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Selective Endoscopic Discectomy™

Twelve Years of Experience

Anthony T. Yeung, MD

INTRODUCTION

More than 12 yr have passed (1991) since I learned and adopted arthroscopic microdiscectomy (AMD) from pioneer endoscopic spine surgeon Parviz Kambin, who, along with Sadahisa Hijikata, first established the technique for percutaneous nucleotomy in the early 1970s. A cadaver dissection of the traditional posterior anatomy of the lumbar spine compared with the foraminal anatomy clearly illustrates the feasibility and advantages of the foraminal approach to the lumbar disc (Fig. 1A,B). Kambin's AMD technique evolved gradually to allow for more dorsal placement of the cannula to effect posterolateral fragmentectomy and resection of the posterior annulus for stenosis, and it made possible the removal of extruded and sequestered herniated discs *(1–4)* (Fig. 2). Hijikata *(5)* also recently reviewed his 12 yr of experience with endoscopic discectomy. In 1996, a new design of the operating spine endoscope adding multichannel irrigation and complementary instrumentation (Fig. 3) *(6)* allowed further development of endoscopic spine surgery to include the treatment of annular tears causing discogenic back pain *(7,8)*. Advanced techniques of foraminoplasty for central and lateral recess stenosis followed *(9–12)*. The third-generation system design change to the Yeung Endoscopic Spine Surgery (YESS) system gave me more flexibility to maneuver the endoscope and improved ability to probe spinal anatomy in a conscious patient *(13)*. Continued evolution of this technique afforded me the ability to better evaluate the pathological process causing the patient's discogenic back pain. Conditions previously not considered surgical, such as annular tears, were evaluated and managed successfully through the endoscope. Synovial facet cysts, inflammatory membranes containing neoneurogenesis, osteophytosis impinging on sensitive nerves, anomalous furcal nerves, autonomic nerves, and conditions irritating the dorsal root ganglion (DRG) of the exiting nerve were identified as sources of discogenic pain and sciatica.

From 1991 to 2004, I treated more than 2300 patients with discogenic pain, degenerative conditions of the lumbar spine, and the whole spectrum of disc herniations including extruded and sequestered fragments *(14,15)*. The success rate in the first 500 patients was 432 of 500 (86%) good/excellent results according to the modified MacNab criteria *(11)*.

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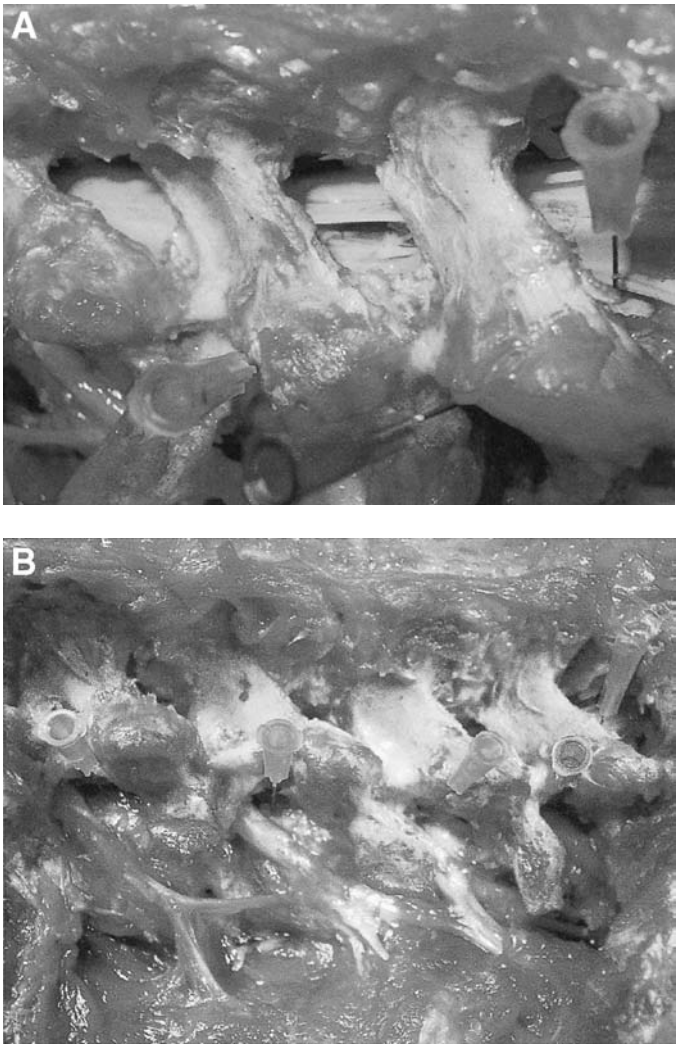

Fig. 1. (A) Anatomy of the posterior port provides easier access to the posterior disc and spinal canal at L5-S1 (blue hubbed needle), but with planning, most contained disc herniations can be removed posterolaterally. **(B)** Anatomy of posterolateral foraminal port from L2-S1. Only in the L5-S1 disc space is access to the spinal canal restricted because of the pelvis and the relatively wide facet (gray hubbed needle in the L5-S1 disc). High lumbar disc herniations from L1 to L3 are easier to reach endoscopically through the posterolateral foraminal portal. L4-L5 provides ample room for either approach. Note the furcal nerve branches entering the psoas muscle.

A subsequent retrospective study of 219 consecutive patients with radiculopathy secondary to large intracanal noncontained lumbar disc herniations demonstrated a satisfactory outcome in 204 (93.1%) patients based on modified MacNab criteria, but the rate was even higher (94.8%) when patients were asked to respond to a study patient-based outcome questionnaire *(16)*. In this chapter, I review my 12 yr of experience evolving from Kambin's AMD into the treatment of discogenic back pain and sciatica by selective endoscopic discectomy.

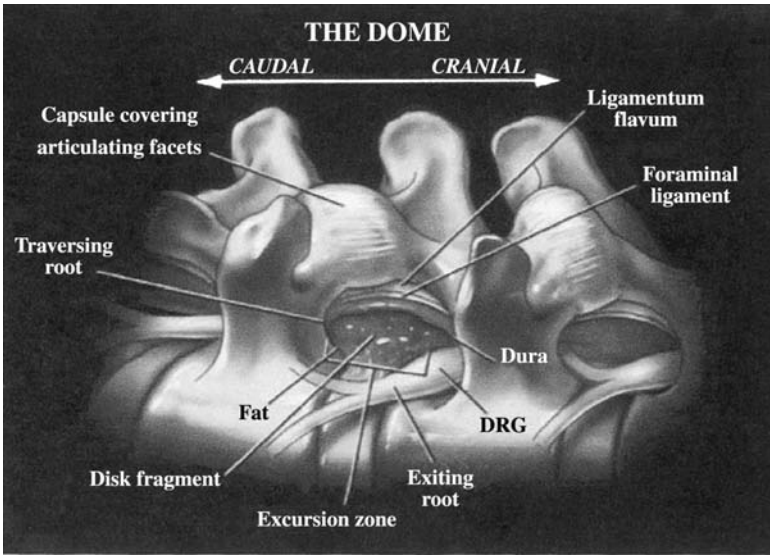

Fig. 2. The dome. Spinal structures in the foramen accessible to visualization and surgical intervention and probing via the posterolateral approach include the annulus, disc, pedicle, facet, and epidural space. This approach also visualizes neurocompression in the "hidden zone" of the lateral recess, a common cause of failed back surgery syndrome (FBSS). (Courtesy of Hal Matthews, MD.)

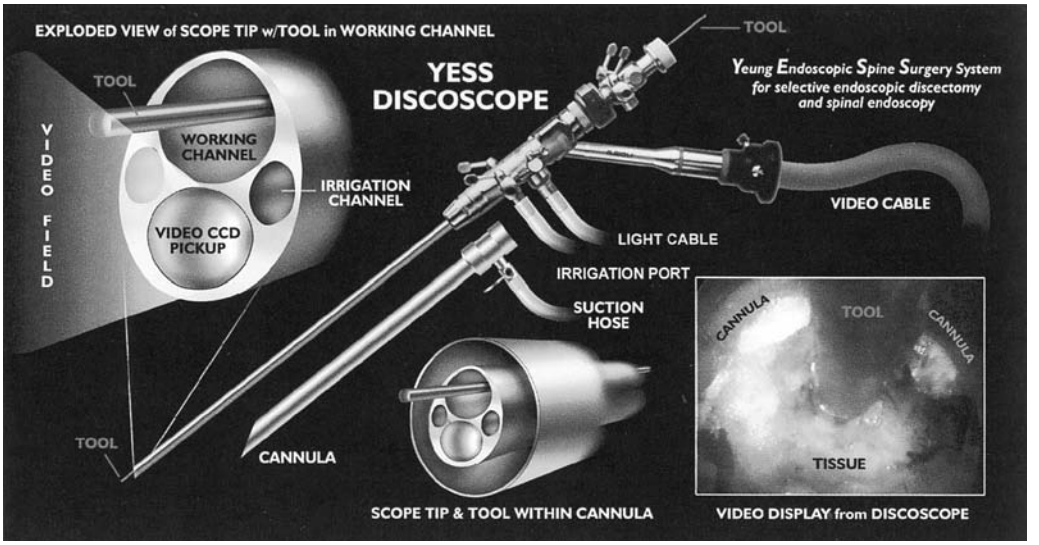

Fig. 3. Yeung spine scope system. YESS discoscope and partial instrument set. The spinal endoscope is designed with multichannel irrigation and a cannula system that allows access to targeted areas while protecting sensitive nerves. (From ref. *15*.)

ROLE OF EVOCATIVE CHROMODISCOGRAPHY

At Kambin's 1991 course, Prof. Hans Joerg Leu described the use of indigocarmine dye to stain and label the nucleus pulposus (NP). To maintain the ability to recognize structural anatomy, it was necessary to dilute the dye to a 10% solution to effect differential tissue

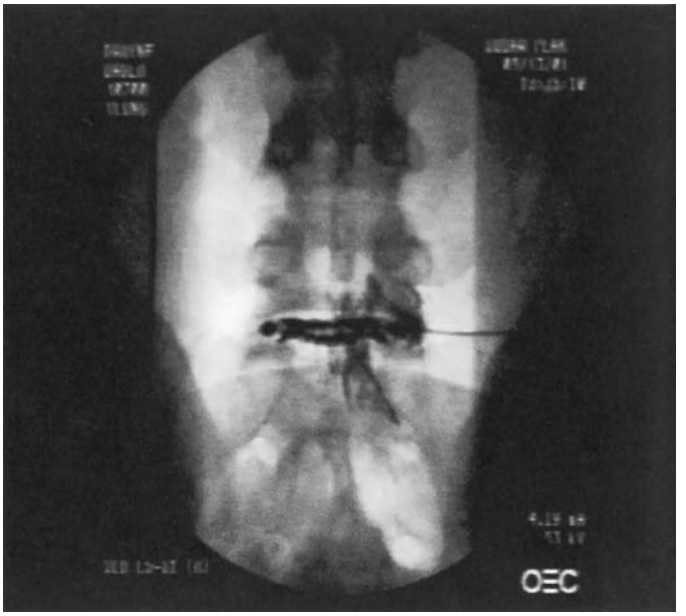

Fig. 4. This intraoperative discogram in a patient with a papacentral herniated nucleus pulposus (HNP) by magnetic resonance imaging (MRI) not only confirmed the patient's concordant back pain and sciatica, but the leakage of contrast to the traversing and exiting nerves alerted the surgeon to look for extruded disc fragments and grade V annular tears, especially in the lateral zone.

staining that did not overwhelm the NP with stain. I adopted this adjunctive technique initially to help with a visualized nuclectomy *(17)*. With differential staining, it was easier to recognize NP from annulus and from facet capsule. The epidural space with its epidural vessels and fat was simple to recognize. When pain was reproduced by discography, the clinical improvement in the patient's back pain correlated well with concordant pain reproduction. The use of discography also helped predict whether the herniation was extruded or contained, and the nuclear material was clearly stained for easier endoscopic extraction *(18)* (Fig. 4). I trademarked evocative chromodiscography™ as an integral part of spinal endoscopy. The process of removing the indigocarmine dye-labeled nucleus was trademarked selective endoscopic discectomy™ and this technique is the focus of this chapter *(15)* (Fig. 5).

The literature on discography is currently considered controversial only 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. Although much of the literature that contributes to the controversy of discography points out the pitfalls of depending on discography, the majority of the literature supports its use by clinicians who know how to use it. The surgeon who is accomplished in endoscopic spine surgery prefers to do the discography himself or herself in order to decrease the interobserver variability in interpreting the patient's response. When a discographer compares his or her own assessment of the patient's pain response with the report of another discographer, there can be some variability in diagnosis and interpretation. This variability may result in unpredictable treatment results. The incidence of "false-positive" discograms,

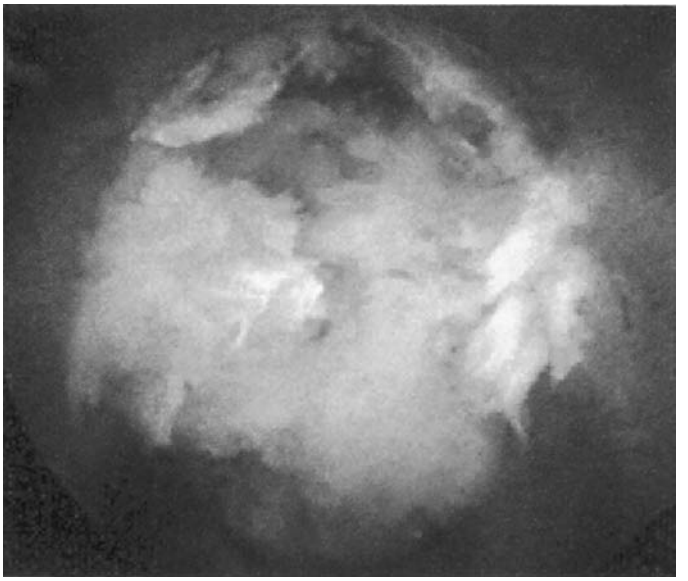

Fig. 5. NP stained with indigocarmine dye. The indigocarmine dye stains the NP light blue, helping the endoscopic surgeon target the stained nucleus for extraction. Here, the herniation has extruded past the unstained annulus. Removal of the extruded herniation will expose the traversing nerve in the epidural space.

however, can be significantly decreased in the hands of an experienced endoscopic surgeon. False-positive discography should really be false interpretation of positive discography results. The experienced endoscopic surgeon learns to correlate the patient's response to the discogram pattern of the painful disc that is being treated. 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 vs 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 vs nonpainful annular tear. Discography is used by the surgeon as a means of further identifying concordant discogenic pain in clinical situations in which the patient's clinical presentation is matched with MRI findings. Controversy in the literature has arisen because of the lack of a good spectrum of therapeutic surgical treatments once the pain is confirmed, and because of the plethora of articles pointing out the pitfalls of false interpretation *(19,20)*.

ROLE OF ELECTROTHERMAL THERAPY

Prior to my adoption of AMD, I was using the potassium-trideuterium-phosphate (KTP) laser for laser disc decompression. When I combined the two techniques for nuclectomy, the laser provided hemostasis and better visualization *(21–24)*. I observed that patients with disc protrusions but with predominant back pain who were not candidates for traditional transcanal surgery found relief of their back pain with KTP-assisted AMD. The staining of the disc provided a chromophore that enhanced the efficacy of the KTP laser *(25)*. In 1993, I tested a unipolar electrode by Ellman and introduced to me by

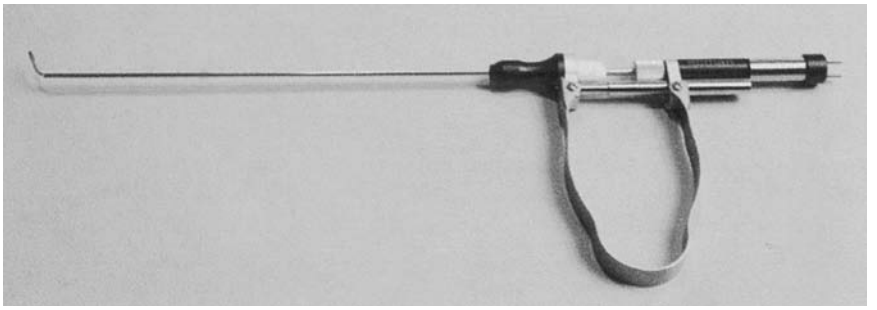

Fig. 6. Ellman Bipolar Triggerflex Probe. This bipolar flexible device has provided effective hemostasis as well as electrothermal shrinkage of disc tissue and annular tears under visualized control. It offers better control of the energy source by its bipolar design.

Dr. Peter Morrison. Later, an electrode made by Smith and Nephew was used with the Ellman unit and the new working channel endoscope. In a retrospective 2- to 4.5-yr follow-up study of my first 100 patients by Farouq Al-Hamdan, a spine fellow under Alex Hadjipavlou, it was documented that the use of the KTP laser as an adjunct to AMD relieved back pain as well as leg pain in 65% of the patients. The overall good/excellent result by MacNab criteria was 89% for sciatica. The KTP laser was initially used to provide hemostasis and better visualization, but its side effect of laser thermal annuloplasty prompted an International Review Board (IRB) study using a temperature-controlled flexible probe by Oratec in lieu of the laser.

In 1998, an IRB-approved study commenced at St. Luke's Medical Center to evaluate the efficacy of electrothermal treatment in the process of arthroscopic microdiscectomy for herniated discs. This study, sponsored by Oratec, using a temperature-controlled flexible probe, provided a better tool to contract annular defects caused by the disc herniation and ablating granulation tissue in annular tears. The patient's response to this application of electrothermal energy provided information that electrothermal treatment of the disc was effective in decreasing discogenic back pain, but the fluctuations in temperature control caused me to switch to a bipolar flexible probe *(26,27)*. Oratec investigated the intradiscal electrothermal (IDET) catheter in the same time period. I now use a bipolar flexible probe by Ellman designed specifically for thermal annuloplasty that has proven to be as effective as the Oratec probe, but with a more established and accepted use of electrothermal energy in spine surgery *(27)* (Fig. 6).

Rauschning's cryosections of normal and pathoanatomy have more recently demonstrated inflammation in and around the sensitive DRG and identified granulation tissue in annular tears *(28,29)* (Figs. 7 and 8). 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 that is resistant to conservative management *(30)*. What may be very painful in one person may be well tolerated or painless in another. Evocative discography has been shown to be helpful in identifying the disc as a pain generator in axial back pain and sciatica *(18,31–37)*, and electrothermal treatment of the disc is demonstrated to be effective in decreasing discogenic back pain.

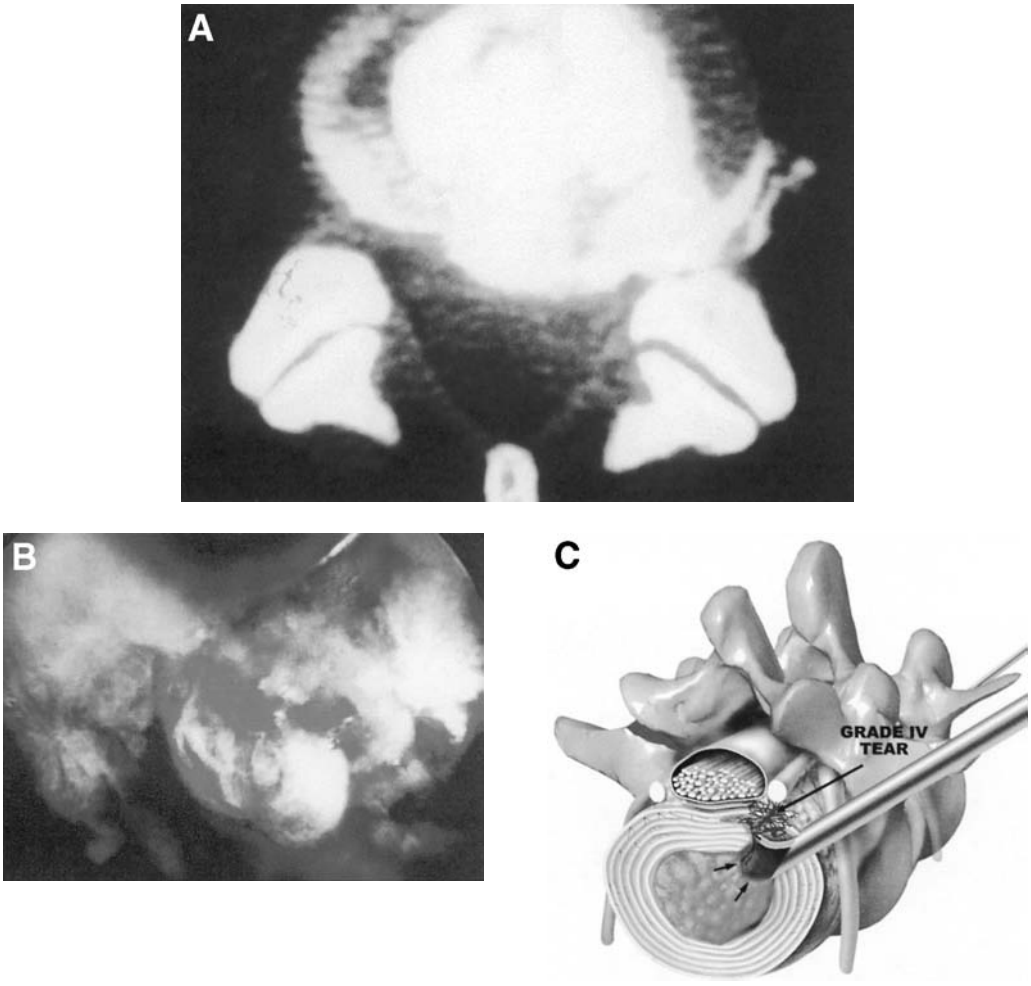

Fig. 7. (A) Annular tears. This computed tomography (CT) discogram outlines a foraminal HNP and far-lateral annular tear that will irritate the DRG of the exiting nerve. Endoscopic visualization of the foramen may reveal the presence of an inflammatory membrane, extruded NP, and granulation tissue. **(B)** Granulation tissue and inflammation surrounding small disc fragment in foramen. Grade V annular tears open into the epidural space or psoas muscle, allowing the ingrowth of nerves and capillaries and creating an inflammatory response, which, if next to a spinal nerve or the DRG, can cause pain out of proportion to what may be anticipated from traditional imaging studies. Tears in this area will also result in groin pain by irritating the psoas muscle and genital-femoral nerve. Patients with annular tears who obtain pain relief from foraminal epidural blocks may experience more lasting relief of 2 or more years with selective endoscopic discectomy and thermal annuloplasty. **(C)** Bipolar radiofrequency treatment of annular tears under direct visualization. Interpositional disc material should be removed from the annular layers to treat the annular tear effectively. **(D)** Preoperative endoscopic view of grades V annular tear demonstrating granulation tissue in tear. **(E)** Postoperative view of annulus after thermal modulation with Ellman Bipolar Triggerflex Probe.

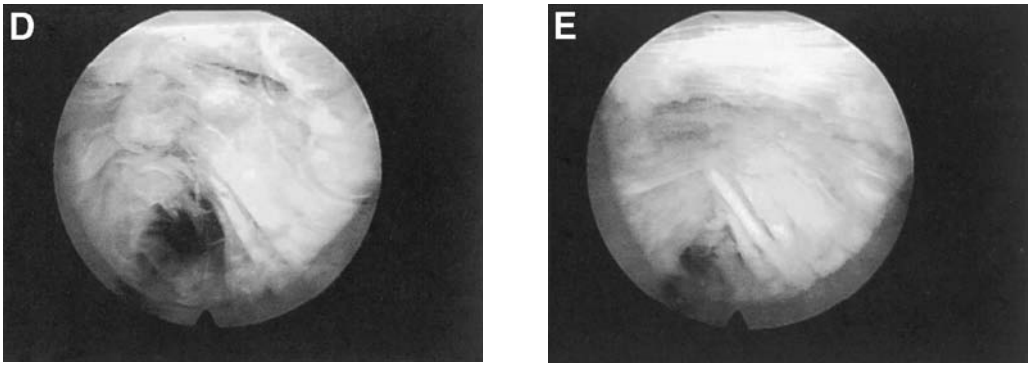

Fig. 7. *(Continued)*

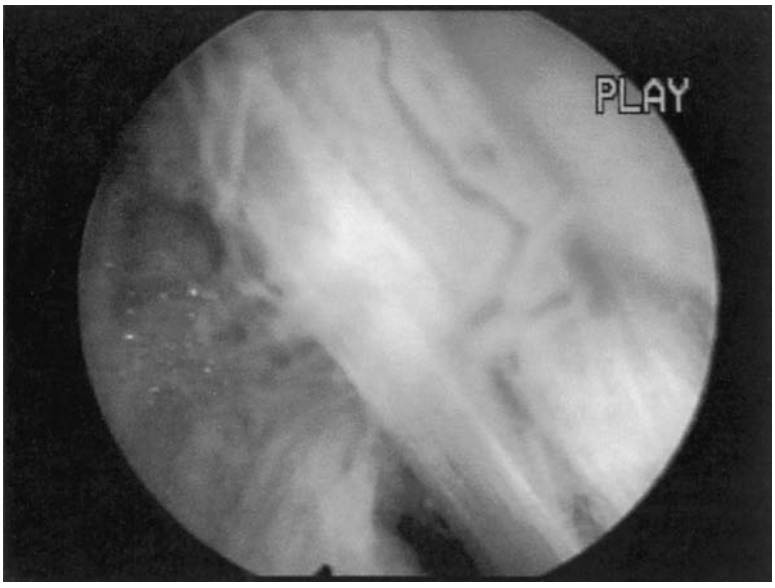

Fig. 8. Exiting nerve. The exiting nerve is in the "hidden extraforaminal zone" that is irritated by far-lateral annular tears and disc herniations that escape detection by MRI and transcanal surgical exploration. It contains the DRG, which, when sensitized by the inflammatory byproducts of a degenerative disc, is responsible for the "nondermatomal" distribution in patients with chronic sciatica. The presence of fat around the exiting nerve is a more sensitive indication of lateral recess stenosis than findings on MRI or CT myelogram.

ROLE OF THE LASER

Laser technology also evolved to become more user friendly. The first laser to be approved by the Food and Drug Administration was the KTP laser, a laser in the blue/green wavelength spectrum that was effective for soft-tissue ablation, but the bright light limited its use when direct visualization was desired *(22)*. The Holmium:yttrium-aluminum-garnet (YAG) laser was effective for the ablation of soft tissue as well as bone. Current designs now include a side-firing irrigated probe and a straight fiber that can be delivered through a curved guide that will angle the laser beam up to 45°. The laser has opened the door for the removal of osteophytes and lateral stenosis that cause neuropathic pain in patients who

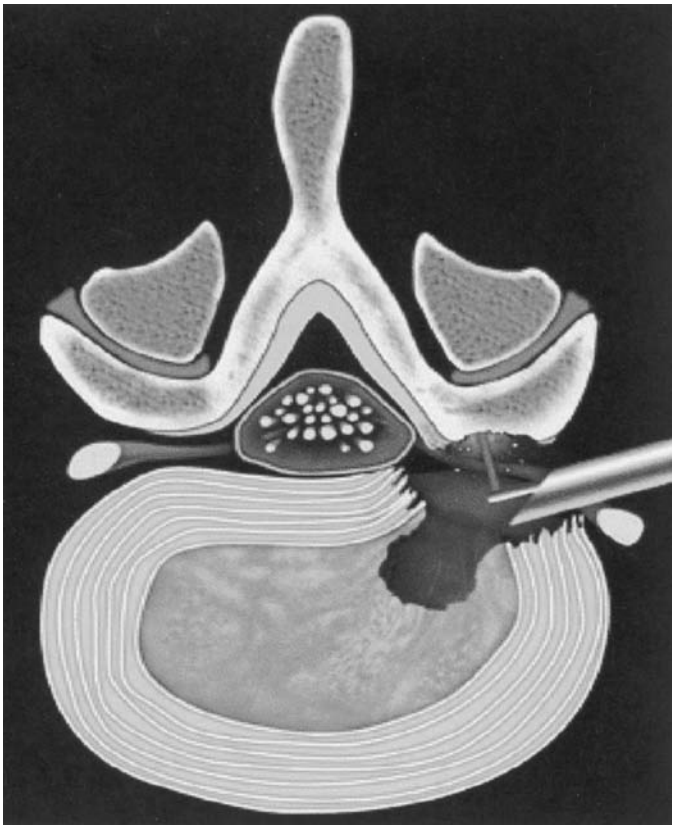

Fig. 9. Role of laser in foraminoplasty. Side-firing laser (Trimedine) or end-firing laser fibers (Lisa) directed by a flexible cannula are used for precise foraminoplasty of the lateral recess.

have no other surgical options *(15)*. Figures 9 and 10 demonstrate the use of the laser in foraminoplasty.

ADJUNCTIVE THERAPY WITH CHYMOPAPAIN

Chymopapain is the only minimally invasive technique that has been validated with two large double-blind studies and numerous cohort studies that found it effective for the treatment of contained disc herniations. I have used chymopapain to assist the extraction of large noncontained disc herniations that extrude past the outer annular fibers, with a good/excellent result by MacNab criteria 10% higher than when no chymopapain was used *(38)*. If the height of the herniation is greater than the base on MRI, it is likely that the herniated nucleus is collared by the annulus, making it more difficult to remove from within the disc. Chymopapain-treated NP is soft and slippery, making mechanical removal easier. If chymopapain extravasates along the course of the contrast agent used for discography, it will theoretically denature and treat the extruded fragment to make it less inflammetogenic. The extruded fragment is also exposed to phagocytosis and eventual absorption if exposed to the epidural vasculature. In more than 500 surgical cases of chymopapain-assisted selective endoscopic discectomy, I have never had any complications from the use of chymopapain. Because of the absence of complications when used in conjunction with endoscopic disc removal, I

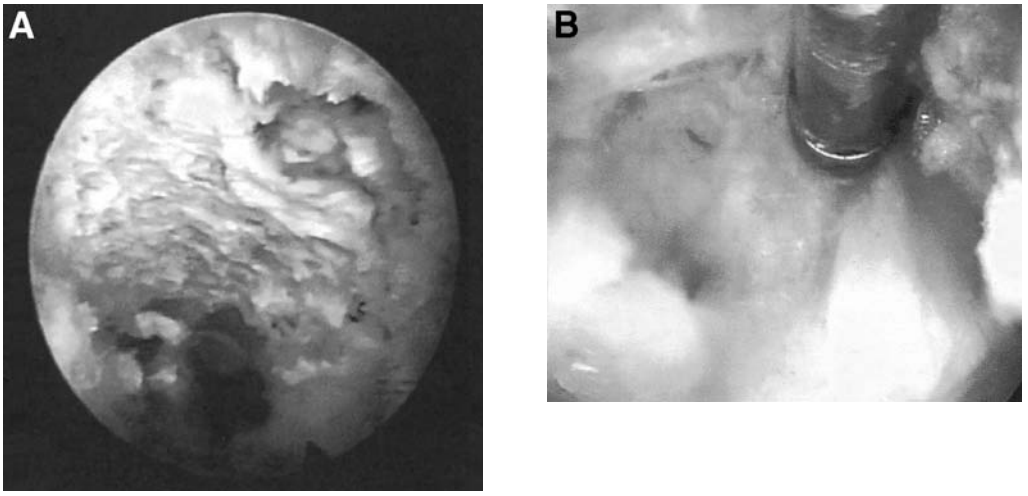

Fig. 10. (A) Postoperative endoscopic view of foraminoplasty of superior articular facet at L5-S1; **(B)** postoperative view of decompressed exiting nerve after foraminoplasty.

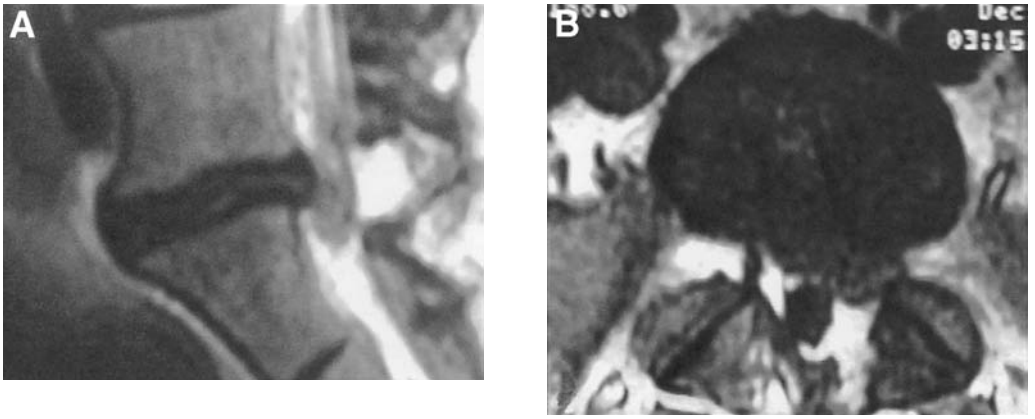

Fig. 11. (A) Chymopapain-assisted selective endoscopic discectomy. **(B)** Preoperative MRI of extruded fragment in horizontal disc at L5-S1 that is anatomically difficult to reach. By using chymopapain, the results of endoscopic removal have been demonstrated to be improved by 10% overall, by reducing the rate of residual HNP or recurrent HNP.

now do not find it necessary to test routinely for antibodies to chymopapain with the Chymofast test unless the patient requests it (Figs. 11–13).

NEUROMONITORING

In 100 consecutive cases, I studied neuromonitoring to determine whether sensory/motor complications could be reduced. I specifically studied whether neuromonitoring by continuous electromyogram (EMG) or somatosensory evoked potentials (SSEP) would affect the incidence of dysesthesia or help predict decompression of the nerve *(39)*. Although an increase in conduction velocity was identified when a mechanically compromised nerve was decompressed, I concluded that neuromonitoring was no more effective than monitoring the patient for intraoperative pain when a dilute solution of lidocaine (0.5%) was used. There was no difference in the dysesthesia or complication rate of the 100 cases vs a

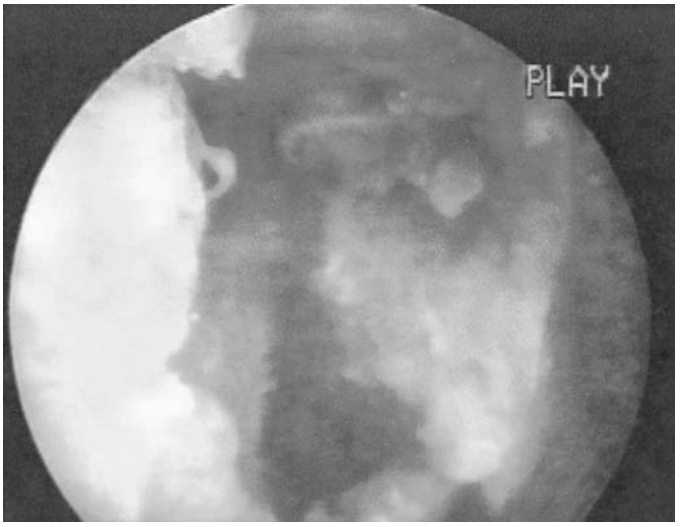

Fig. 12. An extruded fragment labeled by indigocarmine and pretreated by chymopapain allowed for easier manual extraction. The chymopapain loosened the fragment, making it easier to remove, aided by suction on the working channel of an endoscope.

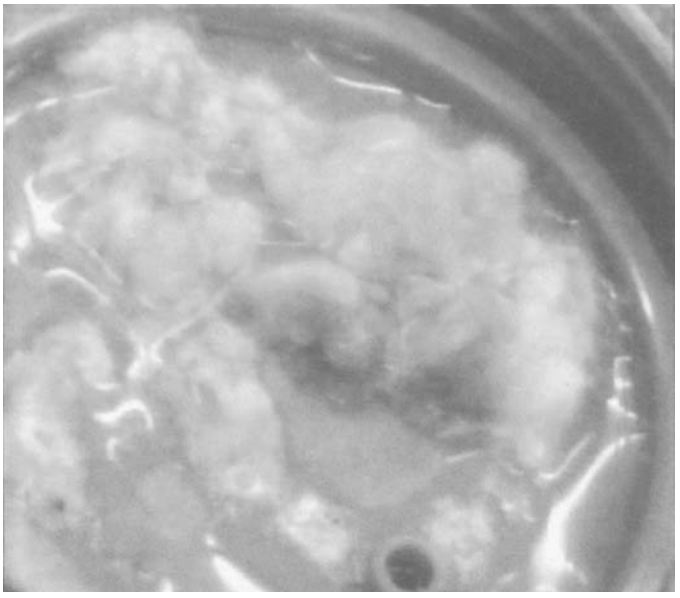

Fig. 13. Chymopapain-treated NP. Note the differential staining of the extracted nuclear material. Unstained collagenized disc was extracted from the epidural space where the indigocarmine dye did not reach. By visualizing the decompressed foramen, successful relief of leg pain was immediate postoperatively.

matched number of patients who had no neuromonitoring. Although neuromonitoring may give the novice surgeon a greater sense of security early in his or her endoscopic practice, analysis of the results of the prospective study of 100 consecutive patients did not shown

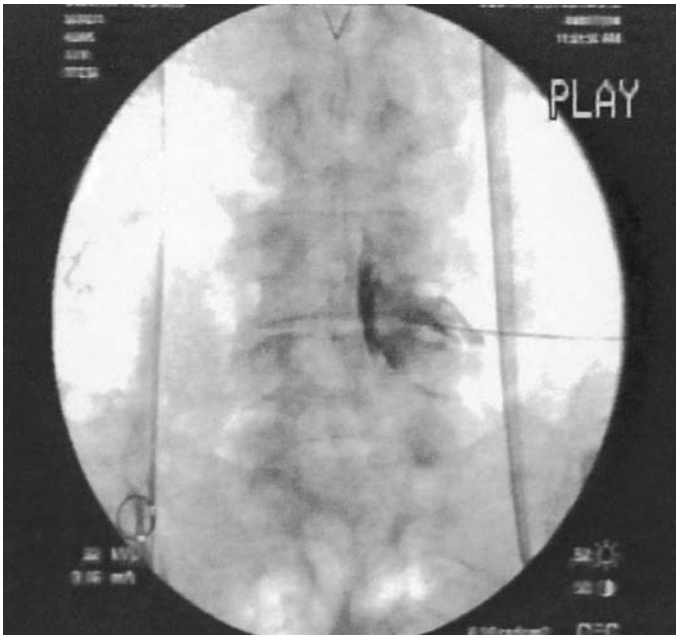

Fig. 14. Foraminal epidurograms. Foraminoepidurography is a new technique for foraminal needle placement from the far-lateral skin portal mimicking surgical access to the epidural space that allows the surgeon to produce an epidurogram that complements the MRI by outlining the position of the traversing and exiting nerves in the foramen. This information provides the surgeon with additional information preoperatively and serves as a "practice run" for surgery.

neuromonitoring to be any more useful for avoiding complications than patient feedback on pain during the procedure.

FORAMINOGRAPHY AND THERAPEUTIC INJECTIONS

The efficacy of endoscopic lumbar disc surgery can be enhanced by surgeons performing than own discography and foraminal injections. Foraminal epidurography and foraminal therapeutic injections are correlated with identification of pathoanatomy in the lumbar spine (Figs. 14–17). Surgeons use information gleaned from these injection procedures to better select patients for surgical interventional techniques that the they have incorporated into their endoscopic surgical practice. Patients with disc protrusions, annular tears, and foraminal stenosis may get temporary relief with the therapeutic injection, but if the response is short-lived, additional information gathered by performing the epiduralgram will help guide surgeons when they must consider the technical feasibility of using the same or similar portal for the insertion of the operating cannulas. By performing epidurograms, surgeons can obtain additional information of the anatomy of the foramen, the outline of the traversing and exiting nerves, and the therapeutic response afforded by the epidural injection *(37)*. Injection at L5-S1 will also help surgeons with preoperative planning if surgery is eventually required.

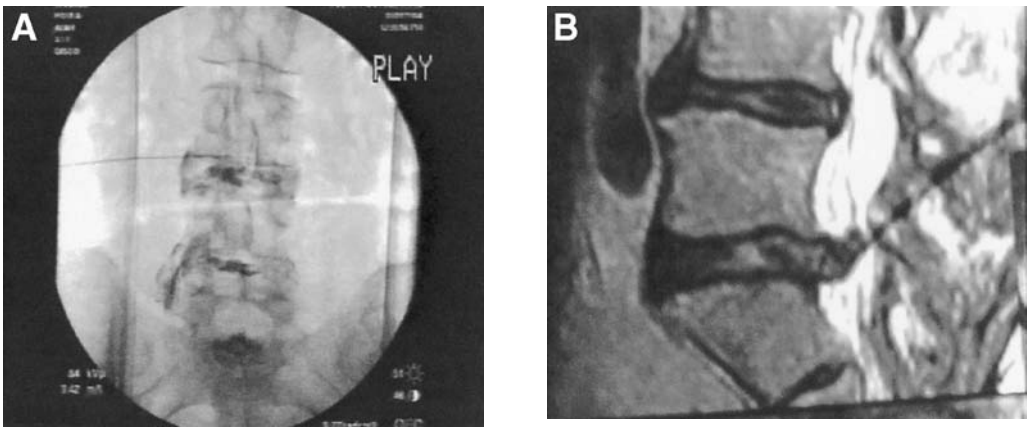

Fig. 15. **(A)** Anatomical limitations at L5-S1. The narrow pelvis in this patient limited access to the disc, but it was still possible to insert a needle into the disc for discography. Depending on the type of disc protrusion, the endoscopic surgeon will have a better idea about the prognosis of the surgical procedure contemplated. If this patient had an extruded disc herniation, it would be better to opt for the transcanal approach. **(B)** Horizontal L5-S1 disc. The pelvis becomes an even greater obstacle at L5-S1 if the disc is horizontal, which makes it much more difficult to get into the epidural space. Removal of the lateral facet could overcome this obstacle. Good preoperative planning is enhanced by foraminoepidurography.

PRESENT APPLICATIONS AND FUTURE TRENDS

Indications

Any pathological lesion that is accessible, is visible, is treatable, or requires endoscopic confirmation through the foramen may ultimately become an indication for diagnostic and therapeutic endoscopy. Patient selection for pain and radiculopathy from disc herniation is similar to selection criteria for traditional spine procedures. Endoscopic surgical indications, however, 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 spine surgery. At L5-S1, anatomical restrictions may cause the surgeon to opt for the posterior transcanal approach (Fig. 15A,B). For herniations from T10 to L4, the foraminal approach provides excellent access to the disc and epidural space. As the experience of the surgeon increases, previous contraindications become relative, depending partly on the surgeon's ability to endoscopically visualize, probe, and access the pathological lesion. Restrictions are dictated only by anatomical considerations in accessing the patient's spinal pathology and the rationale for the endoscopic procedure itself. As the surgeon's experience increases, former contraindications become relative, depending on the surgeon's experience, and his or her ability to address the spinal condition to be treated. The three zones within reach of the spine endoscope transforaminally are illustrated in Fig. 16.

Inclusion Criteria

Discogenic pain as determined by evocative discography implicates the disc as a pain generator. Symptomatic disc herniation is the obvious indication, limited only by the accessibility of endoscopic instruments to the herniated fragment. The ideal lesion

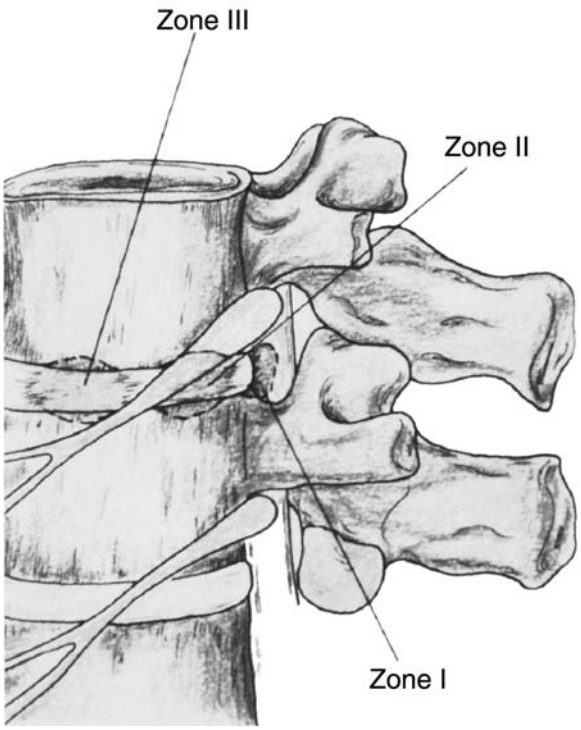

Fig. 16. Three zones on foramen accessible by endoscope. Zones II and III are not usually visualized by surgeons using the transcanal approach unless they are experienced in the paramedical approach to the lateral recess.

for endoscopic discectomy is a far-lateral, extraforaminal disc herniation. Traditional approaches to far-lateral disc herniations are more difficult, requiring a paramedian incision through very vascular tissue. The exiting nerve and the DRG are at risk of neuropraxia in both approaches *(28,29)*. Although a traditional spine surgeon can access the lateral zone of the disc with a paramedian incision, it is easier to access the extraforaminal zone through the foramen. A typical foraminal view of NP extruded past the posterior annulus is shown in (Fig. 17). Through this approach to the disc, endoscopic excisional biopsy and disc space debridement are also ideal for surgically debriding infectious discitis (Fig. 18). Currently treated with immobilization and parenteral antibiotics, discitis is much more effectively treated when augmented by endoscopic excisional biopsy and debridement. The surgeon will not have to be overly concerned about creating dead space for the inflamed or infected disc material to spread into the dead space created by a posterior approach. 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.

Foraminal stenosis in selected patients will respond to foraminoplasty by endoscopic techniques. Lateral recess stenosis is one cause of FBSS that can absolutely be diagnosed and treated by foraminal decompression *(40)*. The pathoanatomical finding may be osteophytosis tethering the exiting nerve at the superior vertebral end plate and/or

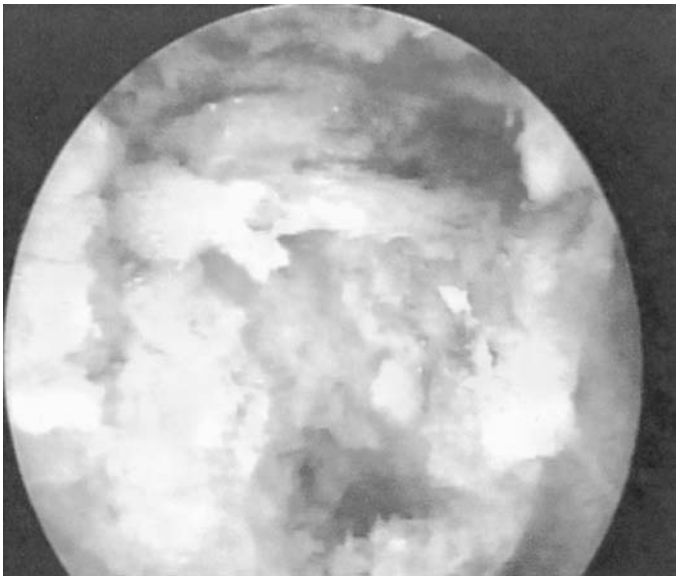

Fig. 17. Foraminal view of HNP. The indigocarmine-stained disc tissue has extruded past the posterior longitudinal ligament in this foraminal HNP at L4-L5.

Fig. 18. Discitis. Intradiscal view of discitis after 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.

stenosis and lack of fat around the exiting nerve (Fig. 19). Although trephines, rasps, and burrs can be used, the Ho:YAG side-firing laser is feasible as a visually controlled soft-tissue and bone ablation device. The cannula chosen for this task has an open side channel that will protect the exiting nerve while the laser is used to dissect the tethering

Fig. 19. Dissecting exiting nerve. In lateral recess stenosis, the scarred exiting nerve is released with a bare laser fiber. This picture demonstrates lateral recess stenosis as the most common cause of FBSS.

osteophyte and scar tissue from the nerve. Endoscopic foraminoplasty has not been shown to cause increased instability even in spondylolisthesis. When mild degenerative spondylolisthesis is present, the disc bulge can be successfully treated by selective discectomy and thermal annuloplasty when there is a sciatic component to the patient's complaint. The technique is most useful for lateral recess stenosis, a condition 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 spondylolisthesis, when there is more leg than back pain, this is usually owing to impingement on the exiting nerve by the pseudoarthrosis at the pars defect. The goal is then to decompress the compromised exiting nerve by elevating the dome formed by the inferior facet and lamina without further destabilizing the spinal segment.

Exclusion Criteria

Except for pregnancy, there are no absolute exclusion criteria, only relative contraindications depending on the skill and experience of the surgeon. Spinal endoscopy and spinal probing can be used for diagnostic purposes in extremely difficult or confusing clinical situations. 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. 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

The spine scope will eventually be used for any condition for which visual inspection of the foramen is desired. I have used spinal endoscopy for the following reasons: to inspect a spinal nerve that is suspected of being 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 MRI. In single- and multilevel discogenic pain, for which the patient has no viable options, endoscopic discectomy and thermal annuloplasty have been successful for treating chronic lumbar discogenic pain. A minority of patients may continue to have significant back pain, and a few may feel worse, but in the context of a progressive degenerative condition, the results are encouraging and will give most patients relief while awaiting the development of newer procedures such as nucleus replacement, total disc replacement, and minimally invasive stabilization procedures of the posterior spinal column.

Current Imaging Methods

In my experience, imaging studies are only about 70% accurate and specific for predicting pain. Conditions such as lateral annular tears, rim tears, end-plate separation, small subligamentous disc herniations, intranuclear herniations, anomalous nerves, and miscellaneous discogenic conditions are cumulatively missed approx 30% of the time. These conditions can be diagnosed by means of spinal endoscopy. Tears that are in the lateral and anterior aspect of the disc are routinely missed on MRI studies. 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 bulging annulus, but really containing a subligamentous herniation. When the nerve root is "swollen" or enlarged, MRI is not always capable of distinguishing it 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 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.

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 anatomical area.

Technique

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 toward the center of the disc (Fig. 20). Reference points are the anatomical 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 anatomical considerations and the pathology to be accessed.

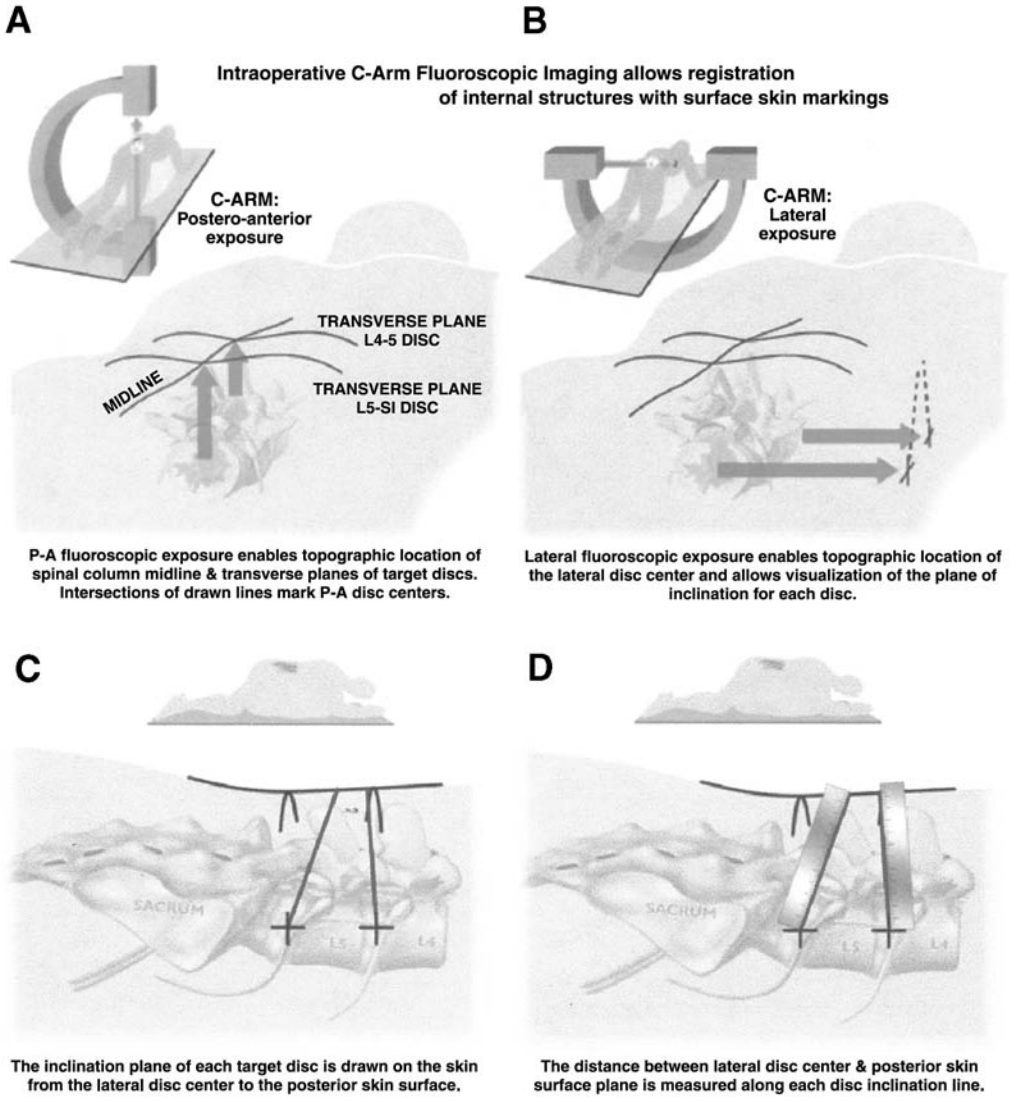

Fig. 20. YESS technique determination of optimal instrument path using the Yeung instrumentation trajectory protocol. Interoperative C-arm fluoroscopic imaging allows registration of internal structures with surface skin markings. **(A)** Posteroanterior fluoroscopic exposure enables topographic location of spinal column midline and transverse planes of target discs. Intersections of the drawn lines mark posteroanterior disc centers. **(B)** Lateral fluoroscopic exposure enables topographic location of the lateral disc center and allows visualization of the plane of inclination for each disc. **(C)** The inclination plane of each target disc is drawn on the skin from the lateral disc center to the posterior skin surface. **(D)** The distance between the lateral disc center and the posterior skin surface plane is measured along each disc inclination line. **(E,F)** This distance is then measured from the midline along the respective transverse plane line for each disc. At the end of this measure, a line parallel to midline is drawn to intersect each disc inclination line. This intersection marks the skin entry point of "skin window" for each target disc. Needle insertion at this point toward the target disc at an angle of 25–30° to the surface skin plane will determine the path of all subsequent instrumentation.

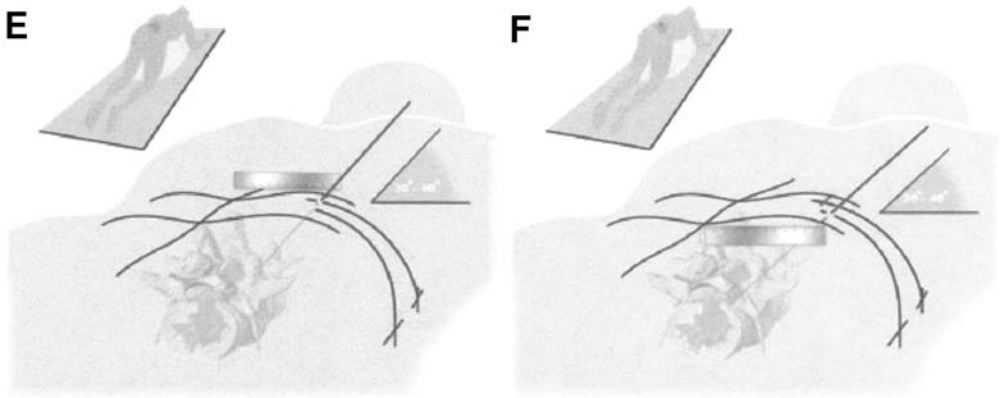

Fig. 20. *(Continued)*

Once the optimal trajectory is established, the cannulas are inserted to allow for endoscopic surgery under direct visualization.

Endoscopic spine surgery has a very 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 it may vary according to the skill and experience of each surgeon. The endoscopic technique, because of its approach, may pose additional risk for iatrogenic injury, but it is possibly safer than traditional surgery because the patient is awake and able to provide immediate input to the surgeon when pain is generated. Those surgeons who can master the technique to the extent that they prefer endoscopic surgery over traditional surgery for the same condition will have the ability to perform the surgery without causing the patient undue pain. 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.

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 diminish 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 spine 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 clinicians view and approach patients with back pain, especially when endoscopic spine surgery is further validated with outcome studies and becomes routinely available.

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