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Clinical Comparison of Percutaneous Endoscopic Transforaminal Discectomy with Foraminoplasty and Unilateral Biportal Endoscopic Discectomy for Lumbar Disc Herniation: A Retrospective Study

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ABSTRACT

Objective: To compare the clinical outcomes and respective advantages of percutaneous endoscopic transforaminal discectomy with foraminoplasty (PETD) and unilateral biportal endoscopic discectomy (UBED) in patients with lumbar disc herniation (LDH).

Methods: A retrospective analysis was conducted on patients who underwent UBED (n=90) or PETD (n=65) at Xi'an Honghui Hospital from October 2022 to October 2023. The demographic and perioperative variables included sex, age, BMI, disease course, surgical time, intraoperative blood loss, hospitalization duration, postoperative hospitalization duration, number of fluoroscopies, incision length, and follow-up period. Clinical outcomes were assessed via lumbar/leg visual analog scale (VAS) scores and the Oswestry Disability Index (ODI). Radiographic assessment before and after surgery focused on intervertebral disc height changes. Complications (incision infections, nerve root injuries, cerebrospinal fluid leaks, postoperative headaches) and recurrence rates within 6 months were recorded.

Results: Both techniques significantly improved the VAS and ODI scores postoperatively, with no intergroup differences. The UBED group had longer operative times (98.93±38.24 vs. 82.89±46.06 mins, P=0.019) and greater blood loss (76.89±66.29 vs. 47.23±45.89 mL, P=0.002). PETD was associated with shorter incisions (0.85±0.18 vs. 1.78±0.21 cm, P<0.001) but required more fluoroscopic exposures (6.95±3.10 vs. 3.84±1.10, P<0.001). The complication rates were low in both groups, with UBED resulting in no recurrences versus 4.6% for PETD. Patient satisfaction was high (UBED: 93.3%; PETD: 92.3%, P=0.806).

Conclusion: UBED and PETD achieve comparable efficacy for LDH. While UBED reduces fluoroscopy dependence and recurrence risk, it increases surgical duration and blood loss. These findings align with existing evidence, but further randomized trials are needed to address selection bias and confirm long-term benefits.

Keywords: Minimally invasive surgery; Percutaneous endoscopic transforaminal discectomy; Unilateral biportal endoscopic discectomy; Lumbar disc herniation; Clinical efficacy

INTRODUCTION

Lumbar disc herniation (LDH), characterized by the displacement of intervertebral disc material causing nerve root compression, is a leading cause of lower back pain and radicular symptoms that severely impair patients' quality of life. While conservative management remains first-line, surgical intervention becomes necessary for refractory cases. Although effective, traditional open discectomy carries risks of iatrogenic instability and prolonged recovery. The advent of minimally invasive techniques, particularly percutaneous endoscopic lumbar discectomy (PELD) and unilateral biportal endoscopic discectomy (UBED), has revolutionized LDH treatment by balancing efficacy with reduced tissue trauma.[1, 2]

PELD encompasses two primary approaches: percutaneous endoscopic transforaminal discectomy (PETD) and percutaneous endoscopic interlaminar discectomy (PEID). Recently, UBED has emerged as a promising alternative, leveraging dual portals for enhanced visualization and instrument maneuverability.[3,4] Compared with PETD, UBED may reduce fluoroscopic exposure and recurrence rates, albeit with potential trade-offs in operative duration and blood loss.[5]

However, existing studies exhibit variability in reported outcomes for UBE regarding blood loss, operative duration, fluoroscopic exposure, incision length, and complications. Furthermore, distinct surgical techniques are optimized for specific indications rather than universal applicability, necessitating surgeon proficiency in diverse approaches to address heterogeneous pathologies. This paradigm enables tailored therapeutic strategies while minimizing secondary trauma. Building upon prior investigations, this study evaluated the clinical and radiographic outcomes of UBED versus PETD to identify optimal treatment algorithms for LDH.

CLINICAL DATA

General information

Informed consent was obtained from all patients who adhered to the Strengthening the Reporting of Cohort Studies in Surgery (STROCSS) criteria.[6] The study was approved by the Ethics Committee of Honghui Hospital.

The inclusion criteria were as follows: (1) imaging-confirmed LDH diagnosis aligned with clinical symptoms; (2) characteristic nerve root compression symptoms and imaging findings; (3) persistent low back and leg pain without significant relief after ≥3 months of conservative treatment; and (4) a follow-up period of ≥12 months. The exclusion criteria were as follows: (1) Pfirrmann grade ≥3, Modic changes ≥2, severe facet joint degeneration, severe osteoporosis, spondylolisthesis, or segmental instability unsuitable for endoscopic surgery; (2) inability to tolerate general anesthesia; (3) severe systemic diseases or psychiatric disorders; (4) contralateral foraminal or central stenosis requiring contralateral decompression, or additional surgery concurrently for other reasons; and (5) incomplete or missing follow-up data.

Surgical procedure

Informed consent was obtained before surgery, and comprehensive preoperative assessments, including lumbar X-rays, CT, MRI, complete blood count, liver and kidney function tests, and coagulation profile, were conducted to exclude surgical contraindications. All surgeries were performed by experienced surgeons under general anesthesia, with L4–5 level herniation used as an example.

PETD procedure

Following aseptic preparation and imaging localization of the L4–5 intervertebral space via C-arm fluoroscopy, the spinal needle was advanced through a posterolateral trajectory (8–10 cm from midline) under bidirectional fluoroscopic guidance, with its tip positioned at the medial pedicular boundary and ventral superior articular process (SAP). A sequential dilation system established an 8 mm working channel, through which a visualized trephine resected approximately one-third of the ventral SAP cortex under saline irrigation, with confirmation via AP fluoroscopy to ensure that bone removal remained medial to the pedicle. The working cannula was then replaced with a 30° beveled endoscope, allowing identification of the lateral ligamentum flavum and nerve root epineurium. Adhesiolysis was performed via blunt probes, followed by bipolar radiofrequency to ablate annular neovascularization. Herniated nucleus pulposus fragments were evacuated via annular fenestration until dural sac pulsatility and neural mobility were restored. The procedure included tract withdrawal, subcuticular suturing, and compressive wound dressing (Figure 1).

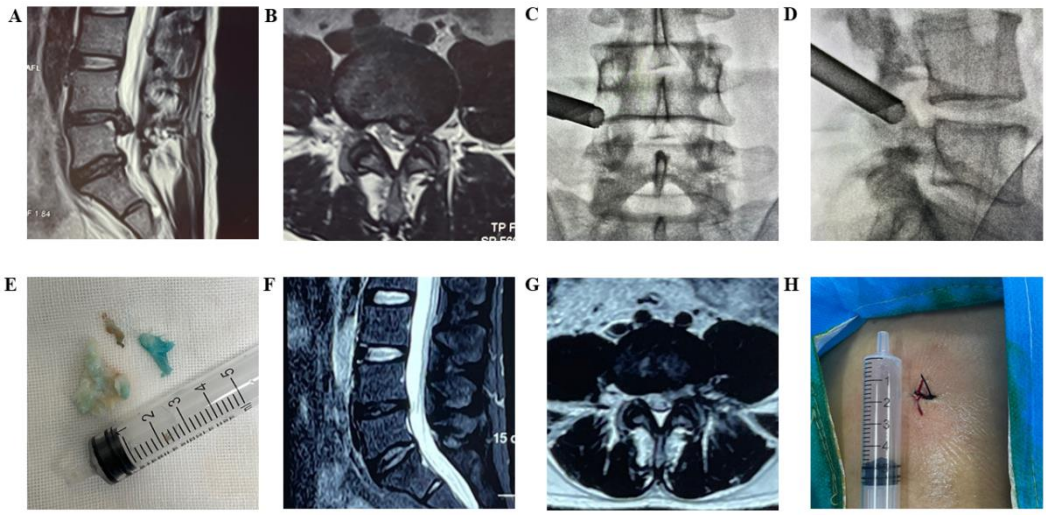

Figure 1: A 40-year-old male patient experienced cramping pain and numbness in the left lower limb for 3 months. (A-B) Lumbar spine MR image showing a paracentral protrusion of the intervertebral disc on the left side at the L4--5 level, which compresses the dural sac and the L5 nerve root. (C-D) The vertebral interspace is accurately positioned in the anteroposterior and lateral views under the C-arm. (E) The free nucleus pulposus

tissue indicated by the contrast agent was removed. (F-G) The herniated intervertebral disc tissue was removed, and the dural sac bulged. (H) The size of the postoperative wound was approximately 0.75 cm.

UBED procedure

The patient was positioned prone, and the L4–5 interspace, midline, and projection line of the left L4–5 pedicle were marked. Two transverse incisions were made at a horizontal distance of approximately 1.5 cm between the intervertebral spaces. The size of the upper observation mirror incision was approximately 0.75 cm, and the size of the lower operation incision was approximately 1 cm. Fluoroscopy confirmed the needle tip within the interlaminar space, establishing a working channel. A power drill was used to remove a portion of the left lower vertebral plate of L4 until the upper insertion point of the ligamentum flavum was exposed. Similarly, the lower and outer insertion points of the LF were exposed via the same method. Vertebral plate forceps were used to completely remove the ligamentum flavum. The herniated nucleus pulposus was excised, and bipolar radiofrequency electrodes were used for hemostasis and field clearance. Pulsations of the dural sac and nerve root were observed, and hemostasis was reconfirmed before removing the instruments and suturing the incision (Figure 2).

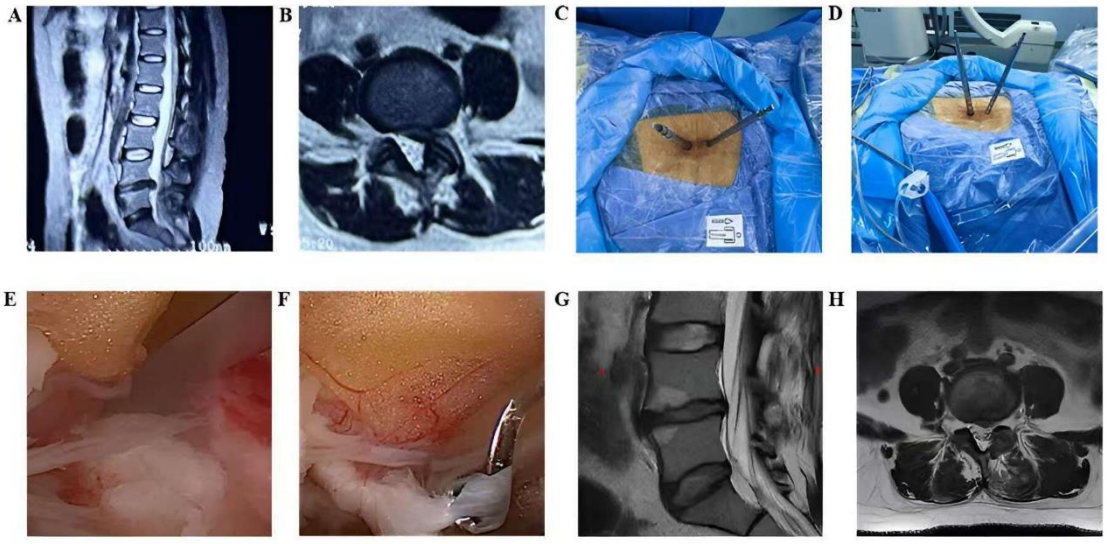

Figure 2: A 31-year-old female patient presented with cramping pain in the left lower limb for 9 months and numbness for 4 months. (A-B) Lumbar spine MR scans revealed paracentral disc herniation at the left L4-5 level, compressing the dural sac. (C–D) The L4–5 intervertebral space was located, and sequential dilators were used to separate the muscles. (E-F) The herniated intervertebral disc was exposed, and the nucleus pulposus tissue was removed with nucleus pulposus forceps. (G-H) Postoperative lumbar spine MR image showing that the herniated disc had been removed.

Clinical indicators

Lumbar function was evaluated preoperatively and at 1 day, 3 months, and 6 months postoperatively via the visual analog scale (VAS) and Oswestry Disability Index (ODI).[7] The VAS, ranging from 0 to 10, measures pain severity, with higher scores indicating more pain. The ODI ranges from 0 to 50, where higher scores reflect greater disability.

Intraoperative complications included incision infection, nerve root injury, cerebrospinal fluid leakage and headache. Recurrence was defined as symptom recrudescence within 6 months postoperatively with imaging confirmation of recurrent disc herniation at the same anatomical level. Patient satisfaction was evaluated via the modified MacNab criteria, where "excellent" indicated no pain or unrestricted activities; "good" indicated occasional nonradicular pain with symptom relief and a return to work; "fair" indicated improved functional ability but with disability or unemployment; and "poor" indicated persistent radicular symptoms requiring additional surgical intervention.

Radiographic indicators

Disc height quantification is standardized on lateral digital radiographs (DRs) as the perpendicular intervertebral distance between the geometric centroids of the superior and inferior endplates. The disc height was measured preoperatively and at 1 month and 6 months postoperatively in both groups.

Statistical analysis

Statistical analyses were conducted via SPSS 26.0. Continuous variables are presented as the means ± standard deviations (x±s) and were compared via independent t tests. Categorical data were analyzed via the χ^2 test. $P < 0.05$ was considered statistically significant.

RESULTS

Baseline characteristics

The UBED cohort comprised 46 male patients and 44 female patients (mean age: 51.61±12.29 years; BMI: 24.94±2.95 kg/m²), with a mean disease course of 39.07±45.66 months. The disc herniation distributions included L2-3 (1), L3-4 (2), L4-5 (47), and L5-S1 (40). The PETD group consisted of 36 males and 29 females (mean age: 54.43±14.88 years; BMI: 24.32±2.61 kg/m²) with a 35.63±41.77-month disease course, demonstrating a distinct level distribution: L2-3 (7), L3-4 (11), L4-5 (41), and L5-S1 (6).

No significant intergroup differences were observed in hospitalization duration (P=0.276) or postoperative length of stay (P=0.092). Operative metrics revealed a significantly longer procedure time in UBED patients (98.93±38.24 minutes vs. 82.89±46.06 minutes), with greater blood loss (76.89±66.29 mL vs. 47.23±45.89 mL, both $P<0.01$). The PETD group required substantially more fluoroscopic exposures (6.95±3.10 vs. 3.84±1.10, $P<0.001$) but presented shorter incision lengths (0.85±0.18 cm vs. 1.78±0.21 cm, $P<0.001$).

Postoperative complications in the UBED group included two cerebrospinal fluid leaks (2.2%) and one surgical site infection (1.1%) compared with one cerebrospinal fluid (CSF) leak (1.5%) and one symptomatic nerve root injury (1.5%) in the PETD group. Notably, UBED showed superior durability, with no recurrences during the 6-month follow-up, compared with three recurrent herniations (4.6%) in the PETD cohort (Table 1).

Table 1: Comparison of baseline characteristics

Group	UBED	PETD	T	*P*
Gender (Male/Female, n)	46/44	36/29	0.277	0.599
Age (Mean ± SD, years)	51.61±12.29	54.43±14.88	-1.29	0.199
BMI($\bar{X}$±S,kg/m$^{2)}$	24.94±2.95	24.32±2.61	1.346	0.18
Disease course	39.07±45.66	35.63±41.77	0.477	0.634
Surgical time (Mean ± SD, minutes)	98.93±38.24	82.89±46.06	2.364	**0.019**
Blood Loss (Mean ± SD, mL)	76.89±66.29	47.23±45.89	3.108	**0.002**
Hospitalization duration (Mean ± SD, days)	6.44±2.11	6.02±2.78	1.092	0.276
Postoperative hospitalization duration	2.89±1.17	2.54±1.40	1.694	0.092
Fluoroscopic exposures	3.84±1.10	6.95±3.10	-8.789	**＜0.001**
Incision length	1.78±0.21	0.85±0.18	28.587	**＜0.001**
Disc level				
L2-3	1	7		
L3-4	2	11		
L4-5	47	41		
L5-S1	40	6		
Complications				
Cerebrospinal Fluid Leak	2	1		
Nerve root injury	0	1		
Incision infection	1	0		
Recurrence	0	3		
Follow-up Duration (Mean ± SD, days)	11.36±2.95	11.51±3.38	-0.298	0.766

Clinical efficacy

The results indicated that postoperative VAS scores significantly decreased in both groups, with substantial improvements in the ODI. No significant differences were observed in the VAS score or ODI score between the two groups, either preoperatively or postoperatively (Table 2).

Table 2: Comparison of preoperative and postoperative VAS, JOA, and ODI scores between the UBED and PETD groups

Group	UBED	PETD	T	*P*
Preoperative Lumbar VAS	4.51±1.12	4.78±0.89	-1.626	0.106
Postoperative 1day Lumbar VAS	1.93±0.86	1.85±1.09	0.556	0.579
Postoperative 1 Month Lumbar VAS	1.17±0.50	1.92±1.10	-1.618	0.108
Postoperative 6 Months Lumbar VAS	1.37±0.48	1.49±1.03	-1.011	0.314
Preoperative Leg VAS	6.52±1.13	6.78±0.89	-1.55	0.123

Postoperative 1day Leg VAS	2.92±0.86	2.89±0.95	0.189	0.85
Postoperative Month 1 Leg VAS	1.63±0.66	1.85±1.09	-1.506	0.134
Postoperative Months 6 Leg VAS	1.39±0.51	1.49±1.03	0.821	0.413
Preoperative ODI	29.37±3.15	29.67±3.29	-0.56	0.576
Postoperative 1Day ODI	17.28±2.39	18.11±3.33	-1.805	0.073
Postoperative 1 Month ODI	9.98±2.11	10.71±2.64	-1.908	0.058
Postoperative 6 Months ODI	6.87±2.49	7.43±2.49	-1.391	0.166

According to the modified Macnab criteria, the UBED group included 64 excellent, 20 good, 5 fair, and 1 poor rating, resulting in an overall satisfaction rate of 93.3%. In the PETD group, 46 patients were rated excellent, 14 were rated good, 3 were rated fair, and 2 were rated poor, yielding a satisfaction rate of 92.3%. No significant difference in satisfaction rates was observed between the two groups (P =0.806) (Table 3).

Table 3: Comparison of postoperative patient satisfaction between the UBED and PETD groups

	Modified Macnab Criteria （n）				
Group	Excellent	Good	Fair	Poor	Excellent-Good Rate
UBED	64	20	5	1	93.30%
PETD	46	14	3	2	92.30%

Radiographic outcomes

Radiographically, the preoperative disc heights in the UBED and PETD groups were 9.65 ± 2.13 mm and 9.31 ± 2.11 mm, respectively (P = 0.326). At 1 month postsurgery, the disc heights measured 9.47 ± 1.92 mm (UBED) and 9.27 ± 2.28 mm (PETD); at 6 months postsurgery, these values decreased to 9.33 ± 2.09 mm (UBED) and 9.13 ± 2.27 mm (PETD). No significant differences in disc height were observed between the two groups at any timepoint (preoperatively, 1 month, or 6 months postoperatively). Both groups exhibited a mild postoperative reduction in disc height (Table 4).

Table 4: Comparison of Preoperative and Postoperative Disc Height between the UBED and PETD Groups

Group	UBED	PETD	T	*P*
Preoperative Disc Height	9.65±2.13	9.31±2.11	0.986	0.326
Postoperative 1 Month Disc Height	9.47±1.92	9.27±2.28	0.59	0.556
Postoperative 6 Months Disc Height	9.33±2.09	9.13±2.27	0.568	0.571

DISCUSSION

In our study, we conducted a retrospective analysis to compare the clinical outcomes and safety profiles of PETD and UBED in patients with symptomatic LDH. The findings revealed that there were no significant differences in general information, including sex, age, BMI, disease course, or follow-up time, between the two groups of patients, indicating the comparability of the data between the two surgical techniques.

Previous reports have shown that, compared with PETD, UBED results in greater intraoperative blood loss, longer surgical time, longer hospitalization duration, and higher hospitalization costs,[8-11] which aligns with the findings of the present study. The UBED technique involves partial laminectomy to localize the ligamentum flavum insertion site. However, the extended operative duration and bone resection inherent to this approach contribute to increased intraoperative blood loss. Similarly, compared with the PELD group, the UBED group demonstrated longer operative times and postoperative hospitalization periods.[12,13] Notably, this study revealed no significant difference in hospitalization duration. While the standard hospitalization period for both UBED patients and PELD patients is approximately 2 days, factors such as preoperative diagnostic evaluations and patient anxiety regarding symptom recurrence or postoperative pain significantly prolong hospitalization durations. Future investigations should employ larger sample sizes and minimize subjective confounding factors to validate these observations. Additionally, dissection of the multifidus muscles and surrounding soft tissues may further increase intraoperative blood loss. Although UBED appears more invasive to paraspinal musculature, Wang et al.[13] reported no significant differences in serum CPK levels or the change rate of lean multifidus cross-sectional area between the UBED and control groups during follow-up exceeding 1 year postoperatively, suggesting minimal muscular trauma associated with UBED. However, whether this technique is correlated with complications such as postoperative low back pain or lumbar muscle weakness requires further investigation. While our study did not evaluate cost-effectiveness, prolonged operative times and blood loss in UBED may contribute to higher overall costs because of factors such as extended hospitalization, surgical/anesthesia fees, and ancillary care.

This study demonstrated that, compared with PELD, the UBED technique requires less intraoperative fluoroscopic exposure, which is consistent with prior reports.[12] This discrepancy arises from UBED's interlaminar decompression approach, which eliminates the need for highly precise localization, whereas PETD necessitates traversal of Kambin's triangle—a step that often demands additional fluoroscopic guidance for less experienced surgeons. Consequently, PETD significantly increased the fluoroscopy frequency. Notably, although PETD involves only a single incision with a shorter total length than UBED does, the increased incision length in UBED does not increase the incidence of postoperative low back pain, as the blade is limited to the fascial layer without violating deep muscle tissues. During facet joint osteotomy, the PETD removes less than one-third of the articular process; exceeding this threshold may heighten the risk of low back pain. With respect to recurrence rates, no cases were observed in the UBED cohort, with prior studies suggesting that UBED may achieve lower recurrence rates than PELD may achieve.[9] We hypothesize that this stems from UBED's broader decompression scope—analogous to open discectomy with partial laminectomy—whereas PETD prioritizes targeted precision therapy.

Both groups demonstrated significant and comparable clinical efficacy at all evaluated timepoints, which aligns with the findings of previous studies.[8] Radiographically, a mild postoperative reduction in disc height was observed in both cohorts. Notably, no patients required reoperation due to secondary foraminal stenosis or exiting nerve root compression attributable to disc height loss during the 6-month follow-up period. On the basis

of clinical experience, surgeons should avoid excessive removal of intradiscal tissue when addressing mildly degenerated discs with en bloc herniated nucleus pulposus (HNP). Conversely, in cases of severe disc degeneration characterized by fragmented HNP, thorough evacuation of loose fragments is recommended to minimize the risk of recurrence.

During the early learning phase of UBE, complications such as dural tears, hematomas, incomplete decompression, recurrence, instability, neurological deficits, and infections are commonly reported.[14,15] In this study, two cases of CSF leakage occurred in the UBED group, similar to previously reported incidence rates,[16] which was attributed to insufficient caution during ligamentum flavum dissection. Meticulous hemostasis is critical, and decompression should only proceed under clear visualization. Given that all dural defects were <0.5 cm, primary repair was deferred. A subfascial drain was placed distal to the defect site, followed by layered wound closure. Postoperative management included aggressive hydration with ambulation resumed 4–5 days after drain removal. One superficial infection patient presented with localized erythema and tenderness without systemic fever, which resolved after four consecutive days of daily dressing changes. In the PETD group, one dural tear case was resolved with identical protocols. One nerve root injury resulted from compression by the working cannula during neural corridor establishment. Surgeons must verify anatomical landmarks—particularly in hypertrophic facet joints—to ensure that the trajectory remains within Kambin's triangle and avoid excessive retraction of the exiting root during nucleus pulposus extraction. According to reports, the cutoff value of UBED's learning curve is 32.18 cases,[17] while PETD results in a steeper learning curve than UBED does.[1]

This study revealed fewer PETD applications for L5-S1 LDH, primarily because the high iliac crest obstructs the surgical trajectory. We do not recommend drilling or resecting the iliac bone to access Kambin's triangle unless no superior minimally invasive alternatives exist. Conversely, UBED may be technically challenging for far-lateral migrated fragments, whereas both techniques are feasible for central or paramedian herniations. For L5-S1 LDH, anatomical constraints favor prioritizing UBED or PEID to reduce operative risk and duration.[18,19] In conclusion, minimally invasive endoscopic surgery demands appropriate patient selection, advanced technical skills, and extensive experience to achieve optimal outcomes.[20,21] When evaluating minimally invasive surgery for patients, the advantages and disadvantages of both types of surgery should be balanced, and the most suitable surgical method should be selected for the patient.[22] Comprehensive complication management—encompassing detailed preoperative planning, refined intraoperative techniques, meticulous surgical execution, and vigilant postoperative care—is equally critical.[19]

CONCLUSION

Both PETD and UBED are effective for treating LDH, with comparable clinical outcomes in terms of pain relief and patient satisfaction. Compared with UBED, the PETD method may have advantages in reducing intraoperative bleeding, shortening surgical time, and reducing incision length, but it seems to have a higher recurrence rate. Ultimately, the choice of surgical technique should be individualized on the basis of patient-specific factors, surgeon expertise, and anatomical considerations of the herniation. The retrospective design

inherently poses challenges, including potential biases in patient selection and the accuracy of reported outcomes. Additionally, the sample size, while adequate for preliminary comparisons, may limit the generalizability of the findings across diverse patient populations.

STATEMENT

Ethics statement

This retrospective study was formally approved by the Ethics Committee of Xi'an Honghui Hospital. The study was conducted in strict compliance with the ethical principles outlined in the World Medical Association (WMA) Declaration of Helsinki.

Consent to participate

Not applicable.

Availability of data and material

The datasets used or analyzed during the current study are available from the corresponding author upon reasonable request.

Competing interests

All the authors declare that there are no conflicts of interest associated with this study.

Clinical trial number

Not applicable.

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No application

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