

Percutaneous Spinal Endoscopy and Discectomy: State of the Art

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Background: Minimally invasive techniques in spine surgery have progressed rapidly, giving the surgeon endoscopic tools that improve his ability to diagnose and treat discogenic pain. This paper reviews the author's experience with endoscopic spine surgery for disc herniations and for conditions previously addressed only with more invasive methods or conditions that give the patient no other surgical alternatives.

Materials and Methods: The author reviews his experience in spinal endoscopy with 600 patients from 11/91 to 5/99. In dealing with these conditions, emphasis was placed on visualizing spinal structures and targeting the removal of offending disc tissue. In certain cases, adjunctive therapies were used. These adjunctive therapies, radio-frequency, chymopapain, and intra-operative steroids, were employed in various clinical situations when visualized pathology dictated its use. An ongoing study continues, correlating patient outcomes who had endoscopic spine surgery for various spinal conditions usually reserved for more invasive traditional methods. Outcomes of each individual patient are recorded on a database at the time of discharge from care.

Results: Good/Excellent results were obtained in 432/500 (86.4%) reviewed from 11/91 to 12/98. The need for consistent clear visualization led to the development of the Yeung Endoscopic Spine System (YESS) which features an endoscope with an integration of inflow and outflow ports. The endoscope has a 2.8mm operating channel that is adequate in size for standard micro instruments yet strong and small enough to allow manipulation in the disc and spinal canal. This type of endoscope has made it possible for the experienced surgeon to remove osteophytes, perform foraminoplasty, and remove extruded and sequestered disc fragments.

Conclusions: The author's use of the endoscope in a posterolateral approach to the lumbar spine in 500 cases shows the following results: 1) The endoscope can produce clear and dependable pictures; 2) The primary use of the endoscope contests microdiscectomy as the best type of alternative surgical treatment for herniated lumbar discs; 3) By offering a minimally invasive method for diagnosing and treating discogenic pain, the patient's surgical risks are reduced while the diagnostic capabilities are increased; 4) The introduction of secondary adjunctive treatments improve and enhance the ultimate efficacy of selective endoscopic microdiscectomy.

Key Words

- herniated lumbar disc
- discogenic pain
- endoscopic discectomy
- chymopapain
- thermal-modulation
- annular tear
- radio-frequency
- adjunctive therapy

Introduction:

Before the advent of percutaneous techniques, the only accepted surgical treatment for herniated lumbar discs was laminectomy and partial discectomy or microdiscectomy. These procedures were reserved only for patients with severe, disabling leg pain (with or without neurologic deficit) who did not respond to an adequate course of conservative treatment.

In order to decrease surgical morbidity, surgeons have attempted to minimize surgical trauma to soft tissue by using smaller incisions and microscopes or loupes for magnification. This approach, however, has not been proven to improve results or alter the morbidity of surgically breaching the spinal canal.

As alternative approaches to the intervertebral disc and adjacent structures developed, viewing the onsite pathologic condition has remained limited due to the misplaced emphasis on using smaller flexible fiberoptic scopes and disposable equipment.

The use of expensive disposable fiberoptic scopes and a search for a standard sized instrument limited the clinical application and popularity of endoscopic spine systems. The new generation of spinal endoscopy systems, however, may be able to address these deficiencies. The new Yeung Endoscopic Spine System (YESS) emphasizes reusable durable equipment and quality imaging. With YESS it is now possible to clearly visualize the intervertebral disc, the epidural space, and the nerve roots traversing the disc segment. It is also possible to perform foraminoplasty with trephines, rasps, burrs, and lasers, since the system has a cannula system that will protect soft tissue but allow access to the pedicle and facet.

New rod lens spinal endoscopy systems give the surgeon the ability to diagnose and treat painful conditions in the lumbar spine previously not possible with conventional open surgery. As an additional benefit, the surgery is performed with the patient in a conscious state. Thus the surgeon is able to correlate visualized anatomy and symptoms while the anatomical structures are being stimulated.

Materials and Methods:

Five hundred (500) patients with disc herniations and discogenic pain underwent spinal discography, spinal endoscopy and intradiscal therapy from 11/91 to 12/98. Most of these patients had a variety of symptomatic disc protrusions, including recurrent, migrated, and sequestered disc fragments within reach of endoscopic spinal instruments introduced through the posterolateral approach. A subgroup with discogenic back pain from annular tears was studied prospectively.

All 500 patients followed an endoscopic protocol that included a preoperative or intra-operative discogram. Indigocarmine dye (American Reagent Laboratories) was mixed 1 cc with 4 cc of isovue 200 and injected in the nucleus pulposus. The presence or absence of back and/or leg pain provocation was recorded, then correlated with endoscopic findings. Each patient was followed by recording their response to treatment using modified MacNab criteria and asking the patient about their satisfaction with their procedure and whether they would recommend the procedure to others. Each patient's findings were recorded on a computer database, and endoscopic findings were included in the patient's chart by video prints of the spinal structures visualized. In addition, each patient's surgery was recorded on videotape. The patient's operative report was dictated on Image Manager, a commercially available system that allowed the recording of the patient's MRI, discogram, and endoscopic findings in a single report. This made it possible for the surgeon to

easily correlate his results with the endoscopic findings. This also allowed the surgeon to modify his surgical technique or to use adjunctive therapy when the condition dictates. For this reason, the patient selection and technique was in continuous evolution, guided by the correlation of findings with results.

In the first 100 patients, the KTP laser was merged with endoscopic discectomy (1). The laser aided visualization by clearing the cavity and by creating a bloodless field. It was also utilized to help ablate visualized disc tissue in the area of the herniation not reached by first generation endoscopic instruments. The thermal effect on the herniation site was felt to be potentially beneficial. Low dose chymopapain (500 units) was occasionally used as adjunctive therapy when disc fragments were extruded and migrated behind the vertebral body, or when the herniation was recurrent. It was hypothesized that chymopapain will help digest or denature any residual disc tissue out of reach of the first generation endoscopic instruments and help prevent a third recurrence by treating the residual disc tissue left behind. Those collagenized disc fragments pretreated with chymopapain were soon noted to be easier to extract. The fragments were more likely to be removed in one piece rather than in fragments. Following this observation, and buoyed by a string of successful surgeries, large disc protrusions that had a narrow base (height greater than width) were soon added to indications for chymopapain as an adjunct to endoscopic disc extraction. Pre-treating the extruded fragment with chymopapain made it more likely that the fragment was extracted in one piece without breaking off. In a separate retrospective study of 31 consecutive patients within the 500 patient group, a 93% success rate was noted (utilizing modified MacNab criteria) when chymopapain was used in conjunction with mechanical fragmentectomy, even when chymopapain was reserved for the more difficult cases.

The need for consistent, optimum visualization also prompted the development of an improved operating endoscope utilizing integrated inflow and outflow ports. The Yeung Endoscopic Spine Scope System (YESS), manufactured by Richard Wolf GmbH Knittling, Germany, and approved by the FDA April 1998, evolved in the period of time these cases were being treated. The inclusion of irrigation ports at the tip of the scope and the use of laser or electro-thermal electrodes for hemostasis improved and allowed for consistent clear visualization of spinal structures.

When chymopapain was used, patients were informed about its risks and benefits as an adjunct to mechanical fragmentectomy and given the option to accept or decline its use. The patient was pre-tested for chymopapain sensitivity with a test for antibodies to chymopapain as a standard practice when there was enough lead time to get the test. Very occasionally, with informed consent and no history of allergy to papaya, the test was waived when the peri-operative discogram leaked contrast into the epidural space outlining an extruded fragment. When an extruded and or sequestered fragment was identified by discography but not identified by MRI, the patient was given the choice to abort the endoscopic procedure or to add chymopapain to the procedure to improve the chance of success. All but one elected to proceed with the endoscopic procedure.

In all patients treated with chymopapain, cimetidine 100 mg and benadryl 50 mg were given intravenously prior to chymopapain injection. Low dose chymopapain (500 units diluted to 1 cc) was injected and left in the nucleus pulposus for 5 - 10 minutes before fenestration of the annulus. A small amount of isovue 200 was placed in the nucleus to confirm retention of the injectate in the disc space. If the contrast was immediately absorbed into the blood stream or entered the

thecal sac, chymopapain was not injected.

At discography, the morphologic pattern of the disc and annular fibers was recorded. The disc annulus bordered by the superior facet of the inferior vertebra or traversing nerve root, the exiting nerve root and end plate was then visualized. The annulus was fenestrated bluntly when appropriate, or by annulotomy knife or trephine.

In the second 100 patients, a radio frequency electrode (Ellman), was substituted for the KTP laser. This was a cost saving decision to eliminate the additional cost of the laser and probe. This probe substituted for the laser for coagulating bleeders and contracting the disc and annulus. The KTP laser, because of its spectrum, was also difficult to visualize without a special filter. The development of deflecting instruments to remove disc tissue reduced the need for expensive laser equipment that was used to target tissue not accessible by mechanical instruments. After disc tissue was thermally contracted, loose, soft, and collagenized disc tissue was removed with manual instruments and motorized suction devices. The area of disc protrusion or annular tear was thermally treated again. At the end of the procedure, the epidural space was visualized and probed. When an inflammatory membrane was a significant part of the clinical findings, depomedrol 80 mg/cc was placed intradiscally at the conclusion of the procedure. Where indicated, the epidural space and the traversing and/or exiting nerve were also visualized or probed.

Extracted tissue was sent to surgical pathology for gross and microscopic examination. Extracted disc tissue was also weighed. The amount of disc material removed was recorded for future correlation with results and the presence or absence of segmental settling or instability.

When a unipolar, flexible, temperature controlled electro-thermal probe became available (Oratec Interventions Inc., Menlo Park, California), fifty patients with positive provocative discograms enrolled in a prospective study on the treatment of painful annular tears with the Oratec Oraflex Probe. This study to investigate the efficacy of the probe for collagen shrinkage and treating back pain was approved by the Institutional Review Board at St. Luke's Medical Center Phoenix, Arizona. Patients with discogenic pain from disc protrusions or annular tears undergoing selective endoscopic discectomy with the YESS scope were asked to participate in the study. All had annular tears with predominant back pain, but may also have leg pain from a chemically sensitized nerve root. The patients were examined pre-operatively, at 1 month, 3 months, and 6 months postoperative periods. A modified SF- 36 questionnaire was filled out by each patient at each visit. In these patients, a visualized endoscopic technique, (YESS), was utilized for diagnostic endoscopy. Each discogram was performed with a radio opaque contrast agent (Isovue-200) mixed with indigocarmine dye. The dye stains degenerative structures within the nucleus pulposus and annulus. The patients' response to provocative discography was noted and recorded on a visual analog scale (1-10) separately for back pain and leg pain.

Leg pain patterns were not required to be in a dermatomal distribution to be considered valid, since the patient would not always have exact pain reproduction. The degenerated disc material was thermally contracted under direct vision through an operating endoscope. Loose and degenerated disc material was extracted. Inflammatory membranes, when encountered, were also ablated. The area of the annular tear was then treated with the Oraflex probe at 65 degrees C.

Endpoint treatment was determined by observing tissue as it was thermally modulated. The

annular tear was not always visualized, but the radial fissure leading to the annular tear was always detected. When all interpositional disc tissue was removed, the collagen fibers of the inner annulus were easily visualized.

The patients' clinical results were rated in accordance with modified MacNab criteria and the intraoperative discogram pattern was recorded using Adam's classification for degenerative discs (2). The extent of the tear was determined by a modification of the Dallas Discogram Description (3). The tear pattern was further divided into radial and circumferential components per Osti, et.al (4).

The result was a Modified Dallas Discogram Description that utilized discogram patterns and its radial extension into the peripheral annular fibers by the number of quadrants involved, but did not depend on a CT scan to rate the tear.

Results:

Overall, good/excellent results were found in 432/500 (86.4%) patients. Since the YESS system allowed for more dependable visualization, more difficult disc herniations were included in the surgical indications. In spite of wider inclusion criteria, results remained stable and patient selection improved.

Out of the first 100 patients, (follow-up 2-4.5 years), 80 were independently analyzed and reviewed by Dr. Al-Hamdan and Dr. Hadjipavlou (UTMB Galveston). Twenty patients who had been discharged were not able to be contacted or did not return for a personal examination by Dr Al-Hamdan. In this series of patients with disc protrusions, the KTP laser was the thermal energy source used to coagulate bleeding tissue and shrink disc tissue out of reach of first generation endoscopic spine instruments. Good or excellent results were noted in 56/80 patients (70%). This population included similar numbers of workman's compensation patients, litigation patients and private patients.

Mean age was 41.9 years (range 25 - 69 years). Twenty-four patients 24/80 (30%) were rated fair or poor. The 32/80 patients who presented with predominant leg pain had a success rate of 80% (good/excellent), and the 49/80 patients who had predominantly lower back pain was 63%, good or excellent. Sixty-nine patients 69/80 (89%) said that they were satisfied with the procedure and would recommend it to others who have similar conditions. This group of patients included those who were rated fair or poor. Eight patients 8/80 (10%) did not improve after the procedure and continued to have significant symptoms. These patients underwent subsequent successful open discectomy. Cause of failure was either from failure to remove an extruded fragment completely or unrecognized foraminal stenosis.

Post operative pain improvement on a visual analog scale of 1-10 averaged 7.2. Twenty-eight patients 28/56 (50%) of the good or excellent rated group had immediate improvement of symptoms. The remaining 28/50 patients had gradual resolution of symptoms over a period of days or weeks.

Post operative complications included only two cases of transient paraesthesia of the lower extremity; both cases resolved spontaneously. The operated levels are identified in Table 1.

Table 1

L2,3	2
L3,4	12
L4,5	28
L5,5	21
L4,5 and L5,5	17

The 50 consecutive patients in the Institutional Review Board (IRB, St. Luke's Medical Center) approved electro-thermal probe study is now complete and awaiting independent review. Preliminary results indicate very high patient satisfaction. Observations correlating annular tears with discograms and endoscopic findings with electro-thermal response revealed these findings:

- Cotton ball and central lobular patterns and (Adams Classification) Grade I and II tears never produced pain.
- Grade III radial tears produce pain at moderate pressures, and were the most amenable to thermal shrinkage.
- A high intensity zone on MRI is correlated with Grade IV and V tears of the outer annulus on discography, but is detected only in the posterior annulus. The painful response is often non-dermatomal and dependent on the location of the tear.
- Grade V tears are often associated with an inflammatory membrane, which can spread beyond the area of the tear.
- Annular tears far laterally and ventrally are usually undetected by HIZ, but readily identified with provocative discography and visualized endoscopically.
- Ventral and far lateral tears do not reproduce dermatomal pain. Both far lateral and dorsal tears have soft nucleus pulposus interposed between the collagen bundles of the annulus.

The soft disc material is visualized to contract and pull away from the annulus. While most annular defects decrease in size, the defect may sometimes open further if the tear is large. Ventral tears produce groin pain, even at L5-S1, possibly from irritation of the femoral genital nerve along the psoas muscle. Groin pain was a very common finding. Thermal-modulation of the nucleus pulposus will cause the degenerative disc material to shrink, loosening fragments of disc that are easily extracted with motorized shavers. Unstained disc tissue is usually more firm and is adherent to the annular wall. Granulation tissue and inflammatory tissue is seen with grade IV and grade V tears. The combination of disc decompression and thermal modulation of the annular defect produced high patient satisfaction.

In the IRB study, 45/50 patients (90%) responded positively on the SF-36 questionnaire for pain relief and would opt for the procedure again. Grade III tears involving less than one half of the dorsal annulus responded fastest and best, with pain relief occurring in one week to three months.

These types of Grade III tears are painful only with moderate pressure when the discogram is performed, and do not usually stain the outer annulus. Grade IV tears involving 50% or more of the annulus took an average of 3 to 6 months for back pain relief and Grade V tears may take up to 9 months to improve. These patients were followed for 6 to 15 months.

In a preliminary prospective study reviewing 50 patients not part of the IRB study, early results of 84% good/excellent by MacNab criteria is quite promising for the electro-thermal procedure. It is minimally invasive and only minimally destabilizes the disc since the annulus is fenestrated bluntly. Complications have been limited to dysesthesia, attributed to thermal irritation of the traversing nerve or dorsal root ganglion of the adjacent exiting nerve by the spread of heat through annular fissures or defects.

A 20% incidence of dysesthesia is troublesome, but usually temporary. A higher and more severe incidence in the first thirty patients was found to be related to large fluctuations of temperatures of as much as 40 degrees C as measured by the Endoflex Oraflex probe. Symptoms take from 2 weeks to 9 months to resolve. Two patients continue to have paresthesia or residual numbness and quadriceps atrophy. These results occurred when the probe tip was buried in the annulus or disc and the probe was not constantly irrigated by cold saline. The Oratec probe may not be able to modulate the temperature as quickly or accurately as desired. The author will investigate Ellman bipolar electro-thermal probes to determine whether it will mitigate the dysesthesia problem.

Fortunately, dysesthesias usually resolved completely, but can be very bothersome to the patient. Severe dysesthesia can be relieved by nerve root blocks and opioid analgesics until the pain resolves.

Discussion:

Treatment of Herniated Nucleus Pulposus

In 1963, Lyman Smith (5) reported on the effects of chymopapain on symptomatic disc herniations. The enzymatic debulking of the nucleus pulposus is still the only minimally invasive technique validated by two large double blind and a number of cohort studies (6,7,8) as effective in the treatment of contained, soft lumbar disc herniations. Unfortunately, the enzyme may not be effective on hard collagenized fragments (9,10) or sequestered and migrated fragments.

The limitations of chemonucleolysis are not as much due to its effect on the nucleus pulposus but the failure of our current imaging capabilities to help with patient selection by differentiating between soft versus collagenized disc tissue. MRI and CT myelograms are also deficient in detecting small disc fragments that may have extruded beyond the reach of the enzyme. Earlier chymopapain experience with much higher doses (2,000 units) produced severe back spasms and disc collapse, but low dosage (500 units) was effective for leg pain relief without the spasm and disc space narrowing.

The apparent simplicity of chymopapain injection invited overutilization. Poorly trained surgeons began injecting the enzyme in areas outside the nucleus pulposus and a few devastating complications occurred (11). Failure to recognize the possibility of systemic vascular dispersion of the enzyme through the end plate or extension with nuclear material into the thecal sac contributed to the small percentage of patients who experienced a systemic reaction or intrathecal bleeding. The perceived unacceptable risks and a lower clinical success rate of the procedure compared with standard discectomy curtailed its use in the United States. In this study no adverse reaction was observed.

The Author's Modification of the Dallas Discogram Description

The Dallas Discogram Description incorporates the radiographic view and the axial view seen by CT/discography. The scheme focuses on the annular appearance to describe degeneration and annular disruption as separate phenomena. Since the author's modified description does not have the detail of CT/discography, the details of numerical grading of tears was simplified to describe only its radial extension to the annulus based only on the AP and lateral views. Grades I and II were considered normal patterns to be correlated with a cotton ball or lobular pattern that did not extend beyond the central half of the disc. The radial extension was simplified to describe its distance to the inner annular fibers (grade III), the outer fibers (grade IV), and beyond the outer annulus (grade V). A circumferential component was simply noted and graded by the number of quadrants involved. Table 2 shows the author's Modified Dallas Discogram Description. The patient's pain response was recorded only for the presence of back and/or leg pain as estimated by the unanesthetized and unседated patient on a visual analog scale. Because it was usually not possible for the patient to accurately define concordant versus non-concordant pain, it was just as informative to simply separate pain to the presence of back and/or leg pain.

Table 2
Modified Dallas Discogram Description

Grade	Degeneration (nucleus)	Radial Annular Disruption (contrast extension)	Circumferential Annular Disruption (by quadrant)	Pain 0-10 Back/leg
I	Round cotton ball	circular		0/0
II	Round or oval lobular	oval		0/0
III	Fissured	extension to inner annulus (no disc protrusion)	focal 1/4, 1/2, 3/4, 4/4	1-10/1-10
IV	Degenerative to outer annulus	extension to outer annulus (may include disc protrusion)	focal 1/4, 1/2, 3/4, 4/4	1-10/1-10
V	Degenerative past annular extension disc (with disc protrusion)	beyond outer annulus (may include extruded disc fragment)	focal 1/4, 1/2, 3/4, 4/4	1-10/1-10

Use of Adjunctive Therapy

The use of chymopapain and electro thermal probes in endoscopic spine surgery has improved the results of endoscopic surgery. The disadvantages of limited access are mitigated when these adjunctive therapies enhance the contraction and removal of targeted tissue. Low dose chymopapain may help "dissolve" soft nucleus that is seen to act as an interpositional tissue barrier between the disrupted collagen bundles of the annulus. The softened retained collagenized fragments are easier to extract if pretreated with chymopapain. When chymopapain is not used, thermal contraction of the annular fibers will dislodge or expel disc fragments trapped in the annulus.

The clinical results of long term back pain relief from the independent study of the first 80 patients using the KTP laser as adjunctive therapy resulted in further studies incorporating the use of electro-thermal energy to treat back pain and to shrink or modulate disc and annular tissue. The laser served to clear the disc cavity and provide hemostasis for better visualization. The heat effect of laser therapy was speculated to be the reason for back pain relief. It may have ablated the annular pain nociceptors along with shrinkage of the type 1 collagen fibers in the annular wall.

For patients without disc protrusion but with painful grade III and IV annular tears, the endoscope has identified nucleus pulposus as the most common interpositional material between the collagen bundles. This interpositional tissue may be responsible for the tear not healing. Other tissues identified include granulation tissue and inflammatory membranes adjacent to grade V annular tears that extend to the epidural space and outer annulus. These tissues can be ablated easily with a thermal probe. Annular tissue will contract, effectively closing the herniation defect.

The Discogram as a Diagnostic Aid

The intraoperative discogram is invaluable as an adjunctive test just prior to spinal endoscopy. A painful provocative discogram with an abnormal pattern usually confirms the pathology seen on preoperative imaging tests. It can fill the herniation defect, warn the surgeon of non-containment if contrast extravasates, or simply outline the annular defect for thermal shrinkage. When a vital tissue dye is used, it helps target the degenerative tissue for removal. Classic extruded disc herniations are usually caused by collagenized fragments that are trapped by the annulus and cannot retract back into the disc space. These herniations are often seen as a void on the discogram as opposed to contrast material filling the protrusion. When this appears intraoperatively, the surgeon is alerted to the presence of a collagenized disc fragment that must be extracted. These fragments can be examined in previously unappreciated detail after removal to further understand the pain process (fig.5).

The mechanical endoscopic approach to the disc through a posterolateral portal was described by Hijikata (12,13) and Kambin (14 - 16) in the early 1970s. Both used Craig-type cannulas (17) and mechanical manual instruments to remove disc tissue from the triangular zone between the traversing and exiting nerve roots. Kambin (14 - 16) continued to refine his system to allow for targeted fragmentectomy using uniportal and biportal techniques. The system was also initially dependent on one cannula size and configuration and limited irrigation and fluid control. Later development of an oval cannula was helpful to allow the fanning of instruments more dorsally and ventrally to target disc tissue.

Kambin's aversion to routinely exploring the spinal canal to confirm nerve decompression was foreign to most surgeon's desire to explore the spinal canal where herniated and extruded fragments were likely to b