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Posterolateral Transforaminal Selective Endoscopic Discectomy™ and Thermal Annuloplasty for Chronic Lumbar Discogenic Pain.

A minimal access visualized intradiscal surgical procedure

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ABSTRACT

Background Context

Chronic lumbar discogenic pain (CLDP) impairs the patient's physical abilities to function within the normal physiologic loading ranges of activities of daily living. The pathogenesis of CLDP is multi-factorial and not well understood. Conservative therapeutic regimens often fail to achieve sufficient pain relief. Surgical options vary greatly in surgical invasiveness as well as outcome. Definitive surgical treatment is often 360° fusion. The morbidity associated with this approach is significant when considering only 65-80% of patients obtain satisfactory clinical results. This has spawned interest in minimally invasive surgical options like IDET, but results are conflicting.

Purpose

The authors describe their surgical technique of minimal access posterolateral transforaminal Selective Endoscopic Discectomy™ (SED™) and bipolar radio-frequency thermal annuloplasty to treat CLDP. The procedure's rationale is based on the hypothesis that annular defects are the focal points of chronic exposure between neural sensory receptors in the defect and the inflammatogenic nucleus pulposus. In contrast to other percutaneous procedures, this technique allows direct visualization and targeting of the disc nucleus and annular fissures. Our two year clinical result is reported.

Study design/Setting

This is a retrospective review of consecutive surgical cases performed by one surgeon (ATY). The procedures were carried out between January 1997 to December 1999. Each patient has a minimum postoperative follow-up of two years.

Patient sample

One hundred thirteen patients met the generally accepted clinical criteria for chronic lumbar discogenic pain and were selected for the procedure.

Outcome measures

Two outcome measures were used for clinical assessment: a surgeon based modified MacNab method and a patient-based questionnaire. A mandatory poor result was given to any patient who had repeat spine surgery at the same level or has indicated dissatisfaction with the surgical result on the questionnaire response.

Method

After meeting CLDP selection criteria, provocation contrast/indigo carmine dye discography was performed. This test was used to confirm the suspected discs as pain generators. The subject surgery then followed. Only cases with one and two levels of confirmed painful discs were entered into the study. The non-operating author (PMT) analyzed the data.

Results

Using the surgeon assessment method seventeen patients (15 %) had excellent results; thirty-two patients (28.3 %) had good results; thirty-four patients (30.1 %) had fair results; thirty patients (26.5 %) had poor results. Of the thirty patients in the poor result group, twelve reported either no improvement or worsening, and refused further surgical treatment. Of the remaining 18 patients in the poor group, eight had spinal fusion, three had laminectomy, and seven had repeat spinal endoscopic surgery. The patient-based questionnaire yielded similar percentages in each category, however, only 73.5% of the 113 patients returned the survey questionnaire. There were no aborted procedures, unexpected hemorrhage, device related complications, neurologic deficits, perioperative deaths or late instability.

CONCLUSIONS

Posterolateral transforaminal SED™ and radio-frequency thermal annuloplasty were used to interrupt the purported annular defect pain sensitization process, thought to be necessary in the genesis of chronic lumbar discogenic pain. Lack of clinical benefit from the subject procedure did not degrade any subsequent surgical or non-surgical treatment options. The experience gained from this study warrants further investigation into the cellular and molecular processes that provided back pain relief in these patients.

KEY WORDS AND PHRASES:

Chronic lumbar discogenic pain

Posterolateral transforaminal minimal access

Intradiscal endoscopy

Provocation discography

Evocative discography™

Selective endoscopic discectomy™

Radio-frequency annuloplasty

Indigo carmine dye stains degenerative nucleus and annular defects.

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Introduction

Experimental in vivo stimulation of the annulus fibrosus of intervertebral disc produced back pain, and the term "discogenic pain" was coined[1] to establish the association between annulus stimulation and the subjective pain perception. Histologically the end organ neural sensors are located in the outer layers of the annulus, epiannular surface and the juxta end-plate region[2,3,4].

The condition, called "chronic lumbar discogenic pain (CLDP)," typically has no distinct chronologic starting point or causative event. It is believed that local, regional and central nervous system interactions[5,6,7] all play an important part in the chronic pain sensitization process. Nucleus pulposus and its metabolic by-products are known contact irritants to the nerve tissues and are known to reduce their membrane excitation threshold[8,9,10,11]. There is no direct contact between the neural end sensors and the intradiscal irritants in an intact disc. Annular defects are demonstrated in degenerative discs in post-mortem studies[12,13,14] and in vivo discographic examinations[15,16,17]. The authors hypothesize that the degenerative process, trauma, and possibly metabolic changes lead to fissuring of the annulus fibrosus and defects in the end plates which bring the neural end sensors into chronic contact with the intradiscal irritants. Under these

conditions, irritants have unimpeded entry into the sensory fields through annular fissures/tears/clefts. Defects in the annulus create an inflammatory response and ingrowth of granulation tissue[18], new vessels, and new nerve endings (figure 1 & 2). Chronic exposure of the neural end sensors to the irritant in the annular defects is hypothesized to be the local pain sensitization pathway that leads to chronic discogenic pain.

Selective Endoscopic Discectomy™ (SED™) is performed using the Yeung Endoscopic Spine Surgery™ system (YESS™, Richard Wolf Surgical Instrument Company, Vernon Hills, Illinois, USA) in order to selectively remove nucleus pulposus in contact with and interposed within the annular tears. The thermal annuloplasty portion of the procedure uses a bipolar radio-frequency (RF) electrode. (Ellman Trigger-flex probe, Ellman International, Hewitt, New York, USA) The RF electrode ablates ingrown granulation tissue[18,19,20,21,50] and nerve endings already in the annular defects, and shrinks the annular openings.

The preliminary clinical results are reported here. This is the first report in the English language literature using the endoscopically visualized technique for the management of CLDP.

Historic background

Lumbar posterolateral intradiscal nuclectomy for the purpose of indirect nerve root decompression was first independently attempted by Hijikata[22] and Kambin et al[23] in

1973. Forst[24] and Housmann used an arthroscope to view the intradiscal space in 1983. The concept of non-visualized central nuclectomy with indirect nerve root decompression was further advanced by Hijikata[25] who utilized forceps, Onik[26] who used a 2.8 mm. automated shaver, and others[27,28] using various heat ablation devices. Refinements in the access method, endoscope optics, and ablation tools in the last few years have enabled endoscopic spine surgeons[29,30,31,32] to develop new techniques to remove extruded and sequestered herniated lumbar discs, and obtain results comparable to that of traditional open methods.

Schreiber[33] et al. in 1989 injected indigo carmine, a blue color vital dye, for intradiscal differential staining. Indigo carmine (10-20%) selectively stains the more acidic and fragmented degenerated nucleus pulposus, as demonstrated by direct visualization. The staining helps the surgeon locate and selectively remove or ablate this blue-stained degenerative tissue interposed within annular fissures.

Although acute lumbar disc herniation has reliable correlating clinical symptomatology and imaging studies, CLDP has no generally agreed upon criteria in either area. Abnormal patterns of intradiscal radiologic contrast images were first reported by Lindblom[12,13] in 1941 in a postmortem injection study. Patterns of abnormalities in discographic images have been classified[15,17,34]. Hirsch[35] introduced the concept of provocation saline disc injection to identify painful/symptomatic discs when patients experienced a subjective painful response to disc pressurization. Other investigators have studied provocation discography[14,36,37,38], with mixed conclusions regarding the reliability

of this test for clinical use. Due to the conflicting literature, provocative discography remains controversial, but is the only practical provocative test to identify a painful disc (discogenic pain). It is commonly used to confirm that a disc is a pain generator, and thus a suitable target for treatment by fusion, disc arthroplasty, or other minimally invasive intradiscal procedures including SED™ and RF thermal annuloplasty.

For this study the authors used provocation radiographic non-ionic contrast/indigo carmine dye discography for localization of the painful disc level(s) and to visually mark the degenerative nucleus and annular defects. In order to differentiate our method of discography from other published techniques, we have coined the term evocative-chromo-discography™.

Materials and Method

Patient Selection

Between January 1997 to December 1999 the senior author (ATY) performed posterolateral transforaminal lumbar endoscopic surgery in 510 patients for various pathologies. The senior author specializes in endoscopic treatment of degenerative conditions of the lumbar spine that include treatment of herniated lumbar discs, foraminal stenosis, degenerative and isthmic spondylolisthesis, pyogenic discitis, and chronic lumbar discogenic pain. One hundred fifty-one patients had a pre-operative diagnosis of chronic discogenic pain. In this group, 32 had a three level endoscopic disc procedure and six had a four level procedure. The remaining 113 patients had one or two level painful discs and they are the subjects of this study.

The study group included 66 male patients, with an average age of 39.4 years (range 20-73), at time of index operation. There were 47 female patients, with an average age 43.2 (range 22-69). The average length of conservative treatment before surgery was 31.1 months, with a minimum of six months. The average postoperative follow-up period was 31.3 months, the median was 30 months, and the minimum was 24 months. Thirteen patients (12 %) reported that their back pain was related to an automobile accident. Thirty patients (27 %) had workers compensation claims. This population clearly did not fare as well as private patients, but the outcomes were not separated out because the small numbers. Post operative follow-up is on days 7, 14, 30, and 60, and thereafter every six months.

The patients in this study had symptoms that fulfilled our clinical definition for CLDP. The definition emphasizes axial spinal pain as the chief complaint, and little if any extremity radiation. The axial pain and functional impairment consistently occurred within the normal physiologic loading ranges of activities of daily living for longer than six months. The discogenic origin of this pain is confirmed by positive pressure challenge during discography using similar parameters as defined by Derby et al[39]. The clinical findings of CLDP may overlap the following clinical entities: degenerative disc disease, disc internal derangement[40], internal disc disruption, isolated disc resorption[41], dark disc disease, and lumbar spondylosis.

Patients in the study group were refractory to supervised non-surgical management. They failed to respond to spinal orthosis, modified physical activities, anti-inflammatory medications, analgesics, and a lumbar stabilization and back hardening exercise program. The CLDP group had no clinical symptoms related to spinal stenosis and spondylolisthesis. Degenerative disc narrowing was not excluded even if severe. This is in contrast to IDET selection criteria. Annular bulges, as demonstrated by MRI images, were limited to less than five millimeters expansion beyond the posterior bony vertebral margins.

After the patients are screened by the above selection process, they are then scheduled for evocative-chromo-discography. The discography is carried out by the operating surgeon using a 6 inch 18 gauge spinal needle and a 10cc syringe. It is important to obtain a negative control disc level to validate the discography and minimize false positives. The suspected disc(s) are confirmed as a source of back pain by demonstrating injection pressure sensitivity within physiologic ranges, and reproducing concordant back pain greater than 5/10 on an analog pain scale. The disc morphology should be abnormal and demonstrate a disc protrusion or annular tear. The adjacent control level should clearly show no concordant pain or significantly lower pain sensitivity during the injection. The above diagnostic requirements for endoscopic spinal surgery are commonly accepted criteria for spinal fusion[42,43,44,45,46,47] and disc replacement procedures[48,49]. If discography did not meet the above criteria, surgery was not recommended. Some of the study patients were offered various fusion procedures by other spine surgeons, but declined fusion and elected endoscopic surgery as a minimally invasive first option.

Surgical technique

Each patient gives informed consent for the operation. A preliminary study to evaluate the use of a monopolar flexible radio-frequency temperature controlled probe (Oratec, Menlo Park, CA) was approved by the Institutional Review Board of Saint Lukes Medical Center, Phoenix, AZ. After the initial study of 50 patients indicated favorable results for back pain relief, the senior author continued to use radio-frequency to help treat discogenic pain. The bipolar Ellman Trigger-flex RF probe is now used for its benefits as a bipolar device. All of the patients in this study were treated with this bipolar RF probe.

The procedure is performed in an outpatient setting. The patient is placed prone on a radiolucent hyperkyphotic frame with the arms away from the body. Local anesthesia with half percent lidocaine and conscious sedation with fentanyl and versed (administered by an anesthesiologist) are used. The sedation is kept light enough to allow for patient feedback if they feel any nerve root irritation. The conscious patient serves as a dependable warning system for nerve root irritation. Biplanar fluoroscopy with one C-arm is used throughout the case. A method for optimal needle placement previously described by Yeung[31,32] is utilized to estimate the optimal skin entry point and trajectory for the 6 inch 18 gauge needle rather than arbitrarily starting 9-11cm lateral to the midline as other authors suggest. The needle is placed into the posterior 1/3 of the disc via Kambin's Triangle (figure 3). The needle typically enters the disc at a 25°-35° angle in relation to the coronal plane and is parallel to the endplates (figure 4).

Once the needle is positioned appropriately within the nucleus, evocative-chromo-discography is performed. It is mixed with Isovue 300 in a 1cc:10cc ratio. This 10% concentration of indigo carmine still allows for visible radio-opacity on discographic images and light blue chromatization of the pathologic degenerated nucleus within the annular tears (figure 5).

A 1.2 mm wire stylet is placed down the spinal needle and the needle is removed. A dilating 2 channeled obturator is placed over the wire down to the outer fibers of the annulus. A long needle is placed down the offset second channel and the annulus is anesthetized circumferentially around the wire with half percent lidocaine. The wire is removed and the annulus is then bluntly fenestrated with the obturator. A 7 mm beveled cannula is then advanced over the obturator and docked within the annular fibers. The obturator is removed and replaced by the operating endoscope. The beveled cannula allows for a larger viewing area than a flat ended cannula. It allows for same field viewing of the epidural space, annular fibers, and nucleus pulposus if desired.

The blue-stained nuclear tissue is then removed under direct visualization with the endoscopic rongeurs placed down the working channel of the endoscope. An intradiscal working cavity (figure 6 and 7) is created with larger straight and hinged rongeurs and straight and flexible suction-irrigation motorized shavers. The flexible tip motorized shaver (Endius Inc., Plainville, MA) is an efficient debulking tool (figure 8). When the

shaving debris becomes pinkish in color in the suction tube we stop the shaving and inspect the disc cavity and the deep annular surface.

Under endoscopic visualization the bipolar RF electrode is introduced into the annular fissure/cleft/ gap, already marked by the blue stain (figures 9). The high frequency 4.0 megahertz Ellman Trigger-flex RF probe is set to a power setting of 12-15 which is equivalent to 15-20 Watts. The RF heating process ablates granulation tissue in the defects and theoretically the sensory receptors that have grown into the surfaces of the fissures and the crevices. The RF device is removed after visual confirmation of granulation tissue ablation and fissure shrinkage is observed. The bipolar RF probe is also used to cauterize any epidural bleeders.

A standard 30° viewing endoscope is routinely used. A 70° endoscope is also available to get a better look at the deep surface of the posterior annulus.

Post operative follow-up is on days 7, 14, 30, and 60, and thereafter every six months. An orthosis is not used routinely. Basic activities of daily living for self care are allowed upon discharge. Activity progression starts four to six weeks postoperatively, including trunk muscle strengthening.

Evaluation method

Two outcome measures were used for clinical assessment; a surgeon-based modified MacNab method and a patient-based questionnaire. Each patient's clinical data including

history and physical examination, consultation, MRI images, provocation pain responses, discographic images, operative notes, intraoperative video tapes, and follow-up assessments were recorded by the senior surgeon (ATY) and an outcome rating was assigned based on MacNab's criteria[51]. The independent review surgeon (PMT) compiled the information into a computer data base. The review surgeon took no part in the endoscopic surgery or patient care. Additionally, a self-administered patient satisfaction survey questionnaire[31,32] consisting of eight questions, was mailed to the patient's last known home address. The survey was conducted between January and March of 2002. The questionnaire was then mailed back to the review surgeon for tabulation and analysis.

The results of this endoscopic procedure were each graded excellent, good, fair and poor for the modified MacNab and the questionnaire methods (table 1 & 2). Since this study attempts to determine the benefits of a specific surgical technique, mandatory poor grade is given even if the poor result is patient selection or technique related. The poor grade is assigned if the surgeon determines the two year post-operative outcome was the same or worse than the pre-operative status. A poor grade is mandatory if there had been a subsequent operation at the index level. Even if the patient received some clinical benefit, but opted for another surgery in hopes of getting even more symptom relief, the patient was rated poor. Four questionnaire items also placed the outcome in the poor category. These are as follows: if the patient expressed dissatisfaction about the operation; the patient judged his over all back symptoms was unchanged or worse than they were pre-operatively; the patient reported secondary back operation at the index

level; patient would not select endoscopic spine surgery again in the future if presented with the same clinical indications.

If the mandatory poor grade is not applicable, the patient's assessment grade will be either excellent, good, or fair. The patients overall questionnaire grade is based on the cumulative score of four questions (questions 1-4, table 1). Each question is assigned a point value of 0-3. Three points is best, and zero point is least. Questions 1-3 are time dependent. These referred to the time from operation to resumption of their customary occupation (question 1), to resumption of activities of daily living including recreational sports (question 2), and to the need for prescription analgesics (question 3). In question 4, the patient self assessed the degree of clinical recovery after the endoscopic operation: complete-3 points, almost complete-2 points, partial-1 point, no improvement-0 point. The cumulative point rating was 9-12 points for excellent, 5-8 points for good, 3-4 points for fair.

Results

The one hundred and thirteen consecutive patients in the study group were followed for a minimum of two years postoperatively for surgeon based assessment. Forty-seven patients had single level and sixty-six patients had two level procedures (table 3). Follow-up period averaged 31.3 months, with a minimum of 24 months. The total number of questionnaires returned was eighty-three (73.5%). Thirty questionnaire mailings were either unanswered or returned without a known forwarding address.

Using the surgeon's assessment data, eighty-three patients (73.5%) were in the satisfactory outcome group (table 4). This group of patients included excellent, good, and fair categories. Excellent outcome was reported in seventeen patients (15%); good in thirty-two patients (28.3%); and fair in thirty-four (30.1%). Thirty patients (26.5%) were determined to have poor results. The specific reasons were as follows: twelve patients were not improved after the endoscopic surgery, eight patients had subsequent lumbar fusion; seven patients had repeat lumbar endoscopic surgery; and three patients had lumbar laminectomy. Twelve patients in the poor category elected to have no further back surgery, and continued to required more than fifty controlled release oxycodone hydrochloride, or DEA schedule II drugs per month. Of the eighteen patients who had secondary back surgery, ten reported improvement after the subsequent operation. The satisfied group of patients would select the lumbar endoscopic surgery again in the future given the knowledge gained from their endoscopic experience.

Out of the eighty-three patients that returned the questionnaire, 14 (16.9%) were rated excellent, 24 (28.9%) were rated good, 26 (31.3) were rated fair, and 19 (22.9%) were rated poor. The response rate to the questionnaire was only 73%, but the distribution of the patient grading was very similar to the surgeon based assessment. In fact the questionnaire respondents have a higher percentage in the excellent group 16.9% (14/83) vs. 15% (17/113) and lower percentage in the poor group 22.8% (19/83) vs. 26.5% (30/113).

Complications

Peri-operative adverse events from the procedure included three cases of dysesthesia, and one case of thrombophlebitis. The etiology of the dysesthesia is still incompletely understood. Dysesthesia had also occurred in endoscopic spinal procedures performed for other diagnoses. The condition was diagnosed in the immediate postoperative period in some patients, or detected later during follow-up in others. The symptoms of dysesthesia subsided within four to six weeks. Treatment with Neurontin® (Pfizer, Inc., New York, New York, USA), foraminal epidural blocks, or sympathetic blocks was very effective in mitigating this transient condition. There were no deaths, vascular complications, motor deficits, infections or aborted procedures. Post-operative flexion /extension X-rays were performed yearly. In this relatively short period of follow-up no degenerative spondylolisthesis or evidence of postoperative instability was detected.

Discussion

Posterolateral transforaminal Selective Endoscopic Discectomy™ and thermal annuloplasty is a minimal access visualized surgical procedure. This paper focuses on the role of annular defects as the first portal leading to pain sensitization. The authors' hypothesis on chronic pain sensitization is based on the following established findings. Nucleus pulposus (proteoglycan) and its metabolic by-products are known to be contact irritants to neural tissues[8,9,10,11]. End neural sensors, in a normal disc, are found in outer layers of the annulus fibrosus and juxta end plate zone[3,4,52]. These end sensors normally are shielded from direct contact with irritants by intact inner layers of annulus and cartilaginous end plates. Defects which develop in the inner annular layers or cartilaginous end plates potentially expose the end sensors to chronic direct contact with

the proteoglycan. The chronic contact triggers a repair process in the annular defects resulting in in-growth of new vessels[18] , new nerve endings, and granulation tissue into the defects. The migrated cellular elements in the defects are in constant anatomic contact with the proteoglycan of nucleus pulposus. Chronic direct contact between the irritants and end sensors is hypothesized to be the local process that initiates the back pain sensitization cascade. The interposed nuclear tissue may also prevent the annular tears from healing properly.

The treatment rationale for SED™ and thermal annuloplasty is based on the removal/ablation of the nucleus pulposus and granulation tissue interposed within the annular tears. This not only removes the painful irritant, but also creates an environment to allow the tear to heal as the edges can now re-approximate and the intradiscal pressure is reduced. The annular defects are endoscopically observed to contract and shrink after RF treatment. The RF electrode heating process is also hypothesized to ablate the sensitized neural sensory endings that have grown into the fissures. The continuous saline irrigation during the endosopic procedure flushes out the toxic metabolites within the disc. It also prevents the accumulation of any by-products of the thermal treatment. Only scant carbonization of the tissues are observed.

This procedure thus has many theoretical advantages over some of the other percutaneous intradiscal procedures such as IDET and Nucleoplasty (Coblation). IDET and Coblation rely solely on fluoroscopic guidance and are thus blind procedures. They are not

designed to remove the interposed tissue within the annular tears or remove any by-products of their energy treatment.

The amount of nucleus pulposus removed, averaging 3 grams by wet weight as reported our pathology reports, does not seem to change the biomechanical behavior of the whole disc[53]. No clinical interspace instability was detected at the latest follow-up after two years. The long-term biomechanical effects of RF energy on the human annulus are not known.

Only 83 out of 113 patients (73.5%) returned the questionnaire. 77.1% of the respondents reported satisfactory results compared to 73.6% based on the surgeon assessment. It is possible that the satisfactory group percentage would be smaller if the entire group had responded. The surgeon assessment rating, however, correlated well with the self assessment of the patients who returned their questionnaires. This makes it likely that the unreturned questionnaire patients would generate a score similar to, or better than the surgeon-based assessment.

Recent investigations on fusion outcome, with interbody implants, showed successful fusion rates, up to 98%, but the rate of clinical inprovement[42,43,44,45,46] ranged from 65% to 85 %. While our results fall within this same range, comparison of results by the different surgical methods from the available literature data is not feasible because of the lack of uniformity in the important issues concerning this condition[54]. Consensus is lacking in the definition of the condition, in patient selection criteria, in procedural details

of provocation discography, as well as in the selection of outcome instruments. The available surgical options vary greatly in their invasiveness and in their hypothesized treatment mechanism[21,28,41,42,43,45,46,47,48] . A better understanding of the local intradiscal process that leads to pain sensitization is especially important, because all established operative procedures attempt to achieve one or more of the following: nucleus removal; changing the biomechanical properties of the interspace; and ablating annular neural sensors.

A significant shortcoming of this study is its retrospective format. The timeline does not permit randomization for comparison. Even a favorable randomized study cannot provide a direct proof that initial pain sensitization occurred from the annular neural receptors. Such a direct proof will have to resort to in vivo laboratory animal studies involving electro-physiologic recordings while controlled manipulation of the annulus is carried out simultaneously. One other notable feature of this study is the use of an eight item survey questionnaire and surgeon based evaluation for outcome assessment. Both of these methods are admittedly not validated. Since this is a paper on a new surgical technique, however, the parameters for procedure failures are well defined. These are re-operations, no clinical improvement, dissatisfaction, and negative recommendation of the procedure. Procedure related early and late complications are low, 3.6% (4/113).

The authors believe, in the absence of a better objective diagnostic test, that evocative discography provides a gross estimation of the presence or absence of discogenic pain[16,34,39] and localizes the painful level(s). Surgeon performed pre-operative

provocation (evocative discography™) has patient selection advantages because the overall pain response in un-sedated CLDP patients can be compared with the patient's overall reaction to needle insertion. The patient's behavior during the procedure provides additional clinical information that helps the surgeon's patient selection.

The authors emphasize that posterolateral transforaminal Selective Endoscopic Discectomy™ technique has a steep learning curve and is equipment intensive. The technique was originally developed for nerve root decompression secondary to herniation lumbar disc and focal lumbar stenosis[29,30,31,32]. Mastery in spine endoscopy developed for the original purposes has enabled the authors to expand its capabilities, including paying attention to the annular fissures. As spinal endoscopy continues to evolve, other spinal pathology can be addressed by using the transforaminal endoscopic method. The roles of annular defects, and the cellular and molecular interactions within the defects are worthy of further investigation. Intradiscal endoscopy has established a window into intradiscal pathology.

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Table 1

Patient-based questionnaire surgical outcome measurement

Patient-based outcome questionnaire - Self administered A = 1-2 months, b = 3-6 months, c = 7-12 months, d = >12 months	a	b	c	d
1. After my arthroscopic back surgery, I returned to my usual occupation in,	x	x	x	x
2. After my arthroscopic back surgery, I returned to my usual activities of daily living and recreational sports in,	x	x	x	x
3. After my arthroscopic back surgery, I ceased to take prescription drugs in,	x	x	x	x
4. My overall residual back/leg pain, a none: b mild, minimal functional adjustment: c occasional, moderate work and ADL modification	x	x	x	
Mark if statement applies: 5. Since my arthroscopic back surgery my back/leg pain is no better or worse than before surgery.				x
6. I had a re-operation at the arthroscopic back surgery level.				x
7. My arthroscopic back surgery was not satisfactory.				x
8. I will not select arthroscopic back surgery again if I encounter similar back problems in the future.				x

Items 1-4, a = excellent(3), b = good(2), c = fair(1), d = poor(0)
Items 5-8, column d = agree = technique failure = mandatory poor grade
x = possible answers

Table 2

Modified MacNab surgeon assessment outcome measurement

Surgeon assessment (Modified MacNab)	**Rating**
9. no pain and no functional restrictions	Excellent
10. occasional back/leg pain, brief functional restrictions	Good
11. improved over-all function, permanent work & ADL modification	Fair
12. no improvement of pain/function, or had index level re-operation	Poor

Table 3.

Patients underwent operation at following disc levels.

Single levels, N=47

Disc level	L5-S1	L4-5	L3-4	L2-3
N=	22	23	1	1

Two levels, N=66

Disc level	L5-S1 & L4-5	L4-5 & L3-4	Skipped levels
N=	50	10	6

Table 4.

Results of posterolateral transforaminal endoscopic lumbar nuclectomy and annuloplasty

Grade	Surgeon assessment N=113 (100%)	One level N=47 (41.6%)	Two levels N=66 (58.4%)	Questionnaire respondents N=83 (73.5%)
Excellent	17 (15%)	8 (17%)	9 (13.6%)	14 (16.9%)
Good	32 (28.3%)	14 (29.8%)	18 (27.3%)	24 (28.9%)
Fair	34 (30.1%)	13 (27.7%)	21 (31.8%)	26 (31.3%)
Poor	30 (26.5%)	12 (25.5%)	18 (27.3%)	19 (22.9%)

Legend

Figure 1

Wolfgang Rauschning's axial section through a severely ruptured L4-L5 disc. The disc is bulging circumferentially and abuts the superior articular processes. In the center-portion of the posterior annulus lumps of reddish tissue are seen (black arrow). This tissue represents granulation tissue that fills annular ruptures in the midline and paramedian region. This granulation tissue is cellular and carries blood vessels that are accompanied by nociceptive pain fibers.

Figure 2

A posterior annular fissure viewed with the 30° endoscope. Granulation tissue has grown into the tear (black arrow). This endoscopically visualized pathologic lesion correlates with the location of a high intensity zone on MRI. The granulation tissue will be ablated with the bipolar RF electrode.

Figure 3

Kambin's triangular working zone is the site of surgical access for posterolateral transforaminal SED™. It is defined as a right triangle over the dorsolateral disc. The hypotenuse is the exiting nerve root, the base (width) is the superior border of the caudal vertebra, and the height is the dura/traversing nerve root.

Figure 4

Axial view showing L4-5 disc for the posterolateral transforaminal endoscopic approach. The trajectory into the intradiscal space is lateral to the spinal canal and posterior to the

peritoneal cavity. The safe skin window is located medial to the quadratus lumborum (QL) and the trajectory enters the foramen at its lateral extent (transforaminal) then penetrates the annulus between the medial and lateral borders of the same pedicle. The needle trajectory should be 25-35 degrees in the coronal plane in order to access the posterior portion of the disc.

Figure 5

Large posterior annular defect viewed through the 70° endoscope. The edges of the defect have inflamed granulation tissue (black arrow). There is also blue stained degenerated nucleus pulposus within the defect (white arrow). All of this will be targeted with the bipolar RF probe.

Figure 6

The working cavity is created with selective nucleotomy utilizing rongeurs and motorized suction-irrigation shavers adjacent to the suspected annular tear. The working cavity is shown by the small arrows. The annular tear, interposed nucleus, and ingrown granulation tissue is visualized and ablated with the bipolar RF probe.

Figure 7

Lateral view of a lumbar mobile segment. Degenerative nucleus pulposus interposed within the annular fissures is stained blue. A radio-frequency electrode is in close proximity to an annular fissure. Surgical working cavities are outlined. Solid arrows –

posterior working cavity and potential anterior working cavity. Open arrow – potential working tunnel.

Figure 8

Axial view of L4-5 disc – two shavers are pictured in anterior and posterior working positions for illustration purposes. The blue stained degenerative nucleus pulposus abutting annular defects is excavated using a flexible motorized shaver (MS). Removing nucleus material just deep to the annular defects reduces outward herniation pressure and chemical irritation to the neural sensors in the peri-annular spaces. The excavated surgical spaces are also necessary for unobstructed endoscopic intradiscal visualization.

Figure 9

Axial view of a whole L4-5 disc is to the left. The bipolar RF electrode is pictured in separate anterior and posterior working positions inside the disc. Most symptomatic annular tears are located posterior near the neural structures, but anterior tears can be targeted also. The deep end of the operating endoscope is in the working cavity. The enlarged inset to the right shows the flexible tip bipolar RF electrode extending beyond the endoscope. Under endoscopic visualization the RF electrode cauterizes blue stained granulation tissues in annular fissures and shrinks defect size. The same energy source is also used to reduce annular collagen fiber length.