<cn>CHAPTER 18

<ctl>Arthroscopic Lumbar Decompression: The Foraminal Approach

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<t>Endoscopic disc surgery is evolving rapidly because of improvements in surgical technique, endoscope design, and instrumentation (Fig. 18-1). These third-generation systems with excellent optics give the endoscopic spine surgeon the ability to probe spinal anatomy in a conscious patient and evaluate the pathologic process causing the patient's pain. Now that spinal endoscopy can be performed, conditions previously not even considered for surgery may be evaluated and managed. Patients who previously were not candidates for traditional surgery may find relief with endoscopic spine surgery directed toward the pain generator. 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.

{INSERT FIG. 18-1 HERE}

<1>THE EVOLUTION OF SPINAL ENDOSCOPY

<t>Just as it was for early arthroscopic surgery, spinal endoscopy is poised to parallel the development and evolution of knee, shoulder, and ankle arthroscopy. Without endoscopy, spine surgeons must depend heavily on imaging systems that, although extremely sensitive in identifying pathologic conditions, cannot correlate those conditions with the patient's pain. With endoscopy, aided by discography, it will be possible to evaluate, diagnose, and treat spinal conditions not usually considered for the more invasive open surgical techniques. We will gain a

better understanding of the biology of back pain and sciatica, and also be able to study the pathoanatomy and pathophysiology of pain in specific individuals. Kuslich has improved our understanding of the pain generators in the lumbar spine through spinal probing under local anesthesia. Rauschning's cryosections of normal and patho-anatomy has more recently implicated inflammation in and around the sensitive dorsal root ganglion. It is also is 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. 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. When spinal probing complements discography and is performed with the patient in an aware state, the painful and non-painful anatomic parts can be probed and visually correlated with imaging studies. The increased knowledge of back pain and the alternative treatment options this knowledge may bring will give the patient more treatment options, justifying the growing interest and enthusiasm for endoscopic spine surgery.

<1>INDICATIONS

<t>Any pathologic lesion that is accessible, visible, 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.

Indications may become less restrictive because of the decreased morbidity of the less invasive procedure. While at L5-S1, anatomic restrictions may cause the surgeon to opt for the posterior transcanal approach (Fig. 18-2, *A*). for herniations from T10 to L4, the foraminal approach provides excellent access to the disc and epidural space (Fig. 18-2, *B*). As the experience of surgeons increases, previous contraindications become relative, depending 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 for the endoscopic procedure itself. As the surgeon's experience increases, former contraindications became relative, depending on the surgeon's experience, and his or her ability to address the spinal condition to be treated. Anatomic structures within reach of the spine endoscope transforaminally are illustrated in Fig. 18-3.

{INSERT FIGS. 18-2 AND 18-3 HERE}

<2>Inclusion Criteria

<t>Discogenic pain as determined by evocative discography may implicate 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. Perhaps the ideal lesion 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 dorsal root ganglion is at risk for neuropraxia. 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 nucleus pulposus extruded past the posterior annulus is shown in Fig 18-4. Through this approach to the

disc, endoscopic excisional biopsy and disc space debridement are ideal for surgically debriding infectious discitis (Fig. 18-5). Currently treated with immobilization and parenteral antibiotics, discitis is much more effectively treated when augmented by endoscopic 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.

{INSERT FIGS. 18-4 AND 18-5 HERE}

Foraminal stenosis in selected patients will respond to foraminoplasty by endoscopic techniques. Lateral recess stenosis is one cause of failed back surgery syndrome (FBSS) that can absolutely be diagnosed and treated by foraminal decompression. The patho-anatomic finding may be osteophytosis tethering the exiting nerve at the superior vertebral endplate and/or stenosis and lack of fat around the exiting nerve. (figure 18-6) Although trephines, rasps, and burrs can be used, the Ho:yag side firing laser has made it 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 osteophyte and scar tissue from the nerve. Endoscopic laser foraminoplasty (ELF) is further validated by research studies by Osman and Panjabi demonstrating that decompression through the foramen can be as effective as posterior decompression but will not produce further instability (Fig. 18-6). The foramen may be enlarged up to 45.5% vs. the 34.2% attainable with the standard posterior technique of removing only the medial one third of the facet. Posterior decompression of the lamina with removal of the medial one third of the facet will produce increased extension and axial

rotation postoperatively. 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 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 spondylolysthesis, when there is more leg than back pain, this is usually due 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.

{INSERT FIG. 18-6 HERE}

<2>Exclusion Criteria

<t>Except for pregnancy, there are no absolute exclusion criteria but only relative contraindications depending on the skill and experience of the surgeon. Spinal endoscopy and spinal probing can be used for diagnostic purposes in very difficult or confusing clinical situations. Therefore, if endoscopy is helpful for diagnostic purposes, exclusion criteria may depend mainly on the accessiblilty 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.

<2>Future Considerations

<In the near future, the spine scope will eventually be used for all conditions where visual inspection is desired. The author has used spinal endoscopy for the following reasons: (1) to inspect a spinal nerve that is suspected of being irritated by orthopedic hardware adjacent to the pedicle; (2) to remove suspected recurrent or residual disc herniations that do not show up on imaging studies; (3) to decompress the lateral recess by foraminoplasty; (4) to remove osteophytes and facet cysts that cause unrelenting sciatica; and (5) to locate painful lateral annular tears or small disc herniations not evident on physical examination or MRI. Single and multi-level discogenic pain, where the patient has no viable options, endoscopic discectomy and thermal annuloplasty has 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 newer procedures such as total disc replacement and minimally invasive stabilization procedures become available. The discogenic condition is diagnosed by evocative discography. The lateral zone is rarely visualized by surgeons (Fig. 18-7). Yeung and Ranade has reported that most tears that do not heal are too extensive or are caused by interpositional disc material keeping the tear from healing. Just removing the interopsitional disc tissue will 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 (Fig. 18-8), challenging the old concept that disc surgery is merely nerve decompression surgery. For example, discogenic pain from annular tears is currently being evaluated and correlated with the pathoanatomic conditions seen.

{INSERT FIGS. 18-7 AND 18-8 HERE}

Some spine surgeons who perform minimally invasive procedures use an endoscope but only through the traditional posterior approach. Because most surgeons are more comfortable with the anatomy encountered in a traditional approach, this is a good way to begin the transition to other endoscopic techniques. Once a surgeon feels comfortable with the endoscope, however, it is not difficult to make the transition to the posterolateral port. 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.

<2>Conservative Treatment

<t>With endoscopy, conservative treatment should be labled “nonoperative” 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 epidurograms, foraminal epidural blocks and selective nerve blocks, may be labled “conservative,” but they are therapeutically beneficial and are valuable tools for predicting the eventual efficacy of endoscopic decompression or thermal treatment of the pain source. (add figure “11”**Foraminal Epidurography**) Therapeutic injections may be limited in their ability to ultimately correct the painful condition, but endoscopic spine surgeons who utilize these techniques can address correctable lesions. The surgeon’s effectiveness is enhanced by incorporating the assistance interventional pain management specialists as a part of a multidisciplinary team.

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 nonoperative versus operative treatment, because the ability to more specifically diagnose a painful condition in the lumbar spine with the use of endoscopy makes early surgical intervention the more conservative approach.

<1>PLANNING

<t>Patients with chronic back pain and atypical sciatica are the most difficult to treat. Traditional methods of nonsurgical treatment are often not effective or very transient, and the patient is often labeled as drug seeking and psychologically unstable. In this situation it is extremely helpful to use a multidisciplinary team approach. Psychological profiling, behavioral modification, active exercise, and manual therapy help patients to overcome their pain and focus on becoming functional. The team approach, involving psychologists, physiatrists, addictionologists or medical pain management specialists who are all working with each other and agree on the overall treatment plan, has helped rescue many persons with chronic pain 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 epidural injection is a good indication for a foraminal approach to the pathologic lesion to be addressed surgically.

<2>Current Imaging Methods

<t>In our experience, imaging studies are only about 70% accurate and specific for predicting pain. Conditions such as lateral annular tears, rim tears, endplate separation, small subligamentous disc herniations, intranuclear herniations, anomalous nerves, and miscellaneous discogenic conditions are cumulatively missed approximately 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 contains 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 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 anatomic area.

<l>Evocative Discograms

<t>We use evocative chromodiscography as an integral part of spinal endoscopy. 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. The surgeon who is accomplished in endoscopic spine surgery prefers to do the discography himself in order to decrease the interobserver variability in interpreting the patient's response. When we compare our 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, however, can be significantly decreased in the hands of an experienced endoscopic surgeon. The 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 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 non-painful annular tear.

<1>TECHNIQUE

<2>Endoscopic Spine Surgery: The Posterolateral Approach

<t>The technique that we currently use evolved over since 1991 after we learned arthroscopic discectomy from Dr. Parviz Kambin. Previously we 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 and thermal discoplasty and annuloplasty. It continues by incorporating endoscopic foraminoplasty techniques for degenerative conditions of the lumbar spine. The foraminal approach is further refined by a standardized surgical protocol that helps decrease the learning curve. An institutional review board approved the prospective study of 56 patients undergoing selective endoscopic discectomy (SED), and the thermal discoplasty that we perform for conditions ranging from discogenic pain to spondylolisthesis.

This technique study revealed a satisfactory outcome in 89% according to modified MacNab criteria and 91% by patient questionnaire. Surgical results continue to improve, which is consistent with the refinement of indications and techniques for specific conditions treatable by this endoscopic 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 toward the center of the disc (Fig. 18-9). 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 endplates 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.

{INSERT FIG. 18-9 HERE}

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. The posterolateral approach can avoid the spinal canal if desired, and does not require the stripping of muscles or ligaments 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 central 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.

<1>POSTOPERATIVE CARE

<t>Postoperative management may differ from the typical postoperative program used for disc herniations with radiculopathy. Endoscopic treatment of discogenic back pain often involves multiple levels and disc segments with extensive circumferential annular tears that involve the entire 360-degree circumference. This differs from a disc herniation, which 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 nonaxial loading movement is allowed. After 6 to 8weeks, 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, mobilization and aerobic conditioning is the goal toward functional recovery.

<1>PROBLEMS AND COMPLICATIONS

<t>As with arthroscopic knee surgery, the risks of serious complications or nerve injury are low—approximately 1% in our experience. The usual risks of infection, nerve injury, dural tears, bleeding, and scar tissue formation are always present, as they are with any type of spine surgery. Fenestration past the anterior annulus is a potential hazard creating a bowel or vascular injury. 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 into the working channel of the endoscope and their use 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 using windows as surgical ports. 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, we have 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, but this has never been documented endsocopically (Fig. 18-10, *A*). The inflammatory membrane may contain tiny nerves and blood vessels that contribute to severe discogenic pain (Fig. 18-10, *B*).

{INSERT FIG. 18-10 HERE}

Dysesthesia, the most common postoperative complaint, occurs approximately 5% to 15% of the time but is almost always transient. Its cause is still incompletely understood 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 because neuromonitoring with dermatomal somatosensory evoked potentials and continuous electromyography, the most sensitive means of monitoring, has not identified the cause of dysesthesia. The symptoms can be similar to those of complex regional pain syndrome, but less severe, and usually without the skin changes that accompany CRPS. Stimulation of the dorsal root ganglion of the exiting spinal nerve, even with gentle retraction, can also result in dysesthesia

when foraminoplasty is performed, even with the exiting nerve clearly identified and protected by the cannula.

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. 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 surgery 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 currently used at our institution help warn the surgeon of nerve irritation even when there is no direct contact between surgical instruments and the nerve proper. Neuromonitoring may make surgeon feel more comfortable to warn him of nerve irritation from the procedure when he first practices endoscopic spine surgery, but after analyzing the result of a prospective study of 100 consecutive patients, it has not been shown to be any more useful than patient feedback reporting pain during the procedure for avoiding complications.

<2>Alternatives to Fusion for Treatment of Back Pain

<t>Fusion has traditionally been reserved for spinal instability and deformity. More recently, the use 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 and adjacent-level disease remains a problem. Discogenic pain has been discovered to arise primarily from the annulus but can also involve the endplates (intranuclear herniations), the inflammatory membrane surrounding the annulus, and sensitized tissue surrounding the annulus. Patients with debilitating back pain are currently being 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 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 currently the most widely used for the treatment of back pain due to painful annular tears in the lumbar disc. Patient selection is critical, but follow-up studies have reported significant deterioration of results, even when they seem beneficial in the early postoperative period. A visualized endoscopic variation of the technique, selective endoscopic discectomy, and thermal annuloplasty overcome some of the pitfalls of the blind technique. The tear is detected by evocative discography. Indigo carmine dye, mixed with a nonionic 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 positive confirmation by evocative discography. The author's endoscopic version of IDET has converted 80% of IDET failures to satisfactory results. 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, since annular modulation may incorporate injection of therapeutic solutions using hypertonic dextrose, glucosamine sulfate, and chondroitin sulfate. These novel approaches warrant further 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.

<1>OUTCOMES

<t>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, range 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 the spine surgeon. When performed by an experienced endoscopic surgeon, Kambin found results equal to those achieved with traditional microdisectomy, but with less morbidity and earlier return to work. The high learning curve has curtailed its universal acceptance at this time, but those surgeons who are 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 the physicians document their findings by video imaging and study the tapes postoperatively. By studying the videos of their surgeries in the early part of the learning curve, they will soon learn to associate visualized conditions with their ability to affect those conditions. This will help surgeons to more rapidly develop their diagnostic and surgical skills.

<2>The Author's Experience with Endoscopic Spine Surgery

<t>Since 1991 we have used a rod-lens system for endoscopic disc excision through a posterolateral approach, as described by Parviz and 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 (Yeung Endoscopic Spine System) 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 patients who are sedated but awake. From 1991 to 2004, we have treated over 2200 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 (86%) of 500 good/excellent results according to the modified MacNab criteria. 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%) 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. The evolving methodology in the treatment of discogenic back pain by selective endoscopic discectomy is reviewed in a prospective study that validates Selective Endoscopic Discectomy as an alternative for a variety of spinal conditions treated by traditional methods. The practice of minimally invasive spinal technique is summarized in a recent book with the same name, 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.

<1>NEW HORIZONS

<2>The Future of Endoscopic Spine Surgery

<t>The learning curve in endoscopic spine is steep compared to that in knee surgery because surgical misadventures are unforgiving in the spine. Intensive surgical instruction with preceptorship programs has produced a small number of spinal endoscopists worldwide. It is strongly recommended, however, for further advancement of endoscopic spine surgery that a preceptorship be completed before endoscopic spine surgery is attempted. Eventually, for further advancement, endoscopic spine surgery may have to be a subspecialty for most surgeons. If young surgeons can get their training in a fellowship or post-fellowship program, endoscopic spine surgery will advance more rapidly. For now, the small number of surgeons should hone their endoscopic skills by limiting their indications to contained, small, soft disc herniations.

<1>CONCLUSION

<t>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 we view

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

<l>KEY POINTS

1. <nlp>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. New terminology and concepts, evocative discography, evocative chromodiscography, selective endoscopic discectomy, and thermal annuloplasty are introduced and explained in the text. The terms have U.S. registered trademarks to distinguish the terminology described from other percutaneous discectomy procedures reported in the literature.
4. 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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LEGENDS

<l>Fig. 18-1. The Yeung Endoscopic Spine System 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 Yeung AT, Yeung, CA. Advances in endoscopic disc and spine surgery: Foraminal approach. In Szabó I, Coburg AJ, Strange PS, et al., eds. Surgical Technology International. XI. San Francisco: Universal Medical Press, 2003, p 257.)

Fig. 18-2. **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 the posterolateral foraminal port from L2-S1. Only in the L5-S1disc 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. L4-5 provides ample room for either approach. Note the furcal nerve branches entering the psoas muscle.

Fig. 18-3. The dome. Spinal structures in the foramen accessible to visualization and surgical intervention and probing via the posterolateral approach (courtesy of Hal Matthews, M.D.).

Fig. 18- 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.

Fig. 18-5. Intradiscal view of discitis after debridement. Usual findings of inflammatory disc material and loose endplate 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.

Fig. 18-6 The technique of endoscopic foraminal decompression. The annulus can be decompressed and even resected, whereas 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.

Fig. 18-7. 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.

Fig. 18- 8. **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, which, if next to a spinal nerve or the dorsal root ganglion, can cause pain out of portion to what may be anticipated from traditional imaging studies. If patients with annular tears obtain relief from foraminal epidural blocks, more lasting relief of 1 or 2 years is possible with selective endoscopic discectomy and thermal annuloplasty. **B,** Bipolar radiofrequency treatment of annular tears under direct visualization. Interpositional disc material should be removed from the annular layers to effectively treat the annular tear. **C,** Preoperative endoscopic view of a grade V annular tear before and after visualized thermal annuloplasty. **D,** Postoperative view.

Fig. 18-9. Determination of optimal instrument path: 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 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** and **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 25 to 30 degrees to the surface skin plane will determine the path of all subsequent instrumentation.

Fig. 18-10. Anomalous nerves. Anomalous nerve identified in the annular fat in the foramen. These communicating branches are described as furcal nerves in the surgical literature. Small sympathetic nerves with attached ganglion are occasionally seen. **A,** Large furcal nerve in the foramen connecting the exiting and traversing nerve. When it is in the foramen, it is considered an anomalous branch, but furcal nerves are common branches from the exiting nerve entering the psoas muscle. **B,** Neoangiogenesis and neoneurogenesis 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.

Fig. 18-11 Foramino-epidurography: a new technique for foraminal needle placement from the far lateral skin portal mimicking the surgical access to the epidural space 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 additional information pre-operatively and serves as a "practice run" for surgery.