# Minimally Invasive Surgical Techniques for HNP

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## Introduction

The evolution of minimally invasive spine surgery for the herniated nucleus pulposus in the lumbar spine has spanned years of varied focus and controversy. The focus has ranged from refining patient selection for decompressive procedures to visually targeting the pathology and anatomic structures at risk. Contemporary methods, spurred by continued refinement of techniques and instrumentation, makes minimally invasive spine surgery the mantra for the next millennium. This process has always had a sustained goal: to surgically address the herniated disc with the least amount of morbidity, limiting the paradoxical surgical effects of segmental destabilization and post-operative scarring.

Removal of a herniated lumbar disc was first described in the United States by Dandy in 1929. Minimally invasive techniques, however, began with percutaneous methods. Chemonucleolysis, the only minimally invasive method validated by numerous cohort and three double blind studies, is the benchmark for comparison purposes. Percutaneous nucleotomy, automated percutaneous nucleotomy and laser disc decompression, while still being utilized on a limited basis, has fallen out of favor because it could not match the success and visualization afforded by the traditional procedure. Their success depended on very rigid patient selection that was difficult to adhere to because of the inadequacies of traditional imaging studies, the inability to clearly visualize pathology, and the tendency for clinicians to stretch surgical indications. Endoscopic percutaneous nucleotomy and discoscopy addresses the visualization obstacle and now provides the basis for endoscopic techniques that remain viable in contemporary minimally invasive methods.

The philosophy for perpetual investigation into improved percutaneous surgical alternatives to conservative treatment was well stated by Mayer and Brock. They propose that "...reducing lumbar disc surgery to a mere 'nerve root decompression procedure' falls short of the standards set by modern surgical philosophy, since failure not only arises from persisting or recurring neurological symptoms but also from anatomical and biomechanical disturbances caused by the surgical approach itself." The principle objective of this chapter will be to examine the current minimally invasive surgical techniques for herniated lumbar discs, but new percutaneous procedures to address compression fractures in the thoracic and lumbar spine warrant mention, as it utilizes many of the same surgical skills as endoscopic discectomy.

## Epidemiology

Back pain and sciatica represents a tremendous challenge to all healthcare systems. It affects the work force in lost time and direct expenses. In 1997, Schwartz and Schafer reported that "up to 80% of the population of industrialized nations has sought medical treatment for low back pain."8 In 1988, 22.4 million cases of low back pain resulted in lost work time of 149.1 million days. The report citing these statistics further notes that in the United States, about one fourth of workers' compensation claims can be attributed to back pain. Relative to the cost of low back pain in the United States, Frymoyer (1996) reported that in 1990 the cost of low back disorders ranged from

$25 billion to $85 billion. Gus and colleagues in 1995 reported that back pain is responsible for one fourth of the U.S. workers' compensation claims. A 1998 report by Argoff and Wheeler quantified spine and radicular pain. Both generated economic costs and disability of epidemic proportions. While these reports do not subdivide causes to diagnostic subcategories such as herniated discs, degenerative disc disease, instability, or stenosis, they still provide statistical information relative to the ever-increasing scope of spinal disorders affecting patients in search of definitive and efficacious intervention.

Management strategies must be based on a comprehensive approach to the evaluation of every patient. Variables include well defined pathology, previous spine history [conservative and/or operative] and general health status. Psychosocial factors, compensation, litigation, and pain control issues must also be factored in the equation. Minimally invasive spine surgery for herniated discs is less costly with less surgical morbidity. Direct savings are 30-60% less, but less morbidity translates into more rapid return to work. Rapid return to recreational activities also results in great satisfaction in patients with a more realistic outlook on their spinal condition.

## Pathophysiology

The pathophysiology of low back pain with associated radiculopathy is a discovery in progress. Simple compression of spinal nerves may not always generate radicular pain. In the presence of an annular tear associated with a herniated nucleus pulposus, leakage of products of nuclear degradation may initiate an inflammatory response at the nerve root, causing more pain than a contained herniation. The release of phospholipase A2 and nitric oxide have been demonstrated to be induced by free fragments yielding noxious effects on the root and its extension. Herniated discs have been noted to promote an increase in matrix metalloprotenase, nitric acid, prostaglandin E2 and interleukin 6 which have been postulated as being involved in disc degeneration and radiculopathy. Quite recently, it has been observed that free glutamate exists in the herniated disc and may have an impact on the dorsal root ganglion relative to radicular pain.

Ongoing investigation seeks to succinctly explain the etiology of radiculopathy associated with herniated nuclear pathology. This summary does not begin to address all possible pathophysiologic and histochemical factors but aims to present some of the most recent findings that may contribute to the ultimate understanding of radiculopathy associated with disc herniations and allow for expanded options treatment beyond just the removal of compressive nuclear pathology.

## Diagnostic Imaging

Magnetic resonance imaging is probably the best single study for the radiologic diagnosis of the herniated disc, although CT is still the most utilized world wide. MRI provides information on disc location and deformation, and can identify free or sequestered fragments as well as annular tears, represented by a high intensity zone (HIZ).

Discography, controversial through articles stressing its variability in interpretation, provides a relevant adjunctive study in the hands of physicians who know how to use it. When there are multiple bulges and/or herniations, pain provocation at the time of the study can identify the pain generator(s) to which surgical intervention can be directed. If followed by computed tomography, details relative to annular fissures or tears can be identified and further contribute to surgical planning. Discography will give additional information on annular tears not detected by MRI.

Discography, therefore is felt by some proponents of minimally invasive spine to be an integral part of endoscopic spine surgery.

Myelography with CT is usually reserved for morbidly obese patients that the average MRI scanner cannot support or for older patients with stenosis or osteophytes in addition to disc herniation.

An important factor in diagnostic imaging is the surgeon's ability to interpret imaging studies. While most radiologists review a broad range of radiologic tests on any given day, the seasoned spine surgeon develops a keen eye for subtle pathology. Therefore, it is essential that the spine surgeon interpret his or her own studies in the patient evaluation process. Never should a surgical plan be pursued based solely on a radiology paper report. Of utmost importance is that the diagnostic images themselves be present in the operative suite at the time of surgery for the surgeon's review. Imaging studies are relevant to surgical planning since they present a tool that can correlate pain with the pathology that is being addressed..

**Conservative Care**

In a managed care environment conservative care has become defined by time and by an ever-lengthening list of required conservative treatment regimens Because indications for minimally invasive disc surgery often serve as the bridge between conservative and traditional surgical treatment, controversy can result when authorization is needed from the insurer.

It is almost universally expected that the patient's symptoms and conservative treatment span a minimum of 6 weeks. The typical insurance algorithm to authorize a surgical procedure relates symptoms and their duration to physical findings that must be confirmed by diagnostic imaging. Results of radiologic studies, however, often perplex insurance "data collectors" since they rely solely on a radiologic report and do not know how to integrate the operative surgeon's interpretation that differ or add new information not in the written report.

Insurance inquires about the length of conservative therapy and how many hours a day a patient's symptoms dictate their disability. Has the patient tried non-steroidal anti-inflammatories as well as oral and epidural steroids? What is the patient's work and/or activity tolerance? Has the patient had physical therapy? Even with most algorithm criteria satisfied, the surgeon may be subjected to a physician peer review with an insurance medical director in order to "plead" the patient's case. This exercise may result in approval of treatment requested, but could be obstructed by plan policies that give complete latitude to simply call new and innovative procedures "experimental" to avoid payment.

Certainly there are also instances where conservative care is not indicated and may in fact, endanger the patient. An example of such a circumstance could be an acute herniation with significant canal compromise and the potential for a cauda equina syndrome.

Nevertheless, a trail of conservative care is always preferred since a significant percentage of disc herniations can be conservatively resolved with selected modalities and "tincture of time." Surgeon experience with specific herniations and its clinical presentation at times warrant shortening the conservative treatment period, especially with the newer minimally invasive techniques that limit the paradoxical effects of surgical intervention.

**Patient Selection: A General Overview**

While there may be unique selection criteria for some of the newer endoscopic procedures, there is usually concurrence on identifying the appropriate patient for a posterior percutaneous procedure to address the herniated lumbar nucleus pulposus. The procedure chosen depends heavily on the endoscopic surgeon's experience and success with each herniation type.

Patients usually present with leg pain greater than back pain. Symptoms are usually reported to have been present for 3-6 weeks. Positive straight leg raising is a common finding and a significant percentage of patients can pinpoint the initiating event such as a workers' compensation injury, an accident such as a fall or a motor vehicle incident or any activity of daily living including recreation during which the patient describes hearing and/or sensing a "pop" with acute onset of symptoms. Description of radicular symptoms may range from frank pain to other neuro-pathic symptoms such as numbness, tingling, burning or aching. There may be diminished sensation to light touch or pinprick and pseudoclaudication that imaging studies may or may not detect. Lateral recess stenosis, inflammatory nerve irritation from annular tears, and relative canal compromise are extremely difficult to detect by traditional imaging studies.

In most procedures, virgin disc pathology is preferred for optimum surgical outcome and patient satisfaction. Previous surgery, by virtue of its effect on neural tethering and segmental stability, adds a less predictable factor for evaluating the efficacy of these percutaneous procedures. Confronted with extrusion of disc material and potential free fragments that may have migrated and become sequestered, these can be addressed only by the most experienced endoscopic surgeons. The same is true for the size of the herniation and the degree of canal compromise.

The location of the herniation and associated pathologies may dictate the ideal percutaneous approach. It is therefore appropriate at this point to proceed to a description of contemporary posterior percutaneous techniques. Attention will be given to unique patient selection criteria and associated indications for and contraindication to surgical intervention for each technique.

## Surgical Preparation

As with any new procedure, informed consent should be very thorough, and clearly spelled out. With minimally invasive procedures it is an "easy sell," so it is imperative that the indications as well as the risks are specifically addressed. Expected outcomes and options available should the outcome be less than expected must also be clear. At no time should the patient hear or read of guarantees, even the implied guarantee that because the procedure is minimally invasive, there will be no adverse effects. By educating the patient about the entire process from diagnosis to recovery, the informed patient will be confident in his surgeon and be a willing and active participant in his recovery.

## Surgical Techniques

Arthroscopic Microdiscectomy was introduced in the United States by Dr. Parviz Kambin with reports of the technique dating back to the early 80's. This technique is the backbone of newer systems that build on the concept of visualization.

Patient selection features generally accepted indications including failure of conservative care, leg pain greater than back pain, evidence of neurologic deficit, and correlation with imaging studies. Contraindications, as determined by Kambin are fairly universally acknowledged; low back pain only, cauda equina syndrome, disc recurrence, and the likelihood of scar interfering with the

approach and setting up the potential for dural insults. Severe ligamentous or bony stenosis also number among the contraindications as well as multilevel degenerative disc disease and anatomic barriers to the L5/S1 disc, albeit a relative contraindication. Newer advanced techniques are designed to overcome some of these contraindications and make them "relative contraindications," limited only by the endoscopic surgeon's ability and experience.

Arthroscopic microdiscectomy is performed either uniportally or biportally depending on the offending pathology. The uniportal approach is indicated for paramedian and small central discs. Additional acceptable targets are foraminal and extraformaminal herniations. Large central herniations, subligamentous or extraligamentous sequestered herniations are best addressed with a biportal approach allowing continuous visualization.

The surgical technique for intradiscal work begins with a posterolateral approach of approximately 9-12 cm. off the midline. Slight lateralization of the approach may be necessary to access foraminal pathology or for canal inspection. Careless needle approach can be a setup for surgical misadventure and serious complications. Too vertical an entry threatens the bowel and vascular structures while an excessively far lateral approach can invade the abdominal cavity with potential visceral injury.

Via the posterolateral approach a needle is introduced. Needle position is extremely important since the obturator and cannula that follows should be close to the herniation at the foramen. AP and lateral fluoroscopy should confirm needle positioning at the mid-pedicular line and posterior to annular fibers respectively. For extraforaminal work, fluoroscopic landmarks should be lateral to the pedicle at the dorsolateral corner of the annulus.

Proceeding with uniportal intradiscal intervention for paramedian and small central disc pathology, a K wire replaces the stylet of the needle. A cannulated obturator is then passed over the K wire that is then removed. An access cannula passed through the obturator accompanied by firm, sustained docking on the annulus aids in the reduction of bleeding. With the removal of the obturator, annular fenestration is afforded using an appropriate sized trephine. Annular topical anesthesia is required for this painful portion of the procedure. A pathway has now been created for delivery of an arthroscope or working channel endoscope fashioned with irrigation and suction portals. In this instance a 0° - 30° endoscope can provide for visualized inspection and protection of at-risk structures while manual and automated surgical tools are introduced through the working channel for resection of disc and disc fragments resulting in decompression of the nerve root. Operative excursion is confined in a triangular working zone defined by the exiting nerve root anteriorly, the traversing root and thecal sac medially and the inferior (caudal) vertebral endplate. Kambin prefers to be on the asymptomatic side for his approach, reaching across the patient to operate on the symptomatic side.

For the biportal approach to the disc, usually considered for large central, subligamentous and extraligamentous (sequestered) herniations, the arthroscope is introduced from one side while the working channel scope is introduced contralaterally. Larger scopes (6.4 mm outer diameter) and oval cannulas are usually used in this technique for maximum excursion of articulating instruments to address the pathology.

A key element to this and all visualized endoscopic techniques is the need for high optical resolution rod-lens scopes with variable angle lenses. Multiple sizes help with special situations where the standard size is not appropriate. Local anesthetic and IV sedation should be employed

although Kambin has used general or spinal anesthesia, local anesthesia is preferred. General anesthesia takes away the surgeon's ability to communicate with the patient regarding sensations suggestive of nerve root encroachment or sensory response to successful nerve root compression. Critical to this technique and all other visualized endoscopic techniques is hand-eye coordination and special orientation as well as an understanding of neurovascular anatomy and structures at risk. These technique mandate mastery of a steep learning curve and proficiency maintained by regular surgical application.

As we proceed to describe other techniques, the advantages of these endoscopic techniques are similar. Surgical morbidity is low, recovery time is speedy and extensive rehabilitation is not usually necessary. Postoperative pain is minimal and return to preoperative lifestyle is timely and satisfying.

**Foraminal Epidural Endoscopic Discectomy**

The foraminal epidural endoscopic approach to herniated nuclear pathology was the next step forward in advancing and expanding surgical options for herniated lumbar discs. With this technique, established indications for endoscopic spine surgery were expanded. A technique to address preferably virgin, single-level paramedian, foraminal or extraforaminal herniated discs now allowed for access to contained or non-contained fragments of equal to or less than 50% of the spinal canal diameter if within the confines of the axilla and the pedicle.

Contraindications and the importance of correlating the patient's clinical symptoms with imaging studies essentially mirror the list already annotated. Advantages of the technique virtually parallel those of arthroscopic microdiscectomy.

For foraminal epidural endoscopic discectomy, the patient is placed on a padded radiolucent frame with standard prepping and draping. The surgeon is position on the side of offending pathology with the endoscopic monitor and light source at the foot of the surgical table. Fluoroscopy equipment is placed to allow unrestricted AP and lateral imaging throughout the procedure. Prophylactic broad spectrum antibiotics are administered preoperatively.

Anesthesia is twofold. Local anesthetic is administered at the skin level and in the musculature of the approach trajectory, taking care not to advance to the point of anesthetizing the neural structures at the foramen. Monitored anesthesia care provides for the delivery of light IV sedation only to the extent that patient-physician dialog can be maintained relative to procedural sensation. The presence of anesthesia professionals also allows for timely conversion to an open procedure if necessary.

At the commencement of the surgical intervention, a K wire placed at the surgical level allows for fluoroscopic verification of accuracy. If there is equivocation relative to the pain generator in suspected multilevel pathology or if these is question as to the state of containment or fragmentation of the nuclear material, discography may precede the actual procedure.

The surgical approach at approximately 9-13 cm from the midline and a discogram-type needle advanced to the pars is then directed medially to the foraminal ligament, an extension of the ligamentum flavum. At this point, the needle is position at the foramen. In the foraminal approach, a cannula is passed over the needle, the needles is removed and the rod-lens working channel endoscope is then passed through the cannula with delivery to the foramen from which

intradiscal or epidural access can proceed. The optics and lighting provide for clarity of visualization to identify, inspect and avoid critical structural anatomy and pursue pathology. Approach structures may dictate the size and sturdiness of the endoscope with a working channel diameter than can accommodate surgical tools appropriate to the targeted pathology.

Within the safe neural working zone of the epidural space, manipulation of the endoscope allows delivery of instruments designed to address pathology at distances from and angles to the scope. This safe working zone is defined by the offending level's exiting nerve root, the traversing nerve root which courses along the pathologic disc and exits at the caudal foramen and the intervertebral disc itself.

As visualized dissection ensures, cool (62º) free flow irrigant via the endoscope disperses debris from the operative field, promotes hemostasis and analgesia and also provides a safety factor. Bubbles generated by irrigation aid in special orientation since they exclusively migrate posteriorly. The irrigant also maintains an expanded work space for facilitation of surgical dissection and video documentation of operative success by way of visual inspection.

Upon conclusion of the procedure, sterile adhesive strips and elastic bandages are applied. The patient is placed in a neoprene corset with an ice pocket. Ice addresses postoperative pain and swelling.

Post-anesthesia care concludes when the patient is safely ambulating and demonstrates no negative anesthesia effects such as nausea and vomiting or vital sign instability.

Return to activities begins with walking and the avoidance of bending, twisting, lifting as well as long periods of sitting and impact recreational activities. Follow-up at one week allows planning for return to work and other activities that may take place at the one week point or may extend up to six weeks for patients with more demanding work of lifestyles.

Complications in addition to those related to malpositioned approach trajectory can include nerve root impingement though unlikely in the awake patient, epidural hematoma, discitis or recurrent herniation usually related to failure to adhere to postoperative activity guidelines. Post-procedure headache has been observed in the absence of dural insult.

The foraminal approach allowing for intradiscal as well as epidural intervention has been described by Matthews as "microdiscectomy though through a tube."

### Laser-Assisted Foraminal Discectomy

Casper and Stoll have integrated a rod-lens working channel endoscope with the right angle (side firing) Ho Yag laser wave length of 2.1 $\mu$m delivered via the foraminal approach as previously described. Indications for this technique are intradiscal and/or epidural disc herniations and fragments that can be visualized via angled endoscope lenses and addressed with a steerable laser fiber, the wavelength of which is cool and well tolerated by hydrated tissues. Laser energy serves to ablate the offending pathology. Flexible grabbing instruments adaptable to the working channel also aid in selective discectomy.

Contraindications to this technique include previous-procedure scarring, severe lateral recess or central stenosis or herniated pathology posterior and medial to the facet. Satisfactory outcome is seen in both single and multi-level interventions.

Relative to intradiscal work, this combination technique features a 5 mm outer diameter fiberoptic endoscope with a working channel of 1.5 to 1.8 mm. Lateral and posterolateral herniations are best addressed by this technique with 5 second on: 5 second off intervals for laser delivery up to 20,000 joules. Holmium laser energy may also be used for foraminal bony decompression to assist in lateral recess stenosis procedures.

Complications for this procedure are low due to visualization and controlled, cool laser energy. Potential complications include infection, discitis and transient dermatomal discomfort or nerve block. This procedure is done under local anesthetic with light IV sedation also has a high level of patient satisfaction and clinical success.

**Microendoscopic Discectomy**

Microendoscopic discectomy was introduced by Foley and Smith in the later '90's and of all posterior percutaneous procedures described, most closely resembles open microdiscectomy is its capabilities. The technique features an interlaminar approach to herniated disc pathology via successively delivered dilators through the paraspinous musculature with the final dilator providing for insertion of a tubular retractor that provides a corridor for insertion of a working channel endoscope. The approach allows for selective operative exposure based on the choice of dilators. Broader exposure allows for attention to both disc and bony pathology that may be the cause of neural compressive symptomatology. Lateral recess stenosis and/or foraminal stenosis can also be addressed by microendoscopic capabilities.

Instruments unique to this system in conjunction with the retractor and endoscope allow for both intradiscal and extradiscal intervention spanning from pedicle to pedicle and irrigation maintains a clear lens and divers operative debris from the surgical field. Upon conclusion of the procedure, removal of the retractor allows for spontaneous closure of the surgical corridor and the 12 mm incision that facilitates this technique is closed with a single suture.

In a preliminary report, these surgeons report 100% good to excellent results for far lateral herniations, herniations within the spinal canal as well as free fragment pathology. This outpatient procedure with timely recovery and return to premorbid activity levels has demonstrated only one complication in the 41 patients, that being a self-limiting cerebrospinal leak.

Microendoscopic discectomy offers a system with broadened endoscopic indications and low morbidity with satisfying clinical outcomes. Because of its ability to mimic open microdiscectomy through a tubular retractor, this endoscopic minimally invasive procedure offers most surgeons the comfort of familiar anatomy, and allows them to gradually transition to a fully endoscopic approach from the posterolateral portal. It may also offer the most flexibility, as it can easily be converted to an open traditional procedure if more exposure is needed.

**Selective Endoscopic Discectomy**

Bringing together the best elements of contemporary techniques, Anthony Yeung, M.D. introduced selective endoscopic discectomy. The broad applicability of this technique is based on a specially designed system of endoscopes, cannulas, and instruments known as the YESS (Yeung Endoscopic Spine Surgery System - Richard Wolf Medical Instrument Corporation).

The system is capable of addressing discogenic back pain as well as all types of herniated discs as long as they are contiguous with the disc space. More recent advancements that give the surgeon

the ability to remove bone endoscopically have allowed for improved surgical access and success with free and migrated fragments. Further technical advancements, combined with surgeon experience, allow surgical interventions such as neurolysis and/or foraminotomy even in previously operated patients.

As with all percutaneous procedures, success is based on patient selection and the surgeon's clear understanding of neurovascular anatomy and pathology as well as mastery of the technique through education, proctoring and frequent application. In the patient selection process, the surgical approach has to be uniquely tailored to the individual patient. An adjunct for surgical planning is careful study of the MRI to assure that the disc space and/or spinal canal is accessible. Lack of accessibility and/or failure to achieve the learning curve pinnacle are the main relative contraindications to this technique. Dr Yeung feels these skills are transferable and within the grasp of most dedicated spine surgeon willing to overcome the steep learning curve.

The YESS system features a variety of scopes and instruments that provides for tailoring the surgical technique to the anatomy to be inspected or the targeted pathology.

The most broadly applicable scope has been a rod lens endoscope with a 2.8 mm working channel. Additional channels for irrigation inflow, outflow, and suction controls visualization and capillary bleeding by hydrostatic pressure.

Discography with a contrast dye (Chromodiscography) precedes the procedure to verify the disc pathology through symptom provocation and to identify potential extrusions or the presence of annular fissures or tears. The dye contains a non-ionic contrast agent (isovue 300M) and a vital dye (indigo carmine) to stain degenerated tissue in contact with the dye.

Preferring the posterolateral approach, the technique for discectomy is performed under intermittent flouroscopy. A needle is directed to the disc and the position must be confirmed as consistent with the pathology and surgical plan since subsequent instrumentation will follow the trajectory of the needle. The needle further provides for palpation and penetration of the annulus.

Subsequent steps in the procedure begin with placement of a sturdy wire directed through the needle to the annulus. With removal of the needle, a dilator is delivered to the annulus. The dilator has an accessory channel that can be used for probing or anesthetizing structures adjacent to the central hole of the dilator. A cannula is then placed into the disc through which an endoscope is passed followed by removal of the dilator and cannula.

Inspection via the endoscope can assure that no neurovascular at-risk structures are in harm's way. The working channel endoscope can then be advanced to inspect and address the visualized pathology. With irrigation, suction and the adjunct channel now attached, a trephine facilitates an opening in the disc that then allows for the use of mechanical and motorized instruments appropriate to the disc location to achieve the discectomy goal. The obturator is also designed to allow for blunt fenestration of the annulus. Discoscopes with varied optical angles may be required to best view the pathology t