

Smith-Petersen, Larson, and Aufranc in 1945 described an osteotomy of the spine to correct the flexion deformity that often develops in ankylosing spondylitis and sometimes in rheumatoid arthritis. Since then, others have reported similar procedures. The technique described by Smith-Petersen et al. is done in one stage. Others have described surgery done in two stages, consisting of division of the anterior longitudinal ligament under direct vision instead of allowing it to rupture when the deformity is corrected by gentle manipulation, as in the method of Smith-Petersen et al.

If the flexion deformity is severe, the patient’s field of vision is limited to a small area near the feet, and walking is extremely difficult. This is evident by looking at the chinbrow to vertical angle (Fig. 39-54). Respiration becomes almost completely diaphragmatic. Gastrointestinal symptoms resulting from pressure of the costal margin on the contents of the upper abdomen are common; dysphagia or choking may occur. In addition to improvement in function, the improvement in appearance made by correcting the deformity is important to the patient. If extreme, the deformity should be corrected in two or more stages because of contraction of soft tissues and the danger of damaging the aorta, the inferior vena cava, and the major nerves to the lower extremities. According to Law, 25 to 45 degrees of correction usually can be obtained, resulting in marked improvement functionally and cosmetically. Initially, mortality was about 10% with operative treatment; however, a later series reported no deaths or serious complications.

The safest and most efficient position for this procedure is with the patient lying on his or her side. This lateral position has several advantages: (1) it is easier to place the grossly deformed patient on the table; (2) the danger of injuring the ankylosed cervical spine by pressure of the forehead against the table is eliminated; (3) the anesthesia is easier to manage because maintaining a clear airway and free respiratory exchange is less difficult; and (4) the operation is easier because any blood would flow out from the depth of the wound rather than into it. Adams described hyperextending the spine with an ingenious three-point pressure apparatus, and Simmons described surgery with the patient on his or her side and under local anesthesia. When the osteotomy is complete, the patient is turned prone, carefully fracturing the anterior longitudinal ligament with the patient briefly under nitrous oxide and fentanyl anesthesia.

The osteotomy usually is made at the upper lumbar level because the spinal canal here is large, and the osteotomy is distal to the end of the cord. A lumbar lordosis is created to compensate for the thoracic kyphosis; motion of the spine is not increased. Osteotomy methods include resection of the spinous processes from the laminae to the pedicles, simple wedge resection of the spinous processes into the neural foramina (Fig. 39-55A and B), chevron excision of the laminae and spinous processes (Fig. 39-55C and D), and combined anterior opening wedge osteotomy after posterior resection of the spinous processes and laminae.

An average correction from 80 to 44 degrees has been reported after upper lumbar osteotomy, with correction maintained by internal fixation. Manual osteoclasis worked best in patients with calcified ligaments. Complications from this procedure include hypertension, gastrointestinal problems, neurological defects, urinary tract infections, psychological problems, dural tears with leakage, retrograde ejaculation, and, rarely, rupture of the aorta.

Spinal osteotomy is a demanding procedure for which proper training and experience are mandatory. The surgeon should be familiar with the several options available.

SMITH-PETERSEN OSTEOTOMY

The Smith-Petersen osteotomy is an excellent option for correction of smaller degrees of spinal deformity. Bone is removed through the pars and facet joints (Fig. 39-55C and D). If a previous fusion has been done, care should be taken to thin the fusion mass gradually until the ligamentum flavum or dura is exposed. Symmetrical resection is necessary to prevent creating a coronal deformity. Removal of the underlying ligament also is helpful in preventing buckling of the dura or iatrogenic spinal stenosis. Approximately 10 degrees of correction can be obtained with each 10 mm of resection.
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Excessive resection should be avoided because it may result in foraminal stenosis. In patients with degenerative discs, decreased flexibility may limit the amount of correction that can be obtained. The osteotomy is closed with compression or with in situ rod contouring, and bone graft is applied.

PEDICLE SUBTRACTION OSTEOTOMY

Pedicle subtraction osteotomy (Fig. 39-55A and B) is best suited for patients who have significant sagittal imbalance of 4 cm or more and immobile or fused discs. Pedicle subtraction osteotomy is inherently safer than the Smith-Petersen osteotomy because it avoids multiple osteotomies. Typically, 30 degrees or more of correction can be obtained with a single posterior osteotomy, preferably at the level of the deformity. If the deformity is at the spinal cord level, pedicle subtraction osteotomy can be used, but manipulation of the cord must be avoided. Thomasen and Thiranont and Netrawichien described the use of this osteotomy after laminectomy and pedicle resection. In their technique, compression instrumentation was used, along with simultaneous flexion of the head and foot of the operating table (Fig. 39-56). Care must be taken to avoid compression of the dura or creation of a coronal deformity. A wake-up test is done after correction and cancellous bone grafting have been completed.
EGGSHELL OSTEOTOMY

The eggshell osteotomy requires anterior and posterior approaches and usually is reserved for severe sagittal or coronal imbalance of more than 10 cm from the midline (Fig. 39-57). This is a spinal shortening procedure with anterior decancellation followed by removal of posterior elements, instrumentation, deformity correction, and fusion.

ADULT SPINAL DEFORMITY

Although nearly 60% of the adult population has some form of spinal deformity, only approximately 6% are symptomatic. Most patients with symptoms from their spinal deformity are 70 years of age or older, and most report pain and impaired health-related quality of life. Approximately 60% of patients with late-onset degenerative scoliosis are female. Degenerative curves tend to be short segment, usually lumbar, and less severe than the curves in idiopathic scoliosis. Symptoms of spinal stenosis are more common in patients with degenerative scoliosis. The goal of treatment of degenerative scoliosis is to relieve back pain and the symptoms of spinal stenosis, whereas the treatment goals for adult idiopathic scoliosis usually are pain control and deformity correction. Treatment of adult idiopathic and degenerative scoliosis requires a different approach from that used for typical adolescent idiopathic scoliosis, is more challenging, and is more likely to have complications such as dural tears, nonunion, implant breakage, and wound infection. Adult spinal deformity curves tend to be more rigid than those in adolescents, and surgery is further complicated by the prevalence of medical comorbidities and osteopenia in these older patients.

INCIDENCE AND PROGRESSION OF DEFORMITY

Adult idiopathic scoliosis is defined as a coronal deformity of more than 10 degrees with associated structural changes in a patient older than 20 years at time of diagnosis, most commonly in patients in their late 30s. Women are affected much more frequently than men, similar to the incidence of adolescent scoliosis. Studies have shown a prevalence of 2% to 4% for curves of more than 10 degrees. According to Weinstein and Ponseti, thoracic curves of more than 50 degrees progress approximately 1 degree per year up to 75 degrees, when progression slows to about 0.3 degrees per year, finally stopping at about 90 degrees. Lumbar curves progress at a rate of 0.4 degrees per year after reaching only 30 degrees; a more aggressive approach is warranted for lumbar curves, especially after progression is documented. Predictors of lumbar curve progression include L5 above the intercristal line, apical rotation of more than 30%, an unbalanced or decompensated curve, a thoracic curve of more than 50 degrees, and a thoracolumbar or lumbar curve of more than 30 degrees. Sixty-eight percent of adult curves progress more than 5 degrees over time.

Patients with idiopathic scoliosis rarely develop significant pulmonary complications, even with curves exceeding 100 degrees. In the absence of overt thoracic lordosis, surgery generally is not warranted to maintain or improve pulmonary function in adults.

Degenerative scoliosis develops in patients with previously straight spines after age 40 years, typically affecting the lumbar spine with an associated lumbar hypolordosis, lateralolisthesis, and spinal stenosis. Men and women are affected more equally than patients with idiopathic curves, with 60% to 70% of those affected being women. Degenerative scoliosis occurs in 6% to 30% of the elderly population, with most curves being minor, affecting fewer segments (two to five segments) than in adult idiopathic scoliosis (seven to 11 segments), with an equal distribution of right and left lumbar curves. Rotary subluxation varies and seems to be worse after decompression surgery without fusion. Curves can be progressive, but the natural history has not been elucidated conclusively. Progression of 1 to 6 degrees a year has been reported. Symptoms of spinal stenosis occur most often in degenerative curves that have defects in the convexity and concavity, possibly because significant degenerative changes preceded the development of the scoliosis. As a result, treatment of degenerative scoliosis often is necessary to relieve spinal stenosis by decompression, with instrumented fusion to prevent instability and further progression of deformity.

CLASSIFICATION

In general, adult scoliosis can be broadly divided into two categories: deformity due to progression of untreated or inadequately treated adolescent idiopathic scoliosis (AIS) or de novo scoliosis, which is primary degenerative scoliosis that results from asymmetrical disc and facet joint degeneration. Deformity as a result of progression of AIS typically manifests as long, gradually progressive thoracic or thoracolumbar curves, whereas de novo deformity presents as sharp lumbar or thoracolumbar curves with an apex at L2-3 or L3-4. A third type of adult spinal deformity can be caused by an adjacent idiopathic curve or metabolic bone disease. More recently, the Scoliosis Research Society (SRS)-Schwab classification system has been developed. This system takes into account the coronal curve type, pelvic parameters, and sagittal balance (Fig. 39-58). It has been validated in a number of studies and has shown excellent interobserver and intraobserver reliability.

SAGITTAL AND CORONAL BALANCE

In the treatment of adult spinal deformities, whether idiopathic or degenerative in origin, it is important to understand the normal sagittal relationships. In a normal spine, the primary curvature is kyphosis of the thoracic spine, which develops first in infants. Subsequent to upright posture, the secondary lordotic curvatures in the cervical and lumbar

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Sagittal and coronal vertical axes are used to evaluate and estimate global balance. Global balance is the result of segmental alignment of the functional spinal unit and regional alignment of the cervical, thoracic, and lumbar segments. Bernhardt and Bridwell measured 102 radiographs of normal spines to determine normal sagittal plane alignment (Fig. 39-59). By convention, kyphosis is represented as a positive measurement and lordosis is represented as a negative value. In a normal adult spine, there is a small amount of kyphosis segmentally at each end of the thoracic kyphosis, reaching a maximum at the apical region (T6-7) of about +5 degrees. Apical discs or vertebrae are identified in the sagittal plane as those that are parallel to the floor. Considered independently, the thoracolumbar junction is a transition zone of force transmission and alignment. In this region, a shift occurs from the thoracic kyphosis to lumbar lordosis. The first lordotic disc is typically at L1-2, and normal thoracolumbar alignment as measured from the cephalad T12 endplate to the caudal L2 endplate is 0 to −10 degrees. The lumbar spine is a region of lordosis, reaching a maximal segmental lordosis at L4-5 and L5-S1. The sagittal apex of the lumbar spine usually is L3. Greater than 60% of lumbar lordosis is created by the discs at L4-5 and L5-S1, which contribute −20 degrees and −28 degrees to the regional lordotic measurement.

Because most lordosis is present in the distal lumbar spine, it is important to maintain normal segmental and regional interrelationships so that global balance is preserved. As a rule of thumb, on a lateral radiograph taken with the patient facing the surgeon's right, there is a "sagittal clock," as described by Bridwell. In a normal, standing patient, the...
the bicoxofemoral axis (Fig. 39-61A). It is important to understand that pelvic incidence is a fixed morphologic parameter that does not change after skeletal maturity. Pelvic incidence can be considered the “take-off” degree of the lumbar spine; the higher this angle, the more lumbar lordosis required to maintain an upright posture. Average pelvic incidence in adults is $52\pm10$ degrees. Pelvic tilt, on the other hand, is a variable angle that represents the amount of compensatory pelvic retroversion the patient is using to maintain an upright posture (Fig. 39-61B). It is defined as the angle between a vertical reference line through the bicoxofemoral axis and a line from the center of the bicoxofemoral axis to the center of the sacral endplate. A pelvic tilt of less than 20 degrees is considered normal, and values of more than 30 degrees are considered markedly increased. Finally, sacral slope is defined by the angle between a horizontal reference line and a line parallel to the superior sacral endplate.

### SPINOPELVIC ALIGNMENT

Recent research has established the importance of spinopelvic parameters—pelvic incidence, pelvic tilt, and sacral slope—in the evaluation of adult patients with spinal deformity (Fig. 39-60). Pelvic incidence is defined as the angle between a line perpendicular to the center of the sacral endplate and a line drawn from the center of the sacral endplate to the center of the bicoxofemoral axis (Fig. 39-61A). It is important to understand that pelvic incidence is a fixed morphologic parameter that does not change after skeletal maturity. Pelvic incidence can be considered the “take-off” degree of the lumbar spine; the higher this angle, the more lumbar lordosis required to maintain an upright posture. Average pelvic incidence in adults is $52\pm10$ degrees. Pelvic tilt, on the other hand, is a variable angle that represents the amount of compensatory pelvic retroversion the patient is using to maintain an upright posture (Fig. 39-61B). It is defined as the angle between a vertical reference line through the bicoxofemoral axis and a line from the center of the bicoxofemoral axis to the center of the sacral endplate. A pelvic tilt of less than 20 degrees is considered normal, and values of more than 30 degrees are considered markedly increased. Finally, sacral slope is defined by the angle between a horizontal reference line and a line parallel to the superior sacral endplate.

### CLINICAL EVALUATION

Back pain occurs in 60% to 80% of patients with idiopathic scoliosis, which is similar to the occurrence in the general population. Pain is the chief presenting complaint in 25% to 80% of patients with adult idiopathic curvatures. This can include mechanical back pain, buttock pain, and, occasionally, radiculopathy or neurogenic claudication. Neurogenic claudication occurs in 13% as a result of degenerative changes in the apical L3 disc or endplate points at the 3-o’clock position, L4 points at the 4-o’clock position, and L5 points at the 5-o’clock position. If this regional alignment is maintained, the likelihood of a postoperative flatback deformity is minimized.

Achieving appropriate sagittal balance in adult spinal deformity correction is essential. The relationship between balanced sagittal vertical axis (SVA) and health-related quality of life scores has been well established in the literature. Sagittal malalignment results in compensatory pelvic retroversion (increased pelvic tilt), which helps the patient maintain an upright posture; however, pelvic retroversion has been shown to increase energy expenditure and negatively affect ambulation. Some patients are limited in their ability to compensate with pelvic retroversion because of hip flexion contractures or stiffness. Schwab et al. listed as goals of surgical correction (1) SVA less than 50 mm, (2) T1SPI less than 0 degrees, (3) pelvic incidence-lumbar lordosis mismatch less than 9 degrees, and (4) pelvic tilt less than 20 degrees.
within or, more commonly, distal to the lumbar curve. Radiculopathy occurs in only 4%, with entrapment of nerve roots within the foramina of the concavity. In contrast to degenerative scoliosis, most adult patients with idiopathic scoliosis have more mechanical symptoms than neurological complaints. Patients may relate symptoms of curve progression, such as progressive lean or list to one side, changes in waistline symmetry, hip prominence, protuberant or flaccid abdomen, hemline changes, or a loss in height in the absence of fracture. Neurological symptoms may include radiculopathy or neurogenic claudication, which usually is a result of degenerative changes in the distal fractional curve. Diminished pulmonary function in patients with curves of more than 60 degrees or cor pulmonale in patients with curves of more than 100 degrees occasionally is caused by the scoliosis and should be evaluated carefully to rule out other causes. Predictors of pain include curves of more than 45 degrees, lumbar curves, and thoracolumbar and lumbar curves of more than 45 degrees with apical rotation and coronal decompen-sation.

Physical examination findings usually are negative except for the spinal deformity. The skin should be examined for evidence of pathological lesions and hair patches that suggest underlying intraspinal anomalies. If spinal cord anomalies exist, atrophy may be evident in the lower extremities or intrinsic atrophy of the foot may be present with pes cavus and clawing of the toes. Reflexes should be documented, as should the results of a comprehensive neurological examination.

The deformity should be evaluated by looking for structural features of the rib and lumbar paraspinal prominence on forward bending while also recording flexibility. This test also helps to determine which curve is primary because more rotation and subsequent prominence is found in the more structural primary curve. If rib prominence exceeds 3 cm, thoracoaplasty should be considered if surgery is performed. Trunk shift is identified by dropping an imaginary line perpendicular to the floor from the lateral ribs. This line should symmetrically intersect the pelvis. Plumb lines should be dropped to evaluate for coronal decompen-sation and to help in estimating sagittal balance. Special attention should be paid to the left shoulder because instrumentation of a curve with a structural upper thoracic curve must include this segment to avoid a high left shoulder postoperatively. Waistline asymmetry should be noted, and any limb-length inequality must be considered. Equalizing limb length with \( \frac{1}{4} \) -inch blocks sometimes is helpful if limb-length discrepancy is more than 1 inch. Placing the patient prone on the examination table often gives information regarding curve flexibility and the extent of deformity that will be found during intraoperative positioning. Some surgeons find traction and bending films useful to evaluate curve flexibility.

In degenerative scoliosis, symptoms of neurogenic claudication are present in 71% to 90% of patients and usually cause them to seek medical attention, with deformity incidentally noted. These symptoms often do not improve with forward bending, and to obtain relief patients support the trunk with the arms or assume a supine position. This is in contrast to the usual patient with spinal stenosis and neurogenic claudication. Radiculopathy from facet overgrowth, foraminal stenosis within the concavity of curvature, or nerve root tension along the curve convexity can occur, although neurological deficits are rare, and back pain is ubiquitous. Primary treatment is directed at decompression of spinal stenosis, with fusion or instrumentation indicated based on the potential for increased instability.

Physical findings are nonspecific in most patients. Motion usually is preserved, but patients guard against hyperextension. Symptoms may be reproduced by this maneuver in the presence of spinal stenosis. Neurological examination rarely identifies significant motor, sensory, or reflex deficits; however, any abnormal findings should be documented. Evaluation of distal pulses is necessary to help rule out peripheral vascular disease and vascular claudication. Bilateral absence of Achilles tendon reflexes may be an indicator of peripheral neuropathy. Flattening of the lumbar spine represents degenerative change, and a lumbar prominence on forward bending accentuates the convexity of a coronal deformity. Sagittal and coronal balance should be estimated clinically. When contemplating any decompressive or stabilizing procedure, correction of the entire degenerative scoliotic segment must be considered because of sagittal or coronal decompen-sation.

ANATOMY AND BIOMECHANICS

Adult scoliosis shares most of the anatomical features of idiopathic adolescent scoliosis. Unique to adult patients with scoliosis are the diminished elasticity of the ligamentous structures and the narrowing of disc spaces that combine to stiffen primary and secondary or compensatory curves. Osteopenia also must be considered in older patients, especially in patients with risk factors for osteoporosis, such as glucocorticoid use, postmenopausal status, and a personal or family history of fragility fractures.

The biomechanics of the bone-implant interface must be considered if long instrumentation constructs are used, especially when extended to the sacrum. Because of the long lever arm produced in long deformity constructs and the relatively poor fixation obtained in the sacrum, S1 screws have a high likelihood of biomechanical failure if not protected. To obtain purchase anterior to the biomechanical pivot point at the anterior sacrum, many surgeons choose iliac instrumentation. The two most commonly used modern instrumentation options for protecting the S1 screws are iliac screws and S2-alar-iliac (SAI) screws. Iliac screws provide strong fixation and ease of insertion with the potential risk of hardware prominence and the theoretical technical difficulty of rod alignment with the S1 screws. SAI screws somewhat mitigate the hardware prominence and rod alignment issues of traditional iliac screws. Fixation can be augmented with a load-sharing structural interbody fusion device. The most significant biomechanical increase in posterior instrumentation strength is with the addition of the iliac screws. The superiority of any of these techniques has not been established, and the surgeon's experience and preference determine the choice.

Finally, osteoporosis is a significant consideration in the treatment of these patients. Although there is no cause-and-effect relationship between bone density and degenerative scoliosis, these patients usually are older and more predisposed to osteoporosis. Compression fractures and compromised operative fixation may complicate the treatment of patients with comorbid disease. Attention should be paid to the optimization of bone metabolism and bone density before any major spinal deformity surgery. If indicated,
supplementary vitamin D and calcium should be started before surgery and continued afterward throughout the phases of bone healing.

**DIAGNOSTIC IMAGING**

**RADIOGRAPHY**

For both idiopathic and degenerative scoliosis, standing radiographs on 36-inch cassettes must be obtained and scrutinized for coronal and, more important, sagittal balance. It is critical for this to be conducted in a standardized fashion. Patients should be instructed to stand in a neutral upright position with the hips and knees comfortably extended and the fingers on the clavicles (shoulders at 45 degrees of forward elevation). Lateral bending radiographs over a foam fulcrum are ideal for assessing flexibility, although standard maximal effort bending films often suffice. Often, simple prone radiographs give a good estimate of sagittal and coronal alignment that can be found intraoperatively. For sagittal deformities, appropriate fulcrum bending films can be obtained to determine flexibility. Push prone views, as described by Kleinmann et al. and Vedantam et al., are useful in determining the response of the lowest instrumented vertebra to instrumentation. With degenerative scoliosis, degenerative disc changes and flattening of the normal lumbar lordosis are present. With both degenerative and idiopathic scoliosis, rotary subluxation may be evident in some patients, with lateralolisthesis of varying degrees.

**COMPUTED TOMOGRAPHIC MYELOGRAPHY AND MAGNETIC RESONANCE IMAGING**

By providing information regarding central, lateral recess, and foraminal stenosis, MRI is very useful in the preoperative evaluation of adult patients with spinal deformity. In addition, disc hydration and excessive facet degeneration are useful pieces of information provided by T2-weighted sequences that may influence whether surgery stops at or includes a lower degenerative segment. The degree of desiccation of the L5-S1 disc should prompt extra consideration to end at the adjacent disc above or include the degenerative segment. Adjacent segment pathology is common, and in older patients it may be prudent to include such diseased discs.

CT myelogram can be used instead of MRI in patients with contraindications (such as a pacemaker); however, it is an invasive procedure and should not be used routinely. Nonmyelogram CT scans can be useful in patients with extreme deformity or prior surgery. Finally, DICOM images from CT scans can be used by 3D printers to create life-size, three-dimensional models, which occasionally can be useful for surgical planning in severe deformities.

**NONOPERATIVE TREATMENT**

Recent studies have called into question the value of nonoperative care in adult scoliosis, given the high cost and lack of improvement in outcome measures. However, given the potential morbidity of surgical treatment, we believe that attempting traditional methods of nonoperative treatment of back and leg pain are appropriate in patients with adult scoliosis. Orthoses may be helpful for the relief of axial degenerative symptoms. Intermittent use of a soft thoracolumbosacral orthosis (TLSO) is better tolerated than use of a rigid TLSO by older, often endomorphic, patients. The orthosis should be worn during symptomatic periods and kept to a minimum otherwise. Correction of deformity or prevention of progression of these curves is impossible, and an orthosis is used only for the management of symptoms; the patient should be aware of the treatment goals. Physical therapy should be continued in addition to bracing, with the ultimate goal of para-spinal strengthening and subsequent core stabilization that allow the brace to be discarded. Cognitive behavioral therapy is another key aspect of the patient with chronic pain that should not be overlooked.

**OPERATIVE TREATMENT**

When adequate nonoperative treatment has failed in a patient with unremitting symptoms or radiographic progression, surgery should be considered. Curves of more than 50 degrees with documented progression, loss of pulmonary function (believed to be caused by the scoliosis when curves exceed 60 degrees), progressive neurological changes, and significant coronal or sagittal decompensation are relative indications for surgery. Cosmetic considerations are a genuine concern for patients as well and may play a small role in operative decision-making. The goal of surgery is to maintain a balanced spine, with the head centered over the pelvis, while fusing the minimum number of segments possible.

Although improvement radiographically and clinically can be expected with operative treatment, the overall incidence of complications has been reported to be from 13% to 40% and the incidence of pseudarthrosis is 13% to 17%. Several authors have noted that although elderly patients have the greatest risk of complications, they show greater improvement in pain and disability compared with younger patients. Revision rates are relatively low.

A spinal implant should be used that allows segmental placement of screws and allows iliac fixation. If fusion of the lumbosacral joint is anticipated, interbody fusion has traditionally been obtained with allograft or fusion cages that are cut to maintain the normal segmental lordotic disc alignment. The use of cell-saver autotransfusion is encouraged. Spinal cord monitoring should include somatosensory and transcranial motor evoked potentials. If useful data are obtained and maintained with somatosensory and motor evoked potentials, wake-up testing is unnecessary until the conclusion of the surgery. If pedicle screws are used below T8, pedicle screw stimulation can be useful to confirm proper placement. Although we find free-hand pedicle screw technique to be safe and to reduce patient and surgical team radiation exposure, some surgeons may not be comfortable with this. Fluoroscopy or computer-aided navigation enhances the use of anatomical landmarks and is helpful for some surgeons, especially in the setting of deformity and prior fusion. Regardless, this surgery is complex and has an extended recuperation period, with a significant risk of complications, which the patient must understand when operative treatment is chosen.

**DECOMPRESSION IN DEGENERATIVE SCOLIOSIS**

Decompression alone is a viable option for a patient with symptomatic spinal stenosis and minimal kyphosis, a neutral sagittal vertical axis, and no instability on dynamic imaging. Attempts should be made to avoid destabilizing the spine...
PART XII THE SPINE

Patients with flexible idiopathic curves of less than 70 degrees and no significant kyphosis or decompensation are candidates for posterior instrumentation and fusion alone. This can be done with numerous instrumentation systems and techniques (see Chapter ▷). The ideal candidate for a posterior procedure has a smaller, flexible curve; hypokyphosis; and a flexible compensatory lumbar curve. Posterior procedures also are an appropriate choice for a King type V or Lenke subclass 2 or 4 structural upper thoracic curve. Similar correction clinically and radiographically has been reported with posterior-only approaches combined with anterior and posterior procedures, with the advantages of decreased blood loss, anesthesia, and operative time.

Standard posterior approaches are used, and instrumentation may include hooks, wires, or screws for curve correction. The current trend involves the use of all-pedicle screw constructs for deformity correction because of the segmental fixation that is obtained and the three-column control that is provided by a pedicle screw placed into the vertebral body. With this fixation, derotation may be possible to some extent during the correction maneuver. Another benefit of the use of pedicle screws is the extraspinal placement of implants, which avoids the space-occupying phenomenon created by hooks or wires placed within the spinal canal. Finally, the cortical fixation of a screw through the pedicle is superior biomechanically to hook fixation, which makes this technique appealing for an osteoporotic adult spine. These benefits are not without risks, however, and the primary concern is pedicle screw malposition that affects the great vessels or the spinal cord, dura, or nerve roots. When done by surgeons with proper training, pedicle screw instrumentation is used, and fusion can safely be stopped short of the stable vertebra. For curves with features similar to King types II and V curves without severe kyphosis, pedicle screw fixation seems ideal. This technique allows fusion of the curve from end vertebra to end vertebra, which can save one to three fusion levels distally in some patients compared with typical hook constructs. In adults, flexibility of the compensatory curve must be considered more than in adolescents with scoliosis because overcorrection of the thoracic curve in a spine with a relatively inflexible lumbar curve results in decompression and an unsatisfactory result. It is prudent to apply only a conservative amount of correction that can be accommodated by the compensatory curve so that normal balance is restored and further progression is halted. The amount of correction that can be obtained is estimated from preoperative bending films. Avoiding a flatback deformity during posterior distraction is mandatory because this deformity is much easier to prevent than to treat. Nonetheless, because of pseudarthrosis, implant failure, transition syndromes, adjacent level fracture, patient positioning, and other technical reasons, flatback deformity can occur in some patients under the best of circumstances. Concave distraction of the lumbar spine, especially beyond L2, should be avoided because this maneuver is kyphogenic. Segmental instrumentation allows differential correction along the same rod, which is helpful in preventing flatback deformity and shoulder decompression. Avoiding distraction, or even applying some convex compression, along with precontouring the rods into lordosis helps to maintain normal lumbar alignment.

In a patient with a flexible spine and mild-to-moderate scoliosis, symptomatic spinal stenosis is treated with traditional decompression. Occasionally, facetectomy or partial pedicle resection is necessary to decompress symptomatic nerve roots. In this situation, posterior intertransverse fusion is recommended. If laxity is present, instrumentation should extend from neutral and stable vertebrae at each end of the construct. Ending the instrumentation with the use of all pedicle screws at a level of kyphosis potentiates adjacent segment changes and may result in a proximal junctional kyphosis, which remains a particularly vexing problem for deformity surgeons. Rotary subluxation also can occur after decompression alone in the presence of unstable degenerative scoliosis. The fusion should end at a neutrally rotated, level, and stable end vertebra and should restore sagittal and coronal balance. Care should be taken to avoid stopping instrumentation and fusion at any apical segments or at the apex of a kyphosis or scoliosis because this creates deformity later.

Selection of fusion levels is similar to that in adolescent scoliosis patients. The goal of surgery is a balanced spine with the head centered over the pelvis in the sagittal and coronal planes. Fusion should be from stable vertebra to stable vertebra, unless pedicle screw instrumentation is used, and fusion can safely be stopped short of the stable vertebra. For curves with features similar to King types II and V curves without severe kyphosis, pedicle screw fixation seems ideal. This technique allows fusion of the curve from end vertebra to end vertebra, which can save one to three fusion levels distally in some patients compared with typical hook constructs. In adults, flexibility of the compensatory curve must be considered more than in adolescents with scoliosis because overcorrection of the thoracic curve in a spine with a relatively inflexible lumbar curve results in decompression and an unsatisfactory result. It is prudent to apply only a conservative amount of correction that can be accommodated by the compensatory curve so that normal balance is restored and further progression is halted. The amount of correction that can be obtained is estimated from preoperative bending films. Avoiding a flatback deformity during posterior distraction is mandatory because this deformity is much easier to prevent than to treat. Nonetheless, because of pseudarthrosis, implant failure, transition syndromes, adjacent level fracture, patient positioning, and other technical reasons, flatback deformity can occur in some patients under the best of circumstances. Concave distraction of the lumbar spine, especially beyond L2, should be avoided because this maneuver is kyphogenic. Segmental instrumentation allows differential correction along the same rod, which is helpful in preventing flatback deformity and shoulder decompression. Avoiding distraction, or even applying some convex compression, along with precontouring the rods into lordosis helps to maintain normal lumbar alignment.

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Deformity correction through an anterior approach is described in Chapter ▷, but it warrants mention here because anterior instrumentation and fusion with third-generation implants have given excellent deformity correction in adults and have not caused significant problems with kyphosis as did the early Zielke and Dwyer implants. With single-rod or double-rod implant systems and structural grafts, anterior deformity correction is a viable alternative for lumbar and thoracolumbar curves because it allows short segment correction of flexible curves. Primary thoracic curves with flexible and compensatory lumbar curves in adults also can be treated effectively with anterior fusion. Correction must be appropriate, however, for the ability of the lumbar curve to compensate; overcorrection in adults results in more decompression than in the flexible spines of children with scoliosis. Also, as in pediatric deformities, strict attention must be paid to the upper thoracic spinal segment from T1 or T2 to T6 to prevent shoulder asymmetry owing to a structural upper thoracic curve. An upper thoracic curve is a relative
CHAPTER 39  DEGENERATIVE DISORDERS OF THE THORACIC AND LUMBAR SPINE

contraindication for anterior spinal instrumentation and fusion unless measures are taken to allow persistent tilt of the cephalad end vertebra, which would allow the upper thoracic curve to remain balanced. Anterior interbody fusion, either from a direct anterior or far lateral approach, can be especially helpful in restoring lordosis and indirectly decompressing foraminal stenosis in degenerative scoliosis but usually requires additional posterior stabilization.

Patients are commonly monitored overnight in the intensive care unit with frequent neurological evaluations and observation to prevent complications associated with fluid shifts, which occur after such long procedures. Sitting is encouraged the day after surgery, and formal physical therapy is initiated. Walking as tolerated is encouraged with assistance until independent ambulation is achieved. With modern pedicle screw constructs, a thoracolumbar orthosis generally is not necessary. The Foley catheter is removed when the patient is able to get to a bedside commode with minimal assistance. Antibiotics can be discontinued when drains are pulled or at 24 hours postoperatively, depending on surgeon preference, and oral narcotic analgesics usually are well tolerated by the third day after surgery. Pneumatic leg compression devices are used as prophylaxis against deep vein thrombosis because of the possible risk of epidural hematoma associated with pharmacological agents. These are discontinued when the patient is fully independent with ambulation. Nonsteroidal antiinflammatory medications are avoided for 3 months postoperatively because of their potential inhibitory effect on fusion.

Pedicle screws should be placed as the first step. We prefer using a frehand technique whenever possible to reduce radiation exposure to the operative team and patient.

Extend the central laminectomy to include all posterior elements, using Leksell and Kerrison rongeurs and osteotomes as much as possible to save bone graft material. This posterior element resection is, in essence, a Smith-Petersen osteotomy above and below the pedicles that are to be resected (Fig. 39-61A).

Use an osteotome to create the transverse process osteotomy.

Resect the pedicle itself with a Leksell rongeur, high speed bur, or both.

Carefully dissect along the vertebral wall with a small Cobb or Penfield elevator to avoid injuring the segmental vessels. Place specialized spoon retractors along the lateral aspect of the vertebral body.

To make the osteotomy, a decancellation or sharp osteotomy technique can be used. Using an osteotome provides better control of the geometry of the osteotomy, thereby affording more precise and greater correction. Commercial osteotomy guides can guide the amount of resection required to achieve the desired angular correction. It is critical during this step to avoid iatrogenic injury, via stretch or direct sharp injury, to the dural sac and nerve roots. This is best accomplished with a nerve root retractor and a no. 4 Penfield.

Before the osteotomy is completed, a temporary rod can be placed to allow for controlled closure.

Once the posterior vertebral wall is sufficiently thinned, use specialized impacters to impact the posterior body during the anterior portion of the procedure and is placed at the surgeon’s discretion.

After anterior release and fusion, posterior instrumentation and fusion are done, with segmental fixation from stable vertebra to stable vertebra. Care is taken to avoid ending an instrumentation construct at the apex of a curve in either the coronal or the sagittal plane because of the risk of later decompensation. It also is prudent to include any disc level with severe degenerative changes, especially in degenerative deformities.

Boachie-Adjei and Cunningham reported the use of a hybrid approach consisting of limited anterior and overlapping posterior instrumentation for adult thoracolumbar and lumbar scoliosis. They noted 59% and 86% correction in thoracolumbar and lumbar curves, respectively.

This is a very useful technique for correction of sagittal imbalance when performed below the level of the conus. It can achieve greater correction than Smith-Petersen type osteotomies alone and may be necessary in the setting of sagittal imbalance in a previously fused spine.

Pedicle subtraction osteotomy

Technique 39-29

(BRIDWELL ET AL.)

Pedicle subtraction osteotomy (PSO) is a posterior-only, staged, decompressive approach used for the management of degenerative thoracic and lumbar scoliosis. It is a versatile technique that can be used to correct both deformities and disc herniations. The primary objective of PSO is to achieve a balanced sagittal profile by removing bone and soft tissue from the vertebral body and pedicle, thereby creating a new neutral axis of rotation.

**Indications**

PSO is indicated in patients with severe thoracic scoliosis, especially those with a balanced sagittal profile. It is particularly useful in patients with significant spinal stenosis or neurogenic claudication. PSO can be used as a stand-alone procedure or in combination with other surgical techniques such as anterior release or fusion.

**Technique**

1. **Preoperative Planning:**
   - Preoperative imaging is essential to assess the spinal alignment, disc herniation, and any associated deformities.
   - The planning phase includes determining the extent of the osteotomy and the appropriate level(s) to be treated.

2. **Approach:**
   - The patient is usually placed in a prone position with the use of appropriate retraction and spinal alignment devices.
   - The osteotomy is typically performed in a lateral or parasagittal direction, depending on the location of the deformity.

3. **Osteotomy:**
   - The procedure begins with the removal of bone and soft tissue from the vertebral body and pedicle.
   - The aim is to achieve a balanced sagittal profile by creating a new neutral axis of rotation. This is achieved by removing enough bone to correct the deformity and maintain spinal balance.

4. **Postoperative Care:**
   - Postoperative care includes monitoring for complications such as spinal instability, deep vein thrombosis, and ileus.
   - Patients are usually discharged within 2-3 days after surgery, depending on their condition.

**Complications**

Complications of PSO include spinal instability, neurological complications, and implant-related issues. Proper planning, technique, and postoperative care are crucial in minimizing these risks.

**Conclusion**

PSO is a valuable posterior-only approach for the management of degenerative thoracic and lumbar scoliosis. It offers a balanced sagittal profile and can be used in combination with other surgical techniques. Proper planning and technique are essential in achieving the best outcomes.

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OTHER TECHNIQUES

The newest generation of implants can be used to treat most deformities, allowing instrumentation of all thoracic levels down to the sacrum and pelvis. Approaches and techniques generally have remained the same, however. Pedicle screw instrumentation has been used in all levels in the treatment of spinal deformities, with excellent clinical and radiographic results. For lumbar curves, pedicle screw instrumentation is applied to the convexity and compressed to create lordosis; for typical thoracic curves, the pedicle screws are applied to the concavity of the deformity and distracted to restore kyphosis. Any compensatory curves must be treated appropriately with compression where lordosis is required and with distraction where kyphosis is required. Upper thoracic curves are controlled by compression of the convexity because most of these curves also are kyphotic.

Direct lateral or far lateral approaches to the interbody space in the lumbar spine are especially useful for degenerative scoliosis. These techniques allow for complete disc resection with a bony bed for fusion, excellent correction of coronal deformities, and very good indirect decompression of foraminal stenosis caused by degenerative changes and scoliotic foraminal compression. These are not typically done as stand-alone procedures and deformity corrections benefit from the addition of posterior pedicle screw instrumentation, which can be done posteriorly if the posterior fusion is omitted.

Anand et al. reported that minimally invasive multilevel percutaneous correction and fusion through a direct lateral transpsoas approach allowed multisegment correction with less blood loss and morbidity than an open approach. Reported complications of combined transpsoas extreme lateral interbody fusion and posterior pedicle screw instrumentation have included intraoperative bowel injury, motor radiculopathy, and postoperative thigh paresthesias or dysesthesias. The rate of major complications after a far lateral approach in one study, however, compared favorably to that of other procedures (12%). For these reasons, we commonly perform multilevel lateral interbody fusion and/or anterior interbody fusion as the first stage of adult deformity fusion surgery.

ILIAC FIXATION

Modern instrumentation techniques for correction of spinal deformity in adult patients often include iliac fixation. These large (> 8.0 mm diameter) and very long (> 80 mm) screws obtain purchase anterior to the lumbosacral pivot point. This creates a more rigid construct and unloads the S1 screws, which, even with tricortical purchase, can be prone to loosening and even fracture. Iliac fixation should be considered when fusion constructs extend proximally to L3 or beyond and when there is insufficient sacral fixation, significant sagittal or coronal imbalance that requires correction, L5 or S1 defects from tumor or infection, or an L5-S1 pseudarthrosis.

Although many iliac fixation techniques have been developed, currently the two most popular choices are iliac screws and S2-alar-iliac screws (S2A1). Traditional iliac screws involve placing a screw from the posterior-superior iliac spine (PSIS) toward the anterior-superior iliac spine (ASIS). This screw can be safely placed freehand or with the use of intraoperative fluoroscopy. However, there are two distinct disadvantages of this technique: (1) symptomatic screw prominence and (2) difficulty with aligning the iliac screw tulip with the S1 tulip without the use of an offset connector. Alternatively, the S2A1 screw obviates both of these issues by starting more medially and distally, between the S1 and S2 foramen, extending through the S1 joint, and obtaining purchase in the ilium. Early experience with the S2A1 screws suggest they cause fewer symptomatic hardware issues requiring removal. Adult deformity surgeons should be able to place both types of iliac fixation in case anatomic or hardware issues preclude one option.

COCCYGEAL PAIN

Pain in the region of the coccyx is referred to as coccydynia or coccygodynia. Although the literature indicates that this is...
a rare disorder, physicians in our group who specialize in spine care evaluate and treat several cases of coccygeal pain every year.

The most common causes of coccydynia that we have observed in our practice are a single direct axial trauma, such as falling directly on the coccyx, and a subtle form of cumulative trauma that occurs as a result of long periods of sitting awkwardly. As with other musculoskeletal disorders, however, other causes need to be considered (Box 39-9). In the absence of any obvious pathological changes involving the coccyx, coccygeal pain is classified as idiopathic and may actually be the result of spasticity or abnormalities affecting the musculature of the pelvic floor.

Body mass index appears to correlate with different coccygeal configurations (Table 39-14) and different coccygeal lesions. Obese patients have mainly posterior subluxation, normal-weight patients have mainly a hypermobile or radiographically normal coccyx, and thin patients have mainly anterior subluxation and spicules.

The most common presenting complaint is pain in and around the coccyx without significant low-back pain or radiation of pain. Typically, the pain is associated with sitting and is exacerbated when rising from a seated position. Palpation in the region of the coccyx may reveal localized tenderness and swelling. Although coccydynia is a clinical diagnosis, imaging studies are helpful in the evaluation. Radiographs obtained with the patient sitting and standing are most useful because they allow measurement of the sagittal rotation of the pelvis and the coccygeal angle of incidence (Fig. 39-62). Advanced imaging studies, such as MRI and CT, are most useful because they allow measurement of the sacrococcygeal joint and the spinous processes of the sacrum.

### TABLE 39-14

<table>
<thead>
<tr>
<th>Body Mass Index</th>
<th>Posterior Luxation</th>
<th>Anterior Luxation</th>
<th>Hypermobility</th>
<th>Spicule</th>
<th>Normal Coccyx</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obese patients BMI &gt; 27.4</td>
<td>51%</td>
<td>4%</td>
<td>27%</td>
<td>2%</td>
<td>16%</td>
</tr>
<tr>
<td>Normal-weight patients BMI 19.5 to ≤ 27.4</td>
<td>15%</td>
<td>6%</td>
<td>30%</td>
<td>16%</td>
<td>33%</td>
</tr>
<tr>
<td>Thin patients BMI &lt; 19.5</td>
<td>4%</td>
<td>4%</td>
<td>15%</td>
<td>29%</td>
<td>48%</td>
</tr>
</tbody>
</table>

(Modified from Maigne JY, Doursounian L, Chatellier G: Causes and mechanisms of common coccydynia: role of body mass index and coccygeal trauma, Spine (Phila Pa) 25:3072, 2000.)

### BOX 39-9

**Classification of Coccydynia**

- **Based on Etiology**
  - Idiopathic
  - Traumatic

- **Based on Pathology**
  - Degeneration of the sacrococcygeal and intercocygeal disc and joints
  - Morphology of the coccyx: types II, III, IV, presence of a bony spicule and coccygeal retroversion
  - Mobility of the coccyx: hypermobile or posterior subluxation
  - Reflected pain: lumbar pathology or arachnoiditis of the sacral nerve roots, spasm of the pelvic floor muscles, inflammation of the pericoccygeal soft tissues
  - Other: neoplasm, crystal deposits, infection, somatization or neurosis

- **Based on Coccygeal Morphology**
  - Type I—curved gently forward
  - Type II—marked curve with apex pointing straight forward
  - Type III—angled forward sharply between the first and second or second and third segments
  - Type IV—anteriorly subluxed at the level of the sacrococcygeal joint or first or second intercocygeal joint
  - Type V—coccygeal retroversion with spicule
  - Type VI—scoliotic deformity


### FIGURE 39-62

Evaluation of coccygeal mobility. A, Standing radiograph. B, Sitting radiograph shows flexion of the coccyx (dotted line). C, Superimposition of sitting radiograph on standing radiograph, matching the sacrum by pivoting the sitting film through an angle representing sagittal pelvic rotation (angle 1 = angle of rotation). Coccygeal mobility is indicated by angle 2 (angle of mobility). Angle 3 is the angle at which the coccyx strikes the seat surface (angle of incidence).
COCCYGEAL INJECTION

**TECHNIQUE 39-30**

- Place the patient prone on a pain management table, with the legs slightly abducted and the feet “pigeon-toed”.
- Aseptically prepare the skin area from the lumbosacral junction to the coccyx with isopropyl alcohol and povidone-iodine. Drape the area in sterile fashion.
- Adjust the C-arm to an anteroposterior projection to visualize the coccyx. Insert a 22-gauge, 3.5-inch spinal needle with the bevel facing ventrally in the midline.
- A lateral fluoroscopic image can be used to confirm the depth of the needle. Great care must be taken to prevent overinsertion because of the proximity of the rectum to the ventral surface of the coccyx.
- The needle should be inserted down to the point of maximal tenderness on the coccyx, which will radiographically correlate with a vestigial disc segment. The goal is to dock the needle on the painful vestigial disc in the midline.
- Once the needle is docked, remove the stylet and aspirate to check for blood. If blood is not evident, inject 0.5 mL of nonionic contract dye to confirm placement. When the correct contrast pattern is obtained, slowly inject a 5-mL volume consisting of 2 mL of 1:1 preservative-free lidocaine without epinephrine and 3 mL of 6 mg/mL Celestone Soluspan.

Excision of the mobile segment or total coccygectomy may be indicated for patients in whom conservative management fails, especially those with radiographic evidence of hypermobility or subluxation; success rates ranging from 60% to 91% have been reported in this group of patients. Outcomes of surgery are not as good in patients with normal coccygeal mobility. Excision is considered only if the patient gets relief of the coccygeal pain that corresponds to the duration of the local anesthetic at a minimum. If the local anesthetic yield no relief, then resection of the coccyx is unlikely to be as well.

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OPERATIVE TREATMENT


DEGENERATIVE DISC DISEASE AND INTERNAL DISC DERANGEMENT


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ISBN: 978-0-323-37462-0; PII: B978-0-323-37462-0.00039-2; Author: Azar & Canale & Beaty; 00039
# Codes Change List

The following codes have been either added or deleted since the first proof.

<table>
<thead>
<tr>
<th>Add</th>
<th>Remove</th>
</tr>
</thead>
<tbody>
<tr>
<td>f0010</td>
<td></td>
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</tbody>
</table>