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Percutaneous Transforaminal Endoscopic Spine Surgery

Endoscopic spine surgery is evolving rapidly due to improvements in surgical technique, endoscope design, and instrumentation. In an experienced surgeon's hands, the endoscopic foraminal approach can be utilized for most lumbar disc herniations and for the diagnosis and treatment of degenerative conditions of the lumbar spine. The advantage of the foraminal endoscopic technique is the ability to reach, visualize, and treat intradiscal and foraminal pathologic lesions without destabilizing the posterior muscle column and facets. The learning curve is steep, but once mastered, the surgeon is able to reach any pathologic lesion in the foramen, including noncontained disc herniations, foraminal stenosis, foraminal osteophytosis, facet cysts, and annular tears.

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 should preserve normal anatomy and access the patho-anatomy without injuring normal tissue. The dorsal muscle column, if compromised as part of the surgical exposure, may be partly responsible for spinal instability and failed back surgery syndrome (FBSS).

Due to the morbidity of the posterior surgical approach, disc surgery has traditionally been reserved for disc herniations causing radiculopathy or progressive nerve deficits from mechanical compression on the spinal nerves. This relatively conservative posture was due to the inherent morbidity of traditional posterior surgery that must violate and alter the important function of the muscles and facets of the posterior spinal column. Surgical morbidity has, therefore, limited the use of surgery as an early treatment option in disc degeneration and herniation. Thus, surgery was usually not recommended for herniations without neurologic deficits. The dogma that, "disc surgery is really decompressive nerve surgery," dominates the rationale for decompressive discectomy for herniated 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 painful degeneration, annular tears, and eventual disc herniation. (2) Advances in endoscopic surgery therefore offer surgeons the opportunity to visualize and probe pathologic lesions that may cause pain as a prodromal symptom that progress to a full-blown herniation. Minimally invasive surgical options that do not have the inherent approach-related morbidity are possible with the endoscopic foraminal portal, therefore endoscopic diagnosis and surgical intervention can be considered for painful spinal conditions that were previously operated on only when there was evidence of nerve damage.

The foraminal approach provides excellent cannula access from T-10 to L-5 for foraminal structures illustrated in this cadaver dissection (Figure 1). The endoscope and instruments are introduced through a cannula between the traversing and exiting nerves in an area known as Kambin's Triangle (Figure 2). Yeung developed an endoscopic system that featured beveled and slotted cannulas with the open end directed toward the dorsal foramen, exposing the epidural space and the base of the disc herniation in the same endoscopic view (Figure 3). A multi-channel flow integrated operating endoscope offering high quality imaging became the flagship of the new system (Figure 4, 5).

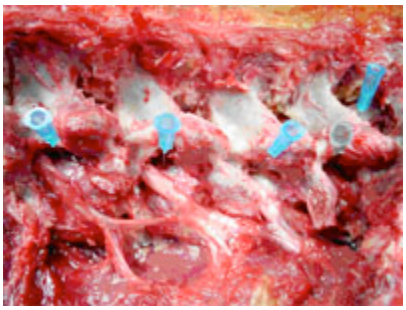


Figure 1. Cadaver dissection of the foramen from L2-S1 demonstrates excellent access to the postero-lateral portion of the disc through Kambin's triangular zone. Blue hubbed needles represent ideal placement of endoscope into the disc. At L-5, S-1, less room is present in the foramen, and a lateral facetectomy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

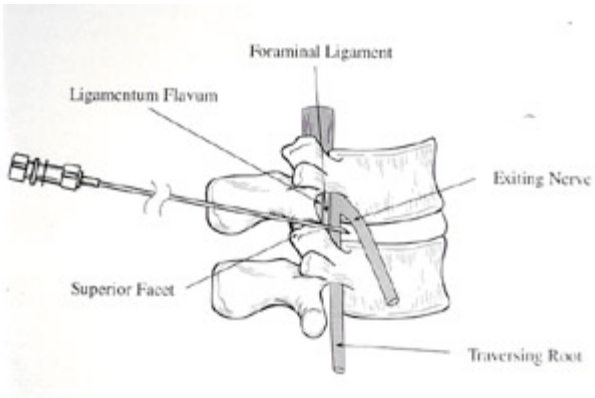


Figure 2. Kambin's Triangle is the site of surgical access for posterolateral endoscopic discectomy. It is defined as a right triangle over the dorsolateral disc. The hypotenuse is the exiting nerve, the base (width) is the superior border of the caudal vertebra, and the height is the traversing nerve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

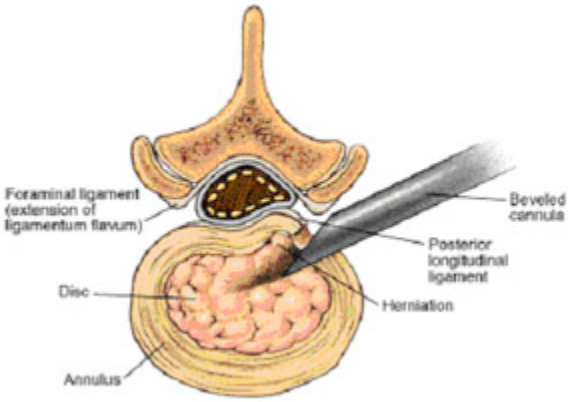


Figure 3a

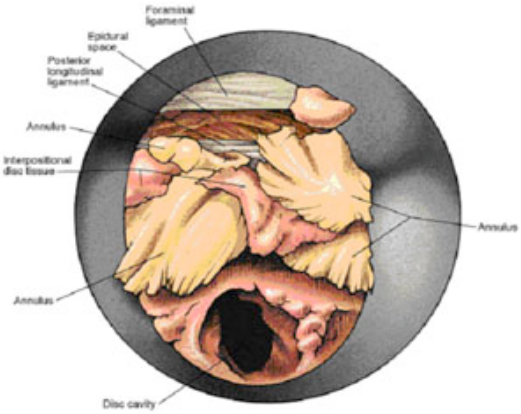


Figure 3b

Figures 3a and 3b. 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. By beveling the cannula, the YESS™ system provided visualization of the epidural space while targeting the base of the herniation. It was also no longer necessary to use a trephine to fenestrate the annulus. (Illustration by David Baker)

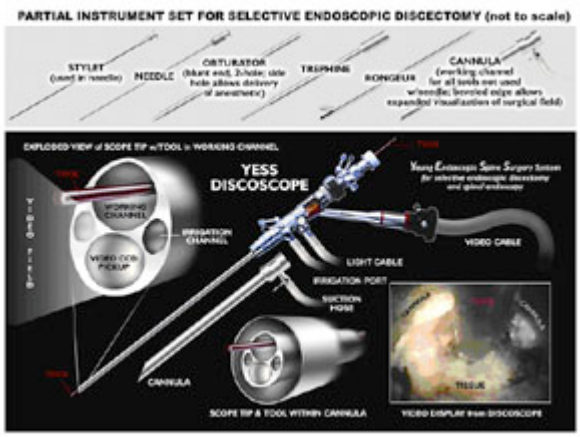


Figure 4. The YESS™ endoscope features multi-channel irrigation and a 2.8-mm working channel. Complementary access cannulas and instruments improved visualization of the epidural space and the foramen. (Illustration by David Azarello)

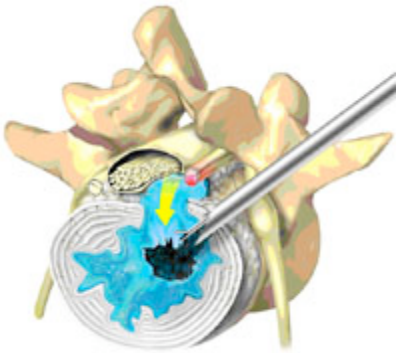


Figure 5. Uniportal technique for selective endoscopic discectomy. Small pituitary rongeurs are used for visualized posterior fragmentectomy. The beveled cannula can be positioned to view the epidural space, annular wall, nucleus pulposus, and intradiscal cavity in the same field of vision. The cannula can be rotated to provide surgical access, but at the same time used to protect the exiting nerve. (Illustration by David Azarello and Christopher Yeung)

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.

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 depends on the 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.

These quality-of-life and functional issues associated with chronic discogenic pain can be addressed with SED™ and thermal-annuloplasty. 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. Yeung and Tsou reported on Selective Endoscopic Discectomy™ (SED™) with visualized thermal discoplasty and annuloplasty for large disc herniations producing radiculopathy; unequivocal candidates for traditional surgery. (3,4) This visualized endoscopic technique (5,6), producing results equal to microdiscectomy, was trademarked in order to prevent confusion with other percutaneous endoscopic techniques that were popularized, but fell out of favor when the results failed to match the results of traditional microdiscectomy.

Annular tears demonstrated in the process of SED™ for disc herniations were demonstrated to contract and shrink when a 4.0 MHz bipolar flexible radiofrequency probe (Ellman Trigger-Flex Probe™), Ellman International, Hewitt, New York, USA) is activated next to the annular defect. (7) 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 (Figures 6a, 6b).



Figure 6a. Ellman Trigger-Flex Probe™ performing thermal discoplasty/annuloplasty. 4.0 MHz frequency shrinks the annulus and ablates inflammatory tissue effectively.

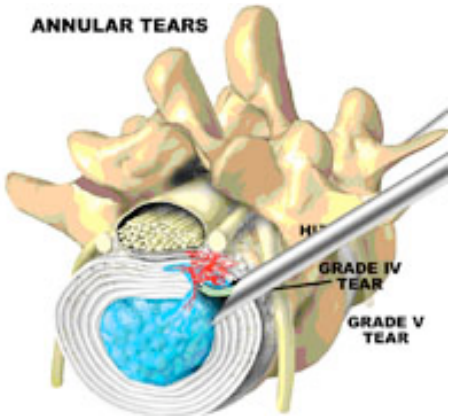


Figure 6b. Illustration of the annuloplasty technique with the Ellman Trigger-Flex Probe™. The annular tear is infiltrated with inflammatory tissue and granulation tissue. The radio-frequency probe is directed to the annular tear under endoscopic visualization to ablate the granulation tissue and shrink the collagen fibers at the tear. (Illustration by David Azarello and Christopher Yeung)

Selective Endoscopic Discectomy™ with thermal annuloplasty is differentiated from IDET because SED™ is a visualized and targeted surgical procedure. (8) A minimal discectomy is done to decompress the intradiscal pressure and more importantly, remove any interpositional nuclear material within the annular fibers that may be preventing the tear from healing. SED™ also utilizes continuous cool irrigation, which flushes out the neurotoxic chemicals within the disc and removes any by-products of thermal modulation.

One ideal indication for Selective Endoscopic Discectomy™ and disc debridement is discitis. (9) This condition can occur as a postoperative infection or as a disc infection from hematogenous inoculation of microorganisms. 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 and debridement through the posterolateral portal has provided almost immediate pain relief and a much more reliable tissue sample for laboratory analysis and culture (Figure 7). 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.



Figure 7. 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.

Perhaps the ideal pathologic lesions for Selective Endoscopic Discectomy™ are the lateral (foraminal) and far lateral (extraforaminal) disc herniations. Although a skilled spine 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/or manipulation of the sensitive exiting nerve root and dorsal root ganglion through the paramedian approach. 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 evocative chromo-discography and 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 to heal or are caused by interpositional disc tissue keeping the tear open. Removing the disc tissue adjacent to the tear enhances annular healing. (10)

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. (11,12) 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 is confirmed by visualization of perineural fat and pulsation of the epidural fat around the nerve. Resection of the bulging dorsal annulus will decompress the traversing nerve in central stenosis (Figure 8). The disc space is usually already collapsed, so no significant instability is created.

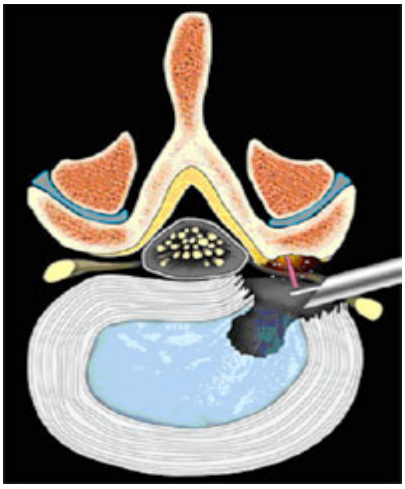


Figure 8. Foraminoplasty for foraminal and lateral recess stenosis is accomplished by resecting the bulging annulus and resecting the undersurface of the superior articular process with cutting basket forceps and a side firing Ho:yag laser.

In knee and shoulder arthroscopy, more detailed findings are possible with arthroscopic probing and imaging of joint anatomy than magnetic resonance imaging (MRI). The same is true with spinal endoscopy.

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, and has occurred even when there were no adverse intraoperative events and the continuous electromyography (EMG) and somatosensory evoked potentials (SEP) did not show any nerve irritation. (13,14) 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. Post-operative dysesthesia is treated with transforaminal epidurals, sympathetic blocks, and the off-label use of Neurontin® (Pfizer, Inc., New York, NY, USA) titrated to as much as 1800-3200 mg/day. Gabapentin (Neurontin®) 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™, 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.

References

1. Rauschning W. ISMISS Pioneer-Guest Lecture, 2001. Pain Mechanisms and Therapeutic Considerations in Segmental Spinal Dysfunction Proceedings of the International 19th Course for Percutaneous Endoscopic Spinal Surgery and Complementary Techniques, Zurich, Switzerland, January 25-26, 2001.

2. Hadjipavlou AG, Simmons JW, Pope MH, et al. Pathomechanics and clinical relevance of disc degeneration and annular tear: a point-of-view review. Am J Orthop 1999; 28:561-71.

3. Yeung AT, Tsou PM. Posterolateral endoscopic excision for lumbar disc herniation-surgical technique, outcome, and complications in 307 consecutive cases. Spine 2002; 27(7): 722-31.

4. Tsou PM, Yeung AT. Transforaminal endoscopic decompression for radiculopathy secondary to intracanal noncontained lumbar disc herniations: outcome and technique. The Spine Journal 2002; 2(1): 41-8.

5. Yeung AT. Minimally invasive disc surgery with the Yeung Endoscopic Spine System (YESS™). In: Szabó Z, Lewis JE, Fantini GA, et al., Eds. Surgical Technology International, VIII. San Francisco: Universal Medical Press, Inc.; 1999. P 267-77.

6. Yeung AT, Yeung, CA. Advances in Endoscopic Disc and Spine Surgery: The Foraminal Approach. In: Szabó Z, Lewis JE, Fantini GA, et al., Eds. Surgical Technology International, XI. San Francisco: Universal Medical Press, Inc.; 2003. (In press).

7. Yeung AT, "Intradiscal Thermal Therapy for Discogenic Low Back Pain" in The Practice of Minimally Invasive Spinal Technique - AAMISMS Education, LLC - First Edition 2000, 237 - 242.

8. Yeung AT, Tsou PM. Selective endoscopic discectomy and thermal annuloplasty for chronic lumbar discogenic pain: a new minimally invasive technique. Spine Journal, 2003. (In progress).

9. Ito M, Abumi K, Shirado O, et al. Transforaminal surgery for pyogenic thoracolumbar spondylodiscitis. Presented at the AAMISMS 3rd World Congress Phoenix, Arizona, December 8-11, 2002.

10. Yeung, AT. "Factors Affecting IDET Outcome: An Endoscopic Analysis of IDET" Western Orthopedic Association 2001 Annual Meeting - San Francisco, California - September 22, 2001.

11. Yeung, AT. "Minimal Invasive Techniques in the Lumbar Spine: Evolving Methodology since 1991. Magisterial Speaker International 20th Jubilee Course for Percutaneous Endoscopic Spinal Surgery and Complementary Techniques Zurich, Switzerland - January 24 - 25, 2002

12. Knight MTN, Goswami AKD. Endoscopic laser foraminoplasty. In: Savitz MH, Chiu JC, Yeung AT, Eds. The practice of minimally invasive spinal technique, 1st Ed. Richmond, VA. AAMISMS Education, LLC. 2000; 42:337-40.

13. Yeung AT, Porter J, Merican C. The value of neuromonitoring in selective endoscopic discectomy: the Arizona experience. Presented at the AAMISMS 2nd World Congress, Las Vegas, Nevada, December 6-9, 2001.

14. Zhu P. Electrodiagnostic studies of radiculopathies+intraoperative neuromonitoring. Presented at the AAMISMS 3rd World Congress, Phoenix, Arizona, December 8-11, 2002.