Advances in Endoscopic Disc and Spine Surgery: Foraminal Approach

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ABSTRACT

Endoscopic spine surgery is evolving rapidly due to improvements in surgical technique, endoscope design, and instrumentation. The current technique expands on the basic features and principles of Kambin's access to the spine through the triangular zone. A standardized method for foraminal surgery, the Yeung Endoscopic Spine System (YESS)™ (Richard Wolf Surgical Instrument Company, Vernon Hills, Illinois, USA) technique is proposed: (1) A protocol for optimal instrument placement by identifying the skin window, annular window, anatomic disc center, and disc inclination plane through topographical coordinates calculated by lines drawn on the skin from the C-Arm image. Adjustments in the trajectory are made to accommodate individual anatomic considerations and the pathologic disorders to be accessed. (2) Evocative Chromo-Discography™ (Richard Wolf Surgical Instrument Company, Vernon Hills, Illinois, USA). (3) Selective Endoscopic Discectomy™ (Richard Wolf Surgical Instrument Company, Vernon Hills, Illinois, USA). (4) Thermal discoplasty and annuloplasty. (5) Endoscopic foraminoplasty. (6) Accessing the epidural space in the axilla between the traversing and exiting nerve root. (7) Partially resecting the posterior annulus to get beneath the herniated fragment, if needed.

This technique allows access to the epidural space from the lumbar disc as far cephalad as the middle of the vertebral body or approximately 2-3 mm caudally. The foraminal approach is routinely accessible from T-10 to L4-5. L5-S1 can be accessed with special techniques that include foraminoplasty of the lateral facet. Surgical results continue to improve, consistent with refinement of indications and techniques for specific conditions treatable by this endoscopic method.

INTRODUCTION

Wolfgang Rauschning's work illustrating the patho-anatomy of degenerative disc disease and degenerative conditions of the lumbar spine serves as a basis for treating pathologic findings with tissue-sparing, minimally invasive spine surgery.[1] Ideally, surgical interventional approaches and surgical instruments should preserve normal anatomy and access the patho-anatomy without injuring normal tissue. Traditionally, decompressive surgery of the lumbar spine is for surgery of herniated lumbar discs. Many disc herniations, however, are not the result of an acute event, but an accumulation of several insults to the spine that lead to degeneration, annular tears, and eventual disc herniation. Advances of endoscopic surgery offer surgeons the opportunity to visualize and probe the pathologic lesions that may cause pain as a prodromal symptom that progresses eventually to a full-blown herniation. Several theories exist regarding disc degeneration, which include mechanical, chemical, age-related, autoimmune, and genetic. Within the mechanical theory, the following types of abnormal loads have been proven experimentally to cause disc injury: torsion, compression, repetitive compressive loading in flexion, hyperflexion, and vibration.[2]

Traditionally, disc surgery has been reserved for disc herniations causing radiculopathy or nerve deficits due to mechanical compression on the spinal nerves. This relatively conservative surgical indication was due to the inherent morbidity of the posterior surgical approach that must violate and alter the important function of the muscles and facets of the posterior spinal column. Morbidity of the standard posterior approach has, therefore, limited the use of surgery as an early treatment option in the cascade of disc degeneration and herniation. Thus, surgery was often not recommended for herniations without neurologic deficits, "small" herniations, central herniations, and annular tears. The dogma that, "disc surgery is really decompressive nerve surgery," dominates the rationale for traditional microdiscectomy for herniated discs.

Minimally invasive surgical options that limit the inherent approach-related morbidity are possible with the endoscopic foraminal portal. This approach to the disc, most difficult at L5-S1, may require reverting to the posterior transcanal portal, but is generally accessible with advanced techniques involving foraminal decompression of the lateral facet. As long as a needle can reach the foramen and disc annulus, access to the disc is routinely possible. The foraminal approach provides excellent cannula access from T-10 to L-5 to foraminal structures illustrated in a cadaver dissection of the foramen (Fig. 1).

Introduction of the operating microscope for discectomy by Yasargil in 1967 encouraged smaller incisions for the standard posterior approach.[3] The trans-

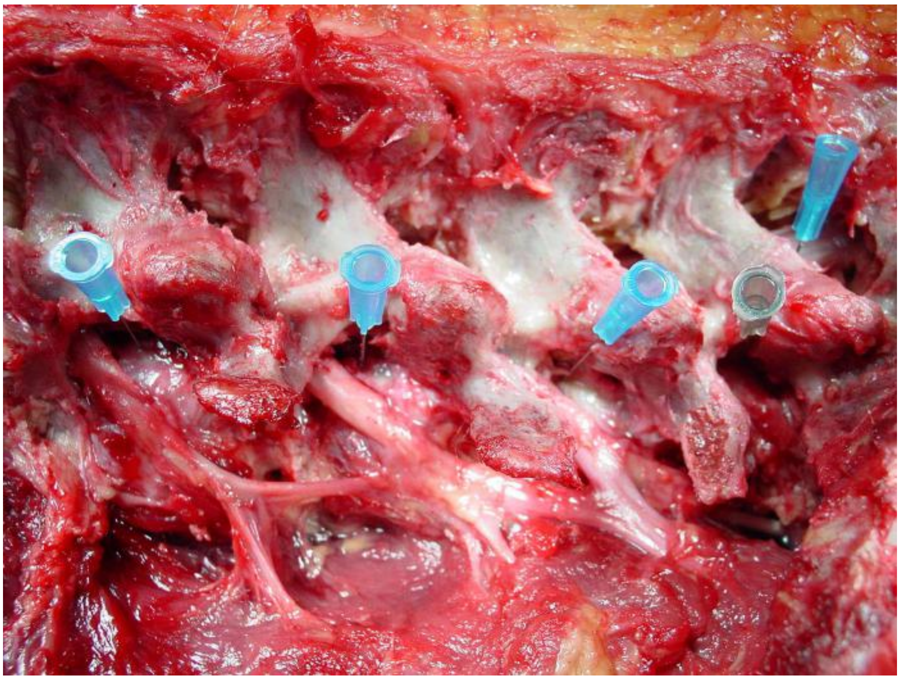

Figure 1. Cadaver dissection of the foramen from L2-S1 demonstrates excellent access to the posterolateral portion of the disc through Kambin's triangular zone. Blue hubbed needles represent ideal placement of the endoscope into the disc. At L-5, S-1, less room is present in the foramen, and a lateral facetectomy may be necessary if a high and narrow Ilium is present. Note the more cephalad the disc, the larger the foraminal portal.

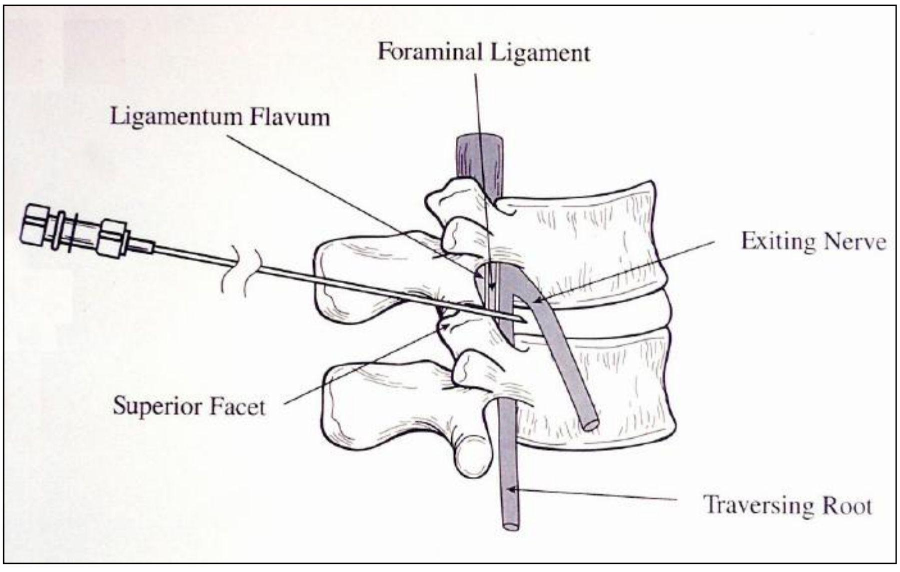

Figure 2. Kambin's Triangle is the site of surgical access for posterolateral endoscopic discectomy. It is defined as a right triangle over the dorsolateral disc. The hypotenuse is the exiting nerve, the base (width) is the superior border of the caudal vertebra, and the height is the traversing nerve root. Kambin initially emphasized avoiding the spinal canal and staying within the confines of the triangular zone.

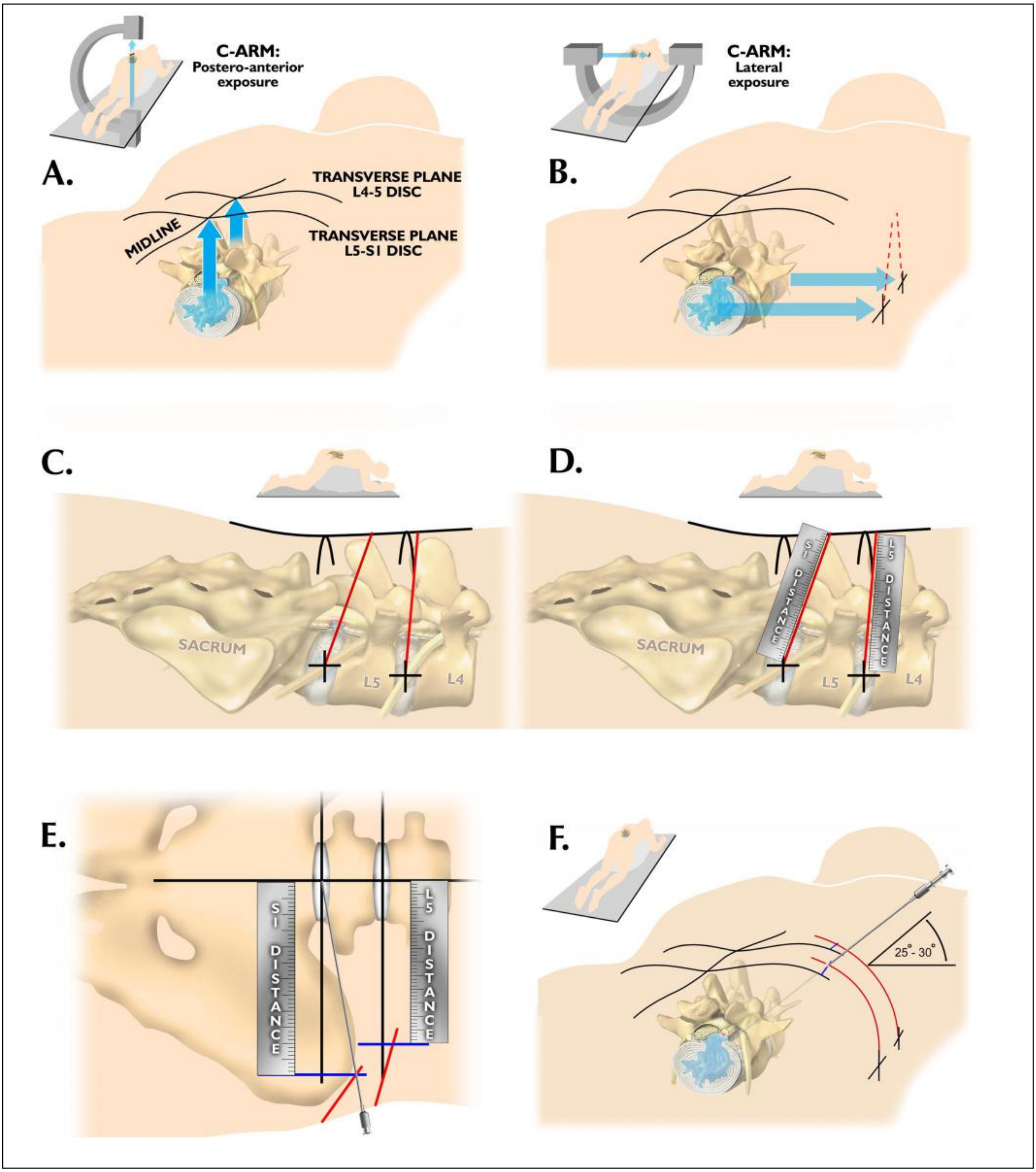

Figure 3. Yeung Protocol for Needle and Instrument placement.

A. P-A fluoroscopic exposure enables topographic location of spinal column midline & transverse planes of target discs. Intersections of drawn lines mark P-A 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 lateral disc center & 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 measurement, a line parallel to midline (black horizontal line) is drawn to intersect each *disc inclination line.* This intersection marks the skin entry point or "skin window" for each target disc. Needle insertion at this point toward the disc is angled approximately 25°-30° to enter the disc at the dorsal quadrant, traversing just under the superior facet of the inferior vertebra to get as dorsal and close to the posterior annulus as possible.

canal microscope-assisted technique became the 'gold standard'; however, it requires retraction of the nerve, periosteal stripping of the muscle and ligaments, hemilaminotomy, and regional or general anesthesia.

The purpose of this article is to present advances in endoscopic technique and equipment that showcase the foraminal endoscopic approach to the spine as a minimally invasive, tissue-sparing alternative to traditional posterior transcanal surgery.

ENDOSCOPIC FORAMINAL APPROACH TO THE LUMBAR DISC (YESS™ TECHNIQUE)

Current techniques in endoscopic surgery were developed from percutaneous procedures that used access cannulas initially, with modified instruments designed for disc removal. Kambin and Hijikata and colleagues were credited jointly with introducing and developing the endoscopic technique through the triangular zone (Fig. 2).[4,5] Both surgeon groups used an arthroscope to inspect the disc and annulus intermittently through the cannula. The actual discectomy was performed under fluoroscopic guidance by placing the grasping forceps down the working cannula after the endoscope was removed. The disc and surrounding structures were checked intermittently during the procedure by placing the endoscope down the cannula. The first opportunity to visualize while working in the disc was made possible with the advent of the biportal technique. This technique allowed for direct visualization of instruments introduced through a cannula inserted into the disc from the opposite posterolateral portal.

The later development of an operating spine scope with a working channel and introduction of beveled and slotted cannulas subsequently allowed for direct visualization of the surgical removal of disc material and foraminal decompression (foraminoplasty) by way of a uniportal approach. Although Kambin had a prototype working channel endoscope, Yeung developed the first working channel rod lens endoscope to become widely available commercially.[6] The scope was developed in 1997 and approved for use by the Federal Drug Administration (FDA) in March of 1998. The Yeung Endoscopic Spine Surgery (YESS™) system (Richard Wolf Surgical Instruments Company, Vernon Hills, Illinois, USA) included a working channel spine endoscope, specialized beveled and slotted cannulas, a two-hole introducing obturator, integrated multi-channel irrigation, and newly designed discectomy tools. Together, these modifications have allowed for constant real-time direct visualization of surgical discectomy and foraminoplasty with a uniportal technique.

Another major change, which allowed for advancement in the field of endoscopic spinal surgery, was the emphasis on placement of the cannula closer to the epidural space and base of the targeted disc herniation. Previous percutaneous modalities all focused on entry through Kambin's triangle, avoiding the spinal canal, and working within the nucleus pulposus with the cannula anchored in the disc annulus. The cannula was later advanced past the annulus and remained there under fluoroscopic control.

Yeung further proposed a method of needle and instrument placement that helped standardize the technique for precise placement of the cannula in the disc for extraction of disc herniations (Fig. 3).[6-9] He developed a method of measurement from the posterior-anterior and lateral C-arm image that helped determine the starting point on the skin, known as the skin window. As the cannula is advanced to the annulus, the fenestration through the annulus is the annular window and the trajectory angle is then calculated in reference to the anatomic disc center.

In 1996, Matthews described a transforaminal approach for microdiscectomy (Fig. 4).[10] This approach allowed for routine visualization of the epidural space, and greater access to the traversing nerve. His dependence on a disposable fiber optic scope, however, limited surgeon acceptance due to the relatively poor visibility compared with a microscope and the steep learning curve.

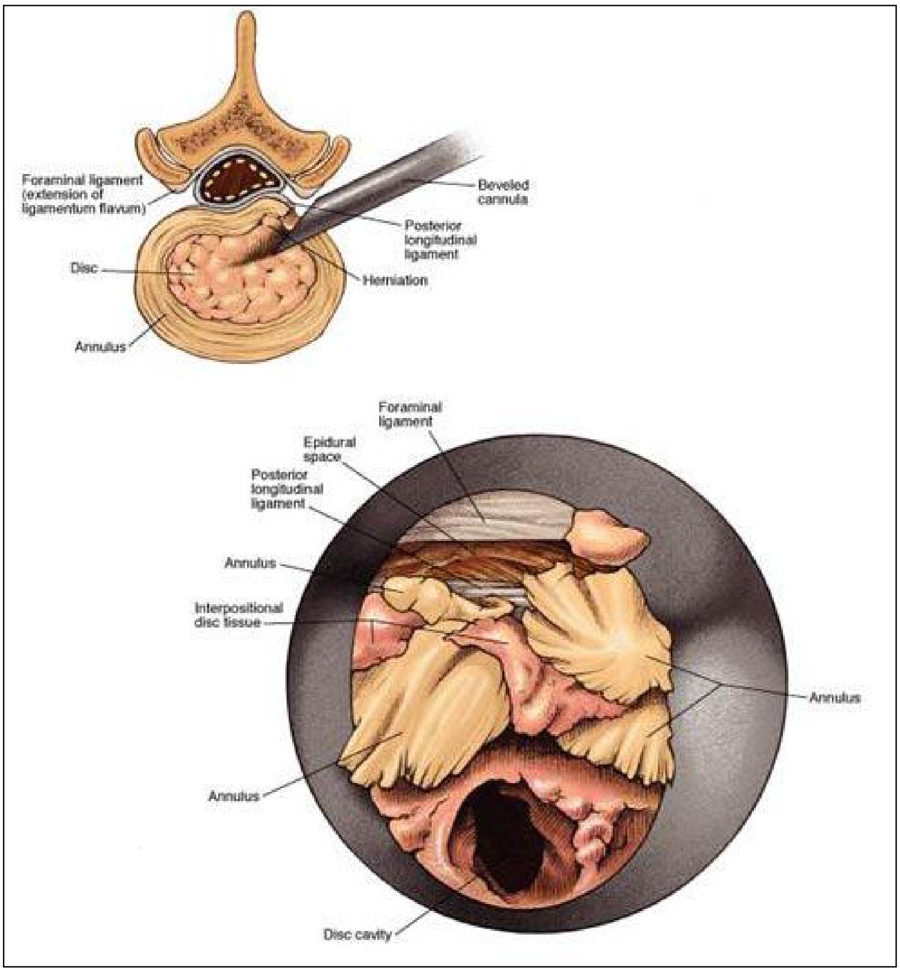

Figure 4. The Foraminal Portal. Matthews and Yeung simultaneously advocated using Kambin's posterolateral approach to target the base of the disc herniation closer to the dura/traversing nerve root. Matthews first described the foraminal ligament as the "door" to the foramen. This approach advocated a more horizontal trajectory to the disc and visualization of the epidural space. *(Illustration by David Baker)*

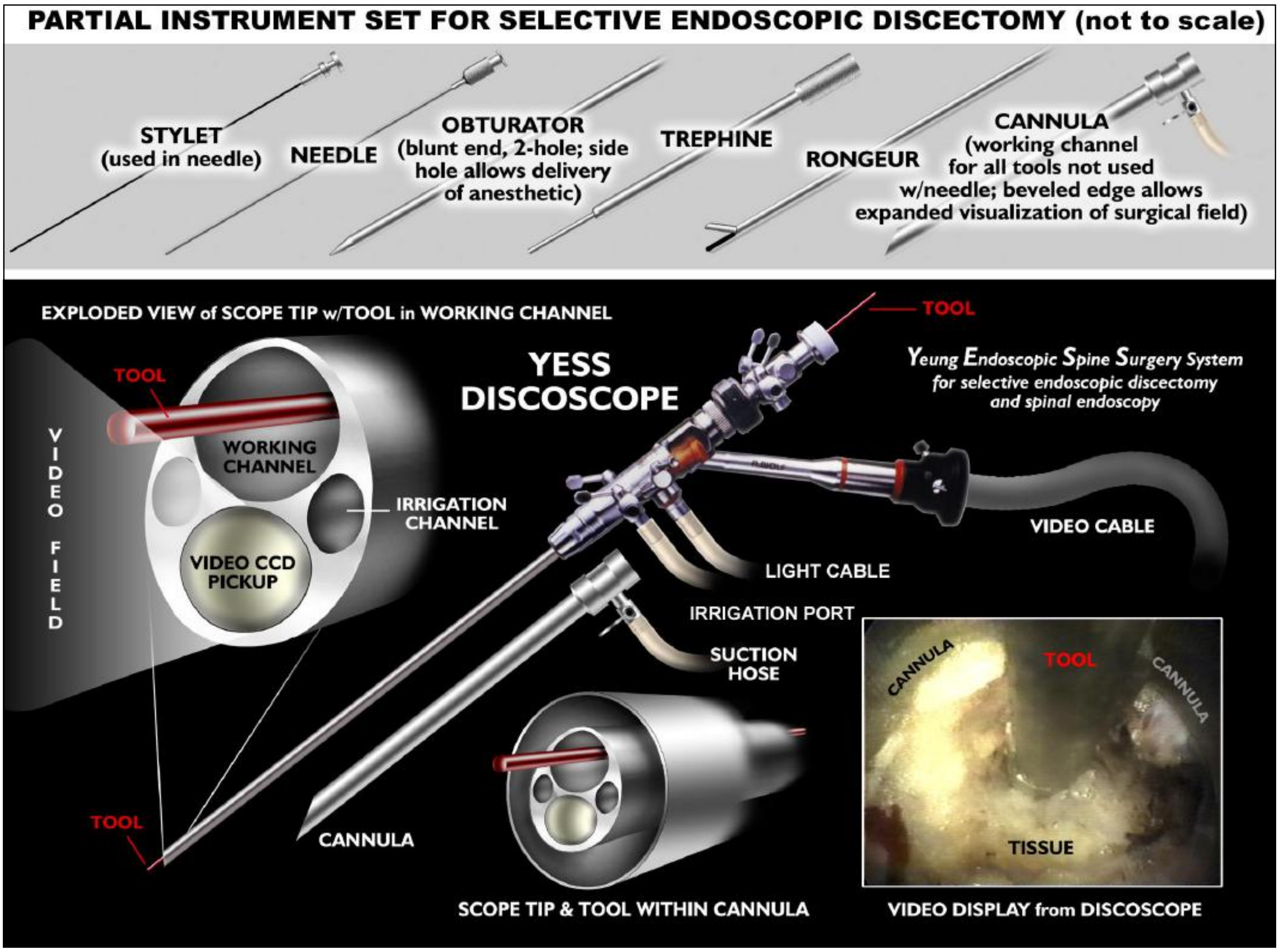

Figure 5. The YESS™ endoscope features multi-channel irrigation and a 2.8-mm working channel. Complementary access cannulas and instruments improved visualization of the epidural space and the foramen. ***(Illustration by David Azarello)***

The development of a rod-lens working channel scope (Fig. 5), and use of the transforaminal approach by way of beveled and slotted cannulas, changed the practice of endoscopic lumbar surgery. The specialized cannulas provided greater access to pathologic lesions, and served to protect sensitive anatomy such as the exiting nerve and sensitive dorsal root ganglion. The cannulas provided significant visual improvement and allowed for same-field viewing of the epidural space, annular wall, and intradiscal space. The design also allowed for rotation of the cannula to protect the neural structures while accessing the pathologic findings during the operation. The working channel in the endoscope allowed for targeted Selective Endoscopic Discectomy™ (Richard Wolf Surgical Instrument Company, Vernon Hills, Illinois, USA) under direct visualization while viewing the anatomic relationships to the epidural space, annulus, and intradiscal cavity (Fig. 6).

Yeung and Tsou reported their initial results using the YESS™ system in their first 307 patients with disc herniations who were candidates for transcanal microdiscectomy.[7] The study included intracanal and extracanal herniations. Recurrent herniations and patients with previous surgery at the same level were not excluded. Results were reported after a 1-year follow up. Ninety-one percent of the patients were satisfied with their results and would opt to undergo the procedure again if they had the same diagnosis and symptoms. The overall complication rate was reported to be 4%.

Tsou and Yeung separated out a subgroup of 219 patients with non-contained herniations and reported the results at 1 year.[8] Patient satisfaction was 91%. These initial results showed that endoscopic surgery could provide equivalent results to reported results of open microdiscectomy, even with noncontained herniations. In a review of his first 500 patients, Yeung reported an 86% good/excellent outcome with modified MacNab criteria for transforaminal percutaneous discectomy for a global group of patients with a variety of disc herniations and discogenic back pain who opted for endoscopic spine surgery over the traditional approach .[9]

Two prospective randomized studies were published that compared traditional microdiscectomy and percutaneous endoscopic discectomy in a group with more restricted selection criteria. Hermantin and colleagues performed a prospective randomized study with 30 patients in each group.[11] The mean duration of follow up was 31 months. Patient satisfaction was 93% in the open surgical group and 97% in the endoscopic group. The endoscopic group had shorter duration of narcotic

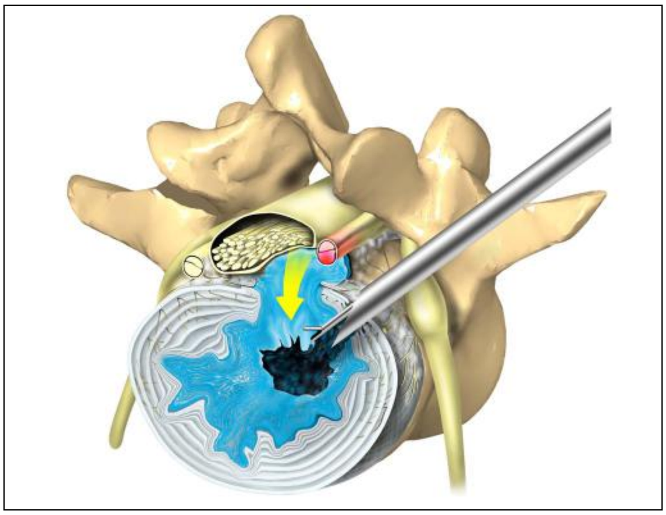

Figure 6. Uniportal technique for selective endoscopic discectomy. Small pituitary rongeurs are used for visualized posterior fragmentectomy. The beveled cannula can be positioned to view the epidural space, annular wall, nucleus pulposus, and intradiscal cavity in the same field of vision. The cannula can be rotated to provide surgical access, but at the same time used to protect the exiting nerve. *(Illustration by David Azarello and Chris Yeung)*

Figure 7a. Ellman Trigger-Flex Bipolar Probe™ performing thermal discoplasty/annuloplasty. 4.0 MHz frequency shrinks the annulus and ablates inflammatory tissue effectively.

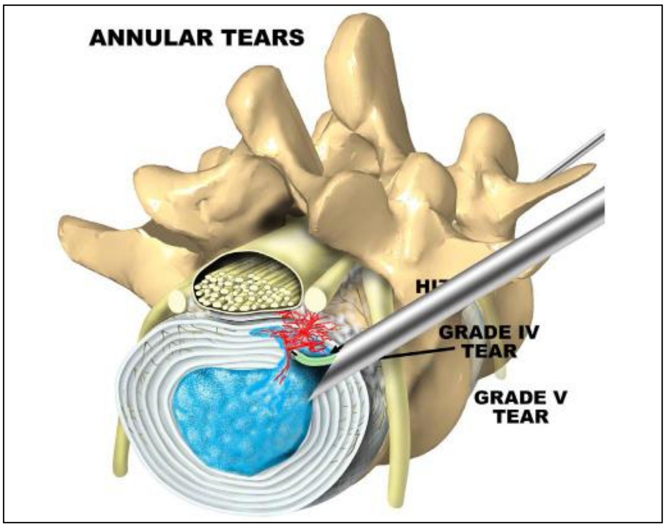

Figure 7b. Illustration of the annuloplasty technique with the Ellman Trigger-Flex Bipolar Probe™. An evocative discogram is first performed with a vital dye to stain the degenerative nucleus. Endoscopic discectomy is then performed, removing the degenerative disc material next to the annular tear. Under direct vision, the tear is treated thermally with the bipolar radiofrequency probe. Granulation tissue in the annulus is observed frequently. *(Illustration by David Azarello and Chris Yeung)*

use and shorter time of work loss compared with the open discectomy. This prospective study led the authors to conclude that arthroscopic discectomy was useful in treatment of herniated discs for surgeons who had received training in this technique.

Mayer and Brock also demonstrated promising results in a prospective randomized study comparing percutaneous discectomy with microscopic discectomy for contained or small subligamentous herniations.[12] The percutaneous group showed comparable or superior results. Long-term disability defined by return to work status produced statistically significant differences. In the percutaneous group, 95% returned to their previous occupation compared to 72% in the microdiscectomy group. Each group had 20 subjects.

The ability to remove pathology effectively using endoscopic surgery also been validated by post-procedure imaging studies.

INDICATIONS FOR FORAMINAL ENDOSCOPIC SURGERY

Most disc herniations are amenable to endoscopic disc excision, and the timing of surgical treatment is similar to transcanal discectomy. The size and types of herniations chosen by the surgeon for endoscopic excision depend on skill and experience of the surgeon, as well as anatomic considerations in the patient relative to location of the herniation. All contained disc herniations are appropriate for endoscopic decompression. The tissue-sparing approach also offers consideration for earlier surgical timing when approach-related risk/benefit ratios are factored in after patients fail conservative treatment and continue to have debilitating pain without neurologic deficit. Quality-of-life and functional issues associated with chronic discogenic pain can provide the patient a minimally invasive surgical option. Therefore, small disc herniations with predominant leg pain, central disc herniations with predominant back pain, and annular tears that cause chemical sciatica are amenable to disc surgery by endoscopic means. Tsou and Yeung have reported on Selective Endoscopic Discectomy™ with visualized thermal discoplasty and annuloplasty.[12] Annular tears demonstrated in the process of Selective Endoscopic Discectomy™ for disc herniations have been shown to contract and shrink when a 4.0 MHz bipolar flexible radiofrequency probe (Ellman Trigger-Flex Bipolar System™, Ellman Innovations, Hewlett, New York, USA) is activated next to the annular defect. Inflammatory tissue will ablate and disc tissue will contract on contact. This endoscopic method of treating discogenic back pain from annular tears has shown promising results in relieving chronic lumbar discogenic pain (Figs. 7a, 7b).[13]

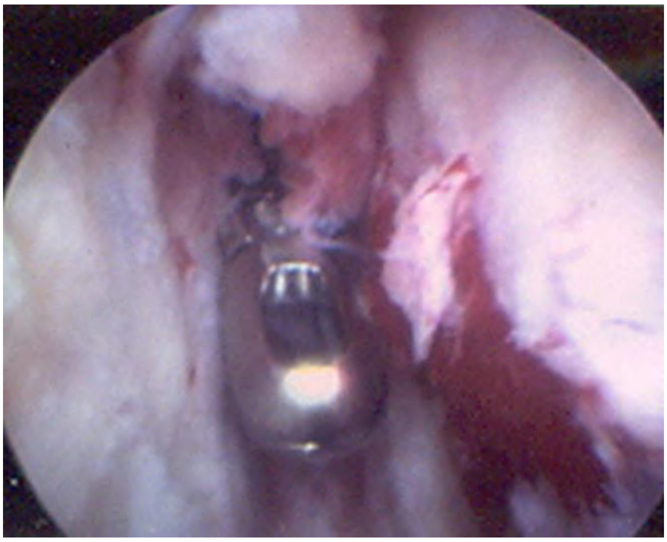

Figure 8. Endoscopic view of sterile discitis. Most discitis following Selective Endoscopic Discectomy™ is not suppurative or bacterial. Inflammatory cells are identified in the tissue specimen, but cultures are usually negative. Occasional positive cultures have only produced alpha strep, a normal skin contaminant sensitive to a wide spectrum of anti-biotics. Back pain is relieved immediately after debridement.

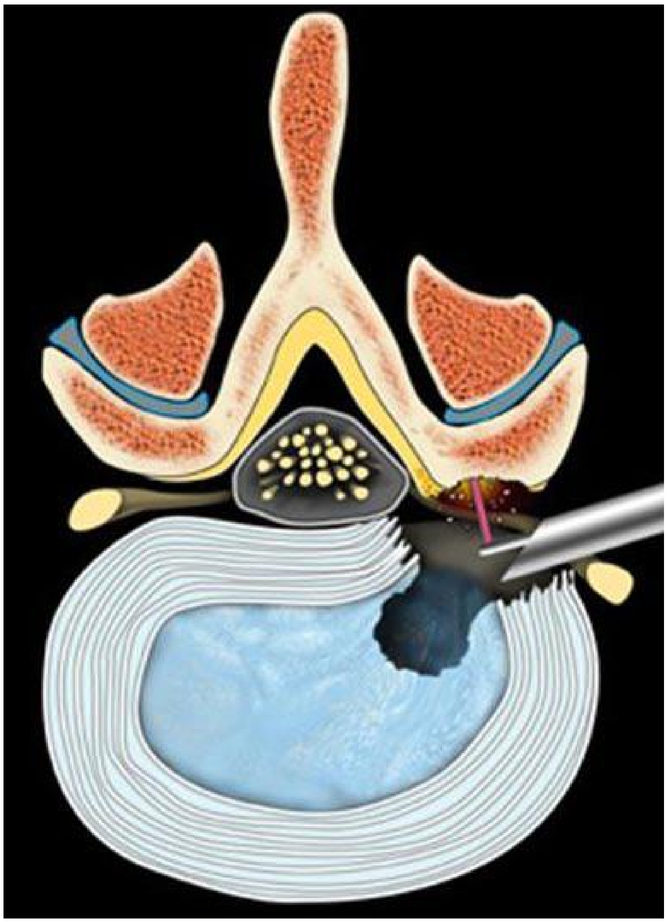

Figure 9. Foraminoplasty for central and lateral recess stenosis is accomplished by resecting the bulging annulus and resecting the undersurface of the superior articular process with cutting basket forceps and a sidefiring Ho:yag laser.

Perhaps one indication for Selective Endoscopic Discectomy™ and disc debridement is discitis.[14] This condition can occur as a postoperative infection or as a disc infection from hematogenous inoculation of micro-organisms. Severe back pain and spasm is the usual presenting symptom. Current methods rely on needle aspiration followed by prolonged antibiotic treatment. Needle aspirations are not as reliable as disc debridement with tissue sampling, and are often negative in the presence of bacterial discitis. Surgeons are hesitant to perform open debridement because of the morbidity of the open approach, creation of dead space and devascularized tissue, and concern of spreading the infection in the spinal canal. Endoscopic excisional biopsy through the posterolateral portal has provided almost immediate pain relief and a much more reliable tissue sample for laboratory analysis and culture (Fig. 8). As only tissue dilation is used, no dead space is created that would allow the infection to spread. This minimally invasive technique, under local anesthesia, also decreases the morbidity of a general anesthetic.

Perhaps the ideal lesion for Selective Endoscopic Discectomy™ is the far lateral, extraforaminal disc herniation. Although a skilled spinal surgeon can access the lateral zone of the disc with a paramedian incision, the posterior approach used by most traditional surgeons requires removal of a significant portion of the facet to reach the herniation, and manipulation of the sensitive exiting nerve root and dorsal root ganglion. Accessing the extraforaminal zone with the endoscope is easier. The exiting nerve is visualized and protected routinely, and the cannula approaches the herniation site directly.

For the skilled spinal endoscopist, diagnostic endoscopy can be used to augment or confirm traditional imaging studies. Yeung has used spinal endoscopy for diagnostic purposes; i.e., to inspect a spinal nerve suspected to be irritated by orthopedic hardware, and to inspect annular tears. Most tears that do not heal are too extensive or caused by interpositional disc tissue keeping the tear open, a finding observed when selective endoscopic discectomy was combined with a visualized thermal annuloplasty of the torn annulus in a series of patients who failed IDET treatment, but refused fusion for continued disabling discogenic back pain.[15]

Endoscopic removal of disc herniation is only limited by the accessibility of endoscopic instruments to the herniation site. Whereas many consider only contained disc herniations as an indication for endoscopic disc decompression, experienced and skilled surgeons have demonstrated the ability to extract protruded, extruded, and sequestered fragments. Even mild lateral recess and foraminal spinal stenosis in selected patients respond to foraminoplasty by endoscopic techniques.[16] The technique of decompressing the traversing and exiting nerves is accomplished by resecting the ventral surface of the superior articular process (superior facet of the inferior vertebra). In lateral recess stenosis, a simple ablation of the facet capsule and attachment of the ligamentum flavum by resecting the tip of the Superior articular process will decompress the exiting nerve. Decompression results in visualization of perineural fat around the nerve. Resection of the dorsal annulus will decompress the traversing nerve in central stenosis (Fig. 9).

In knee and shoulder arthroscopy, more detailed findings are possible with

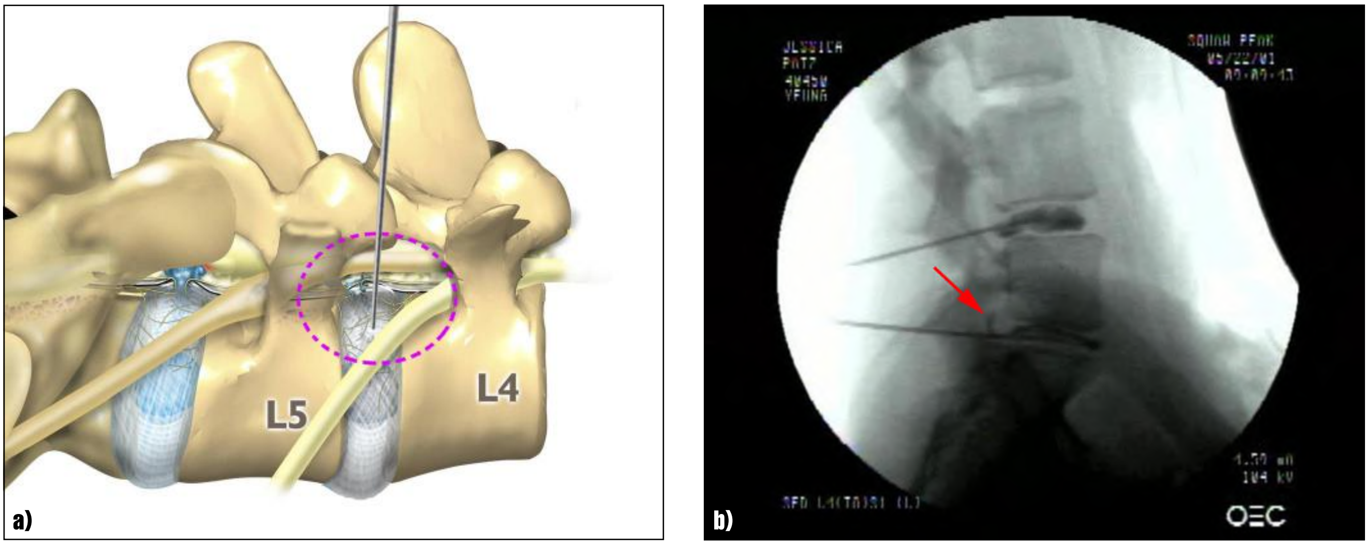

Figure 10. Evocative Chromo-Discography™ confirms the patient's concordant back pain and sciatica intraoperatively, as well as provides a discogram pattern for the surgeon to evaluate. In this illustration, when there were two abnormal levels on the MRI, the discogram outlines the disc herniation visualized as a void on the lateral discogram at L5-S1 and a bulging, soft painful disc at L4-5. Blue staining of the nucleus pulposus helps target the disc material to be extracted.

a) An extruded fragment at L5-S1 may not stain on discography if the fragment is hard and collagenized. It will appear as a void on the discogram. If the herniation is soft, the dye and contrast will show up on the discogam as a protrusion. *(Illustration by David Azarello)*

b) In this evocative chromo-discogram, both L4-5 and L5-S1 evoked concordant pain. At L4-5 the protrusion is contained and represents a soft protrusion with a grade IV annular tear. L5-S1 (arrow) shows a larger herniation of collagenized disc that will alert the surgeon that he may have to look for a large fragment in the epidural space.

arthroscopic probing and imaging of joint anatomy than magnetic resonance imaging (MRI). The same is true with spinal endoscopy.

Evocative Chromo-Discography™

In Selective Endoscopic Discectomy™, discography is used as an integral part of spinal endoscopy. Evocative Chromo-Discography™ (Richard Wolf Surgical Instrument Company, Vernon Hills, Illinois, USA) not only determines if the patient has concordant pain at the target disc, but also stains the degenerated nucleus pulposus allowing for selective discectomy of the stained tissue. The literature on discography is currently considered controversial, only because of the high inter-observer variability by discographers in reporting the patient's subjective pain, as well as the ailing patient's inability to provide a clear response—especially if pain response is altered by use of analgesics or sedation during the procedure. The surgeon accomplished in endoscopic spine surgery should do the discography himself/herself to decrease the inter-observer variability when interpreting the patient's response. When this author compares his own assessment of the patient's pain response with another discographer's report, often some variability is present in diagnosis and interpretation.[17] This variability may result in unpredictable results. False-positive discography, however, can be decreased significantly in an experienced endoscopic surgeon's hands, as the surgeon learns to correlate the patient's response to the discogram pattern of the pathology he is going to treat when the patient's response is correlated to the pain reproduced. Good correlation of the discogram is present with predicted lesions and successful treatment of the visualized condition. For example, the discogram can be used to predict the presence of a collagenized disc fragment versus a soft herniation; extrusion of a disc fragment as a non-contained herniation; or presence of the type, grade, and location of a painful versus non-painful annular tear (Figs. 10a, 10b).

POTENTIAL COMPLICATIONS AND AVOIDANCE

As with arthroscopic knee surgery, the risks of serious complications or injury are low—approximately 1% or less in the author's experience. The usual risks of infection, nerve injury, dural tears, bleeding, and scar-tissue formation are always present as with any surgery. Transient dysesthesia, the most common postoperative complaint, occurs approximately 5%-15% of the time, and is almost always transient. Its cause remains incompletely understood and may be related to nerve recovery, operating adjacent to the dorsal root ganglion of the exiting nerve, or a small hematoma adjacent to the ganglion of the exiting nerve, as it can occur days or even weeks after surgery. It cannot be avoided completely, as has occurred even when there were no adverse intraoperative events and the continuous electromyography (EMG) and somato-sensory evoked potentials (SEP) did not show any nerve irritation.[18,19] The symptoms are sometimes so minimal that most endoscopic surgeons do not report it as a "complication." The more severe dysesthetic symptoms are similar to a variant of complex regional pain syndrome, but usually less severe, and without the skin changes. Postoperative dysesthesia is treated with transforaminal epidurals, sympathetic blocks, and the off-label use of gabapentin (Neurontin®, Pfizer, Inc., New York, New York, USA) titrated to as much as 1800-3200 mg/day. Gabapentin is FDA-approved for post-herpetic neuralgia, but effective in treatment of neuropathic pain.

Avoidance of complications is enhanced by the ability to visualize normal and patho-anatomy clearly, and use of local anesthesia and conscious sedation rather than general or spinal anesthesia. The entire procedure is usually accomplished with the patient remaining comfortable during the entire procedure, and should be done without the patient feeling severe pain except when expected—such as during Evocative Chromo-Discography™, during annular fenestration, or when instruments are manipulated past the exiting nerve. Local anesthesia using .50% lidocaine permits generous use of this dilute anesthetic for pain control and allows the patient to feel pain when the nerve root is manipulated.

CONCLUSION

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 may be higher during the learning curve, and may vary with each surgeon's skills and experience. The endoscopic technique is safer, as the patient remains conscious and is able to provide immediate input to the surgeon when pain is experienced. The surgeon's ability to perform the surgery without causing the patient undue pain self-selects for surgeons who can master the technique, which may evolve to the extent the surgeon prefers endoscopic over traditional surgery for the same condition. For most contained disc herniations and discogenic pain, the experienced endoscopic spine surgeon opts for the endoscopic approach as the treatment of choice for his/her patients. **STI**

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