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Endoscopic Surgery and Minimally Invasive Techniques

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INTRODUCTION

Evolution of Endoscopic Spine Surgery

Spinal endoscopy is poised to parallel the development and evolution of knee, shoulder, and ankle arthroscopy.[1] Without endoscopy, spine surgeons must depend heavily on imaging systems that while extremely sensitive in identifying pathologic conditions, do not always correlate that condition with the patient's pain. Endoscopic disc surgery is evolving rapidly due to the introduction of improvements in endoscope design and instrumentation (Figure 73.1).[2] The introduction of various cannula configurations combined with excellent optics gives the endoscopic spine surgeon the ability to probe spinal anatomy in a conscious patient while protecting sensitive spinal nerves, allowing the surgeon to evaluate the pathologic process causing the patient's pain. When spinal endoscopy can be performed, conditions previously not even considered for surgery may be evaluated and managed.[3]

Endoscopic Surgery Complementing Interventional Pain Management

Patients who find temporary relief with interventional pain management injections directed toward a pain generator may find more lasting and definitive relief with surgical correction or modification of the pathoanatomy. Our understanding of discogenic back pain is enhanced by diagnostic and surgical endoscopy of the lumbar spine, as endoscopic visualization of pathologic lesions not previously seen with traditional techniques is increasing our understanding of the pain generators in the lumbar spine.

The pain pattern does not always match the anatomic dermatome, which confuses many surgeons dependent on identifying a mechanical condition compressing sensitive spinal nerves and on correcting the spinal condition. With endoscopy, aided by discography, epidurography, and therapeutic injections, it is possible to evaluate, diagnose, and treat spinal conditions not usually considered for the more invasive open surgical techniques.[4] The technique first depends on directing a needle to the pain generator, desensitizing or anesthetizing it, dilating a path that will allow a tubular retractor to be inserted, followed by an operating endoscope. With this capability, we will gain a better understanding of the biology of back pain and sciatica, and also will be able to study the pathoanatomy and pathophysiology of pain in specific individuals. It is also well known that although a spinal structure is capable of pain, spinal pathology on imaging studies does not always correlate with the debilitating pain. What may be very painful in one person may be well tolerated or painless in another. Evocative discography™ is helpful in identifying the disc as a pain generator in axial back pain and sciatica.[5] Spinal endoscopy and probing in a sedated, awake patient can identify painful and nonpainful structures and help correlate the patient's pain to imaging studies. This increased knowledge of back pain can eventually lead to more targeted and alternative treatment options.

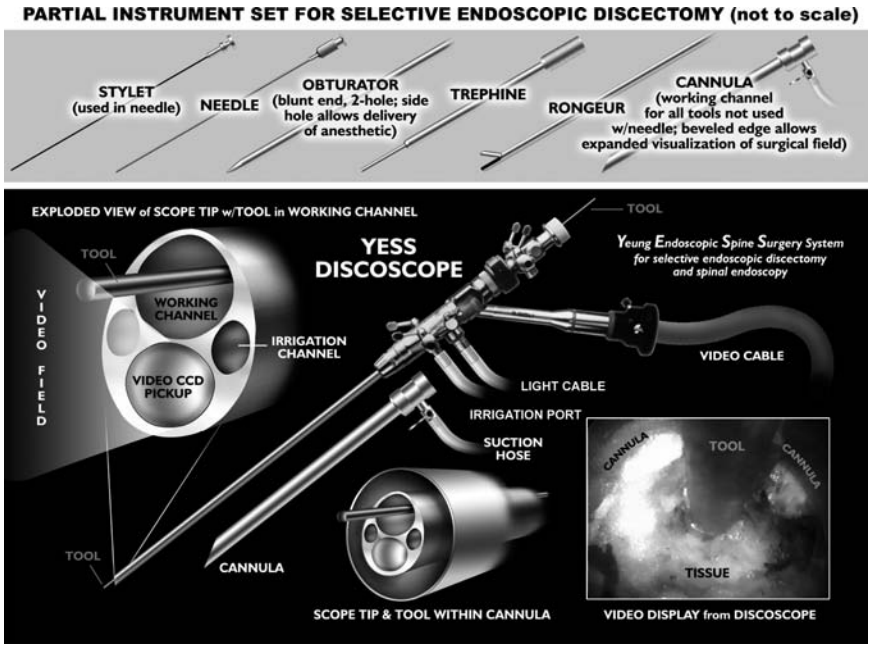

FIGURE 73.1 The YESS discoscope and partial instrument set. The spinal endoscope is designed with multichannel irrigation and a cannula system that allows access to targeted areas while protecting sensitive nerves.

INDICATIONS

Any pathologic lesion accessible, visible, treatable, or requiring endoscopic confirmation through the foramen may ultimately become an indication for diagnostic and therapeutic endoscopy.[6] Patient selection for pain and radiculopathy from disc herniation is similar to selection criteria for traditional spine procedures, but endoscopic surgical indications may be dictated by the limitations of the endoscopic procedure itself with respect to the patient's anatomy or the surgeon's skill and experience with endoscopic spinal surgery.[7] At L5–S1, anatomic restrictions may cause the surgeon to opt for the posterior transcanal approach (Figure 73.2a). For herniations from T-10 to L5, the foraminal approach provides excellent access to the disc and epidural space (Figure 73.2b). As the surgeon's experience increases, previous contraindications become relative, dependent partly on the surgeon's ability to endoscopically visualize, probe, and access the pathologic lesion. Restrictions are dictated only by anatomic considerations in accessing the patient's spinal pathology and the rationale of the endoscopic procedure itself.[8] Anatomic structures within reach of the spine endoscope transforaminally are illustrated in Figure 73.3.

Inclusion Criteria

Discogenic pain as determined by evocative discography may implicate the disc as a pain generator. Symptomatic disc herniation is the obvious indication, with surgical decompression limited only by the accessibility of endoscopic instruments to the herniated fragment.[9,10] Because of the posterolateral foraminal approach, the ideal lesion for endoscopic discectomy is a far lateral, extraforaminal disc herniation. Traditional approaches to far-lateral, extraforaminal disc herniations are more difficult, requiring a paramedian incision through the vascular intertransverse ligament. This surgical area is often called the "hidden zone" for traditional surgeons. Although a traditional spinal surgeon can access the lateral zone of the disc with a paramedian incision, it is easier to access the extraforaminal zone endoscopically via the posterolateral portal. A typical foraminal view of nucleus pulposus extruded past the posterior annulus is shown in Figure 73.4. With this approach to the disc, relatively easy access is possible from T-10 to L5 (Figure 73.2b). This is also the preferred approach for disc herniations in the upper lumbar and lower thoracic spine because the transcanal approach will require more extensive laminectomy that may destabilize the spinal segment if the herniation is above L3–L4.

Recurrent herniations after posterior discectomies are another good indication. The posterior scar usually limits any migration of the herniated disc and the postero-lateral endoscopic approach avoids going through the scar tissue. Endoscopic excisional biopsy and disc space debridement are ideal for surgically treating infectious discitis (Figure 73.3).[11] Currently treated with immobilization and parenteral antibiotics, discitis is much more effectively treated when augmented by endoscopic debridement. Unlike the open posterior approach, no dead space is

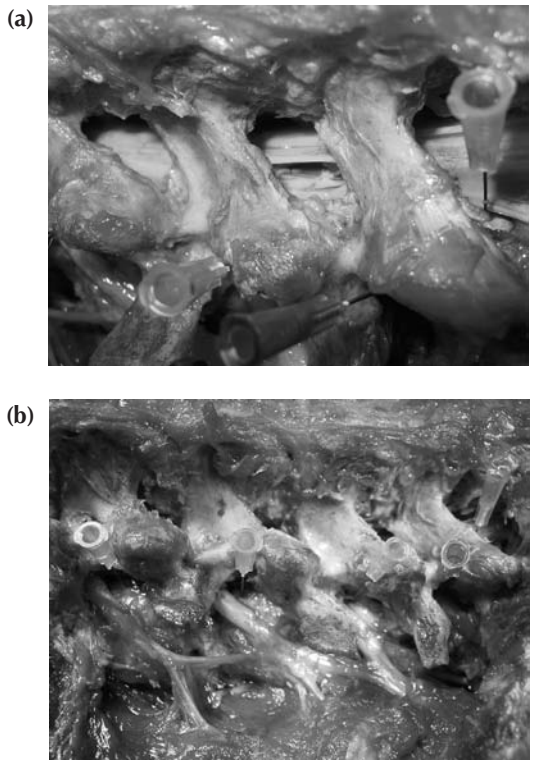

FIGURE 73.2 (a) The anatomy of the posterior portal provides easier access to the posterior disc and spinal canal at L5–S1, but with planning, most contained disc herniations can be removed posterolaterally. (b) Anatomy of the posterolateral foraminal portal from L2 to S1. Only at the L5–S1 disc space is access to the spinal canal restricted due to the pelvis and the relatively wide facet. High lumbar disc herniations from L1 to L3 are easier to reach endoscopically through the posterolateral foraminal portal. L4–5 provides ample room for either approach. Note the furcal nerve branches entering the psoas muscle.

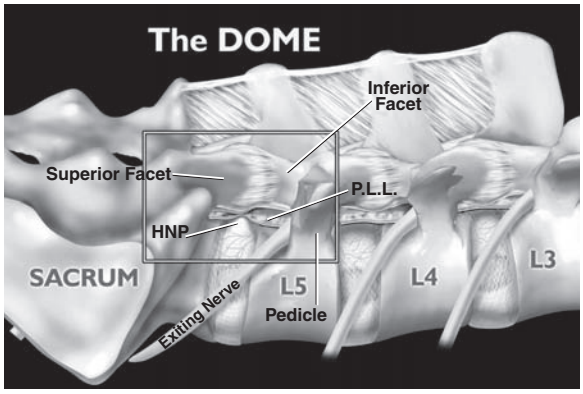

FIGURE 73.3 The dome. Spinal structures in the foramen accessible to visualization and surgical intervention and probing via the posterolateral approach.

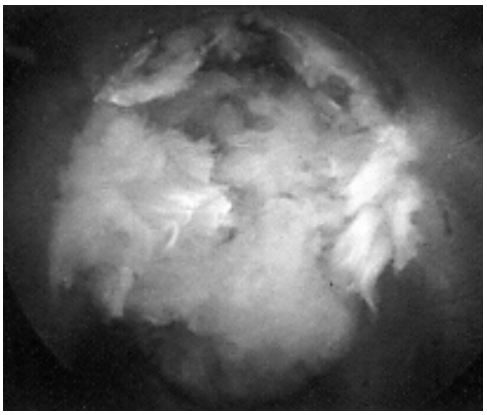

FIGURE 73.4 Foraminal view of an extruded disc herniation through the posterior annulus. The vital dye stains the disc for easier identification and extraction. Here, the herniation has clearly extruded through the posterior annulus.

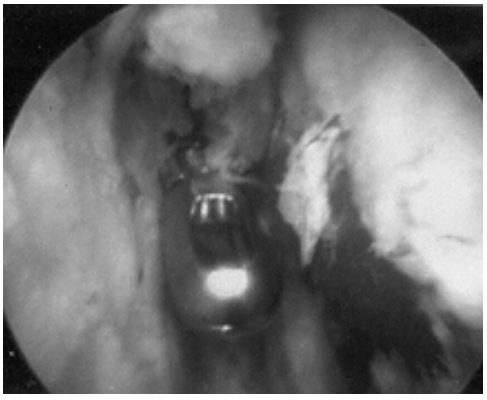

FIGURE 73.5 Intradiscal view of discitis post-debridement. Usual findings of inflammatory disc material and loose end plate cartilage are readily removed from the disc space. Pain relief is immediate, and abundant tissue is available for laboratory analysis. The micropituitary forceps is visualized through a biportal fenestration of the disc.

created. Thus, the surgeon will not have to worry about spreading the infection. The clinical results are dramatic, and tissue biopsy is more accurate than needle aspiration in identifying the cause of discitis. Even sterile discitis will benefit from intradiscal debridement and irrigation.

Endoscopic foraminoplasty by endoscopic techniques is also possible for experienced endoscopic surgeons.[3,7,12] Although trephines, rasps, and burrs can be used, the Ho:Yag laser has enhanced the procedure technically as the laser is a very precise cutting tool for visually controlled soft tissue and bone ablation. Endoscopic laser foraminoplasty is further validated by research studies by Osman and Panjabi[13] demonstrating that decompression through the foramen can be as effective as posterior decompression, but will not produce further instability (Figure 73.6). The foramen can be enlarged up to 45.5% versus the 34.2% attainable with the standard posterior

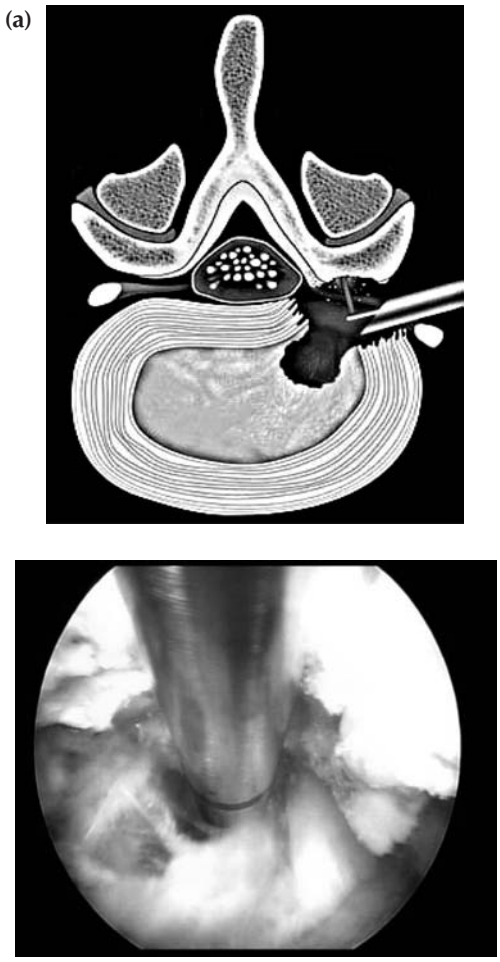

FIGURE 73.6 (a) The technique of endoscopic foraminal decompression. The annulus can be decompressed and even resected, while the capsule, ligamentum flavum, and inferior facet surface can be ablated with a side-firing laser to enlarge the foramen and free the traversing as well as the exiting nerve. (b) Side firing laser ablating bone under the superior articular process. Intraoperative view of foraminoplasty at L5–S1. Note exiting nerve at 5 o'clock.

technique of removing only the medial third of the facet. Posterior decompression of the lamina with removal of the medial third of the facet will produce increased extension and axial rotation postoperatively.[13] Endoscopic foraminal plasty has not been shown to cause increased instability even in spondylolisthesis.[3] The technique is most useful for lateral recess stenosis, a condition that is responsible for atypical leg pain rather than true intermittent claudication of central spinal stenosis. In central spinal stenosis, when there is concomitant posterior disc protrusion, decompression of the spinal canal can be effectively accomplished by resecting the bulging annulus in a collapsed disc, thus lowering the floor of the foramen. In isthmic and degenerative spondylolisthesis, when there is more leg than back pain, this is usually due to impingement on the exiting nerve by the pars pseudoarthrosis defect or the undersurface of the superior articular facet. The goal is then to decompress the compromised exiting nerve by elevating the dome formed by the superior facet and lamina without further destabilizing the spinal column segment.

Exclusion Criteria

Except perhaps for pregnancy, there are no absolute exclusion criteria but only relative contraindications dependent on the surgeon's skills and experience. Spinal endoscopy and spinal probing can be used for diagnostic purposes in a very difficult or confusing clinical problem. Therefore, if endoscopy is helpful for diagnostic purposes, exclusion criteria may depend mainly on the accessibility of the spinal pathology and the endoscopic skills of the surgeon. A high narrow pelvis may make it difficult to access the posterior aspect of the L5–S1 disc, and extract the herniation. If the herniation is sequestered and a free fragment, then a posterior microdiscectomy may be a better option for herniation removal. The risks and benefits of the procedure must be weighed against the need to use this fluoroscopically guided procedure under local anesthesia or sedation.

Future Considerations

It is not inconceivable that the spine scope will eventually be used for all conditions where visual inspection is desired. The senior author (A.Y.T.) has utilized spinal endoscopy to inspect a spinal nerve suspected to be irritated by orthopedic hardware adjacent to the pedicle, to remove suspected recurrent or residual disc herniations that do not show up on imaging studies, to decompress the lateral recess by foraminoplasty, to remove osteophytes and facet cysts that cause unrelenting sciatica, and to locate painful lateral annular tears or small disc herniations not evident on physical examination or on magnetic resonance imaging (MRI). Some of these correctable lesions are responsible for failed back surgery syndrome. The lateral "hidden" zone is rarely visualized by surgeons. It has been reported that most tears that do not heal are too extensive or are caused by interpositional disc material keeping the tear open. Simply removing the interpositional disc tissue will then allow the tear to heal, and the pain to resolve. It has been demonstrated that with endoscopy, it is possible to perform isolated disc and annulus surgery using a visualized thermal modulation procedure (Figure 73.7), challenging the old concept that disc surgery is merely nerve decompressive surgery. For example, discogenic pain from annular tears is currently being evaluated and correlated with the pathoanatomic conditions visualized.[14–25] Some minimally invasive spinal surgeons use an endoscope, but only through the traditional transcanal approach. Because most surgeons are more com-

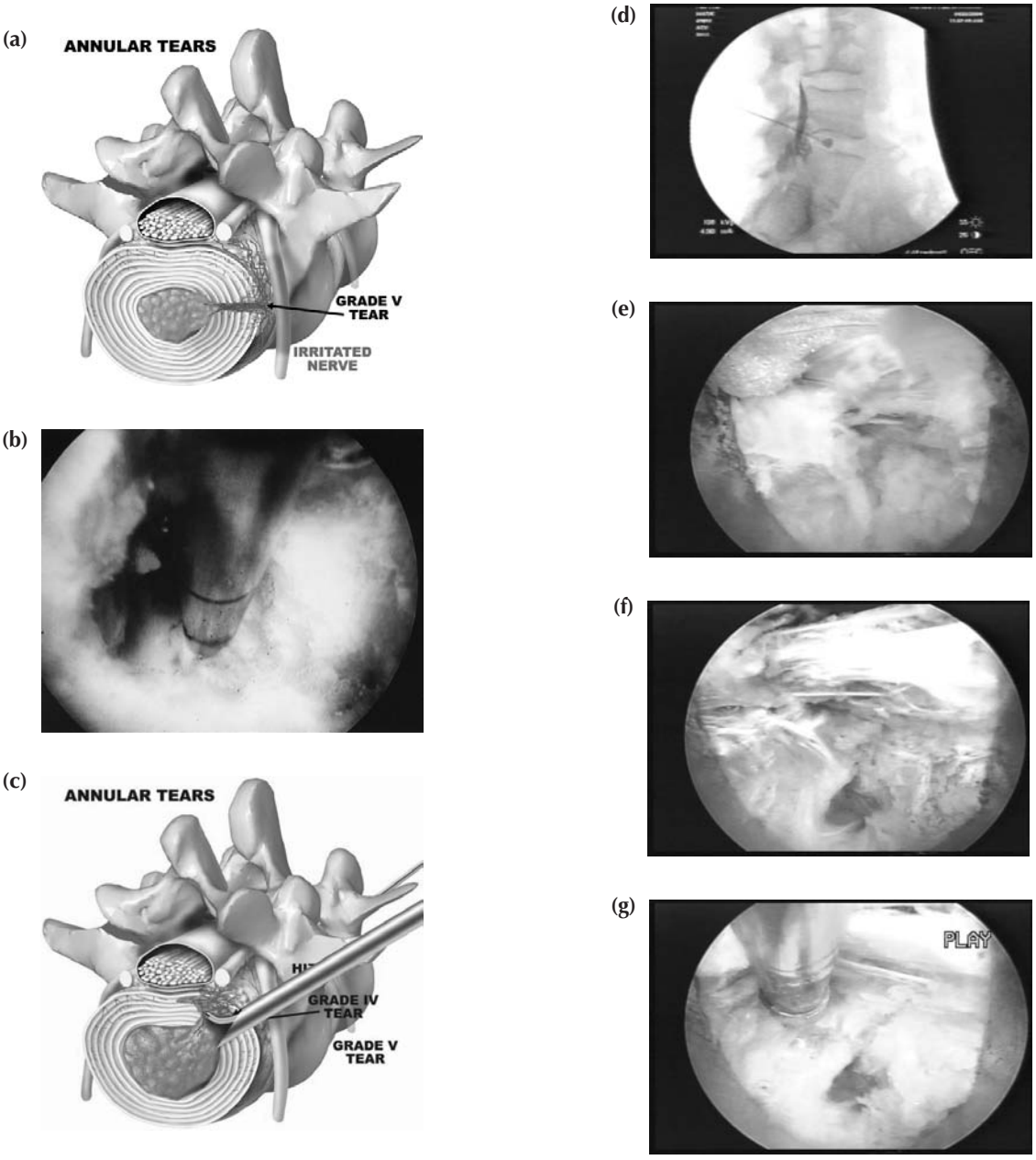

FIGURE 73.7 (a) Annular tears. Grade V annular tears open into the epidural space or psoas muscle, allowing the ingrowth of nerves and capillaries that create an inflammatory response that if next to a spinal nerve or the dorsal root ganglion, can cause pain out of proportion to what may be anticipated from traditional imaging studies. If patients with annular tears get relief from foraminal epidural blocks, more lasting relief of 1 or 2 years is possible with selective endoscopic discectomy (SED™) and thermal annuloplasty. (b) Far-lateral annular tear. This far-lateral annular tear is thermally modulated by a side-firing Ho:Yag laser ablating the interpositional disc tissue that kept the tear open and prevented healing. The laser probe was inserted on the side opposite the tear. (c) Illustration of the Ellman bipolar trigger-flex probe treating a grade IV annular tear. Interpositional disc material embedded in the annular layers is the usual cause of annular tears not healing. Nucleus pulposus should be removed from the annular layers to treat the annular tear effectively. (d) Intraoperative evocative chromo-discography identifies a large grade V annular tear. (e) Nucleus pulposus found in annulus, demonstrating a small herniated foraminal disc fragment unrecognized on MRI. (f) Annular tear exposed after removal of herniation. Vascularization of the tear is demonstrated. (g) Thermomodulation of the annular tear with a bipolar radiofrequency probe helps close the defect.

fortable with the anatomy encountered in a traditional approach, this is a good way to begin the transition to other endoscopic techniques. Once they feel comfortable with the endoscope, however, it is not difficult to transition to the posterolateral portal. Those who take the time to learn other approaches, including the posterolateral approach, will be in the best position to do what is best for their patients.

Non-Operative Treatment

With endoscopy, conservative treatment should be labeled non-operative treatment. Physicians specializing in spinal medicine, rehabilitation, and pain management are becoming more sophisticated in their ability to identify the tissue source of back pain. Once the source is identified, physical therapy and diagnostic and therapeutic injection methods are used for pain relief. These techniques, such as foraminal epidural blocks and selective nerve blocks, may be labeled "conservative," but are therapeutically beneficial. They may also be limited in their ability to ultimately correct the painful condition. Endoscopic spine surgeons are still needed to address correctable lesions, but their effectiveness is enhanced by incorporating the help of a multidisciplinary team. The senior author has devised a new technique for performing foraminal epidurography and therapeutic injections that is done with a far-lateral trajectory into the foramen, mimicking the surgical approach.[4] Familiarity with foraminal injections will enhance the endoscopic surgeon's surgical skills and provide the surgeon with a "trial run" if endoscopic surgery is ultimately required.

The world literature on conservative treatment has presented strong evidence that a multidisciplinary approach to back pain, coupled with behavioral modification and exercise therapy, gives the best results. With spinal endoscopy, a new concept for treatment should be non-operative versus operative treatment, as the ability to more specifically diagnose a painful condition in the lumbar spine with endoscopy makes early surgical intervention the more "conservative" approach.

PLANNING

Patients with chronic back pain and atypical sciatica are the most difficult to treat. Traditional methods of nonsurgical treatment are often not effective or relief is very transient, and the patient is often labeled drug seeking or psychologically unstable. In this situation it is extremely helpful to utilize a multidisciplinary team approach. Psychologic profiling, behavioral modification, active exercise, and manual therapy help the patients overcome their pain and focus on becoming functional. The team approach with psychologists, physiatrists, addictionologists, and pain management specialists who are working with each other and agree on the overall treatment plan has helped rescue many chronic pain sufferers from total disability and reliance on salvage procedures. Around the disc, foraminal epiduroscopy and foraminal epidural blocks will help determine the ease of reaching the disc and epidural space. A temporary response to the foraminal epidural injection is a good indicator for a foraminal approach to the pathologic lesion to be addressed surgically.

Current Imaging Methods

In the senior author's experience, imaging studies are only about 70% accurate and specific for predicting pain.[3,6,26–29] Conditions such as lateral annular tears, rim tears, small subligamentous disc herniations, end plate separations, anomalous nerves in the foramen, and miscellaneous discogenic conditions are cumulatively missed about 30% of the time. These conditions are diagnosable and often treatable with spinal endoscopy. Tears that are in the lateral and ventral aspect of the disc are routinely missed by MRI studies (Figure 73.8). Very small disc herniations that protrude past the outer fibers of the annulus are also missed because the fragment may be flattened against the posterior longitudinal ligament or nerve, appearing on the MRI as a thickened or bulged annulus, but really containing a subligamentous herniation. When the nerve root is "swollen" or enlarged, the MRI is not always capable of distinguishing a swollen nerve from a conjoined nerve or a nerve with an adherent fragment of disc. When the disc tissue is in direct contact with the nerve, the nerve can be irritated and a

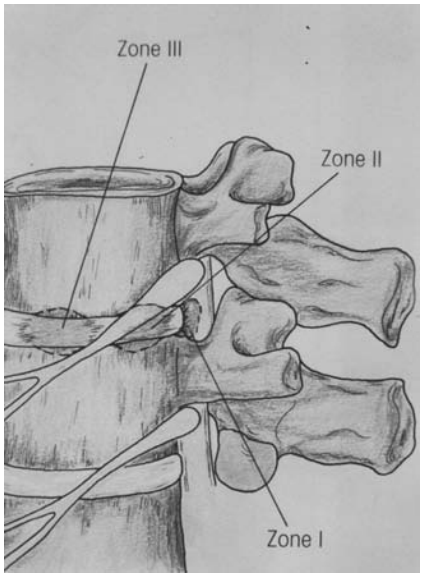

FIGURE 73.8 The three zones of disc herniation and annular tears. Zone III is usually missed on routine imaging studies, often produces nondermatomal symptoms, and is often only identified by evocative discography. Zone III annular tears can cause groin pain at L5–S1, and small extraforaminal disc herniations are difficult to diagnose by physical examination.

painful inflammatory membrane forms. Even an epidural venous plexus that is inflamed can contribute to back pain and sciatica. Anomalous nerve branches known as furcal nerves are never seen on MRI but can be visualized with spinal endoscopy of the foramen.[22,30]

When an inflammatory membrane is present, the patient's pain pattern can be confusing. Diagnostic spinal endoscopy has confirmed "nondermatomal" pain in scores of patients with proximal thigh, buttock, and groin pain at levels distal to the root origin of the anatomic area. Removal of the source of irritation will resolve or improve the patient's pain.

Evocative Discograms

The senior author uses evocative chromo-discography™ as an integral part of spinal endoscopy.[5] The literature on discography is currently considered controversial because of the high interobserver variability by discographers in reporting the patient's subjective pain as well as the ailing patient's ability to give a clear response, especially if the pain response is altered by the use of analgesics or sedation during the procedure. Surgeons who are accomplished in endoscopic spine surgery prefer to do the discography themselves to decrease the interobserver variability interpreting the patient's response. When the surgeon compares his own assessment of the patient's pain response with another discographer's report, there can be some variability in diagnosis and interpretation. This variability may result in unpredictable treatment outcomes. False-positive discography, however, can be significantly decreased in an experienced endoscopic surgeon's hands. The surgeon learns to correlate the patient's response to the discogram pattern of the painful disc the surgeon is treating. There is good correlation of discograms with different types of annular tears and disc herniations. The surgical result can then be predicted on the basis of the visualized condition. For example, the discogram can be used to predict the presence of a collagenized disc fragment versus a soft herniation, the extrusion of a disc fragment as a noncontained herniation, or the presence of the type, grade, and location of a painful versus nonpainful annular tear.

TECHNIQUE

Endoscopic Spine Surgery: The Posterolateral Approach

The current technique used by the senior author has evolved over a 13-year period beginning in 1991 after learning arthroscopic discectomy from Parviz Kambin. Previously the author had experience in the use of chymopapain, automated percutaneous discectomy, laser discectomy, and discography. The current technique combines the best features of each endoscopic procedure into a visualized method that is described as selective endoscopic discectomy (SED™) and thermal discoplasty and annuloplasty. It continues by incorporating endoscopic foraminoplasty techniques for degenerative conditions of the lumbar spine. The foraminal approach is refined further by a standardized surgical protocol that helps decrease the learning curve. A prospective, Institutional Review Board-approved study of 56 patients undergoing SED and thermal discoplasty by the senior author for conditions ranging from discogenic pain to spondylolisthesis, targeting the pain generator, revealed a satisfactory outcome of 89% by modified MacNab criteria and 91% by patient questionnaire.[8] Surgical results continue to improve, consistent with the refinement of indications and techniques for specific conditions treatable by this endsocopic method.

Accessing the foramen is simplified and standardized by drawing coordinates on the patient's skin to determine the optimal skin window and annular window for positioning the surgical instruments to the center of the disc (Figure 73.9). Reference points are the anatomic center of the disc, the superior facet of the inferior vertebra, and the skin window. The needle trajectory must also be in a line of inclination between the end plates of the adjacent vertebrae. Adjustments in the trajectory will be made to accommodate individual anatomic considerations and the pathology to be accessed. Once the optimal trajectory is established, the cannulas are inserted to allow for endoscopic surgery under direct visualization.

The spinal structures accessible with this technique are the facet joints, the pedicles of the superior and inferior vertebra, the traversing and exiting nerve roots, and the disc annulus. The epidural space is accessible with flexible instruments and special cannulas (Figure 73.3). The posterolateral approach can avoid the spinal canal if desired and does not require the stripping of muscle or ligament to access the disc. A third-generation system, the Yeung Endoscopic Spine System (YESS), features a cannula set with configured openings that allow instruments to exit the cannula for surgical work, while a protruding tongue protects and retracts adjacent structures. The beveled cannula allows visualization of the disc and epidural space at the same time, facilitating the removal of subligamentous, extruded, and sequestered disc fragments. Its configuration also allows for dilation of the disc space for intradiscal surgery. The foramen can be enlarged by foraminoplasty to decompress foramenal and lateral recess stenosis. Adjuvant tools and therapies such as radiofrequency, chymopapain, steroids, intradiscal injections, and laser can be employed for tissue modulation or ablation when the visualized spinal pathology dictates its use.

Postoperative Care

Postoperative management may differ from the typical postoperative program used for disc herniations with

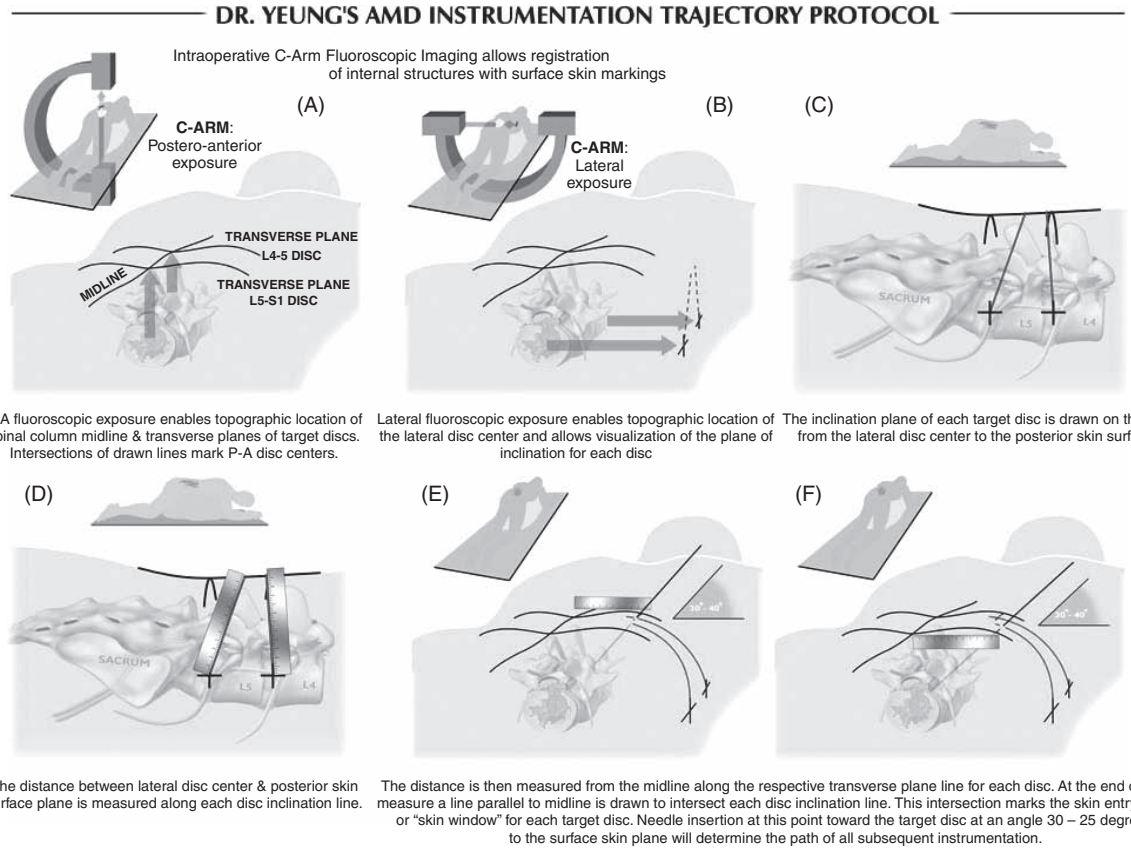

FIGURE 73.9 Determination of optimal instrument path.

radiculopathy. Endoscopic treatment for discogenic back pain often involves multiple levels, and disc segments with extensive circumferential annular tears that involve the entire 360° circumference. This differs from a disc herniation that involves only one quadrant of the annulus that after disc extraction, has a better chance of healing when the disc extrusion no longer acts as a barrier to healing. With an extensive annular delamination and tear, the annulus of the spinal segment must be protected while the collagen of the annulus heals, and only light non-axial loading movement is allowed. After 6 to 8 weeks, gauged by the patient's response to decompression and thermal modulation, a therapeutic exercise program is initiated consisting of lumbar stabilization exercises and MacKenzie extension maneuvers. Ultimately, the goal of mobilization and aerobic conditioning is functional recovery.

PROBLEMS AND COMPLICATIONS

As with arthroscopic knee surgery, the risks of serious complications or nerve injury are low — about 1 to 3% in the senior author's experience.[31] The usual risks of infection, nerve injury, dural tears, bleeding, and scar tissue formation are always present as with any spine surgery. Fenestration past the anterior annulus is a potential hazard creating a bowel or vascular injury. Although this is a rare complication because the thickness of the anterior annulus will usually prevent fenestration, it must be recognized as a potential risk if the annulus is weakened or fenestrated by an anterior disc herniation. This risk is also present with the posterior approach. One limitation of the endoscopic technique is the need to use some instruments in a "blind" fashion. That is, shavers, pituitary rongeurs, and basket forceps are too large to fit in the working channel of the endoscope, and must be monitored with fluoroscopy. The surgeon must be cognizant of the depth of the instruments and develop a feel for the working instruments while in the disc. The cannulas are designed to protect vital structures by utilizing windows as surgical portals. Spinal nerves may be adherent to the disc and annulus, and can be extracted along with the disc or annulus by shavers or cutting instruments. In addition, the author has identified anomalous autonomic and peripheral nerves in the foramen (furcal nerves), buried in the annular fat, that connect with the sacral plexus or the traversing nerve. These nerves are described in the medical literature and can be symptomatic (Figure 73.10a). The inflammatory membrane may contain tiny nerves and blood vessels that contribute to severe discogenic pain (Figure 73.10b).

Dysesthesia, the most common postoperative complaint, occurs about 5 to 15% of the time but is almost always transient. Its cause is still incompletely understood

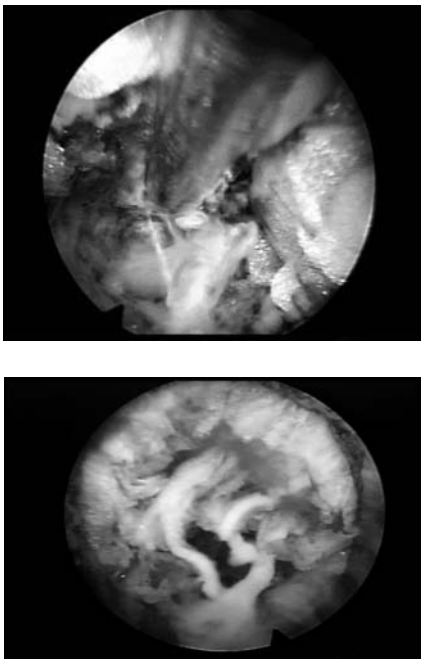

FIGURE 73.10 Anomalous nerves. (a) Anomalous nerve identified in the annular fat in the foramen. When found in the foramen, it is considered an anomalous branch, but furcal nerves are common branches from the exiting nerve entering the psoas muscle. These communicating branches are described as furcal nerves in the anatomy and literature. Small sympathetic nerves are occasionally seen. (b) Neo-angiogenesis and neo-neurogenesis are commonly present in the inflammatory membrane adjacent to annular tears in patients who have severe discogenic pain and sciatica, but a rather benign MRI.

and may be related to nerve recovery, as it can occur days or weeks after surgery, or it may be due to irritation of the dorsal root ganglion. This condition cannot be completely avoided, as neuromonitoring with dermatomal somatosensory evoked potentials (SEP) and continuous electromyography, the most sensitive means of monitoring, has not identified the cause of dysesthesia.[32] The symptoms can be similar to complex regional pain syndrome (CRPS), but less severe, and usually without the skin changes that accompany CRPS. Stimulation of the doral root ganglion of the exiting spinal nerve can also result in dysesthesia when foraminoplasty is performed, even with the exiting nerve clearly identified and protected.

Endoscopic spine surgery has a high learning curve, but is within the grasp of every endoscopic surgeon with proper training. As with any new procedure, the complication rate is higher during the learning curve and may vary with each surgeon's skills and experience. The endoscopic technique, because of its approach, may incur additional risk for iatrogenic injury, but it is possibly safer than traditional surgery for the patient as the patient is awake and able to provide immediate input to the surgeon when pain is generated. The surgeon's ability to perform the surgery without causing the patient undue pain will self-select for surgeons who can master the technique to the extent that the surgeon prefers endsocopic to traditional surgery for the same condition. For most disc herniations and discogenic pain, experienced endoscopic spine surgeons will opt for the endoscopic approach as the treatment of choice for their patients. New neuromonitoring techniques and equipment help warn the surgeon of nerve irritation even when there is no direct contact of surgical instruments with the nerve proper. About 66% of the time, there is EMG activity recorded that warns the surgeon that there is nerve irritation. Neuromonitoring may make the procedure safer, but it has not been demonstrated to be safer than the use of dilute local anesthetic. It is imperative for the surgeon to insist that the anesthesiologist not use general or spinal anesthesia. The senior author requires anesthesiologists not to use propofol or any anesthetic that has the potential for the patient not to feel pain, as the patient's ability to feel pain becomes the surgeon's main safety net. The author also uses only a dilute solution of local anesthetic such as 0.5% lidocaine or its equivalent. The patient's ability to report pain during the procedure will also help the surgeon recognize the pain generators in the spine when the surgeon correlates the production of pain with the anatomy the surgeon is probing.

Frequently observed improvement in nerve conduction latencies and abnormal preoperative EMGs immediately postoperation may help predict the surgical efficacy of each procedure.[32]

ALTERNATIVES TO FUSION FOR THE TREATMENT OF BACK PAIN

Fusion has traditionally been reserved for spinal instability and deformity. More recently, the utilization of spinal instrumentation and intervertebral fusion cages has extended the indications to discogenic pain from internal disc disruption and degenerative disc disease, but, overall, the results remain disappointing; adjacent-level disease remains a problem. Discogenic pain has been discovered to arise primarily from the annulus, but can also involve the end plates (intranuclear herniations), the inflammatory membrane surrounding the annulus, and sensitized tissue surrounding the annulus. Patients with debilitating back pain are currently offered surgical fusion as a treatment option to stabilize the motion segment. However, patients with recurrent, relatively annoying or debilitating pain from annular tears in the lumbar disc may be also be helped by electrothermal treatment. Type III and IV pain nociceptors in the annulus are deformed by heat at 42 to 45°C. When the heat is increased to 65°C, the annulus contracts and thickens. This novel approach, touted in the literature as intradiscal electrothermal therapy (IDET), is limited because of the lack of endoscopic

visualization. Patient selection is critical, but even if initially successful in the immediate postoperative period, follow-up studies have reported significant deterioration of results months to years later. A visualized endoscopic variation of the technique, SED and thermal annuloplasty, overcomes some of the pitfalls of the blind technique. The tear is detected by evocative discography. Indigo carmine dye, mixed with a non-ionic contrast material, Isovue 300, stains the degenerative disc and annular tear a light blue. The degenerative disc is removed from the posterior disc quadrant, exposing the annular tear for thermal annuloplasty. When imaging studies identify these lesions as a high intensity zone, there is a high incidence of concordant pain by evocative discography and endoscopic confirmation of a focus of ingrown granulation tissue. This tissue can then be ablated under direct visualization. The senior author's endoscopic version of IDET has converted 80% of IDET failures to satisfactory results.[33] Spinal endoscopy has enabled surgeons to identify interpositional disc tissue as the single most common finding preventing annular tears from healing. Other novel approaches are currently being studied to help the tears heal, as annular modulation may incorporate injection of therapeutic solutions utilizing hypertonic dextrose, glucosamine sulfate, and chondroitin sulfate. These novel approaches deserve study and may provide a viable alternative to fusion as a first line of surgical treatment for debilitating discogenic back pain from annular tears and internal disc disruption. Ultimately, techniques to enhance disc healing, regeneration, or arthroplasty may replace fusion as treatments of choice.

OUTCOMES

The results of percutaneous spine surgery in the literature focus on blind techniques such as laser disc decompression and automated percutaneous lumbar discectomy. The visualized technique, however, as described by Kambin, ranges from 85 to 93% good/excellent in studies with a minimum 2-year follow-up. In a prospective manner, Kambin has also validated the visualized technique as a valuable tool in the armamentarium of a spinal surgeon. When performed in an experienced endoscopic surgeon's hands, Kambin found results equal to a traditional microdisectomy, but with less morbidity and an earlier return to work.[35–37] The high learning curve has curtailed its universal acceptance at this time, but those surgeons willing to invest the time in learning this technique will soon earn the loyalty and acceptance of their patients and referring physicians.

The evolution of endoscopic surgery is enhanced when physicians document their findings by video-imaging and then study the tapes postoperatively. By studying the video of their surgeries in the early part of the learning curve, surgeons will soon learn to associate visualized conditions with their ability to affect those conditions. This will help surgeons evolve their diagnostic and surgical skills faster.

THE AUTHOR'S EXPERIENCE WITH ENDOSCOPIC SPINE SURGERY

Since 1991, the senior author has used a rod–lens system for endoscopic disc excision through a posterolateral approach as described by Parviz Kambin. Kambin coined the term *arthroscopic microdiscectomy* to describe his method of disc removal from the dorsal half of the intervertebral disc using uniportal and biportal techniques. In 1997, a newly designed spinal endoscope (YESS) featured a working channel and multiple inflow and outflow ports. This allowed consistent clear visualization through fluid volume and pressure control, to provide consistent hemostasis. The ability of the surgeon to visualize structures clearly and the concomitant development of flexible instruments to be used with slotted cannulas opened the door for true endoscopic spine surgery and spinal probing in a sedated, but awake patient. From 1991 to 2004, the senior author treated more than 2,400 patients with discogenic pain, degenerative conditions of the lumbar spine, and the whole spectrum of disc herniations including extruded and sequestered fragments. The success rate in the first 500 patients was 432/500 (86%) good/excellent using modified MacNab criteria.[26] A subsequent retrospective study of 219 consecutive patients with radiculopathy secondary to large intracanal noncontained lumbar disc herniations revealed a satisfactory outcome in 204 (93.1%) by modified MacNab criteria, but even higher (94.8%) when patients were asked to respond to a study patient-based outcome questionnaire.[9] The evolving methodology in the treatment of discogenic back pain by SED is reviewed in a prospective study that validates SED as an alternative for a variety of spinal conditions treated by traditional methods (Yeung & Gore, 2001). *The Practice of Minimally Invasive Spinal Technique* is a recent book edited by Martin Savitz, John Chiu, and Anthony Yeung. A journal by the same name has been endorsed by multiple spine specialty societies to bring endoscopic spine surgery into the next millennium.

NEW HORIZONS — THE FUTURE OF ENDOSCOPIC SPINE SURGERY

The learning curve in endoscopic spine surgery is steep compared with knee surgery because surgical misadventures are unforgiving in the spine. Intensive surgical instruction with preceptorship programs has produced small numbers of spinal endoscopists worldwide. It is strongly recommended, however, for further advancement of endoscopic spinal surgery, that a preceptorship be completed before attempting endoscopic spine surgery. Even-

tually, for further advancement, endoscopic spine surgery may have to be a subspecialization for most surgeons. If young surgeons could obtain their training in their fellowship or post-fellowship program, endoscopic spine surgery would advance faster. For now, the small number of surgeons should hone their endoscopic skills by limiting their indications to contained small, soft disc herniations. With the development of artificial nucleus disc replacements, interest in posterolateral spinal endoscopy is expected to surge, as this represents the best surgical approach for nucleus replacements.

CONCLUSION

The future of endoscopic spine surgery is extremely bright. There will soon be an explosion of new imaging systems, endoscopes, and endoscopic instruments. Refined techniques and image-guided systems may help shorten the learning curve. Coupled with advancements in tissue regeneration and enhancement of tissue healing, and the trend toward tissue healing instead of removal, regeneration over healing, and arthroplasty instead of fusion, the spinal surgeon may no longer have to consider spine surgery as paradoxical. As a treatment modality, it will no longer be considered a last resort in a desperate patient. There will be a paradigm shift in the way we view and approach patients with back pain, especially when endoscopic spinal surgery is further validated with outcome studies and becomes routinely available.

KEY POINTS

1. The endoscopic foraminal posterolateral surgical approach to the lumbar disc offers the least trauma to normal anatomy.
2. Spinal endoscopy offers expanded diagnostic as well as therapeutic benefits not possible with traditional surgery.
3. Spinal endoscopy is a complement to interventional pain management, and techniques are beginning to merge.
4. New terminology and concepts, evocative discography, evocative chromo-discography, selective endoscopic discectomy, and thermal annuloplasty, are introduced and explained in the text.
5. The learning curve is steep, but once mastered, this approach will revolutionize surgical treatment of the lumbar disc, and provide the delivery system for emerging technology in tissue repair and regeneration.

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