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The irony of the transforaminal approach

A comparative cohort study of transforaminal endoscopic lumbar discectomy for foraminal versus paramedian lumbar disc herniation

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Abstract

Transforaminal endoscopic lumbar discectomy (TELD) is useful for soft lumbar disc herniation (LDH). Although the transforaminal approach can reach the foraminal disc zone, the risk of exiting nerve root irritation along the path is considerable. Few studies have assessed the difficulties of TELD for foraminal LDH. The objective of this study is to compare the clinical results of TELD between foraminal or far-lateral LDH and paramedian LDH.

Between June 2016 and July 2017, 135 consecutive patients with single-level LDH were treated with TELD for 2 years. Among them, 25 patients had foraminal or far-lateral LDH (foraminal group), and the remaining 110 patients had central or subarticular LDH (paramedian group). Perioperative data and clinical outcomes were evaluated using the visual analog pain scale, Oswestry Disability Index, and modified Macnab criteria.

The foraminal group showed a higher rate of significant access pain (24.00% vs 8.19%, $P < .05$). The foraminal group also had a longer duration of surgery, length of hospital stay, and return to work (all $P < .05$). Pain scores and functional status were significantly improved in both groups. Although there were no differences in the outcomes at 2 years postoperatively, early pain and disability at 6 weeks were higher in the foraminal group.

Ironically, the early clinical results of TELD for foraminal LDH may be less favorable than those for paramedian LDH. Therefore, great care should be taken during TELD for foraminal or far-lateral LDH.

Abbreviations: LDH = lumbar disc herniation, ODI = Oswestry Disability Index, PLL = posterior longitudinal ligament, TELD = transforaminal endoscopic lumbar discectomy, VAS = visual analog scale.

Keywords: discectomy, endoscopy, exiting nerve root, foraminal, paramedian, transforaminal

1. Introduction

In general, surgical treatment for foraminal or far-lateral lumbar disc herniation (LDH) is regarded as more challenging than for central or subarticular LDH.[1–7] Since Abdullah et al[8] first described extreme-lateral LDH expanding into or beyond the foraminal disc area, the overall incidence ranged from 3% to 12% of all LDH.[7,9–13] Foraminal or far-lateral LDH has some unique clinical features. First, it often occurs in older patients, with a sixth-decade peak age.[14] Second, it usually has a more acute onset and causes more severe radicular pain due to direct pressure on the dorsal root ganglion.[7,12,15] Third, it occurs more frequently at the upper lumbar levels, commonly associated with intracanalicular LDH or stenosis.[14] Finally, the surgical outcomes of foraminal or far-lateral LDH are less favorable than those of central or subarticular LDH.[6,7]

Transforaminal endoscopic lumbar discectomy (TELD) has been developed since Kambin and Sampson[16] and Hijikata[17] reported a percutaneous discectomy technique through a posterolateral approach. The effectiveness of the current TELD for soft LDH has been proven by previous studies.[18–25] This technique's most peculiar theoretical benefit is that it can directly and percutaneously approach the disc pathologies through a foraminal window while preserving the normal neuromuscular structures.

However, the transforaminal approach for foraminal or far-lateral LDH may be somewhat ironic. Theoretically, the transforaminal endoscopic approach may be feasible and effective for foraminal or far-lateral LDH.[26–30] The percutaneous posterolateral or transforaminal approach enables direct access to the disc zones. In contrast, the surgical outcome of

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standard microdiscectomy for foraminal or far-lateral LDH is less favorable than for paramedian LDH.[6,7] The risk of exiting nerve root injury during the transforaminal approach is considerable because the triangular safety zone or Kambin prism is narrower in foraminal or far-lateral LDH. Although TELD is reportedly effective for foraminal or far-lateral LDH, there is a lack of studies comparing the clinical results of TELD between far-lateral LDH and usual paramedian LDH.

This is the first comparative cohort study of TELD for foraminal and paramedian LDH. The current study compared the clinical outcomes of TELD between foraminal or far-lateral LDH and paramedian LDH and discussed the technical keys to success.

2. Materials and methods

2.1. Patients

Between June 2016 and July 2017, 141 consecutive patients with single-level LDH were treated with TELD by a single experienced surgeon (AY). Patients were prospectively entered into the clinical database, and their records were retrospectively reviewed. This study was approved by the institutional review board of Gachon University College of Medicine (approval number: GCIRB2020-004), and written informed consent was obtained from all participants. During the 2-year follow-up period, 6 patients (4.3%) were lost to follow-up. Therefore, data were obtained from the remaining 135 patients. The surgical indications for TELD were as follows: intractable radicular pain with or without low back pain; a single-level LDH as demonstrated on either magnetic resonance imaging or computed tomography; and failure of non-surgical treatments including medical treatments, physical therapies, and epidural blocks. Patients with severe central lumbar stenosis, spondylolisthesis, segmental instability, painless weakness, cauda equina syndrome, and multilevel disc disease were excluded. The patients were categorized into 2 study groups based on the zone of LDH[31]: the foraminal group for foraminal or extraforaminal zone LDH (25 patients), and the paramedian group for central or subarticular zone LDH (110 patients).

2.2. Surgical technique

2.2.1. Preparation. All patients underwent TELD according to the standard technique.[32–35] The surgery was performed under local anesthesia with conscious sedation. Midazolam 0.05 mg/kg was injected intramuscularly and fentanyl 0.8 μg/kg intravenously on call as pre-medication. Additional fentanyl was administered as required. The patient was positioned prone on a radiolucent surgical table.

2.2.2. Transforaminal approach. An 18-gauge approach needle was used for the fluoroscopy-guided transforaminal approach. The approach needle should be inserted into the disc, avoiding the exiting nerve root after a preemptive epidural block. Discography was then performed with a mixture of contrast medium and indigo carmine for nuclear staining. Subsequently, a sequential dilation technique was followed until the working sheath was docked in the epidural or intradiscal space.

2.2.3. Selective endoscopic discectomy. An ellipsoid working channel endoscope was introduced, and the selective endoscopic discectomy procedure was initiated. The decompression process was performed by viewing the anatomical layer from the lateral aspect. The anatomical layers consist of the epidural space, posterior longitudinal ligament (PLL), and intradiscal area with the PLL as the decompression reference line. The disc usually herniated from the intradiscal area to the epidural space through the PLL or an annular tear like an "iceberg" on the ocean; the iceberg should be eradicated. Any remaining fragment of ice may cause incomplete decompression or postoperative recurrence. Sufficient annular release and removal of the entire herniated disc is the primary key to success.

2.2.4. Postoperative management. The endpoint of the procedure was free mobilization and pulsation of the nerve root and dural sac after sufficient discectomy. Postoperatively, the patients were checked for the occurrence of any complications before discharge.

2.3. Outcome evaluation and statistical analysis

Clinical data were obtained at outpatient clinic visits with a patient-based outcome questionnaire and telephone interviews. Pain was evaluated using the visual analog scale (VAS) score, and the functional state was measured using the Oswestry Disability Index (ODI).[36] Global results at the final follow-up were categorized as excellent, good, fair, or poor based on the modified Macnab criteria.[34,37]

According to the patient's response during the transforaminal approach, access pain was evaluated. Access pain may be caused by exiting nerve root irritation or bone pain by the dilators or working sheath. A 4-point pain scale was used for the transforaminal access pain: minimal (no pain or motion response), mild (mild but tolerable discomfort), moderate (definitive complaint of pain), and severe (screaming or withdrawal motion from pain). Moderate or severe access pain was defined as significant pain.

Perioperative data, including the duration of surgery, length of hospital stay, and return to work, were evaluated. Return to work was defined as resuming work tasks after sick leave.[38,39] Surgical complications and recurrent disc herniation were also documented.

Statistical analysis was conducted using SPSS software version 24.0 (IBM, Armonk, NY). The 2 groups were compared using a Mann–Whitney *U* test for continuous variables due to the disparate sample size. Fisher exact test was conducted for categorical variables. Changes in VAS or ODI were analyzed using a mixed ANOVA. P values $< .05$ were considered significant.

3. Results

3.1. Demographics and perioperative data

The foraminal group included 14 women and 11 men, with a mean age of 48.9 years (range, 21–85 years). The paramedian group included 52 women and 58 men, with a mean age of 47.3 years (range, 18–84 years). Sex, age, operative level, and other constitutional parameters were not significantly different between the groups (Table 1).

The foraminal group had significantly higher access pain ($P < .05$, Fig. 1A) and a longer duration of surgery ($P < .01$, Fig. 1B), length of hospital stay ($P < .05$, Fig.1C), and return to work ($P < .05$, Fig. 1D) than the paramedian group.

3.2. Postoperative adverse events

Postoperative dysesthesia was reported in 5.2% (7/135) of patients and resolved within 6 weeks in 4 patients. The remaining

Table 1

Patient demographics.

	Foraminal	Paramedian	*P* value
No. of patients	25	110	
Sex ratio (F:M)	14:11	52:58	NS
Mean age (years)	48.92 ± 17.10	47.26 ± 16.12	NS
Mean BMI (kg/m^2)	24.18 ± 1.96	23.71 ± 3.11	NS
Operative level			NS
L2–L3	1	1	
L3–L4	6	19	
L4–L5	10	64	
L5–S1	8	26	

BMI = body mass index, F = female, M = male, NS = not significant.

3 patients experienced considerable sensory disturbance during the last follow-up. Although the rate of dysesthesia was higher in the foraminal group, the difference was not significant (12% vs 3.6%, $P > .05$). Minor dural tears were detected intraoperatively in 2 patients in the paramedian group. The dural defect was suitably repaired using gelatin sponge and fibrin sealant. Two cases of discitis in the paramedian group were controlled using extensive antibiotic therapy. Recurrent disc herniation occurred in 1 (4%) and 3 (2.7%) patients in the foraminal and paramedian groups, respectively. All patients underwent subsequent revision discectomy. Complications and reoperation were not significantly different between the groups (Table 2).

3.3. Clinical outcomes

The mean VAS score for back pain improved from 5.68 ± 2.88 to 1.88 ± 0.73 in the foraminal group and from 5.87 ± 1.19 to 1.76 ± 0.88 in the paramedian group ($P > .05$, Fig. 2A). The mean pre-operative VAS score for radicular pain was not significantly different between the 2 groups ($P > .05$). At 6 weeks postoperatively, the mean VAS score for radicular pain was higher in the foraminal group (3.12 ± 1.54 vs 2.63 ± 0.98, $P < .05$, Fig. 2B). However, the scores after 6 weeks postoperatively were statistically identical between the groups (1.76 ± 0.66 vs 1.49 ± 0.95, $P > .05$, Fig. 2B). The mean pre-operative ODI was not significantly different between the 2 groups ($P > .05$). At 6 weeks postoperatively, the mean ODI was higher in the foraminal group (35.15 ± 11.58 vs 30.89 ± 7.70, $P < .05$, Fig. 3). However, the ODIs after 6 weeks postoperatively were statistically identical between the groups (19.38 ± 10.59 vs 18.84 ± 10.40, $P > .05$, Fig. 3). Based on the modified Macnab criteria, the global outcome was found to be excellent or good in 84% (21/25) of patients in the foraminal group and 85.45% (94/110) of patients in the paramedian group (Fig. 4). There was no significant difference between the groups.

Table 2

Perioperative adverse events.

	Foraminal	Paramedian	*P* value
No. of patients	25	110	
Dysesthesia	3 (12%)	4 (3.6%)	NS
Dural tear	0	2 (1.8%), minor	NS
Infection	0	2 (1.8%), discitis	NS
Hematoma	0	0	NS
Recurrence	1 (4%)	3 (2.7%)	NS

NS = not significant.

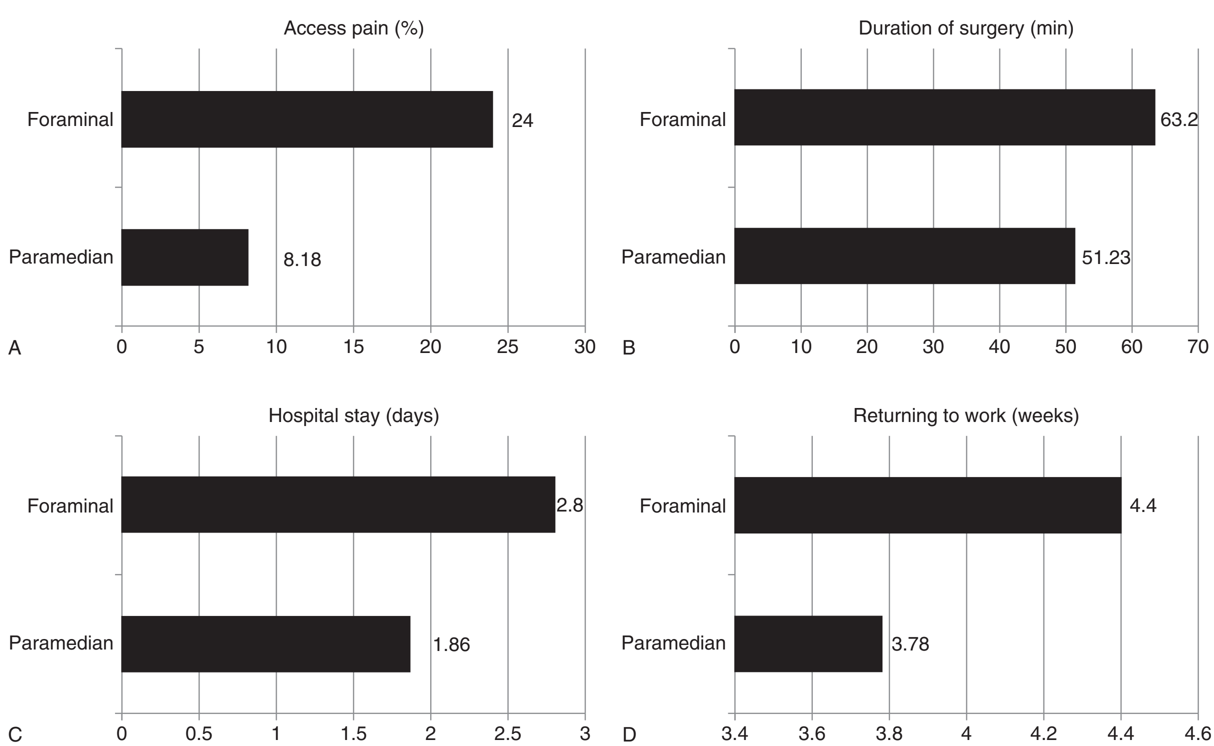

Figure 1. Perioperative data. (A) Access pain rate. (B) Duration of surgery. (C) Length of hospital stay. D. Time to return to work.

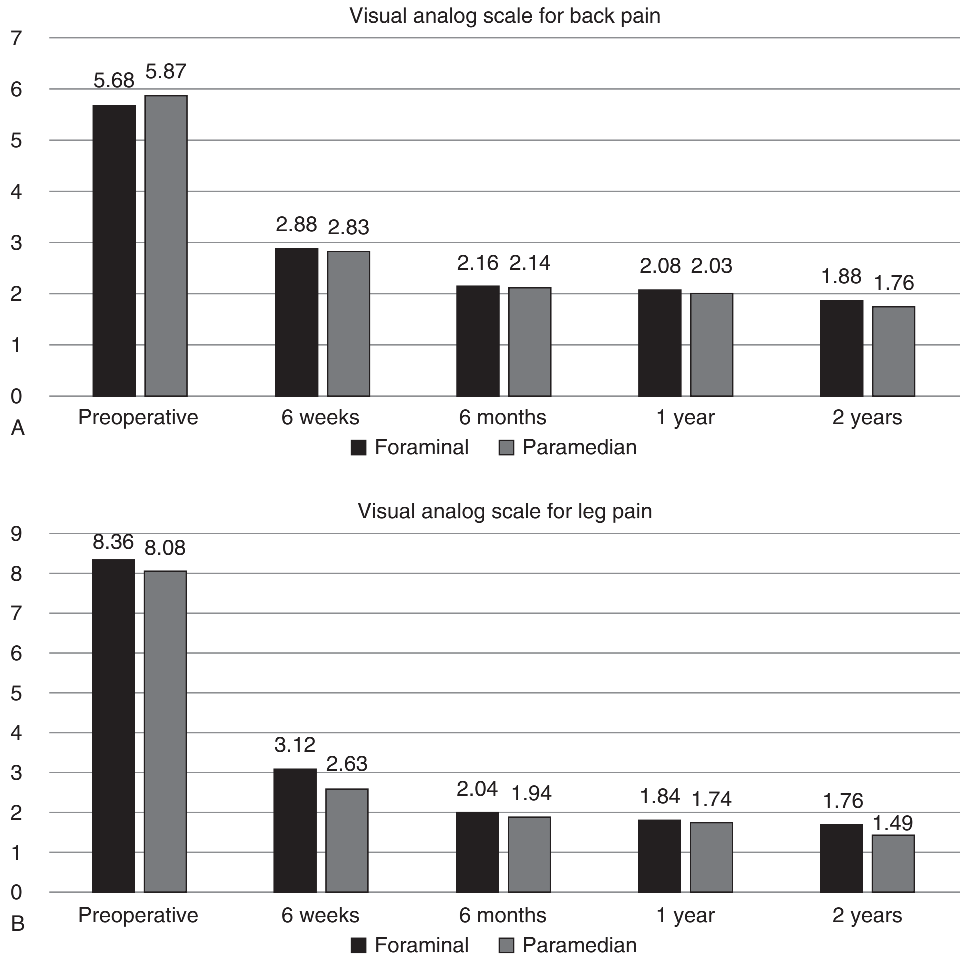

Figure 2. Pre-operative and postoperative visual analog scale for back pain (A) and radicular leg pain (B).

4. Discussion

4.1. Perioperative data

Access pain during the procedure tended to be higher in the foraminal group. There may be several reasons for this. First, the safety margin in Kambin triangle is smaller in the foraminal group due to the extruded disc. The exiting nerve root may be pushed out and exposed in the foraminal window; thus, the risk of exiting nerve root damage is higher. Second, the exiting nerve root and dorsal root ganglion are already inflamed and

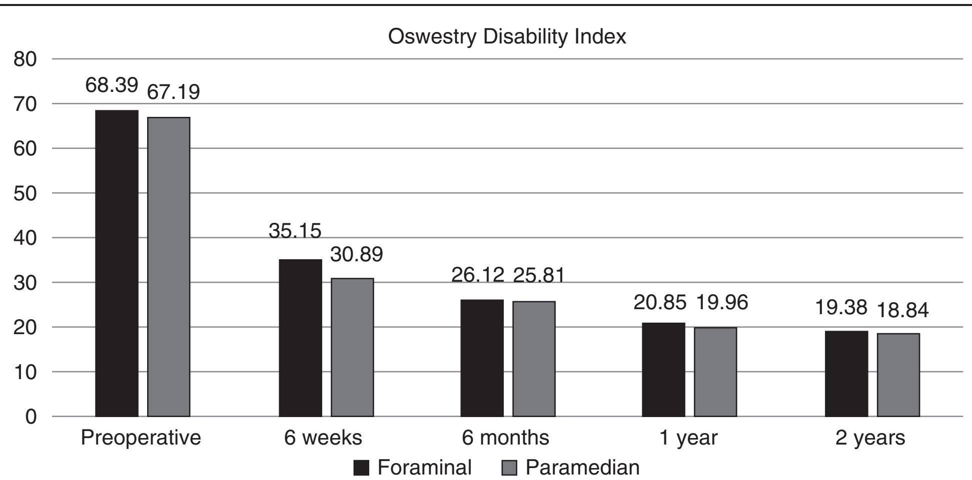

Figure 3. Pre-operative and postoperative Oswestry Disability Index.

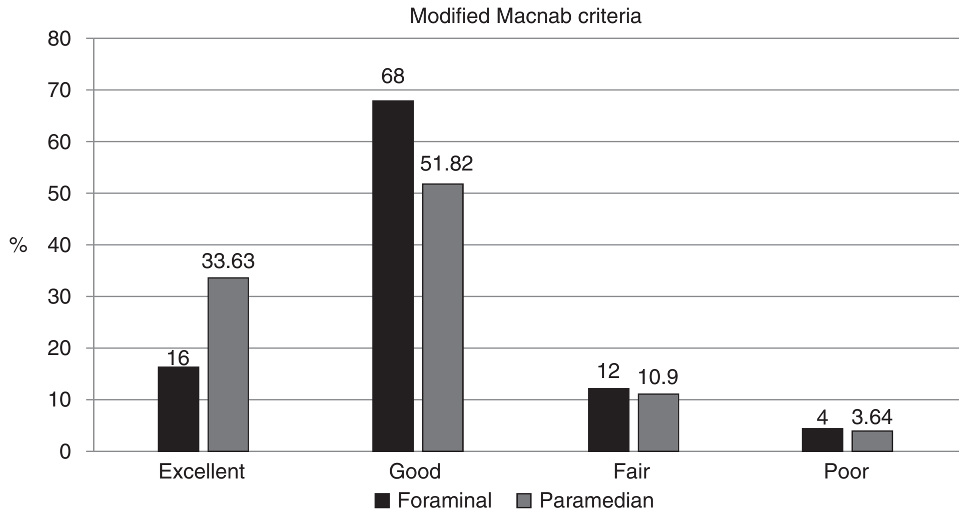

Figure 4. Global outcome according to the modified Macnab criteria.

sensitized. Even mild or indirect irritation may cause severe pain.

The duration of surgery was longer in the foraminal group. Pain during the procedure is the first time-consuming factor. Increased access and manipulation pain may be more common in foraminal neural pathology. Second, the endoscopic anatomy and confirmation of decompression are more complicated in the foraminal group. A rotation or angle change of the endoscope is required for precise foraminal decompression. Moreover, the flourishing vascularity in the foraminal zone may cause unexpected bleeding and subsequent obscured vision.

The length of hospital stay and time to return to work were also longer in the foraminal group. Early postoperative flare and discomfort might influence the total hospital days and recovery time.

4.2. Postoperative dysesthesia

Postoperative dysesthesia may be the specific adverse event in TELD (range, 1.05%–6.7%).[21,33,34,40–44] Neural injury or irritation may occur in the transforaminal approach or selective discectomy process by either mechanical or thermal manipulations.[45] Significant dysesthesia can affect patients' quality of life and satisfaction. Although statistically identical, the dysesthesia rate tended to be higher in the foraminal group. We postulated several reasons for postoperative dysesthesia. First, exiting nerve root irritation during the percutaneous transforaminal approach may cause dysesthesia. Second, pre-injured nerve roots may be more susceptible to surgical manipulation. Third, incomplete decompression or early recurrences may be more common in the foraminal group.

4.3. Clinical outcomes

The clinical outcomes, such as VAS scores for radicular pain and ODI, in the early postoperative period were less favorable in the foraminal group. Nevertheless, the late postoperative data and global outcomes were similar between the groups. Therefore, immediate postoperative flare and functional disability might delay neural recovery after TELD in the foraminal group. Intraoperative access pain and postoperative dysesthesia may be the primary causes of delayed recovery. However, the data also revealed that the adverse neural problem was mostly transient, and TELD was also useful for foraminal or far-lateral LDH.

4.4. The irony of the transforaminal approach

The most crucial safe working zone is Kambin triangle or Kambin prism. The original Kambin triangle is bordered by the exiting nerve root, endplate of the lower vertebra, and traversing nerve root.[16,46] It has evolved to a 3-dimensional working space composed of the original triangle plus the superior articular process as the posterolateral border. The modern concept of Kambin prism is bordered anteriorly by the exiting nerve root, inferiorly by the lower vertebra's endplate, posteriorly by the superior articular process of the inferior vertebra, and medially by the traversing nerve root.[47,48] All types of posterolateral or transforaminal approaches are performed using this prism.

The transforaminal approach refers to posterolateral access to the disc through the foraminal window. Theoretically, this method of access may be suitable for the foraminal disc zone. Some authors reported that the transforaminal approach was useful for foraminal or far-lateral disc herniation [27,28] However, the data indicated that this approach in the foraminal group might cause considerable access pain and flare. It also requires longer surgery and recovery times. "To the foramen" is more complicated and stressful than "through the foramen." Several reasons can explain this irony in the transforaminal approach. First, the foraminal window is narrowed by the herniated disc, and Kamin prism is smaller in the foraminal group (Fig. 5). Second, the exiting nerve root is compressed and inflamed making it more vulnerable to any mechanical or thermal irritation during the approach (Fig. 5). Third, the transforaminal approach is a blind technique under fluoroscopic guidance. Unlike the open method, the percutaneous approach may cause mechanical impact when the dilators or working sheath dock on the foraminal region. Thus, mechanical irritation or injury to the exiting nerve root occurs. Lastly, but importantly, there may be some blind spots behind the working sheath. In general, the endoscope's visual axis usually angles 20° to 30° for a full visual

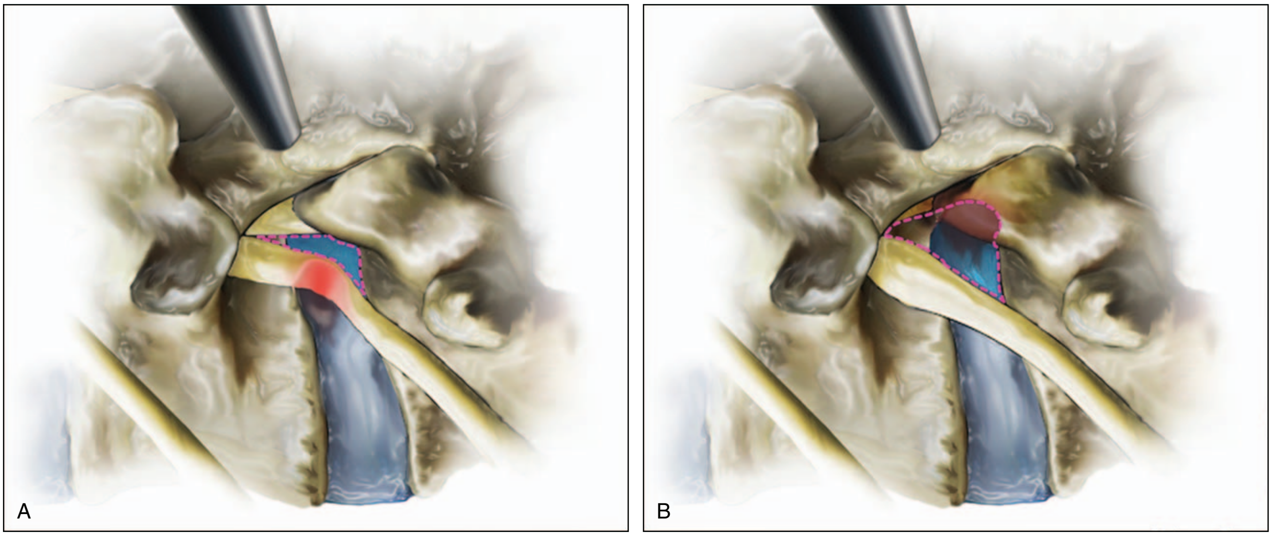

Figure 5. Schematic comparison of the transforaminal endoscopic lumbar discectomy (TELD) for foraminal (A) and paramedian (B) lumbar disc herniation (LDH). Note that Kambin triangle is smaller in the foraminal LDH and the inflamed exiting nerve root is more vulnerable to any mechanical irritation (A).

field. This angled view may create a hidden zone, especially in the extraforaminal area, possibly resulting in incomplete decompression.

4.5. Technical keys to success

Although the transforaminal approach for foraminal LDH is more complicated, there are some practical guidelines for the clinical success of TELD which can be summarized into 2 significant technical steps: initial transforaminal landing to the foraminal disc zone and selective endoscopic discectomy.

Regarding transforaminal landing, there are several technical tips for safe access to the foraminal zone. First, the landing point should be as far from the exiting nerve root as possible.[35,45] In general, the posterior caudal area in the foramen is safer to reduce nerve root irritation. Second, in extraforaminal or far-lateral LDH, the disc puncture may be initiated at the subarticular zone using a serial dilation technique. After a safe intradiscal landing, selective decompression may proceed to the far-lateral area (inside-out technique). Serial dilation from a small annular puncture to a bigger annular hole may reduce exiting nerve root tethering during the approach. Third, in cases of severe foraminal stenosis or huge foraminal LDH, a floating landing on the superior articular process or inferior pedicle (outside-in technique) is needed. Endoscopic decompression can then be initiated just in front of disc herniation without dangerous annular puncture.

Selective endoscopic discectomy has several technical knowhows for effective foraminal decompression. First, the decompression direction is recommended from the posterior caudal end of the foramen to the anterior cranial point of the foramen. Thus, decompression should be started far from the exiting nerve root and then gradually approach the compressed neural elements. Second, the angle of endoscopic visualization should be adjusted according to the pathologic area. The usual perspective of the working channel endoscope is optimized to the lumbar epidural space. However, for the foraminal or far-lateral zone, the angle of view should be changed upside-down. Thus, the angle of light may be focused on the foraminal area of the disc. The foraminal zone can then be decompressed more effectively. Third, to prevent recurrent disc herniation, the intradiscal hernia fragment or loose disc material should be removed with a steeper working angle. Removing only the "tip of the iceberg" may result in postoperative recurrence or incomplete decompression. Removing the whole hernia fragment, including the "base of the iceberg," is key to preventing recurrent disc herniation.

4.6. Limitations and strengths

This study has some methodological limitations. Patient enrollment was not randomized, resulting in possible selection bias. Moreover, the number of patients was relatively small. Furthermore, radiographic parameters and postoperative changes over time were not analyzed. A strength of the study is that access pain during the procedure was prospectively recorded and analyzed. To our best knowledge, this is the first evaluation of access pain during TELD under local anesthesia. The relationship between radiographic parameters, including Kambin prism, and access pain with technical difficulty, will be investigated in the future.

5. Conclusion

TELD may be a practical alternative for foraminal or far-lateral LDH with the typical benefits of minimally invasive spinal surgery. However, a transforaminal approach to these zones may be less favorable in terms of surgical difficulty, early disability, and recovery time. Sophisticated technical considerations are essential for the clinical success of TELD for foraminal or far-lateral LDH.

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