

Posterolateral Endoscopic Excision for Lumbar Disc Herniation

Surgical Technique, Outcome, and Complications in 307 Consecutive Cases

Anthony Tung Yeung, MD,* and Paul Moody Tsou, MD†

Study Design. A retrospective review involving 307 consecutive cases of lumbar disc herniation managed by posterolateral endoscopic discectomy was conducted.

Objectives. To describe a contemporary posterolateral endoscopic decompression technique for radiculopathy secondary to lumbar disc herniation; to evaluate the efficacy of the technique as it is applied to lumbar disc herniation including primary herniation, reherniation, intracanal herniation, and extracanal herniation; and to report outcome and complications.

Summary of Background Data. The concept of percutaneous posterolateral nucleotomy was introduced in 1973. The development of the related equipment and technique had witnessed a slow and lengthy evolution.

Method. A retrospective assessment of 307 patients was performed at least 1 year after their index operation. The outcome was graded according to a modified MacNab method. A patient-based outcome questionnaire also was incorporated into the study.

Results. The surgeon-performed assessment showed satisfactory results in 89.3% of the cases. The rate of response to the questionnaire was 91%. The responses indicated that 90.7% of the respondents were satisfied with their surgical outcome and would undergo the same endoscopic procedure again if faced with a similar herniation in the future. The poor outcome occurred in 10.7% of the primary group and 9.7% of the questionnaire group. The combined major and minor complication rate was 3.5%.

Conclusions. The surgical outcome of posterolateral endoscopic discectomy for lumbar disc herniation is comparable with that for the traditional open transcanal microdiscectomy. Intracanal and extracanal herniations, reherniations, and incidental lateral recess stenosis can be addressed by the same approach. [Key words: anatomic disc center, disc inclination, foraminal anular window, posterolateral endoscopic discectomy foraminal decompression, skin window] *Spine* 2002;27:722-731

From a prospective and randomized study in 1999, Hermantín et al⁸ reported a favorable outcome for video-assisted arthroscopic lumbar microdiscectomy, as compared with open discectomy. In a prospective study the

year before, Kambin et al¹⁹ had reported a success rate of 88.2% for arthroscopic microdiscectomy including foraminal and extraforaminal herniation. The exclusion criteria for these studies involved high iliac crest, large herniations, and sample uniformity. These exclusions reflect the restrictiveness of the procedure. The versatility and reliability of this procedure and its outcome have yet to be validated by other clinicians.

During the study period, there were accelerated refinements in both surgical technique and operating equipment. These factors have enhanced the capabilities of posterolateral endoscopic procedure. This report describes the authors' current posterolateral endoscopic operative technique, including placement of the operating endoscope and excision techniques for the varied lumbar disc herniations that cause radiculopathy. The outcome and complications from percutaneous posterolateral endoscopic excision of lumbar disc herniation in 307 consecutive cases were subjected to retrospective reviews. There were no exclusions on the basis of location or size of herniation, payer type, liability status, or prior surgical intervention at the index level.

■ Historical Background

In 1934, from exploratory laminectomy for radicular pain, Mixer and Barr²⁵ reported 19 surgical cases of lumbar, thoracic, and cervical prolapse of the nucleus pulposus or fracture of the anulus. The concept of indirect spinal canal decompression by nucleotomy using the anterolateral abdominal extra peritoneal approach was first introduced by Hult¹¹ in 1951. Indirect percutaneous spinal canal decompression through a posterolateral extracanal, nonvisualized approach by limited nucleotomy and decompression using a Craig⁴ cannula in conjunction with a standard posterior transcanal exploration was initiated by Kambin in January 1973.¹⁸ Stand-alone nonvisualized posterolateral percutaneous nucleotomy was first introduced by Hijikata in 1975,^{9,10} followed by Kamin and Gellman's¹⁸ report of nine cases in 1983. A nonvisualized motorized aspiration nucleotomy shaver 2.8 mm in diameter was used by Onik et al²⁶ in 1985. Mathews²⁴ published a report of the foraminoscopic approach in 1996. Schreiber et al²⁸ in 1989 used a biportal approach, injecting a nontoxic vital dye, indigo carmine, to blue stain the abnormal nucleus pulposus and anular fissure. In 1998, Kambin et al¹⁹ used the transforaminal approach biportally to excise central herniations and nonmigrated sequestered disc fragments in 59 cases.

From *Arizona Orthopedic Surgeons, Phoenix, Arizona, and the †UCLA Department of Orthopaedic Surgery, Santa Monica, California.

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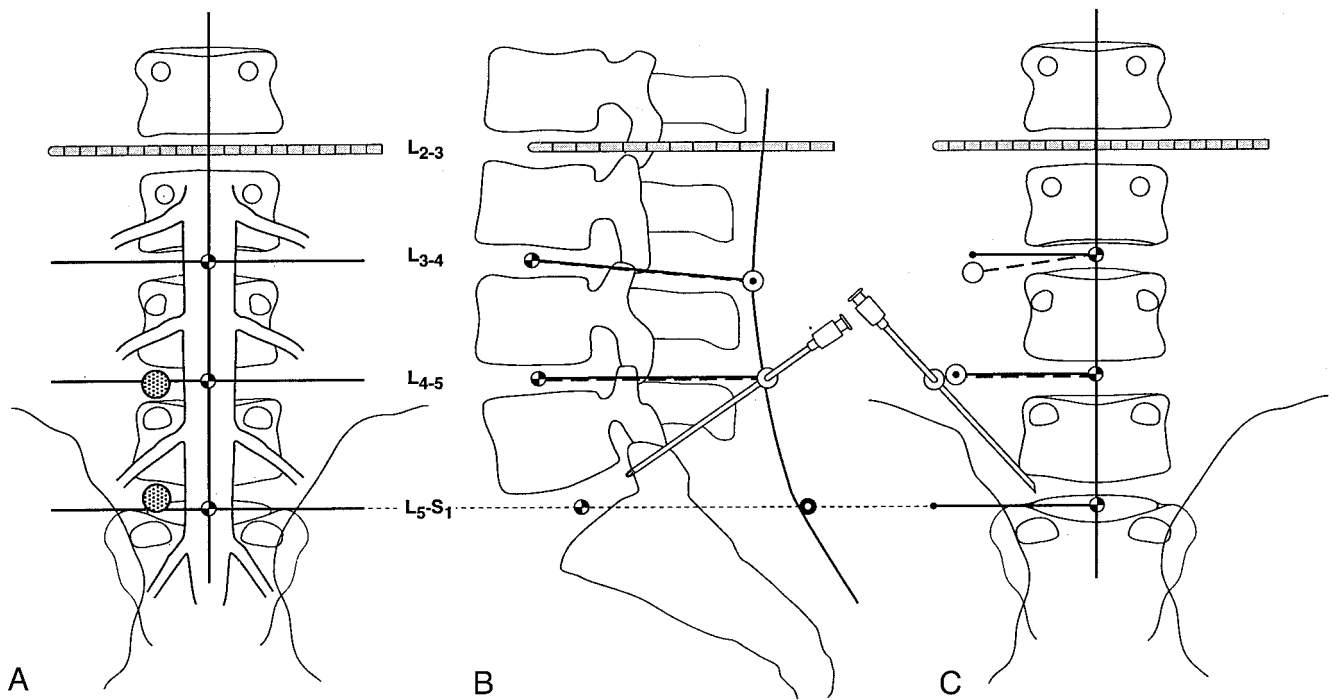


Figure 1. Percutaneous posterolateral endoscope insertion method using freehand, biplane, c-arm guidance. The following three c-arm landmarks are identified: the anatomic disc center; the foraminal anular window, the endoscope safe transit zone for intradiscal and epidural operative tasks (the approach needle should touch this window, confirmed by the c-arm in two planes before anular fenestration; and the disc inclination line that bisects the target disc. The fourth landmark, the skin window location, is calculated from the disc inclination line derivatives. **A**, Posteroanterior projection. Anatomic disc centers (quadrant circles) are located where the horizontal lines intersect the longitudinal midline. A thin metal rod is used as a locator and ruler. The foraminal anular window (dotted circles) is centered within the mediolateral borders of the pedicle. **B**, Lateral projection. The disc bisecting inclination line of the target disc is drawn. The coordinates for the skin window location (open circle) are calculated from the inclination line derivatives. Along the inclination line, the distance from the center of the disc to the plane of the posterior skin line (solid lines between quadrant circles and dots, L3–L4 and L4–L5). The length used is the same as that for the skin window perpendicular distance from the midline (**C**, solid lines). The skin window's cephalad–caudad location is determined at the point where the disc inclination line projects from the plane of the posterior skin. **C**, Posteroanterior projection. The L5–S1 disc skin window (open circle) and needle trajectory clear the iliac crest because of the positive disc inclination (lordosis). Note that the L3–L4 disc has a negative inclination. Therefore, the approach segmented trajectory line is slightly angled cephalad.

The current authors have used the transforaminal approach since 1997.³¹ The foraminal anular window (Figure 1A) within the medial and lateral borders of the same pedicle has become their standard safe needle and instrument annulotomy entry zone.

In 1983, Forst and Hausmann⁷ first reported the insertion of a modified arthroscope into the intervertebral disc space for direct visualization of the disc space. Kambin¹⁴ published the first intraoperative discoscopic view of a herniated nucleus pulposus in 1988. In his later publications, he further propagated the importance of discoscopically visualizing the perianular space.^{15,13,17,21} As a result, beginning in the late 1980s, endoscopic lumbar nerve root decompression progressed from indirect central nucleotomy to direct excision of noncontained extruded disc fragments.^{24,30}

In 1991, Kambin¹⁵ described and illustrated the triangular working zone and the midpedicle line. Foraminal arthroscopic decompression of lateral recess stenosis by annulectomy and osteophlectomy using mechanical tools was reported by Kambin et al in 1996.¹⁷ Knight

and Goswami²² have reported an extensive study of laser-assisted foraminoplasty.

In 1997, the senior author (A.T.Y.) introduced a rigid rod-lens, integrated, multichannel, wide-angle operating spinal endoscope.³¹ A bevel-ended tubular-access cannula allows same-field viewing of the epidural space, anular wall, and intradiscal space. These adaptations allow surgeons a wide-angle view of the surgical field and decompression of nerve roots under direction vision through a single portal in most cases. The outcome described in this report is based on the technical ability to locate, visualize, and physically access the herniated disc fragments.

■ Methods

From August 1991 to December 1999, the senior author (A.T.Y.) performed posterolateral endoscopic excision of lumbar disc herniation (LDH), L2 to S1, in 307 consecutive patients. During the same period, 483 additional patients underwent lumbar endoscopic surgery for various other conditions that did not meet the inclusion criteria for this study. The ex-

Table 1. Location of the Lumbar Disc Herniation in Relation to the Pedicle and Spinal Canal

Location of Herniation	No. of Patients	%
Paramedian	190	61.9
Central	71	23.1
Foraminal	20	6.5
Extraforaminal	26	8.5
Total	307	100

cluded patients had the primary diagnoses of disc protrusions without radiculopathy, chronic discogenic pain, foraminal stenosis, lateral recess stenosis, or pyogenic discitis.

The average period from symptom initiation to index surgery was 10.8 months. The general inclusion criteria required clinical evidence of LDH at one disc level from L2 to S1 and 2 months of conservative treatment that failed to improve major motor weakness, intractable leg pain, and functional impairments. The inclusion criteria met the objective indications for the traditional open transcanal discectomy procedure. Disc protrusion without objective signs of radiculopathy was specifically excluded. On the image study, the herniated nucleus pulposus was 5 mm or more, as measured from the posterior bony margins of the contiguous vertebrae. In more severe cases, the leading edge of the migrated nucleus pulposus had disrupted the full thickness of the annulus fibrosus and the posterior longitudinal ligament. Just before the endoscopic procedure was performed in the operating room, each patient underwent provocation discography at the proposed target level.

This study included intracanal and extracanal (foraminal and extraforaminal) herniations (Table 1). Recurrent herniations and missed fragments after previous surgical intervention at the index level also were included (Table 2). For the group that had undergone prior surgical intervention, there were 27 transcanal discectomies (8.8%), 3 chymopapain injections (0.98%), and 1 endoscopic excision (0.3%). Cases of personal ($n = 83$, 27%) or worker ($n = 22$, 7.2%) injury were included. This study did not exclude high iliac crest or massive intracanal herniations, in which the canal cross-sectional area compromise exceeded 50%. Cauda equina syndrome was not encountered in this consecutive series.

The locations of the lumbar disc herniations in relation to the spinal canal and the pedicles are identified in Table 1. A central herniation, found in 71 patients (23.1%), is defined as a disc herniation that straddles the anterior spinal canal midline between the pedicles. The herniation midline split ratio did not exceed 60:40. A higher midline split ratio for intracanal herniation (65%, $n = 200$) placed the herniation in the paramedian group. In 20 patients (6.5%), the foraminal herniation had its

Table 2. Patients From the 307 Primary Group Noted to Have Factors Associated With a Higher Percentage of Unsatisfactory Clinical Outcome

Prior Procedure at Index Level	No. of Patients	%
Laminectomy & discectomy	27	8.8
Chymopapain injection	3	0.9
Endoscopic discectomy	1	0.3
Worker injury	83	27
Personal injury	22	7.2

Table 3. Location of Lumbar Disc Herniation According to Level

Herniation Level	No. of Patients	%
L5-S1	154	50.15
L4-L5	135	44
L3-L4	14	4.6
L2-L3	3	0.96
L1-L2	1	0.32
Total	307	100

apex within the mediolateral borders of the adjacent pedicle. Its side extensions beyond the pedicle borders did not exceed 20% on either side. In an extraforaminal herniation ($n = 26$, 8.5%), the apex is lateral to the bordering pedicle, with 40% of its medial herniation component or less extending into the foramen. Herniations at L5-S1 dominate the study, occurring in 154 patients, or 50% of the total (Table 3).

Evaluation. Clinical outcome was evaluated by two methods. The first was a surgeon-performed retrospective assessment at least 1 year after the index operation.²³ The second was a patient-based outcome questionnaire mailed a year or more after the index procedure, between August and December of 2000. The reviewer (P.M.T.) did not take part in the procedures, nor did he examine the patients.

The clinical material available for evaluation included all information submitted according to the predetermined protocol. The clinical material included preoperative history and physical examination, consultation, operating note, still-image studies, intraoperative videotapes, and laboratory reports. The postoperative data included follow-up notes, consultation, and any secondary operative note as the clinical situation required. Results were determined to be excellent, good, fair, or poor according to a modified MacNab classification.²³ The fair and better grades also included the requirement that the patients were willing to select endoscopic surgery again in the future given the same indications. Follow-up examinations were carried out on postoperative day 2, then after 2 weeks, 1 month, 2 months, 6 months, 12 months, and every 12 months. The inclusion criteria and minimum follow-up period of 1 year were fulfilled by 307 patients.

The patient-based outcome questionnaire provided the second method of analysis based on the patient's postoperative experience and satisfaction. The outcome also was categorized as excellent, good, fair, or poor. The questionnaire included eight questions. The first four questions were "yes" or "no" type questions. A negative response from any one of the four questions placed the patient's overall result in the poor category. These four questions were as follows:

1. Since your endoscopic spine surgery, have you had subsequent lumbar spine surgery at the same level?
2. Are you satisfied with the outcome of your endoscopic operation?
3. Would you select the same endoscopic spine surgery again in the future, given the same disc herniation and your personal familiarity with the operative experience?
4. Are your current back or leg symptoms, if any, worse than before your endoscopic back surgery?

If the patient answered favorably to these four questions, their responses from the second four questions were further

evaluated and assigned a point value of 0 to 3. In question 5, 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 (no points). Questions 6, 7, and 8 were time dependent. These referred to the time from index operation required to resume customary occupation (Question 6), to resume normal activities of daily living including recreational sports (Question 7), and to discontinuation of prescription analgesics and anti-inflammatory medications (Question 8). For each of these three questions, the patient's condition was rated "excellent" if the milestone was reached within 2 months it, "good" if reached in 3 to 6 months, "fair" if reached in 7 to 12 months, "poor" if reached after 12 months (no points awarded). The cumulative point rating was 9–12 points for excellent, 5–8 points for good, and 3–4 points for fair. The questionnaires were returned directly to the reviewer for tabulation. The total questionnaire return rate was 91%, with 27 questionnaires either unanswered or returned without a known forwarding address.

Posterolateral Endoscopic Technique in the Excision of Lumbar Disc Herniation. Anesthesia consisted of 1% local lidocaine infiltration, supplemented with conscious sedation. The patient was placed in a prone position on a hyperkyphotic frame on top of a radiolucent table. Percutaneous posterolateral endoscopic LDH excision requires an unflinching ability to place the endoscope and the extraction instrument from the skin window to the foraminal anular window at the optimal trajectory. The authors use freehand, biplane, c-arm guidance. Three fixed roentgenographic landmarks of the target vertebra (Figure 1) are located using the c-arm: the anatomic center of the disc, the foraminal anular window centered within the mediolateral borders of the pedicle, and the disc inclination line that bisects the disc in the lateral projection. The fourth landmark, a topographic location, the skin window, is calculated from the disc inclination. The skin window's lateral location from the midline determines the trajectory angle into the foraminal anular window.

Currently, the following method is used to find the four anatomic landmarks. The c-arm is oriented in the posteroanterior imaging position, using a narrow metal rod as a radioopaque locator and ruler, and the midline is marked on the skin surface. Then the metal rod is placed transversely across the center of the target disc. A horizontal line is drawn, bisecting the disc under evaluation. The anatomic disc center (quadrant circle, Figure 1A) is located where the transverse line crosses the longitudinal midline. The surface marking of the anatomic disc center, identified by the line intersections, is used as the first aiming reference point of that disc in the approach. The Ferguson view, achieved by tilting the c-arm in the posteroanterior position until the beam is parallel to the endplates, provides additional aiming reference when the approaching needle is within the c-arm viewing field. The location of the foraminal anular windows is noted at L4–L5 and L5–S1 (Figure 1A, dotted circles).

To view the inclination of the lumbar discs (Figure 1 B), the c-arm is rotated to the lateral projection. The metal rod is held along the side of the patient in the parasagittal orientation equidistantly between the contiguous vertebral endplates of the index disc, and the disc inclination line is drawn on the patient. While the metal rod is held in the same position, the length from the center of that disc to the plane of the posterior skin

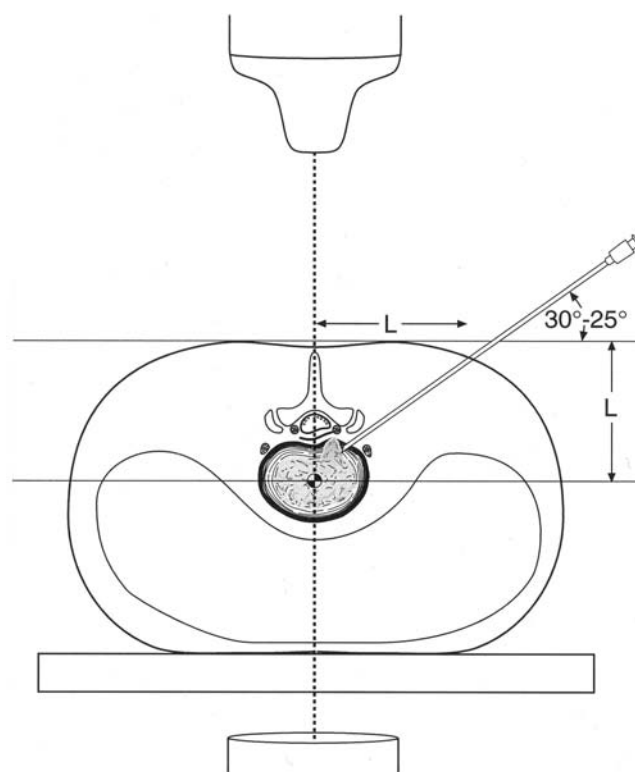


Figure 2. Axial view. Freehand, biplane, c-arm technique for percutaneous posterolateral needle placement. The needle trajectory from the skin window to the foraminal anular window controls accessibility to the perianular space, including the epidural space. A 30° to 25° angle in reference to the frontal plane is illustrated. The skin window location is calculated from the disc inclination line on the c-arm lateral view. The length (L) of the inclination line from the disc center to the posterior skin surface is used as the lateral distance of the skin window from the midline. The location at which the disc inclination line projects above the skin line locates the cephalad–caudad coordinate of the skin window.

surface (length of the solid line from the quadrant circle to the small dot) is recorded (Figure 1B, L3–L4). The length used is the same as that used for the lateral distance of the skin window (Figure 1C, open circle) from the posterior midline.²⁹ The point at which the disc inclination line projects above the posterior skin surface, determined by the metal rod lateral position, is taken as the skin window's cephalad–caudad location (Figure 1B and 1C, open circles).

The positive disc inclination (lordosis) of the L5–S1 disc is noteworthy. A steep positive inclination will position the skin window above the high iliac crests. A flatly inclined L5–S1 disc in the presence of a high iliac crest requires a more medial placement of the skin window, and sometimes a resection of the lateral one fourth of the facet joint. The first neutrally inclined intervertebral disc usually is either L4–L5 or L3–L4. Therefore, the approach angle for the neutrally inclined disc is perpendicular to the midline. A negatively inclined disc, if present, also should be noted. The insertion angle for the negatively inclined L3–L4 disc is cephalad directed.

The skin window, subcutaneous tissue, and trajectory tract are infiltrated using 1% plain lidocaine. A 6-inch-long, 18-gauge needle is inserted from the skin window at a 60° to 65° angle to the parasagittal plane (reciprocal of 25–30°, Figure 2) anteromedially toward the anatomic disc center.

The superficial portion of the needle trajectory usually is outside of c-arm viewing perimeter. Once the needle tip is visible within the c-arm viewing perimeter, the c-arm, beam is tilted parallel to the disc inclination, the Ferguson view. The needle is advanced toward the target foraminal anular window. If minor directional adjustments are necessary, the plane of the needle bevel and the hub pressure are used to navigate.

At the first bony resistance or before the needle tip is advanced medially to the pedicle, the c-arm is turned to the lateral projection. The needle tip should not be advanced medially to the pedicle during the initial approach. Doing so risks inadvertent root and dural puncture. Most frequently, the first bony resistance to the needle advancement is from the facet in the path of trajectory. At this point, the trajectory angle must be reduced, the needle bevel turned medial ward, and the approach continued toward the foraminal anular window. The c-arm lateral projection should confirm the needle tip's correct anular location. In the lateral view, the correct needle tip position should be just touching the posterior anulus surface (Figure 1B, L5-S1). In the posteroanterior view, the needle tip should be centered in the foraminal anular window (Figure 1C, L1-S1). The preceding two views of the c-arm confirm that the needle tip has engaged the safe zone, the center of the foraminal anular window.

The needle is advanced through the full thickness of the anulus. Provocation discography should be performed at this time. The following contrast mixture is used: 9 mL of Isovue 300 with 1 mL of indigo carmine dye. This combination of contrast ratio gives readily visible radio-opacity on the discography images, as well as intraoperative light blue stain of the pathologic nucleus and anular fissures.

A long thin guidewire is inserted through the 18-gauge needle channel. The guidewire tip is advanced 1 to 2 cm deep into the anulus, after which the needle is removed. The bluntly tapered cannulated obturator is slid over the guidewire until the tip of the obturator has firmly engaged the anular window. An eccentric parallel channel in the obturator allows four-quadrant anular infiltration using small incremental volumes of 1% lidocaine in each quadrant, enough to anesthetize the anulus but not the nerves. The obturator is held firmly against the anular window surface and the guidewire is removed. Then, the full thickness of the anulus is infiltrated through the obturator center channel using lidocaine.

The next step is the through-and-through fenestration of the anular window by advancing the bluntly tapered obturator. Anular fenestration is the most painful step of the entire procedure. The anesthesiologist should be advised to heighten the sedation level just before anular fenestration. The entire obturator tip is advanced into the anulus and confirmed on the c-arm views. The beveled access cannula is now slid over the obturator toward the disc. The cannula is advanced until the beveled tip is deep to the anular window.

The foraminal anular window, an easily identifiable c-arm and intraoperative anatomic landmark, is the starting location for endoscopic disc excision. The obturator is removed, and the operating endoscope is inserted. Through the endoscope the surgeon may see various amounts of blue-stained nucleus pulposus. The general-purpose access cannula has a bevel hypotenuse of 12 mm and an outside diameter of 7 mm. When the cannula is retracted slightly to the midstraddle position in relation to the anular wall, the wide-angle scope visualizes the

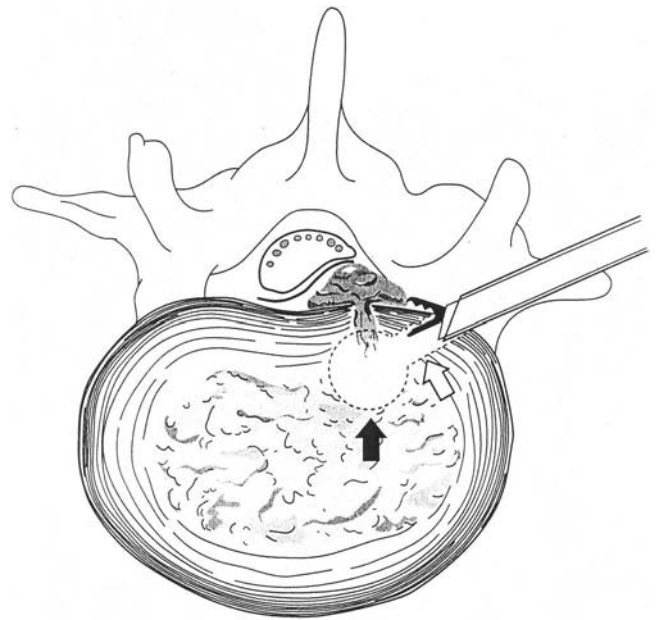


Figure 3. Endoscopic excision of paramedian noncontained lumbar disc herniation. From the foraminal anular window, the working tunnel (open arrow) and working cavity (solid arrow) are excavated. The biting forceps is used to release the anular collar, as illustrated. The anulectomy opening is widened using a side-firing Holmium yttrium-aluminum-garnet laser. Then the extruded nucleus fragments are pulled first into the working cavity, then out through the endoscope working channel.

epidural space, the anular wall, and the intradiscal space in the same field.

The endoscope trajectory from the skin window to the foraminal anular window controls accessibility of the instrument to the epidural space. The 30° to 25° trajectory in relation to the frontal plane allows extraction of intracanal noncontained herniations, whereas the 40° to 45° trajectory is ideal for central nucleotomy. The basic endoscopic method for excising a noncontained paramedian extruded lumbar herniated disc is described (Figure 3).

The 30° to 25° trajectory is used for epidural space herniation extraction. A working tunnel (Figure 3, open arrow) is first created from the foraminal anular window. The excavation is extended to a location just under the apex of the herniation. An endoscopic rongeur is used to extract the blue-stained material in the tunnel. Directly under the herniation apex, a large amount of blue-stained nucleus usually is present, resembling the submerged portion of an iceberg. The nucleus here represents the migrated and unstable nucleus. The movement direction follows the path of least resistance toward the already thinned out and perforated anulus. A bulk decompression is performed using a motorized shaver. This step requires shaver head c-arm localization before power is activated. The cavity thus created is called the working cavity (Figure 3, solid arrow). The debulking process serves two functions. First, it decompresses the disc, reducing the risk for further acute herniation. Second, it removes the unstable nucleus material to prevent future reherniation.

If a noncontained extruded disc fragment is confirmed by blue-stained nucleus material found in the epidural space, additional steps are necessary before the epidural part of the herniation is removed. The blue-stained narrow intraanular her-

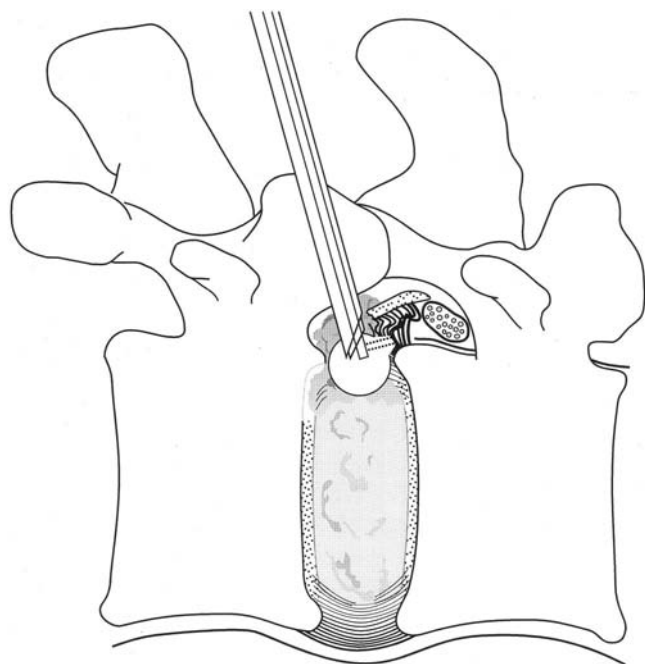


Figure 4. Excision technique for a massive midline herniation, open hinged door type. A working tunnel and working cavity are excavated in close proximity to the posterior vertebral corners. The anulus fibrosus is detached from its remaining vertebral corner insertion. A Holmium yttrium-aluminum-garnet laser beam is used, as illustrated. Then the herniated nucleus and anulus fragments are pulled out *via* the working cavity and tunnel.

niation track and a thin blue dome deep to the herniation track are left undisturbed at this point. The blue-stained intraanular part of the herniated nucleus is a guide leading to the epidural part of the herniation. The anular collar is divided, and a cutting forceps is used to perform the partial anulectomy (Figure 3). The side walls of this anular channel can be widened further by using a side-firing Holmium yttrium-aluminum-garnet (YAG) laser. Any epidural bleeding encountered is controlled by using a wide-sweep, radiofrequency trigger-flex bipolar probe.

When the aforementioned extended anulectomy has been carried out, the subligamentous or extraligamentous components of the herniation are first extracted into the working cavity, then pulled out through the endoscope working channel. The reason for pulling the herniated elements into the working cavity first is more apparent in the massive midline herniation. One variant of the massive herniation is the condition in which the anular attachment at one vertebral corner is avulsed, described as an open hinged door (Figure 4). In this condition, a large amount of the nucleus has extruded into the spinal canal. The detached anulus may rotate up to 180° on its remaining attachment to the other vertebral corner. When faced with this situation, the surgeon should proceed to excavate the working tunnel and create a larger working cavity. The Holmium YAG laser is used to divide the intact anular vertebral corner attachment. Once the large nuclear and anular fragments are free, the fragment is pulled first into the working cavity, then out through the cannula, together with the endoscope.

Endoscopic technique in excising an LDH in patients who have undergone prior surgical intervention at the index level requires modification of operative technique. The most com-

mon reasons for reoperations are either a missed fragment or reherniation after prior surgical intervention. During endoscopic reoperation, the newly herniated nucleus can be anchored firmly to the anular herniation track and cicatrix stretched over the herniation apex. If the prior intervention was a transcanal approach the standard working tunnel and working cavity must be created. The forceps is used to perform partial anulectomy from the anular window toward the herniation fragment (Figure 3). By removal of the intervening tissue the shape and orientation of the reherniated fragment can be ascertained. If the herniated part is firmly adherent to the anular tract, the laser is used as a dissecting tool. The fibrous anchorage is severed by cutting around the base of the herniation tract just outside the inner edge of the anular fibrosus perforation. Once the herniation base is free, the fragment or fragments are pulled out.

When nerve root compression occurs in the lateral recess and the intervertebral foramen,²³ endoscopic decompression is feasible without causing segmental instability (Figure 5). The foramen floor is removed by performing partial annulectomy (Figure 5A). In addition, the bony deep surface of the superior facet is laser-ablated.

■ Results

The 307 patients who met the inclusion criteria and the minimal follow-up period of 1 year were the primary group. The average follow-up period was 19 months (mean, 23 months). There were 205 (66.8%) male patients and 102 (33.2%) female patients. The average ages were 41.8 years for the male patients and 42.7 for the female patients. The age range was 18 to 27 years. The 280 patients in the primary group who also sent back their completed questionnaires and were the questionnaire subgroup. The 105 in the primary group who had work-related or personal injury claims (83 worker compensation and 22 personal injury claims) were the litigation subgroup. The results for these three groups are shown in Table 4. The percentages of excellent or good results were 81.4% for the primary group, 83.6% for the questionnaire subgroup, and 61.9% for the litigation subgroup. The percentages of fair results were 7.8% for the primary group, 7.1% for the questionnaire subgroup, and 23.8% for the litigation subgroup. The percentages of poor results were 10.7% for the primary group, 9.3% for the questionnaire subgroup, and 14.3% for the litigation subgroup.

The mandatory poor ratings were given to patients who had undergone subsequent surgical interventions¹² at the index level, and those who had expressed dissatisfaction¹⁴ about their endoscopic back surgery. Included in the mandatory poor group for reoperations were seven categories of reoperations: dural repair (n = 1), pyogenic disc debridement (n = 2), congenital short pedicles (n = 3), foraminal and lateral recess stenoses (n = 3), recurrent herniation (n = 2), and missed fragments (n = 2).

Postoperative complications (Table 5) included six patients who experienced extremity dysesthesia longer than 6 weeks, and two patients with thrombophlebitis.

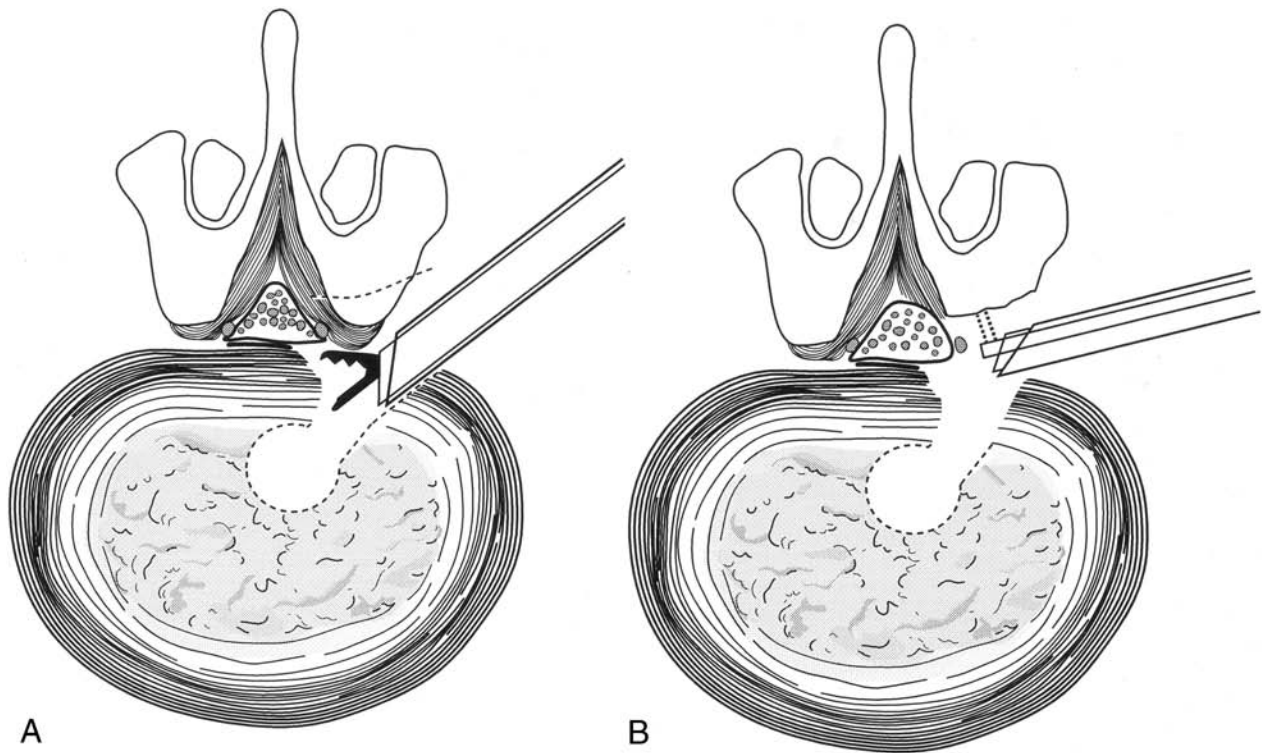


Figure 5. Endoscopic lateral recess and foraminal decompression. **A**, Partial anulectomy of the lateral recess floor excises one portion of the compressing elements. **B**, The decompression of the lateral recess is completed by removal of the dorsal osseous component. The Holmium yttrium-aluminum-garnet laser beam is aimed posteriorly to remove the deep surface of the superior facet of the inferior vertebral. Foraminal decompression is further widened by aiming the laser beam more cephalad to ablate the tip of the same facet.

The patients with these complications fully recovered from their condition after conservative management, and expressed satisfaction with the procedure, so their results were not subjected to the mandatory poor rating rule. Two other patients experienced disc space pyogenic infection, and a third had a dural tear. These three patients were relegated to the poor result group because their complications required surgical management. There were no deaths and no intraoperative vascular injuries.

■ Discussion

The surgical technique, outcome, and complications in 307 consecutive cases of lumbar disc herniation using the posterolateral endoscopic technique were retrospectively evaluated. This patient series included intracanal and extracanal herniations as well as reherniations after prior back

surgery at the index level. There were no exclusions for technique-related reasons, randomization uniformity, payer type, or litigation status. The satisfactory result rate of 89.2% is comparable with the 88.2% in a restricted endoscopic series by Kambin et al.¹⁹ The satisfactory result rate of 87.3% for microdiscectomy reported by Abernathy and Yasargil,¹ and the 92% reported by Abramovitz and Neff's² for their multicenter, 3-month follow-up study also are statistically comparable. Delamarter et al⁶ reported microdiscectomy results of excellent, good, and fair in 99% of 184 patients. In the same study, there were five recurrences, with two patients experiencing dural tears and two having discitis. The reported recurrence rate⁶ after microdiscectomy for LDH was 5% ± 2%.

Hermantin et al,⁸ in their 1999 prospective and randomized evaluation of surgical treatments for lumbar disc herniation, reported satisfactory result rates of 97% in the endoscopic group (n = 30) and 93% in the

Table 4. Outcome

	Physician Performed Assessment*	Patient-Based Assessment by Questionnaire	Worker and Personal Injury-Related Cases
No. of patients in category	307	280	105
Excellent or good n (%)	250 (81.4)	234 (83.6)	65 (61.9)
Fair n (%)	24 (7.8)	20 (7.1)	25 (23.8)
Poor n (%)	33 (10.7)	26 (9.3)	15 (14.3)

* Data from MacNab.²³

Table 5. Complications

Complication	n	%
Deep infection	2	0.65
Thrombophlebitis	2	0.65
Dysesthesia	6	1.9
Dural tear	1	0.3
Intraoperative vascular injury	0	
Death	0	

open laminectomy group ($n = 30$). Surgical technique evaluation, according to prospective randomization study design, requires that uniformity of pathology be assigned to the compared groups. In the report of Hermant et al,⁸ there were notable technique and anatomy-related exclusions. As a result of the exclusions, the comparison was limited to herniations for which both techniques shared common capabilities. For instance, large central herniation and extraligamentous herniation between the fifth lumbar and the first sacral vertebrae were not included in the study. These herniations were excluded because they were thought to be inaccessible or inadequately accessed by the endoscopic technique, whereas foraminal and extraforaminal herniations were excluded because open laminectomy would have required significant surgical approach modification for their excision at these locations. The endoscopic technique requires no such approach modification for disc excision of central, paracentral, foraminal, or extraforaminal herniations.

This study had a combined major and minor complications rate of 3.5%. The published complication rate for endoscopic excision of lumbar disc herniation was low.³ As a technique, posterolateral endoscopic excision of lumbar disc herniation has not yet been fully documented in terms of its versatility and ability to overcome technique-related restrictions.^{12,16,19,21,27} There are several technique challenges for the posterolateral endoscopic procedure. First, safe and effective access is limited to a narrow channel. Second, there is no or little working space, as compared with the procedure for knee and shoulder joints. Third, creation of intradiscal work space is needed before intracanal disc fragment extraction. Fourth, a herniated fragment is accessible only when the operating instrument is placed in the optimal trajectory.

Kambin and other clinicians, including the authors of this report, have developed a variation of the freehand, biplane, c-arm guidance method to gain posterolateral entry into the intradiscal and epidural spaces with the patient under local anesthesia. This approach is shown to be effective and cost efficient. The patient, in a continuous awakened state, is instructed to alert the surgeon if there should be any inadvertent physical trauma to the nervous structures. The authors are aware that computer-assisted navigational systems and nerve monitoring systems are commercially available at the time of this writing. However, with the current state of the technology, the benefits of these systems remain to be documented as compared with the simpler freehand biplane c-arm guidance with the patient under local anesthesia.

Posterolateral endoscopic access to the LDH requires creation of working spaces where no or little space existed before. A new technique and special equipment are needed for work in tight quarters. Excavation of an intradiscal working tunnel and cavity and medial extension of the anulectomy have helped in accessing the epidural noncontained herniation fragments. The bipolar

radiofrequency, flexible, trigger-flex probe has expanded the epidural boundaries of exploration. This device has practical usefulness for reaching out and coagulating bleeders in hard-to-reach places, including the epidural space, with little or no unintended collateral tissue injury.^{32,33} The Holmium YAG laser is used in unique situations to cut thick and hard-to-reach anulus fibrosus attachments and to ablate bone and osteophytes as needed. The laser is the tool of choice for degenerative foraminal and lateral recess stenosis (Figure 5). The laser's unique ability to ablate bone and firm fibrous tissue is used to remove the tip from the superior facet of the inferior vertebra and the deep surface from the same facet. The laser bone removal technique initiated by the senior author^{32,33} (A.T.Y.) and Knight²² (Figure 5) complements Kambin et al's¹⁷ 1996 partial anulectomy method involving "transforaminal arthroscopic soft tissue decompression of lateral recess stenosis." The current authors do not use the Holmium YAG laser to debulk the nucleus pulposus. Use of the power density required to ablate thick collagenized nucleus tissues reduces the beam spot size to less than 0.5 mm. at the point of tissue contact. The use of laser to debulk the nucleus pulposus is a slow process. A highly effective debulking tool is a low-speed high-torque shaver (diameter, 4.5 mm) with straight and flexible heads, which has separate ingress and egress irrigation channels. This shaver has the capacity to remove a large volume of the nucleus and loose strands of anulus efficiently. Caution should be exercised when the flexible shaver head is used in the uniportal approach.³³

The 70° wide-angle operative endoscope allows the surgeon a clear view of the operative field while observing the operative activities. A scope viewing angle of 20° to 90° is available. The endoscope's angled view, periscope-like maneuverability, and 70° of view arc allows a "look around the corner" and a "look backward" for hidden, blue-stained, migrated fragments. The endoscope therefore has various desirable operating optical advantages over the operating microscope with its tunnel vision-like feature.⁵ The endoscope's optical capabilities have far outpaced the mechanical ability to reach and grasp herniation elements. Placement of the endoscope in the optimal trajectory improves the mechanical instrument's effective reach. The suboptimal trajectory keeps the herniated nucleus out of reach. Noncontained herniations in the epidural space require an access trajectory of 30° to 25° so the mechanical instrument can reach posteriorly into the epidural space. A biportal approach may be necessary for large midline herniations.

The minimal follow-up period of 1 year appears to be satisfactory for evaluating the endoscopic excision of a herniated lumbar disc. Pain relief from adequate nerve root decompression in a conscious patient is quickly apparent in the operating room or recovery area. Should the radicular pain persist because of a missed fragment, the problem is readily identified within the immediate postoperative period. The poor results from reherniation

in the current study occurred within the first 12-month postoperative period. Progressive physical rehabilitation begins 4 to 6 weeks after the index operation. Most patients regain their preinjury functional level 2 to 4 months after their index operation.

The mandatory poor result guideline provided a more accurate determination of technique failure and patient dissatisfaction. The poor rating for the worker and personal injury subgroup was higher, with proportionally lower numbers in the excellent, good, and fair groups. Other investigators have noted this tendency, which is attributable to the compensable nature of patients' residual symptoms.^{2,29} Interestingly, although the litigation subgroup patients had fewer good and excellent results, their responses to the question whether they would select the endoscopic surgery again were similar to those of the nonlitigation group.

Kambin¹³ introduced the concept of posterolateral percutaneous lumbar disc decompression in 1973. More than a quarter of a century later, endoscopic lumbar spine surgery still is limited to a small number of surgeons. After many publications concerning the technique by Kambin et al^{12-21,27} and other practitioners,^{9,10,22,24,28,30-33} the percutaneous approach remains an uncommon operation. The perceived steep learning curve and the published exclusions have discouraged many potential users. One of the authors' goals of this report is to lower the learning curve: first, by simplifying the freehand, biplane c-arm-guided access method (Figures 1 and 2); second, by the use anatomic names to identify lumbar c-arm landmarks for endoscopic applications; and finally, by emphasizing the importance of the optimal trajectory from the skin window to the foraminal anular window. Before the advent of endoscopic visualization, it was stated^{16,12,13,19} that the L5-S1 disc space and large herniations generally were inaccessible. The authors' experience with the lumbar posterolateral endoscopic technique indicates that all lumbar disc spaces, including that of the L5-S1 disc, and their adjacent epidural spaces are accessible. The current data indicate that the technique is versatile and safe. The learning curve, with expert instructions and specialized equipment, is no longer steep for surgeons.

■ Key Points

- The posterolateral lumbar endoscopic technique is a viable alternative to the open decompression procedures for radiculopathy caused by LDH in the intracanal, foraminal, and extraforaminal locations.
- The authors use a freehand, biplane, c-arm-guided access and optimal trajectory, oriented by endoscopic landmarks.
- The procedure offers the major advantages of outpatient surgery, no retraction on the intracanal nerve elements, less postoperative pain, and earlier functional recovery.

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Address reprint requests to

Paul Moody Tsou, MD
*Department Of Orthopaedic Surgery
UCLA School of Medicine
2001 Santa Monica Boulevard
Suite 1190 West
Santa Monica, CA 90404
E-mail: ptsou@aol.com*