Observational Report

Percutaneous Endoscopic Lumbar Discectomy for L5–S1 Disc Herniation: Transforaminal versus Interlaminar Approach

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Background: Percutaneous endoscopic lumbar discectomy (PELD) is a minimally invasive spinal technique. The unique anatomic features of the L5–S1 space include a large facet joint, narrow foramen, small disc space, and a wide interlaminar space. PELD can be performed via 2 routes, transforaminal (TF-PELD) or interlaminar (IL-PELD). However, it is questionable that the decision of the endoscopic route for L5–S1 discs only depends on the surgeon's preference and anatomic relation between iliac bone and disc space. Thus far, no study has compared TF-PELD with IL-PELD for L5–S1 disc herniation.

Objective: The goal of this study was to compare the radiologic features and results of TF-PELD and IL-PELD. We have clarified the patient selection for the PELD route for L5–S1 disc herniation.

Study Design: Retrospective evaluation.

Methods: Thirty consecutive patients each were treated with TF-PELD and IL-PELD for L5–S1 disc herniation in 2 institutes, respectively. Radiological assessments were performed pre- and postoperatively. The disc type, disc size, location, migration, disc height, foraminal height, iliolumbar angle, iliac height, and interlaminar space were analyzed. Clinical data were compared with a 2-year follow-up period. Pre- and postoperative pain was measured using a visual analog scale (VAS; 0 – 10) and functional status was assessed using the Oswestry Disability Index (ODI; 0 – 100%) and the time to return to work.

Results: In the 2 groups, the mean VAS scores for back and leg pain, as well as the ODI, were significantly improved. The mean time to return to work was 4.9 weeks with TF-PELD and 4.4 weeks with IL-PELD. Incomplete removal, resulting in the need for subsequent open surgery, occurred in one case (3.3%) of TF-PELD and in 2 cases (6.6%) of IL-PELD. Postoperative dysesthesia developed in 2 patients (6.7%) after IL-PELD; however, there was no dysesthesia after TF-PELD. Recurrence occurred in 3.3% with TF-PELD and in 6.7% with IL-PELD during the 2-year follow-up. A significant difference between groups was demonstrated in terms of disc type, location, and migration. The prevalence of axillary disc herniation (20 cases, 66.7%) was higher than that of shoulder disc herniation (10 cases, 33.3%) in the IL-PELD group. On the other hand, in the TF-PELD group, shoulder disc herniation (20 cases, 66.7%) was more prevalent than the axillary type (10 cases, 33.3%; $P = 0.01$). A higher number of patients in the TF-PELD group had central disc herniation (10 cases, 33.3%) compared with that in the IL-PELD group (2 cases, 6.7%; $P = 0.01$). Eleven cases (36.7%) of high grade migration were removed using IL-PELD and one case (6.7%) was removed using TF-PELD ($P = 0.01$). TF-PELD was used to remov only 3 cases of recurrent disc herniation. There were no significant differences of radiologic parameters between the iliac bone and L5–S1 disc space between the 2 groups.

Limitations: This study has a relatively small sample size and a short follow-up period.

Conclusion: This study demonstrated that TF-PELD is preferred for shoulder type, centrally located, and recurrent disc herniation, while IL-PELD is preferred for axillary type and migrated discs, especially those of a high grade.

Key words: PELD, L5-S1 disc herniation, transforaminal, interlaminar

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Percutaneous endoscopic lumbar discectomy (PELD) is a minimally invasive spinal technique. PELD has several advantages, including less paravertebral muscle injury, preservation of bony structure, and rapid recovery. Since Kambin and Sampson (1) first introduced posterolateral percutaneous lumbar disc decompression, the technique and instrumentation of PELD has significantly improved (2-5). Given the anatomic characteristics of the L5–S1 level, which has a pelvic wing, narrow foramen, and wide interlaminar space, we have considered endoscopic routes: transforaminal versus interlaminar. Although many reports of PELD have been introduced, most studies at the L5–S1 level have reported the interlaminar approach (6,7). It is thought that the high iliac crest, narrow foramen, and a large facet joint are a barrier to performing transforaminal PELD (TF-PELD). On the other hand, Yeung and Tsou (8) suggested that TF-PELD can access all lumbar levels, even L5–S1. It is questionable that the decision of the endoscopic route for L5–S1 discs only depends on the surgeon's preference and anatomic relation between iliac bone and disc space. Thus far, no study has compared TF-PELD with interlaminar PELD (IL-PELD) for L5–S1 disc herniation. The goal of this study was to compare the radiologic features and results of TF-PELD and IL-PELD. We have clarified the patient selection for the PELD route for L5–S1 disc herniation.

Methods

The study was approved by our Institutional Review Board. TF-PELD and IL-PELD at the L5–S1 level were performed at 2 institutes, and a retrospective review was performed. Thirty consecutive patients were treated by TF-PELD for L5–S1 disc herniation between January and December 2010 (by Dr. Choi). Thirty consecutive patients were treated by IL-PELD (by Drs. Ryu and Kim). Inclusion criteria were unilateral radicular pain, single level intracanal disc herniation, and failure of conservative treatment for more than 6 weeks. Exclusion criteria were definite congenital anomalies, including lumbarization, spondylolysis, instability, foraminal/extraforaminal disc herniation, and lateral recess stenosis.

Pre- and postoperative data were obtained from a chart review and a radiologic examination. An independent observer, other than the treating surgeons, performed the radiological assessments preoperatively. The location was classified as central or paracentral. The herniated disc can be classified as shoulder or axillary type. The size was measured as the degree of herniation compromising the spinal canal (≥ 50% or < 50%; [9]). The herniation was described as high-grade if the extent of migration was larger than the measured height of the posterior marginal disc space. On the other hand, migration less than the measured height of the posterior marginal disc space was described as low-grade migration (9). Disc height was checked by examining the vertical distance between the posterior lower plate of the L5 vertebral body (VB) and the posterior upper plate of the S1 VB. Foraminal height was defined as the distance between the lower margin of the L5 pedicle and the upper margin of the S1 pedicle in the lateral view. Iliac height was defined as the vertical distance from the S1 plate to the highest iliac bone in the lateral view (Fig. 1A). The iliolumbar angle was defined as the angle between a line from the superior and medial point of the S1 pedicle to the highest iliac point and a horizontal line in the anteroposterior (AP) view (Fig. 1B). The vertical distance of the interlaminar space was defined as the largest vertical distance in the AP view. The transverse distance was defined as the widest of the interlaminar distance. Pre- and postoperative pain was measured using a visual analog scale (VAS; 0 – 10), and functional status was assessed using the Oswestry Disability Index (ODI; 0 – 100%) and time to return to work. The clinical outcomes were checked preoperatively and at the last follow-up.

Statistical Analysis

Statistical analyses were performed using SPSS for Windows (version 14.0; SPSS, Inc., Chicago, IL, USA). Depending on the variables, intergroup differences were analyzed using Fisher's exact test, chi-square test, or Mann–Whitney U test. The result was considered statistically significant if the probability value was less than 0.05.

Surgical Techniques

Transforaminal PELD

The TF-PELD procedure was performed under local anesthesia in the prone position. The skin entry point was generally superior to the iliac crest and 10 – 13 cm from the midline. After infiltration of the entry point with local anesthetics, an 18-gauge spinal needle was introduced, under the guidance of a fluoroscopic image. The final target point of the spinal needle was the medial pedicular line on the AP image and the posterior vertebral line on the lateral image. When the targeted disc was a central disc herniation, the spinal needle was targeted more towards the medial pedicular line on AP

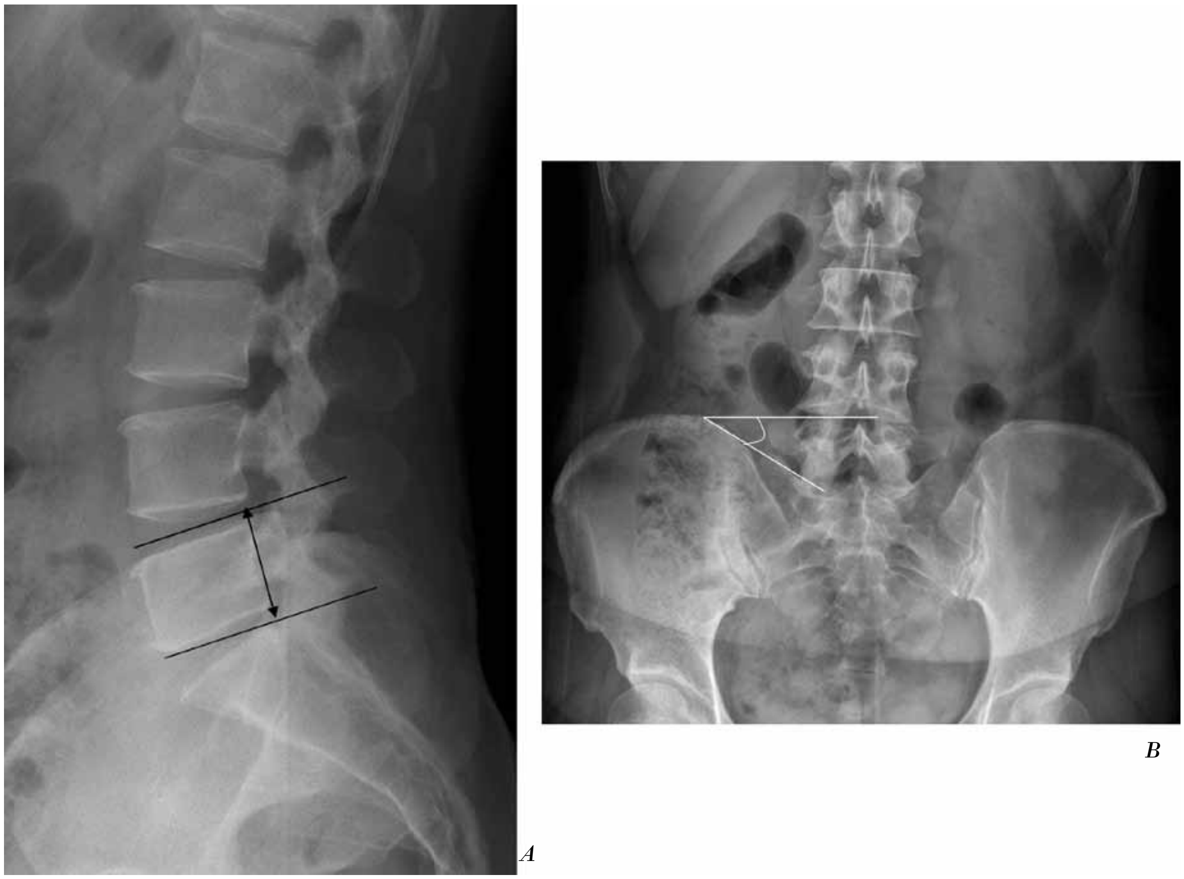


Fig. 1. *The iliac height was defined as the vertical distance (arrow) from the S1 plate to the highest iliac bone in the lateral radiography (A). The iliolumbar angle was defined as the angle between a line from the superior and medial point of the S1 pedicle to the highest iliac point and a horizontal line in AP radiography (B).*

view and the posterior vertebral line on lateral view. Next, an epidurography was performed using contrast media to confirm the location of the exiting and traversing root. After inserting the spinal needle into the disc, the nucleus pulposus was stained blue with a 1 mL mixture of contrast media (Telebrix, Guerbet, France) and indigo carmine (Carmine, Korea United Pharmaceutical, Yoenki, Korea) for discography. The following steps were then performed: a guide wire was inserted through the spinal needle; the spinal needle was removed; a small incision was made in the skin at the entry site; a tapered cannulated obturator was inserted along the guide wire; after touching the annulus, the obturator was inserted into the disc by hammering; and lastly, a bevel-ended, oval-shaped working cannula was inserted into the disc along the obturator, after which the obturator was removed. However, if the spinal needle was on the medial pedicular line on AP view and not on the posterior vertebral line on lateral view, foraminoplasty was performed. The superior facet was undercut a little by a bone reamer or bone cutter (2,4). Needling was retried and the previous step was then followed. Next, an endoscope (YESS system; Richard Wolf GmbH, Germany) was inserted through the cannula. The pathologic nucleus was stained for easy discrimination. The blue-stained disc was removed using endoscopic forceps and a side-firing holmium:yttrium-aluminum-garnet (Ho:YAG) laser. The inflamed nucleus was observed as being anchored by the annular fissure. The herniated disc and fibrotic scar tissues were released and removed using endoscopic forceps and a side-firing Ho:YAG laser. After the herniated fragment was completely removed, the endoscope was removed and a sterile dressing was applied with a one point suture.

Interlaminar PELD

IL-PELD was performed under general anesthesia. Immediately before the induction of anesthesia, each patient underwent provocative discography at the target level with a mixture of 5 mL of contrast media and 1 mL of indigo carmine, which stains the degenerated nucleus pulposus to discriminate it from the neural elements. The entry point was at the inferior edge of the superior lamina of the lesion side in the AP view and parallel to the disc space in the lateral view. For shoulder disc herniation, the entry point was closer to the lateral border of the interlaminar window. For axillary disc herniation, the entry point was made in the mid-portion of the lateral half of the lesion side of the interlaminar window. After a small skin and fascia incision, a dilator was introduced and docked under the inferior edge of the L5 lamina. A working channel was introduced over the dilator and the final position was checked on the AP and lateral fluoroscopic images. The surgery was performed after introducing an endoscope (WOLF, Firma Wolf, Knittling, Germany). Soft tissues, including the paraspinal muscle were cleaned to expose the ligamentum flavum, into which a hole was punched. A working cannula was introduced into the epidural space through this hole, and the dura margin and nerve root were exposed. With gentle retraction of the root, epidural dissection was performed. The protruded or sequestrated disc pieces were found and removed with disc forceps. The mobility of the root was checked after removal of the pathological disc pieces. Wound closure was performed after endoscope removal.

Results

Thirty patients each underwent PELD via the transforaminal or interlaminar route. The mean age of the patients was 33.8 years in TF-PELD and 36.9 years in IL-PELD (Table 1). For TF-PELD, the mean VAS scores for back and leg pain decreased from 5.2 to 2.4 and 7.4 to 1.6, respectively. For IL-PELD, the mean VAS for back and leg pain decreased from 5.5 to 2.4 and 7.6 to 1.8, respectively (Table 2). The mean ODI (%) of TF-PELD and IL-PELD improved from 52.3 to 12.3 and from 51.4 to 14.9, respectively. The mean time to return to work was 4.9 weeks for TF-PELD and 4.4 weeks for IL-PELD. The mean follow-up period was 2.2 years for TF-PELD and 2.3 years for IL-PELD (range, 2 to 2.5 years). Operative failure due to incomplete removal of the disc fragment was observed in one TF-PELD case (3.3%) and 2 IL-PELD cases (6.7%); subsequent open surgery was required in both cases. During the 2-year follow-up, disc herniation recurred in one TF-PELD (3.3%) and 2 IL-PELD (6.7%) cases. Postoperative dysesthesia developed in 2 patients (6.7%) after IL-PELD. There was no dysesthesia or L5 exiting nerve injury after TF-PELD.

Table 1. *Demographic findings between transforaminal PELD and interlaminar PELD.*

		Transforaminal (n = 30)	Interlaminar (n = 30)	*P*-value
Age (year)		33.8 ± 10.1	36.9 ± 11.6	> 0.05
Sex	M	14	15	> 0.05
	F	16	15	
Disc Location	Central	10	2	0.01
	Paracentral	20	28	
Disc Type	Shoulder	20	10	0.01
	Axillary	10	20	
Disc Size	≥ 50% canal compromise	8	4	> 0.05
	< 50% canal compromise	22	26	
Migration	Up-migrated	2	6	> 0.05
	Down-migrated	8	11	> 0.05
	Low-grade	9	6	> 0.05
	High-grade	1	11	0.01
Recurrent disc herniation		3	0	> 0.05

Table 2. ***Radiographic comparison between iliac bone and L5-S1 disc space in 2 groups.***

		Transforaminal	Interlaminar	*P*-value
Disc Height (mm)		7.6 ± 2.2	8.2 ± 1.7	> 0.05
Foraminal Height (mm)		16.3 ± 3.1	16.1 ±3.0	> 0.05
Sacral Slope (°)		27.5 ± 7.5	26.1 ± 8.5	> 0.05
Iliac Height (mm)		34.9 ± 10.6	37.6 ±10.7	> 0.05
Ilio-lumbar angle (°)		22.1 ± 4.6	24.3 ± 5.3	> 0.05
Interlaminar Space	Vertical Diameter (mm)	15.5 ± 2.9	16.2 ± 2.8	> 0.05
	Transverse Diameter (mm)	35.2 ± 5.3	34.8 ± 4.3	> 0.05

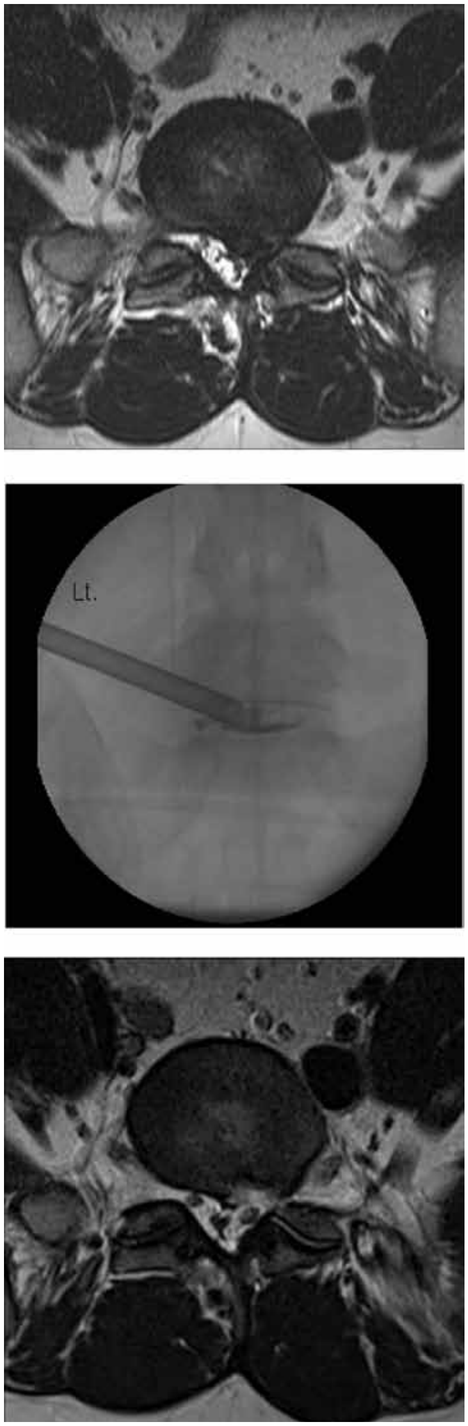
Table 3. ***Clinical comparison between transforaminal PELD and interlaminar PELD.***

		Transforaminal	Interlaminar	*P*-value
Preoperative	VAS Back	5.2 ± 2.0	5.5 ± 1.5	> 0.05
	VAS Leg	7.4 ± 1.5	7.6 ± 1.4	> 0.05
	ODI (%)	52.3 ± 15.8	51.4 ± 18.1	> 0.05
Postoperative	VAS Back	2.4 ± 0.8	2.4 ± 1.0	> 0.05
	VAS Leg	1.6 ± 1.0	1.7 ± 1.5	> 0.05
	ODI (%)	12.3 ± 8.1	14.9 ± 9.4	> 0.05
Postoperative MR	Complete removal	29	28	> 0.05
	Incomplete removal	1	2	
Conversion to open surgery		1	2	> 0.05
Recurrence (%)		1 (3.3%)	2 (6.6%)	> 0.05
Additional Technique	Foraminoplasty	12		
	Medial facetectomy		5	
Time to return to work (week)		4.9 ± 2.6	4.4 ± 1.7	> 0.05
Follow-up period (year)		2.2 ± 0.3	2.3 ± 0.4	> 0.05

A brief radiographic comparison between TF-PELD and IL-PELD is provided in Table 1. A significant difference was observed in terms of the disc type, migration degree, and disc location between patients who underwent TF-PELD and IL-PELD. Prevalence of axillary disc herniation (20 cases, 66.7%) was higher than that of shoulder disc herniation (10 cases, 33.3%) in the IL-PELD group. On the other hand, in the TF-PELD group, shoulder disc herniation (20 cases, 66.7%) was more prevalent than axillary disc herniation (10 cases, 33.3%; $P = 0.01$). The prevalence of central disc herniation was higher in the TF-PELD group (10 cases. 33.3%) than in IL-PELD group (2 cases, 6.7%; $P = 0.01$). Eleven cases (36.7%) of high-grade migration were treated with IL-PELD, and one case (6.7%) was treated with TF-PELD ($P = 0.01$). The discs were migrated upward or downward by up to 8 mm. TF-PELD was only successfully performed for 3 cases of recurrent disc herniation. There were no significant radiologic differences between the iliac bone and L5–S1 disc space relation in the 2 groups (Table 3).

Discussion

The percutaneous endoscopic technique, via a posterolateral route, was developed by Kambin and Sampson, Yeung and Tsou, and Hijikata (1,8,10). Advances in instrumentation such as a working cannula, endoscope, laser, and radiofrequency probe have popularized TF-PELD as a minimally invasive spinal technique. TF-PELD allows easy removal of migrated discs, foraminal/extraforaminal discs, and recurrent discs (11-13). PELD through an interlaminar window at the L5–S1 and even the L4–5 level has recently been introduced (6,7). The interlaminar window is the largest at L5–S1, and thus, it could provide enough room for direct posterior access. Spine surgeons are familiar with IL-PELD as the anatomic orientations involved are similar to open surgery, although there is a learning curve (14). In the lower lumbar spine, especially at the L5–S1, the transforaminal window becomes progressively smaller as the facet joint overlaps the disc space. The unique anatomic fea-



A

B

C

Fig. 2. *T2-weighted axial image of a 29-year-old man, with left leg radiating pain, showing paracentral disc herniation compressing the left S1 nerve root (A). Intraoperative radiography showing an endoscopic working channel at L5–S1 via the transforaminal route (B). Postoperative T2-weighted axial image showing complete removal of the herniated disc (C).*

tures of L5–S1 are a large facet joint, narrow foramen, small disc height, and an inclination of disc space. The iliac crest usually conceals the L5–S1 foramen. These anatomical barriers seem to be impossible to access via the transforaminal route. Suprailiac entry was used in our TF-PELD. Suprailiac entry enables removal of L5–S1 disc. The craniocaudal direction, through suprailiac entry, makes it possible to perform TF-PELD (Fig. 2).

Ruetten et al (15) reported outcomes of endoscopic surgery, including the transforaminal and interlaminar approaches, and found that 94.7% of L5–S1 cases were performed using the interlaminar approach. They achieved good clinical outcomes in 85% of the cases. Yeung and Tsou (8) performed 307 cases via TF-PELD and found that 50% of the cases were at the L5–S1 level. An excellent or good outcome was seen in 81.4% of the cases. They suggested that all lumbar disc spaces are accessible via the transforaminal route. The surgical difference in the treatment of L5–S1 disc herniation stemmed from the transforaminal trajectory between the 2 groups. Yeung and Tsou's technique is a posterolateral approach, similar to our technique while the Ruetten's technique is a more lateral approach; in this lateral approach, the iliac crest obstructs the access to the L5–S1 foramen.

Axillary herniated discs can be removed easily using IL-PELD (Fig. 3). The S1 nerve root exit is at the level of the L5–S1 disc space, which differs from that of other lumbar levels. The S1 root is already separated from the thecal sac. The angle between the S1 root and thecal sac allows access to the axillar portion of the S1 nerve root (16,17). Axillary disc herniation increases the root-thecal sac angle and creates more space for the working cannula, without root damage (6). IL-PELD can directly access the axillary herniated disc and remove the disc fragment with minimal manipulation of the neural structure. However, sometimes in TF-PELD, which has the possibility of incomplete decompression or remnant disc, invasion into the epidural space is required after cutting the posterior longitudinal ligament in order to catch the tail of a dorsally migrated disc fragment. Shoulder disc herniation can be treated using both techniques. However, in IL-PELD, it is not easy to approach the shoulder area of the nerve root. Directly accessing the shoulder of the S1 nerve root can damage the nerve root because the S1 root emerges from the thecal sac at the L5–S1 disc space. Sufficient medial facetectomy to create space is required. In this series, 16.7% medial facetectomy needed. Ruetten et al (15) reported osseous resection in 22% of their IL-PELD

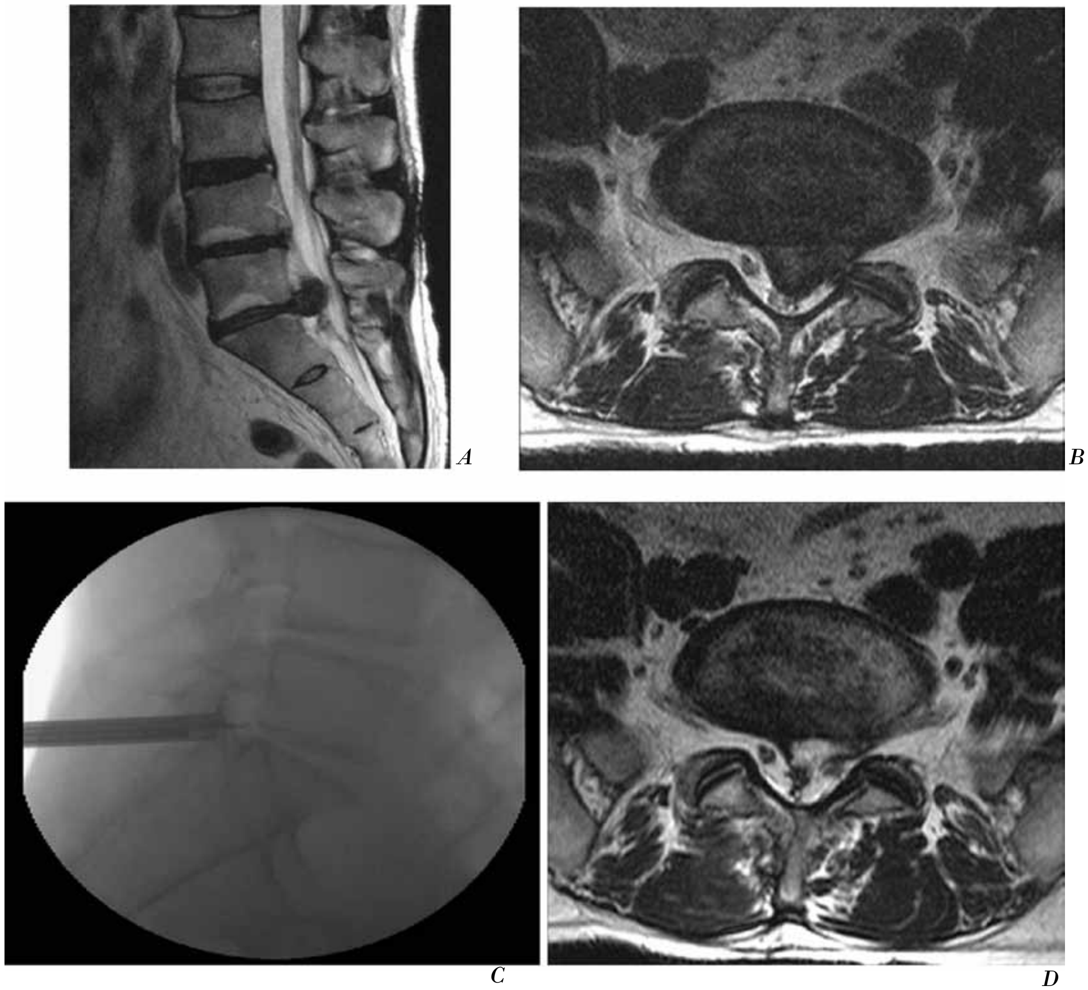


Fig. 3. *T2-weighted sagittal (A) and axial (B) images of a 28-year-old man, with left leg radiating pain, showing a large axillary disc herniation with upward migration. Intraoperative radiography showing an endoscopic working channel and forcep via the interlaminar route (C). Postoperative axial image showing complete removal of the herniated disc (D).*

cases. Although updated instruments such as drills and laser tools have been developed, bone manipulation is still challenging.

TF-PELD can approach the central extruded disc and remove the disc fragment without neural retraction (Fig. 4). TF-PELD requires foraminoplasty to access the central region. There is a concern in IL-PELD with the possibility of cauda equina injury or durotomy because of excessive neural retraction and manipulation of neural tissue.

TF–PELD for a high-migrated disc is challenging, although a few reports have overcome this limitation (12,13). Choi et al (13) introduced a technique for high-migrated discs through TF-PELD with foraminoplasty. However, they excluded the L5–S1 level with a high iliac crest, large transverse process, and upward migration. The inclinatory craniocaudal direction is inaccessible for a high migrated disc via the transforaminal route. High-grade, upward migrated discs at L5–S1 or downward migrated L4–5 discs can be removed via the shoulder of the S1 nerve root through IL-PELD (18). Ruetten et al (7) recommended that cases of craniocaudal sequestering to the maximum half of the adjacent vertebral body should be excluded for complete decompression. Our series of IL-PELD included a maximal 8 mm upward or downward migration (over half of the adjacent ver-

Fig. 4. *T2-weighted axial image of a 36-year-old woman, with radiating pain in both legs, showing a central disc herniation compressing the neural structures (A). Intraoperative radiography showing an endoscopic working channel located at the central portion of the L5–S1 disc space (B). Postoperative T2-weighted axial image showing adequate decompression (C).*

tebral body), and there were no cases of incomplete disc removal. The access to discs migrated upward or downward would depend on the vertical diameter of the interlaminar window. If the interlaminar window is large enough, it would be possible to treat a highly migrated disc by IL-PELD.

Although TF-PELD and IL-PELD are possible as revision surgery for recurrent disc herniation, they are challenging procedures (11,19-21). During recurrent disc herniation it is necessary to apply sufficient decompression and minimize iatrogenic neural injury. The incidence of a dural tear in open revisional surgery ranged from 8% to 18% (22,23). In terms of this point, TF-PELD passes unscarred virgin tissue and can minimize iatrogenic neural injury. TF-PELD has been used for recurrent disc herniation in 3 cases. There was no incomplete decompression or neural injury. Ahn et al (11) also reported no dural tears using TF-PELD for recurrent disc injury. Although Ruetten et al (20) reported no failure with IL-PELD for recurrent discs, generally, IL-PELD passes the previous operative scar and requires additional meticulous dissection and osseous resection, including the lamina and medical facet joint. Ruetten et al (20) reported a 2% rate of dural injury and 7% rate of transient dysesthesia after IL-PELD for recurrent disc herniation. Shin et al (21) reported 5% dural tears and 5% transient dysesthesia for revisional endoscopic disc surgery.

In this study, the radiologic features between the iliac bone and L5–S1 disc space were not significantly different between the 2 groups. All cases in our study were accessible during TF-PELD and IL-PELD. Operative failure resulting from incomplete decompression that required conversion to open surgery was observed in one TF-PELD case (3.3%) and 2 IL-PELD cases (6.6%).

The key step of TF-PELD at L5–S1 is the location of the working cannula. At other lumbar levels (L1–5), the relative wide foramen and disc space permit adjustment of the working cannula to remove the disc by internal decompression and levering. However, at L5–S1, inappropriate location of the fixed working cannula, due to the narrow foramen, disc space, and iliac bone, makes it difficult to remove the disc by levering. Furthermore, foraminoplasty provides a wide safe working zone to enter the epidural and disc spaces, minimizing exiting nerve injury. Ahn et al (2) applied foraminoplasty to foraminal stenosis and lateral exit zone stenosis by a bone reamer. Lee et al (4) introduced a foraminoplastic ventral epidural approach for L5–S1 disc herniation using an endoscopic bone cutter. Choi et al (13) applied foraminoplasty to migrated discs using an endoscopic drill. In this series, 40% of the TF-PELD procedures were performed with foraminoplasty. There may also be concerns about injury to the exiting nerve during TF-PELD at L5–S1. However, we did not observe any case of L5 exiting nerve injury. The safe working zone at L5–S1 is larger than other lumbar levels, although its foramen is the smallest (24). In addition, the trajectory of the craniocaudal inclination and location of the working cannula close to the superior facet can avoid exiting nerve injury.

This study demonstrated that TF-PELD is preferred for shoulder type disc herniation, centrally located disc herniation, and recurrent disc herniation, while IL-PELD is preferred for axillary type disc herniation and migrated discs, especially those of a high grade.

Limitations

There are some limitations to the current study that deserve mentioning, including that the study was retrospective, had a small series, and had a short follow-up period. We did not consider medication requirements and psychological effects. A prospective randomized trial would provide clear elucidation of this answer.

Conclusion

For PELD of L5–S1 disc herniation, characteristics of the disc herniation, which are location, type, degree of migration, and recurrent disc should be considered for an endoscopic trajectory, considering the anatomy of the L5–S1 disc space, iliac bone, and interlaminar window.

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