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CHAPTER 86

# Surgical Decompression for Herniated Nucleus Pulposus

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## INTRODUCTION

Lumbar herniated nucleus pulposus (HNP) falls within the spectrum of degenerative spinal conditions, and can occur with little or no trauma. Lumbar disc abnormalities increase with age.[1,2] The actual incidence of lumbar disc herniations is unknown, as many people with herniations are asymptomatic.[1,3,4] Ninety percent of lumbar herniations occur at the L4–5 and L5–S1 levels.[5,6] More than 200 000 discectomies are performed in the United States each year.[7] The success of this procedure, as with all surgical procedures, depends vastly on proper patient selection and to a lesser extent on surgical technique. However, it is incumbent on the spinal surgeon to be absolutely meticulous with intraoperative technique once the decision for surgery is made. To this end, The authors recommend the use of a microscope for lumbar discectomy. The authors believe that once the learning curve has been traveled, the microscope not only offers advantages over loupes, it forces one to think at a much higher level of clarity about what and where root encroachment pathology is present.[8] More importantly, the patient has less morbidity and an earlier hospital discharge compared to standard or limited discectomy.[6,9–14]

## PATHOPHYSIOLOGY

Intervertebral discs cushion and tether the vertebrae, providing both flexibility and stability. The normally gelatinous nucleus pulposus is surrounded by the ligamentous anulus fibrosus. In the young and healthy disc, the nucleus and anulus blend. Degenerative or pathologic changes can cause separation of the two entities, as well as compromise the integrity of the anulus, such that a sufficient load can cause nuclear fragments to migrate and impinge on neural elements.[15] Lumbar disc herniations may occur with little or no trauma, although patients frequently report a bending or twisting motion as the inciting event, causing the onset of symptoms. Common causes of lumbar herniations include falls, car accidents, repetitive heavy lifting, and sports injuries of all types.

Lumbar disc herniations are commonly described according to the type of annular/nuclear disruption. Lumbar disc *herniation* implies an annular bulge or tear along with nucleus pulposus displacement. *Extrusion* implies nuclear material coming completely through the anulus into the canal. *Sequestration* suggests the nuclear free fragment in the canal separated from the disc space. A *bulging* disc infers the anulus is still intact although bulging into the canal. Disc herniations are also described by size (millimeters), or location (central, paracentral, intraforaminal, and extraforaminal).

## DIAGNOSIS

The radiographic diagnosis of lumbar disc herniation has been made rather simple with magnetic resonance imaging. The clinical diagnosis is frequently straightforward as well. A patient with a lumbar herniation generally presents with some element of low back pain with radiation into the buttocks, thigh, leg, and foot. The leg radiation almost always follows a dermatomal distribution. Patients frequently complain of numbness, tingling, or weakness in the affected dermatome. Lying down may relieve the symptoms, whereas sitting, walking, and standing may exacerbate symptoms. Complaints of bowel and bladder dysfunction may signal a cauda equina syndrome, and should be emergently evaluated.

### Physical examination

Visual inspection may reveal lumbar muscle spasm, fasciculations, and postural changes, including listing to the side and a forward flexed position. Gait observation can reveal a listing antalgic walk. Patients will list towards the side of an axillary disc herniation and away from a herniation lateral to the nerve root. Weakness can give a dropped foot type of gait (anterior tibialis) or buckling of the leg (quadriceps). Range of motion testing may be limited secondary to pain. Neurologic testing is extremely important and should include motor, sensory, and reflex testing. Lumbar herniations may cause varying degrees of dermatomal weakness, sensory deficits, and reflex changes. Straight leg raises are a good indicator of nerve root impingement in lower lumbar herniations, and a positive femoral stretch can indicate an upper lumbar herniation.

### Imaging and other tests

Magnetic resonance imaging (MRI) is the imaging study of choice to diagnose a lumbar disc herniation (Fig. 86.1). Plain radiographs should always be obtained. Patients who cannot obtain an MRI can be diagnosed using computed tomography (CT), CT myelogram, or CT discogram. These imaging tests are so sensitive that discectomy is not indicated if a disc is not found to be herniated by one of these techniques. Other tests can include an electromyogram (EMG) or nerve conduction study (NCS).

### Differential diagnosis

Low back pain with radiating lower extremity complaints can be caused by a number of conditions:

- Herniated disc;
- Intraspinal pathology proximal to herniated disc;
- Spinal stenosis;
- Degenerative disc disease;
- Vascular claudication;
- Tumors (retroperitoneal, pelvic, or sciatic with neural impingement);
- Infection with neural impingement, or herpes zoster;

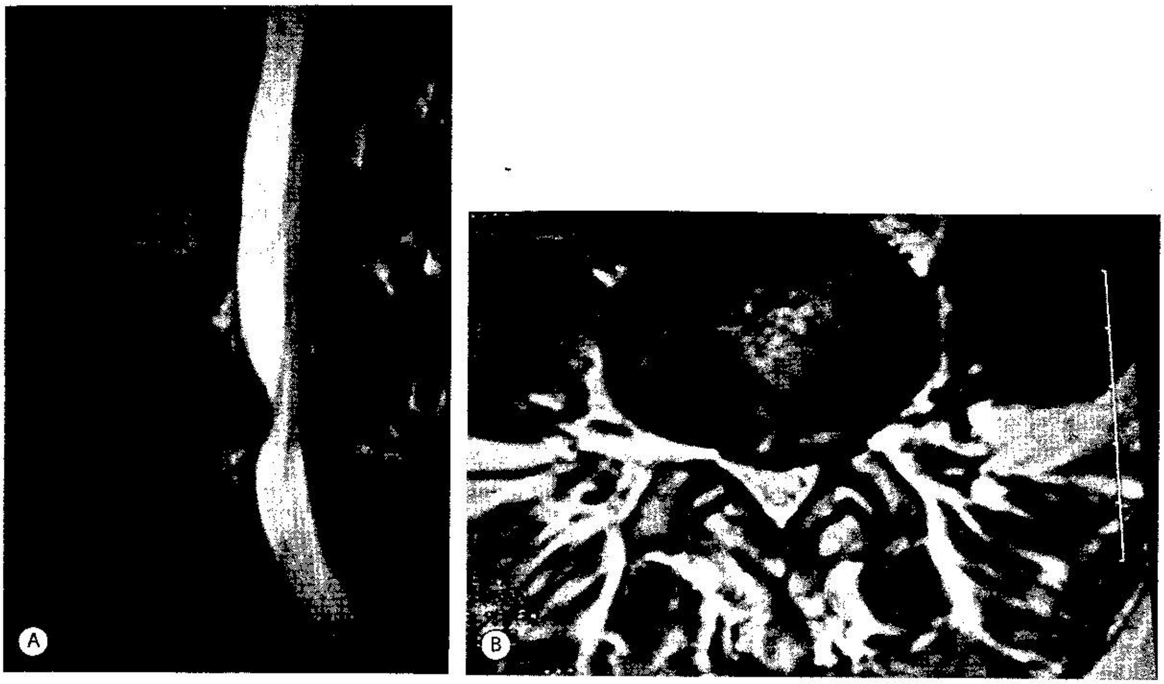



**Fig. 86.1** T2-weighted sagittal (A) and axial (B) MRI images of a herniated nucleus pulposus. The arrowhead denotes the herniation at the L4–5 level, and the axial cut reveals a large left-sided paracentral herniation into the canal, causing significant stenosis in the left lateral recess.

- Inflammation: arachnoiditis;
- Sprain/strain;
- Aortic aneurysm;
- Hip or sacroiliac joint disease;
- Neuropathy (secondary to diabetes, alcohol, tumor, etc.); and
- Gynecologic conditions.

# MANAGEMENT

It is important to understand that most patients with symptomatic herniated lumbar discs will get better over time regardless of the type of treatment. Weber's classic study[16] reported that sciatica from herniated nucleus pulposus (HNP) would improve 60% of the time with nonsurgical methods, and 92% of the time with surgery at 1 year. By 4 years out, he reported no statistical difference between the two groups, and no difference at 10-year follow up. In the absence of cauda equina syndrome, progressive or significant neurologic deficits, most practitioners attempt at least 4–8 weeks of conservative care before suggesting surgical intervention.

## Medical rehabilitation and interventional spine treatment

Conservative treatment may include:

- Modified activity;
- Modified bed rest for 2–3 days (prolonged bed rest should be avoided);[17-19]
- Analgesic and/or antiinflammatory medication (e.g. NSAIDs, steroids);
- Physical therapy (as tolerated) or external support (e.g. corset, brace); and
- Epidural steroid injections (the authors recommend up to 3).

## Indications for surgery

Surgical indications, as currently recommended by the North American Spine Society (NASS) include a definite diagnosis of ruptured lumbar intervertebral disc and:[20,21]

- Failure of conservative treatment;
- Unbearable and/or recurrent episodes of radicular pain;
- Significant neurologic deficit;
- Increasing neurologic deficit (absolute indication); or
- Cauda equina syndrome (absolute indication).

Conservative treatment consists of medical rehabilitation and interventional spine management and careful observation for at least 4–8 weeks. Some may benefit from a short trial of conservative treatment even after 8 weeks if no prior care was given. Failed conservative treatment is the most common indication for lumbar discectomy. Those who have not improved sufficiently and are not experiencing continued improvement might then be offered treatment by surgical excision of the disc. Such patients should be advised that this is an elective operation but that delay for longer than 3–6 months in the face of persistent and severe symptoms may ultimately compromise the best result.[20,22]

The latter four indications are exceptions to the 4–8 week rule. Excruciating pain may not be relieved by medical rehabilitation and interventional spine techniques and may require earlier surgical decompression. Recurrent sciatica should also receive consideration for surgery: the chance of recurrent sciatica after the second episode is 50%, and after the third episode is almost 100%.[22] An example of a significant neurologic deficit may be a foot drop, or weakness that prevents normal posture, gait, or one that affects the patient's profession or a particular skill. Any definite progression of neurologic deficit is an absolute indication for surgery. Cauda equina syndrome is relatively rare, being reported in 1–3% of patients with confirmed disc herniations.[23,24] This is an orthopedic or neurosurgical emergency. Features include rapid progression of neurologic signs and symptoms, bilateral leg pain, caudal sensory deficit, bladder overflow incontinence or retention, and loss of rectal sphincter tone with or without fecal incontinence.

## Contraindications for discectomy

The NASS and the American Academy of Orthopedic Surgeons (AAOS) have identified the following factors as absolute or relative contraindications for discectomy:[20,25]

- Lack of clear clinical diagnosis, anatomic level of lesion, and radiographic evidence of HNP;
- Lack of trial of medical rehabilitation and interventional spine treatment (with the exceptions mentioned above);
- Disabilities with major nonorganic components (multifocal, nonanatomic, or disproportionate signs and symptoms);
- Systemic disease processes which can negatively influence outcome of surgery (e.g. diabetic neuropathy);
- Medical contraindications to surgery (such as major comorbidities, or unfavorable survival); and
- Disc herniation at a level of instability (may need additional stabilization).

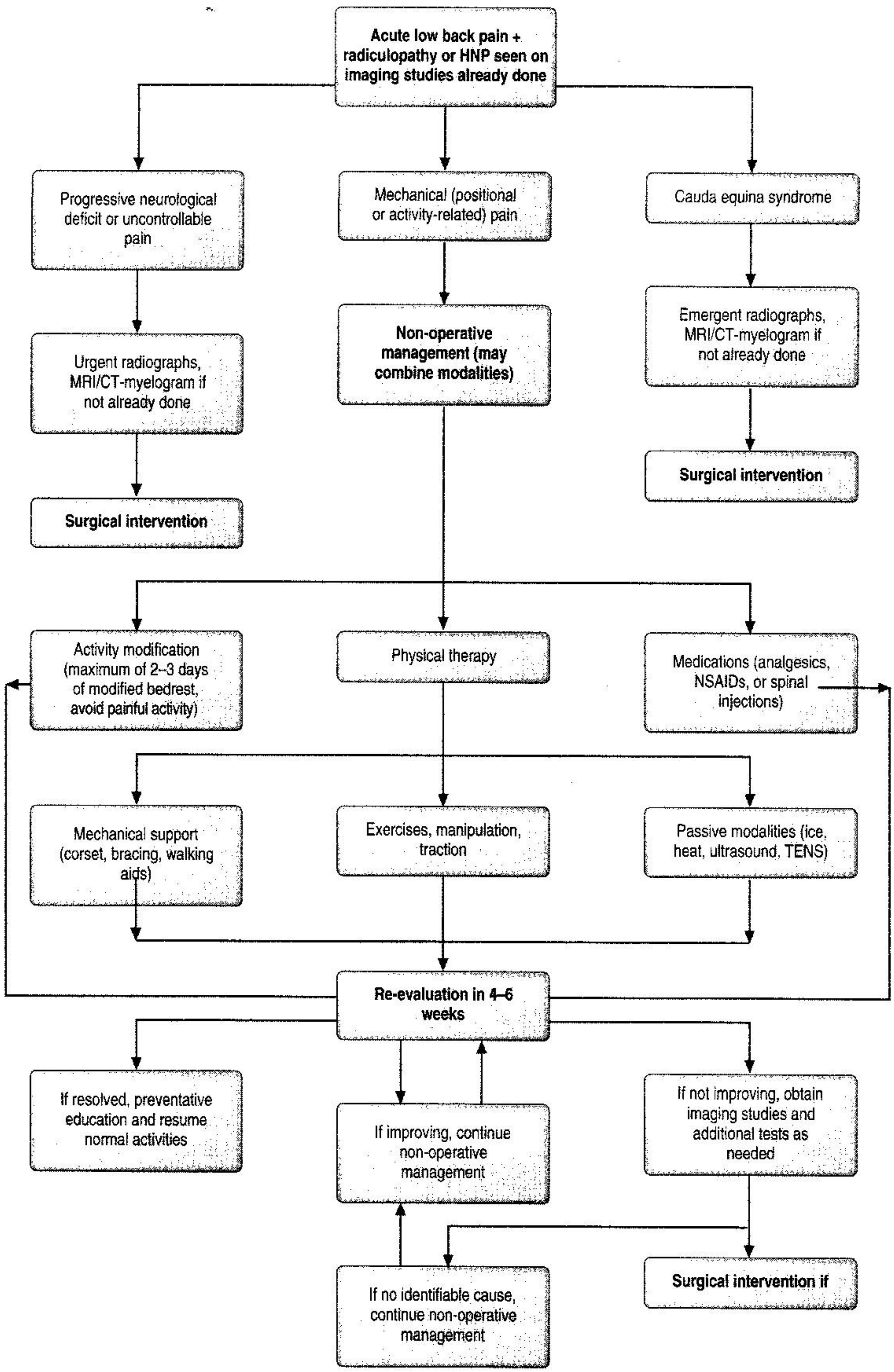



**Fig. 86.2** Flowchart for management of acute radiculopathy.

## SURGICAL PROCEDURES

One only has to review the natural history of lumbar disc disease to realize that spinal surgeons play a palliative role in the management of HNP.[16,26–29] Surgical procedures as treatment for lumbar HNP include the following:

- Lumbar discectomy (microscopic or standard open technique):
  Hemilaminotomy and discectomy,
  Laminectomy and discectomy;
- Minimally invasive percutaneous techniques:
- Chemonucleolysis,
- Percutaneous discectomy (suction, shaver, laser, endoscopic tools).

### The use of an operating microscope

The attempt to improve visualization and illumination has led many spine surgeons to use loupes and a headlight. The authors believe the magnification and illumination built into the microscope offer many surgical advantages, the most important of which is reduced wound size and decreased tissue manipulation. The surgeon can limit the amount of tissue dissection by working through a small exposure directly over the pathology to be removed. Microsurgical techniques can also be used to preserve the ligamentum flavum and epidural fat to minimize postoperative epidural fibrosis and improve clinical results by preserving natural tissue planes.[8,30] With this approach, the disc herniation can be easily removed, lateral recess stenosis can be decompressed, and nerve root manipulation is kept to a minimum. The senior author has used this technique since 1986 for most lumbar disc herniations, and has found the approach to be safe, with fewer dural tears and nerve root injuries and less postoperative epidural fibrosis than with standard discectomy.[6] Table 86.1 lists the many advantages of the microscope over loupes.[8,14,31]

The microscope is not without its disadvantages. Peripheral vision is lost, with the field of vision limited to approximately 4–5 cm. Because of this, the surgeon needs to know detailed anatomy of the spine. This is probably the biggest disadvantage of the microscope, although it in fact forces an increased awareness by the surgeon. The line of vision is fixed through the microscope. To look over structures (to overcome tissue overhang), the patient or microscope has to be adjusted during the surgery. This can be avoided by proper retraction or dissection of tissue away from the line of vision. Focusing of the microscope has to be done manually, unlike the surgeon's own eyes. The shortcut to maintaining focus under the microscope is to have the anesthesiologist pump the table up or down as needed. Large instruments can block the line of vision, and the surgeon may need to look from outside the microscope periodically if this happens. Wilson et al. reported increased disc-space infection after microsurgery.[32,33] This is most likely due to contamination from unsterile parts of the microscope during surgery although, as McCulloch and Young astutely point out, no one has looked at the potential for an increased infection rate when two surgeons with loupes and headlights bump heads over the wound! Recent reports by those who have long experiences with the microscope do not show any increased infection rates.[6,12,14,34]

### Lumbar microdiscectomy

Microscopic discectomy (microdiscectomy) has become the gold standard for operative treatment of lumbar disc herniations, and the latest minimally invasive percutaneous techniques have not been shown to be more effective.[8,35,36] Although no statistical differences can be shown in the ultimate long-term outcomes of microscopic versus standard open discectomies,[10–12,29,37–39] the microscope provides improved illumination and magnification, and patients have less morbidity and earlier hospital discharge when compared to standard discectomies.[6,9–14]

#### 1. Operative setup

General anesthesia is preferable because of patient comfort, airway, and sedation control. Another advantage is the option of hypotensive anesthesia. The procedure can also be done under epidural or local anesthesia with sedation, although this is not the authors' preference. The patient's position is always prone with the abdomen free, thus relieving pressure on the abdominal venous system and, in turn, decreasing venous backflow through Batson's venous plexus into the spinal canal. This has the effect of decreasing bleeding from the epidural veins intraoperatively. Several frames are available for this, but the authors prefer a Wilson frame on a regular operating table because of the ease of setup. The frame is cranked up to induce flexion and opening of the interlaminar space. It is important to place the approximate spinal level of interest at the apex of the Wilson frame so the interlaminar space flexes open. When cranking the frame for increased flexion, careful attention must be paid to the position of the patient's head and neck, as the body of the patient tends to be lifted up, thus increasing neck flexion. Additional padding may be

**Table 86.1: Advantages of the Microscope Over Loupes**

| | Loupes | Microscope |
|---|---|---|
| Magnification | Limited in amount, and fixed | Relatively unlimited and changeable during a case |
| Motion | Long surgery causes neck fatigue and motion of loupes | No motion of microscope |
| Focus | Each time surgeon looks up, refocusing is necessary to restart surgery | Microscope is in constant focus regardless of surgeon's attention |
| Illumination | Not parallel to line of vision (paraxial) | Parallel to line of vision (coaxial), and stronger |
| Deep 3D vision | Limited when the skin incision is less than 65 mm (or surgeon's interocular distance) | Maintained with even a 25 mm skin incision |
| Patient size | The larger the patient, the bigger the wound required | Neutralized (every patient is made the same size by the optics) |
| Teaching | Assistants excluded from vision | Assistants included |
| Surgeon's neck | Fixed in flexion and requiring repositioning – fatigue during long surgeries | Spared – can be adjusted through inclinable binoculars |

necessary to stabilize the head and neck in a neutral position. Padding underneath the shoulders may also be needed to prevent shoulder subluxation or dislocation.

The microscope is prepared and draped for use. It is important to inspect the microscope and lenses, pre-set the focal length and interocular distances if possible beforehand to prevent excessive handling of the nonsterile components during surgery. Although to date there has been no statistically sound study to support the use of prophylactic antibiotics in lumbar microdiscectomies, the authors prefer to administer an intravenous antibiotic (1–2 g cefazolin) approximately half an hour before incision.

## 2. Identification of level and side

A pre-incision lateral radiograph or fluoroscopy image, with a radiopaque skin marker placed according to preoperative radiographs and anatomic landmarks will identify the appropriate incision location for the disc space to be exposed. This is best done by placing a spinal needle as straight vertically as possible approximately 2 cm from midline contralateral to the side of surgery. The side or surgery is usually the more symptomatic side, although occasionally a midline HNP can be approached from either side.

## 3. Skin incision and interlaminar space exposure

A 2–3 cm incision is made midline or up to 1 cm lateral to the spinous process on the symptomatic side, at a level directly over the disc space based on the localizing lateral radiograph. At L5–S1 this incision tends to be directly over the interlaminar space, but as one moves up the lumbar spine, this incision will be progressively over the cephalad lamina. The dissection is carried down to the lumbodorsal fascia, which is sharply incised. The fascial incision is placed carefully just lateral to the spinous processes to avoid damage to the supraspinous–interspinous ligament complex (Fig. 86.3) and to make it easier for lateral retraction. The subperiosteal muscle dissection and elevation are confined to the interlaminar space and approximately half of the cephalad and caudad lamina. The facet capsules are carefully preserved. A Cobb elevator and bovie cautery are used. It is important to watch out for spina bifida occulta while using the Cobb for subperiosteal dissection, especially at the L5–S1 level. A framed retractor is then placed. The medial hook is usually one size smaller than the lateral muscle blade to prevent tilting of the retractor frame.

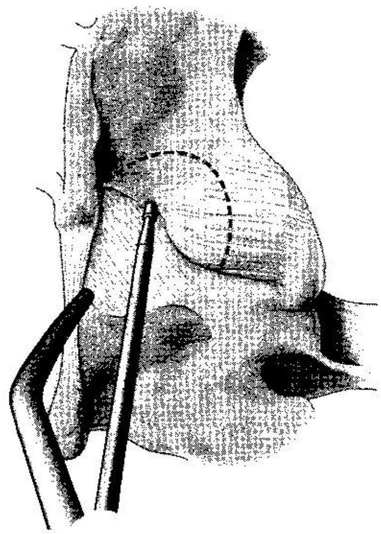


**Fig. 86.4** Following skin exposure and subsequent subperiosteal elevation, the retractor in position reveals the interlaminar interval, with exposure of the upper and lower laminae. Several millimeters of the cephalad lamina and 2–3 mm of the medial edge of the inferior facet are removed with the high-speed burr. This bone can be safely removed because the undersurface is protected by the ligamentum flavum.

Expose the lateral border of the pars as a landmark for preserving enough of the pars during laminotomy to prevent fracture.

At this time, another localizing lateral radiograph should be obtained to confirm the proper level. A forward-angled curette can be placed underneath the cephalad lamina of the interspace. With this intraoperative radiographic verification, wrong-level surgery is unlikely to occur. The radiograph will also indicate how much of the cephalad lamina needs to be removed to expose the disc space. The microscope is then brought into position (Fig. 86.4).

## 4. Spinal canal entry

After exposure of the interlaminar space and placement of the retractor, a high-speed burr is used to remove several millimeters of the cephalad lamina and 2–3 mm of the medial aspect of the inferior facet (Fig. 86.5). Once the cephalad lamina and medial aspect of the inferior facet have been removed, the ligamentum flavum is easily seen as its bony attachments are exposed. The ligamentum attaches at the very cephalad edge of the lower lamina, but approximately halfway up the ventral surface of the upper lamina, and attaches to

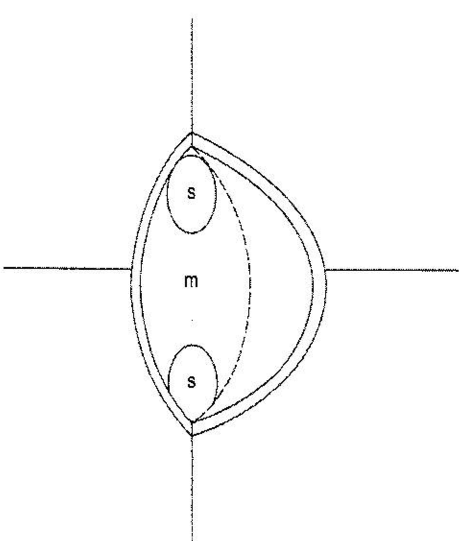



**Fig. 86.3** The curvilinear incision through lumbodorsal fascia and erector spinae fascia (s, spinous process; m, midline supraspinous ligament area) that spares the interspinous–supraspinous ligament complex.

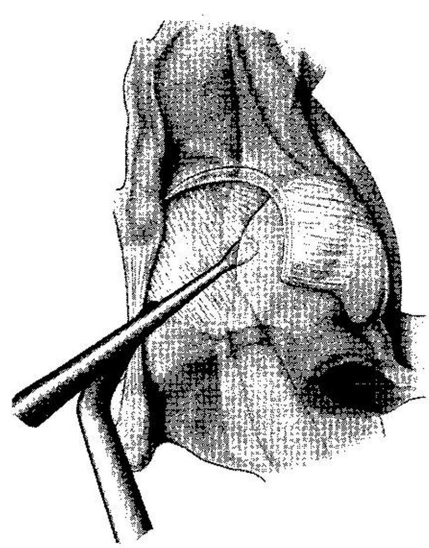


**Fig. 86.5** A small, forward-angled curette frees the ligamentum flavum from its attachment to the medial edge of the superior facet. The ligamentum flavum also can be freed from the undersurface of the upper and lower laminae.

the medial aspect of the superior facet. Thus, the high-speed burr can be used relatively safely on top of the bottom half of the superior lamina as well as the medial aspect of the inferior facet. To prevent tissue overhang from impeding the microscope's line of vision, one may burr down the bulbous side of the spinous process as well.

## 5. Free ligamentum flavum

The ligamentum flavum is then released from the medial edge of the superior facet with a forward-angled curette. It can also be released from the undersurface of the upper and lower lamina (see Fig. 86.5). It is safest to start the curette inferolaterally toward the superior aspect of the pedicle (caudal aspect of the foramen). An unintentional plunge with the curette in this quadrant is likely to avoid damaging a nerve root because the exiting nerve root lies in the cephalad aspect of the foramen, and the traversing nerve root dives anteriorly to curve around the inferior aspect of the pedicle.

A ligamentum- and epidural fat-sparing approach, by creating a flap of the ligamentum as described above, decreases postoperative epidural fibrosis and can improve results.[8,30] This can, however, make it more difficult to get a good view of the nerve root, but certainly this is easier with a microscope than without one. The less-experienced surgeon may perform partial removal of these tissues. The ligamentum flap is also not recommended for large midline disc herniations (with or without cauda equina syndrome) and severely stenotic canals because the ligamentum itself occupies more room in the already severely compromised spinal canal and would also interfere with direct visualization for the delicate manipulation of the thecal sac. Figure 86.6 is a postoperative CT scan illustrating a great example of a level where bilateral laminotomies were performed to remove a broad-based disc herniation: a ligamentum- and epidural fat-sparing approach was used to minimize the greater potential scarring from bilateral laminotomies.

## 6. Lateral recess exposure

After release of the ligamentum flavum, the medial edge of the superior facet is resected with 2–4 mm Kerrison rongeurs. This resection goes from the lower pedicle to the tip of the superior facet (Fig. 86.7). This medial facet resection decompresses any lateral recess stenosis at the level of the pedicle and up into the foramen, and allows easy access to the lateral disc space. If needed, some of the lateral ligamentum flavum, particularly into the foramen, can be removed with the Kerrison rongeurs.

**Fig. 86.6** A postoperative axial CT scan at a level where bilateral laminotomies were performed to remove a broad-based midline disc herniation. Note the straight and vertical facet joint-sparing laminotomy margins (arrowheads). A ligamentum- and epidural fat-sparing technique was used, and the shadow of the ligamentum is visible bilaterally, extending from the base of the spinous process to the facet joints.

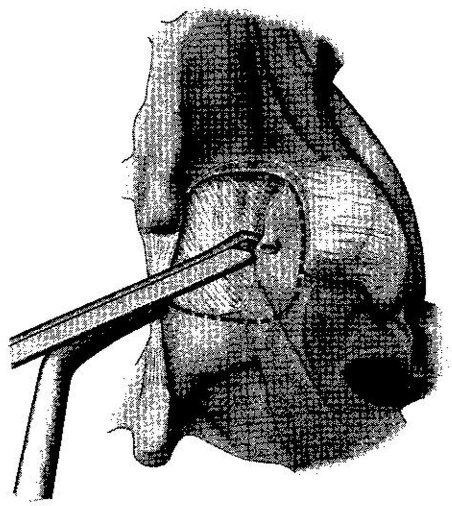


**Fig. 86.7** A 3 mm or 4 mm Kerrison rongeur is used to remove the lateral recess (subarticular) stenosis (i.e. the medial edge of the superior facet) back to the pedicle of the lower vertebra and cephalad to the top of the superior facet. This bony resection removes the lateral recess (subarticular) stenosis and allows exposure of the lateral disc space.

## 7. Nerve root and ligamentum retraction

Bipolar cautery can be used at this time to cauterize any epidural bleeding over the lateral disc space, directly cephalad to the pedicle. The authors recommend finding the pedicle, and then using it as a guide to release the epidural non-neural tissues above the disc space. At this point, a nerve root retractor can be placed on the disc space and the ligamentum flavum, epidural fat, and nerve root are retracted toward the midline, generally exposing the herniation (Fig. 86.8). Again, the bipolar can be used to cauterize any epidural veins over the disc herniation. Any free large fragments of disc can now be removed (Fig. 86.9). If needed, a forward-angled curette can be used to scrape the inferior and posterior bony margins of the foramen, using a unidirectional pulling motion. Using the bony pedicle as a starting point, it is ensured that the end of the curette does not include any neural tissue before scraping.

The classic teaching is that, once inside the spinal canal, it is essential to identify the lateral border of the nerve root before using any degree of force in manipulating the nerve root and before entering the disc space. Once the nerve root is retracted medially, it is possible to become more aggressive with the Kerrison rongeur to achieve more cephalad or caudad laminar excision, as necessary. Some basic principles of Kerrison usage are:[22]

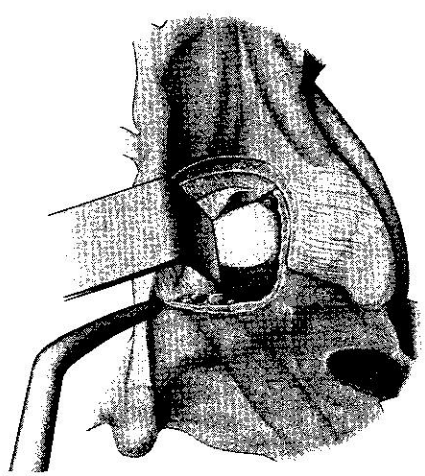


**Fig. 86.8** A nerve root retractor is used to retract the ligamentum flavum, nerve root sleeve, and epidural fat toward midline over the herniated disc. Bipolar cautery can be used to cauterize the epidural plexus over the disc herniation.

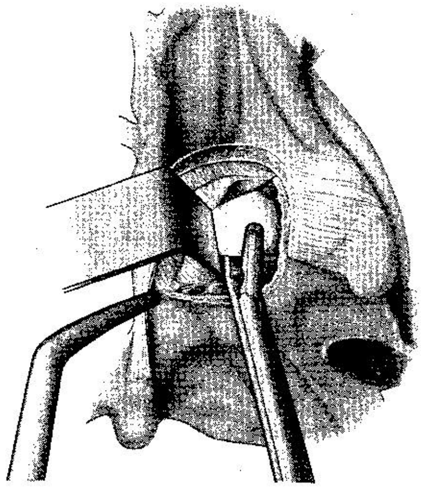


**Fig. 86.9** After exposure of the disc herniation, large free fragments can be removed with a pituitary rongeur, and/or the natural annulotomy from the disc herniation can be enlarged with a No. 11 blade.

- Use the biggest rongeur that will fit;
- Bite at the soft tissue–bone interface if trying to remove soft tissue;
- If near the dura, turn the footplate as perpendicularly as possible against the dura to retract it away from the biting surfaces (remember there are three biting edges to the mouth of the Kerrison rongeur.

If the lateral edge of the nerve root cannot be found, the following are important considerations:

- An axillary HNP is displacing the root laterally;
- Osteophytic lip of the medial edge of the superior facet may be obstructing the view and needs to be removed;
- Adhesions are present; or
- There is an anomalous root.

In such instances, it is important to remember the following basic rule: nerve roots are intimately related to pedicles. If a nerve root cannot be found, find the pedicle it is associated with and the nerve root will be beside it. Even if a nerve root is isolated, it is useful to probe the medial bony wall of the pedicle to ensure there is no other neural tissue laterally.

Microsurgery is a two-handed technique: one hand holds and manipulates the root and the other hand operates. If an able assistant is present, he or she can hold the root retractor while the surgeon holds a sucker in the nondominant hand. This is a matter of surgeon preference. Some believe that root retraction by the surgeon is safer since the surgeon knows when and where to retract, while others believe that root retraction by an assistant prevents excessive forces on the root by the surgeon trying to counterbalance forceful motions with the instrument in the other hand. In either case, excessive root retraction must be avoided when: (1) the patient already has a significant neurologic deficit, (2) a very large HNP has flattened the nerve root, or (3) the spinal canal is congenitally narrowed. Retraction across midline (especially against tension) can be considered excessive.

## 8. Discectomy

Frequently, the anular defect of the disc herniation is all that is necessary to allow cleaning out of any loose nucleus pulposus inside the disc space, although the anulotomy can be enlarged with a No. 11 blade. The herniated nuclear material is then cleaned out with straight or angled pituitary rongeurs, and small back-angled curettes. Care should be taken not to damage or curette the endplates. The anulotomy can be performed in various shapes, which are not discussed in detail here.[40,41] It has been noted, however, that upon repeat surgery the root is found more scarred down to the anulus after more aggressive anulotomies.[8,22]

How much disc to remove from the discal cavity is an unresolved issue. Removal of as much disc as possible implies curettage of the interspace, including possible removal of the cartilaginous endplates. Critics of this approach point out that irrespective of how long the surgeon works, it is impossible to remove all disc material in this fashion. They also argue that this method increases risk of damage to anterior visceral structures, and increases risk of chronic back pain induced by conditions such as sterile discitis and instability. Although some surgeons believe that extensive intradiscal debridement decreases the rate of recurrent HNP, there are others who refute that position.[41–44] In the end, the only reasonable prospective, controlled study is Spengler's, which suggests that limited disc excision is all that is necessary.[45] The advantages of limited disc excision are less trauma to endplates and less dissection, less nerve root manipulation, a lower prevalence of infection, reduced risk of damage to structures anterior to disc space, and less disc space settling postoperatively (theoretically reducing the incidence of chronic back pain).

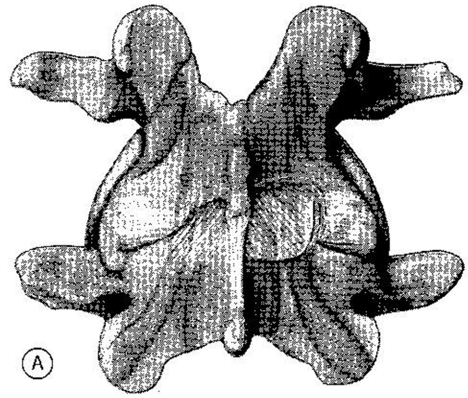
## 9. Disc space irrigation

After the HNP and any remaining loose material is removed, the disc space is irrigated under some pressure with a long angiocatheter, and then the pituitary rongeur is again utilized to remove any loose fragments. The spinal canal is then palpated underneath the nerve root and across the vertebral bodies above and below for any residual fragments. In doing the limited disc excision, one must also be sure to probe under the posterior anulus both medially and laterally for loose fragments. This is an important step to ensure that no displaced or sequestered fragments are missed. Residual disc material will feel rough, whereas the native dural surface is quite smooth. In the end, the patient must be left with a freely mobile nerve root. The preoperative MRI should be carefully studied for displaced fragments, but it is important to keep in mind that fragments may have moved since the MRI was taken.

## 10. Closure

Once the decompression is complete, the entire surgical wound is thoroughly irrigated with antibiotic-containing irrigant. Any final bleeding is controlled with bipolar cautery, thrombin-soaked gel foam, or flo-seal hemostatic gel. After complete hemostasis and removal of all gel foam, the closure is then performed in layers. Many attempts have been made to design substances to seal the laminotomy defect and prevent scar formation, including fat grafts, hydrogel, silicone, Dacron, steroids, etc.[46] The authors simply prefer the ligamentum flap (Fig. 86.10).[6,8,22] The dorsal lumbar fascia is closed with No. 1 or 0 sutures, the subcutaneous layer with 2-0 sutures, and the skin with 3-0 subcuticular sutures. Using this ligamentum flavum-sparing approach, blood loss should be no more than 10–20 cc. With good hemostasis, drainage of the surgical wound is not necessary.

After closure, the skin can be injected with 0.5% bupivacaine with epinephrine, which provides immediate postoperative pain relief, and when injected into the paraspinal muscles also aids hemostasis. Sixty milligrams of ketorolac tromethamine (Toradol; Hoffman-La Roche, Newark, NJ) is given intravenously 20 minutes before closure of the skin, and can be continued at 30 mg every 6 hours for the first postoperative day for very effective analgesia.



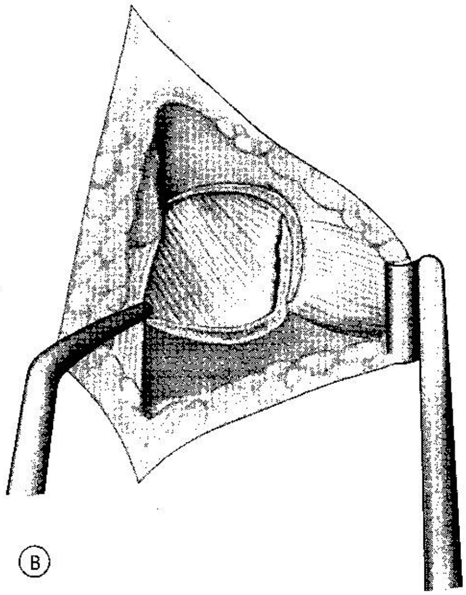


Fig. 86.10 After thorough irrigation, the nerve root retractor is released, allowing the ligamentum flavum and nerve root sleeve to return to their normal anatomic positions.

## 11. Postoperative course

Many microdiscectomy procedures can be done on an outpatient basis.[13,47–49] Most patients are encouraged to walk as tolerated. Sitting is also tolerated, but may be more limited. Many return to work within 5–10 days, especially those with desk-type work. All patients are required to participate in lumbar physical therapy, primary stabilization, and mobilization beginning at around 4 weeks after surgery. Most athletes return to their normal athletic activities within 8 weeks after surgery. However, the postoperative course is variable, and return to normal activities depends on the patient's overall medical condition, and neurologic and overall recovery.[50–52]

## Unusual disc herniations

There are some unique situations where a microscope can be even more invaluable.

### Foraminal or extraforaminal HNP

Foraminal or extraforaminal (far lateral) disc herniations occur in 3–12% of all disc herniations.[53–55] They compress the exiting nerve root, not the traversing one. Attempts to remove this disc herniation through the standard interlaminar window may result in loss of a facet joint, potentially destabilizing the level.[37] Most foraminal disc herniations occur at the L4–5 and the L3–4 levels, affecting the L4 and L3 roots, respectively. They tend to occur in older patients (average age 50) who have a wide disc space rather than degenerated narrow disc spaces. The usual presentation is severe anterior thigh pain of sudden onset, interfering with all functions except sitting. The very positive femoral stretch test together with the fairly negative straight leg raising will alert the examiner to the possibility of a higher lumbar disc lesion. The pain is usually so severe that the patient is not prepared to accept too long a conservative treatment program.

Surgical decompression for foraminal or extraforaminal disc herniations requires a Wiltse paraspinal muscle-splitting approach.[56–58] The skin incision is placed 1½ finger breadths off the midline to the affected side, and the dorsolumbar fascia opened in line with the incision (Fig. 86.11). The paraspinal muscles are bluntly split down to the intertransverse process interval. The intertransverse ligament is carefully released. Again, it is helpful to find the border of the pedicle to use as the starting point for the release, and to march to the disc space.

### Axillary herniated nuclear pulposus

Axillary disc herniations can occur in two ways (Fig. 86.12). First, a downward and medial migration of a disc fragment can lodge in the axilla of the dura and nerve root. This usually occurs at the L5–S1 level, and can push the S1 root into the subarticular recess anterior to the medial edge of the superior facet of S1. This root is vulnerable to damage by a Kerrison rongeur in this location. It may also be impos-

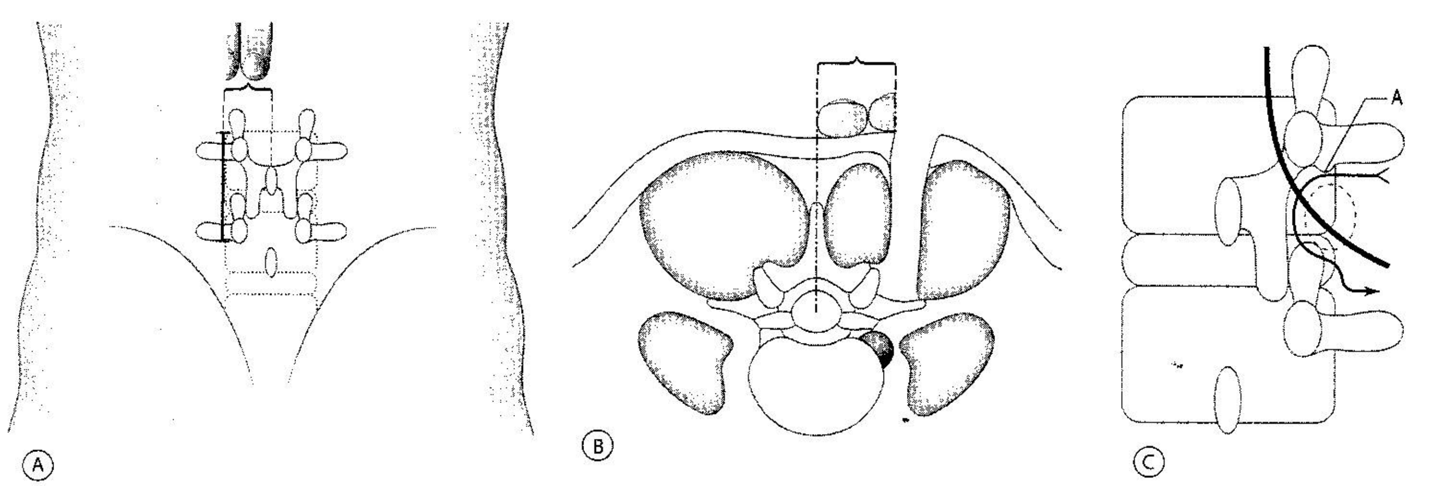



Fig. 86.11 The surgical approach for a foraminal or extraforaminal disc herniation.

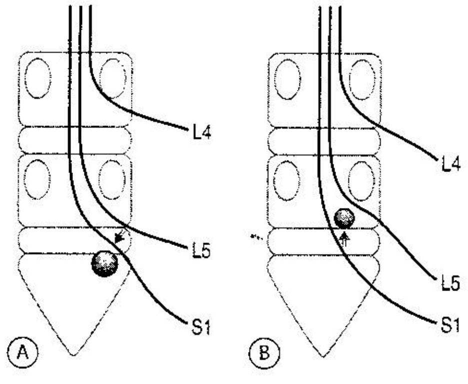



**Fig. 86.12** Axillary disc herniations.

sible to mobilize the root to expose the disc space without the disc fragment being extracted from the axilla first.

Second, upward migration of a disc fragment can cause it to lodge in the axilla of the dura and root above. This is also most common at the L5–S1 disc. However, in this case, the fragment pushes the L5 root up against the L5 lamina, making it vulnerable to damage from the high-speed burr or Kerrison rongeur during the hemilaminectomy.

Sometimes, the first warning of an axillary disc is the appearance of displaced disc material as soon as the ligamentum is retracted. In this situation, as much of the disc material as possible must be teased out with a blunt instrument, then the axilla and the nerve root can be identified.

## Double root involvement

Double root lesions (i.e. changes in more than one nerve root distribution as revealed by neurologic examination) occur in four ways.[8] These are: (1) large herniated fragment migrating distally to compress two subsequent traversing nerve roots, (2) foraminal disc herniation at L4–5 compressing the L4 nerve root and a furcal nerve, (3) large herniated fragment migrating proximally and compressing exiting and traversing nerve roots, and (4) conjoined nerve roots which exit through the same foramen. All of these situations can be handled microsurgically, carefully using the techniques described above. It will be necessary to perform a wider decompression by undercutting the superior facet. Fortunately, most of these issues occur at the L5–S1 level where a more aggressive removal of the facet joint is less likely to compromise stability.

## Disc rupture at the slip level in spondylolytic spondylolisthesis

In this scenario, if there is symptomatic instability (bilateral leg symptoms or significant back pain), it is necessary to fuse the unstable segment. An exception would be an older patient with a stable slip on bending films, and who has predominantly leg pain on one side. In this case a simple disc excision may be very effective.

## Disc rupture at level of spondylolisthesis

In a young patient (under 25–30 years), the potential for increased instability is too great not to consider concomitant stabilization. In an older patient with a spondylolytic slip that is stable on flexion–extension radiography and predominantly radicular symptoms, a simple disc excision may be indicated. An HNP at a degenerative spondylolisthesis level should not be excised without concomitant stabilization.

## Disc rupture into a stenotic canal

These disc herniations and their effect can be difficult to appreciate on MRI or CT-myelography. In such patients, a dominant radicular syndrome is caused by a HNP unless proven otherwise. These ruptures can be approached microsurgically. In the case of a stenotic canal (congenital or degenerative), it is important to carefully perform interlaminar and root decompressions before attempting to mobilize the root to retrieve the disc herniation.

## Herniated nuclear pulposus at high lumbar levels (L1–2, L2–3, L3–4)

High lumbar HNPs are uncommon (5%), and when they occur they are likely to be foraminal or extraforaminal.[22,57] Important skeletal anatomy in the higher lumbar spine for the spinal surgeon to be aware of includes: (1) the pars are narrower, and facet integrity is easily lost with excessive laminotomy, (2) the laminae are broader, (3) the interlaminar window is narrower, (4) the inferior border of the lamina overhangs more of the disc space, (5) at L1–2, the conus cannot be retracted like the cauda equina at lower levels, (6) the nerve roots exit more horizontally, and are less mobile, and (7) epidural veins may be more prevalent. At these levels, due to limited size of the interlaminar space, ligamentum excision rather than sparing is recommended.

## Recurrent disc rupture

The incidence of recurrent HNP is 2–5%.[6,59,60] The microscope is especially valuable in this scenario because of the scar between tissue planes, including neural elements. Adequate time must be spent carefully teasing the tissues apart with a blunt instrument (e.g. bipolar, curette, Penfield, etc.) before forcefully mobilizing the nerve root. The incidence of complications are understandably higher in revision discectomies.

## Cauda equina syndrome

The classic teaching in cauda equina syndrome is that: (1) this is an orthopedic emergency, and (2) a wide decompression through a bilateral approach is necessary. The authors agree with the first point, but not the second. Few disc herniations are too big to be addressed microsurgically. A wider hemilaminectomy may be needed. The microscope is invaluable when working in the severely stenotic canal. If the disc cannot be easily or totally excised unilaterally, bilateral hemilaminotomies may be done.[23,24]

## Herniated nuclear pulposus in the adolescent patient

The risk for recurrence of HNP after surgical excision is higher in adolescents than in adults. Because of the high proteoglycan content in adolescent discs, and the prevalence of disc protrusions rather than disc extrusions, some have recommended percutaneous chemonucleolysis rather than surgical intervention in this age group.[22,61,62] Studies have been published with controversial results for surgical discectomy in this patient population.[63–65] The authors' opinion is that chemonucleolysis may have merit in the treatment of symptomatic disc protrusions, but discectomy is necessary in the setting of an extruded or sequestered disc causing significant or progressive neurologic deficit or pain. These extruded or sequestered fragments are frequently heavily collagenized.[20,66]

## Midline herniated nuclear pulposus

For every true midline HNP, there are probably 100 000 cases of anular bulging.[22,67] This usually occurs in patients under age 40. These discs should be approached from the more symptomatic side, or if both sides are equally affected, from the side suggested by the MRI. The surgeon must be prepared to perform bilateral laminotomies if needed.

## Bilateral or two-level herniated nuclear pulposus

Almost all clinically significant HNP present at one level. However, if a surgeon does encounter a two-level surgical HNP, addressing the higher level will avoid the problem of blood flowing into the wound from the more superficial lower level. Bilateral HNP may be treated with two separate fascial incisions.

## Osteophytes

Osteophytes are problems if they interfere with nerve root mobility, and need to be removed. A diffuse osteophyte is probably best left alone unless it significantly compromises the nerve root. In such a case, the annular covering is stripped off of the bone, the osteophyte is excised, and the annular flap is laid back down. This prevents the nerve root from being in contact with the raw bone, which can compromise outcome.[22]

## Complications

Complications for these discectomy procedures include dural tears, neural injury, visceral injuries, postoperative infection, recurrence of herniation, inadequate decompression, and iatrogenic instability, among others.

Dural tears occur in 1–6.7% of cases, although the incidence decreases with experience.[6,34,52,68–70] If possible, repair should be done by direct suture (5-0 to 7-0 silk, nylon, or polypropylene) with or without a dural patch.[68] The patient should be kept flat for a few days after surgery to lower the hydrostatic pressure in the lumbar thecal sac while the repair seals.

Neural injuries are rare, although the risk is greater with unusual disc herniations as described above. Visceral injuries occur when an instrument penetrates the anterior anulus. Among these, vascular injuries are the most common.[68,71] If these are recognized, immediate laparotomy for surgical repair is indicated.

Postoperative discitis occurs in 1% of cases or fewer in experienced hands, although clearly there is a learning curve in developing facility with the microscope. Higher infection rates (up to 7%) have been reported with the use of a microscope during surgery, although in experienced hands this has been shown not to be true.[68] An MRI is the best diagnostic imaging tool. An image-guided needle biopsy may be performed to assist in appropriate antibiotic selection. Reoperation may not be necessary unless the patient develops root compression, cauda equina syndrome, or an epidural abscess.

The literature reports recurrent HNP occurring anywhere from 2% to 5% after lumbar discectomy.[22,72] When reoperating for a recurrent HNP, it is important to get adequate exposure of the dural sac above and below the disc space. Then using a combination of blunt (nerve hook, Penfield, bipolar) and sharp (Kerrison) dissection, the dural sac and nerve root are exposed and mobilized above the HNP.

Iatrogenic mechanical instability is fortunately a rare occurrence after discectomy, even if a decompressive laminectomy was required for a stenotic canal or to excise a large disc.[15] Symptomatic mechanical treatment may require surgical stabilization. Suboptimal results after discectomy surgery can be due to several other reasons that unfortunately do not have a straightforward medical or surgical treatment. While very rare, these can include epidural fibrosis, arachnoiditis, and complex regional pain syndrome.[68]

# DISCUSSION

Most modern studies utilizing microscopic techniques for treatment of herniated lumbar discs report 90–95% success rates.[6,8,9–13,28,30,32–34,38,39,60,69,72] A multicenter, prospective trial has proved what cannot be repeated often enough – if one selects patients with dominant radicular pain (compared to back pain), with neurological changes and painful straight leg raises, and with a study confirming a disc rupture, one can anticipate a high level of success for discectomy, with or without a microscope.[37] The rate of successful outcome drops significantly as more of these inclusion criteria are not met. Persistent back pain occurs in up to 25% of patients who undergo microdiscectomy.[69,70] This has led to the opinion that it is important to save the supraspinous–intraspinous ligament complex, remove as little lamina as possible, save the ligamentum flavum as a flap, and do a limited discectomy. These steps theoretically reduce iatrogenic instability, epidural fibrosis, sterile discitis, and loss of disc height. All of these steps are facilitated by the use of a microscope, but there is no proof as of yet that these steps reduce the incidence of back pain.

The most frequent cause of poor result from lumbar disc surgery is faulty patient selection due to erroneous or incomplete diagnosis. Technical errors such as wrong-level surgery, incomplete decompression, and intraoperative complications explain a small percentage of failures. A 1981 study assigned the following frequency of missed diagnoses as sources of failure: lateral spinal stenosis 59%, recurrent or persistent herniation 14%, adhesive arachnoiditis 11%, central canal stenosis 11%, and epidural fibrosis 7%. Finally, the results of repeat surgery are not as good as primary surgery, regardless of the reason or whether a microscope was used, because of scar tissue, higher incidence of complications, and larger dissections.

In the past decade, there has been a substantial increase in interest in minimally invasive procedures in all areas of medicine, and particularly for spinal disorders. Several methods to remove HNP have been proposed as alternatives to standard open discectomy. Injected chymopapain can dissolve much of the central nucleus, but is not likely to act on extruded or sequestered fragments, which are often heavily collagenized.[20,62,66] Likewise, percutaneous suction discectomies and removal of nucleus, either mechanically or by laser, from the center of the disc may reduce intradiscal pressure, but are unlikely to influence the effects of extruded or sequestered disc material. So although alternative, minimally invasive techniques hold considerable promise, lumbar microdiscectomy is still the gold standard for surgical treatment of lumbar HNP with radiculopathy. However, the skills and technology to remove herniated discs by such alternatives are evolving.[20,73–77]

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