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Comparison of clinical outcomes and cost-utility between unilateral biportal endoscopic discectomy and percutaneous endoscopic interlaminar discectomy for single-level lumbar disc herniation: a retrospective matched controlled study

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Abstract

Objective This study aimed to compare the efficacy and cost-utility of unilateral biportal endoscopy (UBE) versus percutaneous endoscopic interlaminar discectomy (PEID) for the treatment of single-level lumbar disc herniation (LDH).

Methods A retrospective analysis was conducted on 99 patients who underwent either UBE ($n=33$) or PEID ($n=66$) between July 2022 and December 2023 at the Second Xiangya Hospital. Patients were matched 1:2 based on age, sex, and surgery level to ensure comparability. Clinical outcomes were assessed using Visual Analog Scale (VAS), European Quality of Life-5 Dimensions (EQ-5D), and Oswestry Disability Index (ODI) scores, with quality-adjusted life years (QALYs) calculated for cost-utility analysis. Hospitalization costs were analyzed, and the incremental cost-utility ratio (ICER) was determined.

Results Both UBE and PEID groups demonstrated significant postoperative improvements in VAS, EQ-5D, and ODI scores ($p<0.05$). The operative time, blood loss and nursing cost were significantly higher for UBE compared to PEID ($p<0.05$). UBE has higher gained QALY and overall costs, but the differences are not statistically significant ($p=0.643$ for QALY, $p=0.327$ for costs). The Incremental Cost-Effectiveness Ratio (ICER) for UBE compared to PEID was calculated to be $354.5 per QALY gained, indicating that for each additional QALY gained through UBE, an additional cost of $354.5 is incurred compared to PEID.

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Conclusion In our single-center study conducted in China, both the UBE and PEID procedures have demonstrated comparable short-term efficacy in alleviating pain and improving functional ability in patients with single-level LDH. UBE procedure demonstrates greater cost-utility than the PEID procedure in cost-utility analysis, despite its longer operative time, higher nursing costs and greater blood loss.

Keywords Unilateral biportal endoscopy, Percutaneous endoscopic interlaminar discectomy, Cost-utility analysis, Lumbar disc herniation

Introduction

Lumbar disc herniation (LDH) is a globally prevalent condition, with recent studies indicating that nearly 80% of adults experience low-back and leg pain, among which approximately 20% are diagnosed with lumbar disc herniation [1]. Its prevalence is around 1%, predominantly affecting males aged between 20 and 40 [2, 3], constituting a common cause of low-back pain and radiating leg pain [4]. This represents a serious burden on societal resources and constitutes an area of clinical challenge and research value [5]. Currently, mainstream treatment modalities comprise conservative management, pharmacological therapy, and surgical intervention [3].

With the advancement of endoscopic techniques and the increasing demand for minimally invasive procedures among patients, percutaneous endoscopic lumbar discectomy (PEID) and unilateral biportal endoscopic (UBE) techniques have gradually gained widespread utilization globally. As a minimally invasive surgical procedure via the interlaminar approach, PEID with advantages of avoiding iliac crest obstruction, quicker puncture positioning, shorter operative time, and less intraoperative radiation exposure [6], has been proved to have a comparable clinical efficacy to the traditional open surgery in the treatment of LDH [7]. However, PEID has the drawbacks of a small surgical field, low surgical efficiency, long learning curve and difficulty in mastering [8]. Unilateral Biportal Endoscopy (UBE) represents a novel minimally invasive technique for lumbar spine surgery, characterized by its use of two independent working portals, distinguishing it among various spinal minimally invasive procedures. By employing distinct channels for observation and operation, which function independently, UBE markedly improves endoscopic visualization and optimizes the surgical instrument workspace [9]. Consequently, UBE presents a more gradual learning curve relative to other minimally invasive lumbar spine procedures [10]. However, the use of two portals increases incision length and operation time [11], leading to increased intraoperative and postoperative blood loss [12]. To date, the choice between the two surgical approaches primarily depends on the preferences of the operating surgeon, with no relevant studies conducted regarding the economic cost-utility of either approach.

Economic evaluation is increasingly becoming an integral part of the evidential basis in surgery [13]. Against the backdrop of a growing demand for spinal treatments, the rapid escalation of costs and the limitations of medical resources underscore the importance of conducting economic evaluation studies to determine cost-utility. Cost-Utility Analysis (CUA) is an economic methodology used to assess the economic outcomes of various medical treatment regimens. Its core concept involves comparing the costs of treatment with the corresponding benefits, typically measured in Quality-Adjusted Life Years (QALYs) [14]. The QALY metric is a measure of the disease burden on patients, encompassing both the quality and quantity of life and it represents the optimal approach for evaluating the benefits of two surgical procedures. By integrating cost information, the incremental cost-utility ratio between the two surgical approaches can be calculated, providing a cost value per QALY: the lower the value, the higher the cost-utility of the new strategy [15].

This study aims to compare the efficacy and cost-utility of UBE and PELD, providing economic guidance for the selection of surgical procedures by weighing the costs and benefits of both approaches. This will help us address the relationship between UBE and PEID in terms of costs, outcomes, and utility in our value-based health care system, hope to make a little contribution to the decision of treatment approach in single-level LDH.

Methods

Patient selection and enrollment

This retrospective single-center study was conducted at the department of spine surgery, second Xiangya hospital. The study received approval from the clinical research ethics committee of second Xiangya hospital and adhered to the Good Clinical Practice guidelines and the principles outlined in the Helsinki Declaration. The medical and financial records of inpatients undergoing PEID or UBE for LDH from July 2022 and December 2023 were retrospectively obtained from the hospital`s medical and financial records departments and reviewed. Inclusion criteria were (1) aged over 18 years, (2) Low back pain or radiating pain due to lumbar herniated intervertebral disc confirmed on preoperative MRI. Exclusion criteria were: (1) patients who underwent prior lumbar surgery, (2) thoracic or cervical surgery, (3) not single level surgery, (4) follow-up period less than 3 months, (5) with concomitant conditions including trauma, tumors, or infections.

Matching and follow-up

Patients who were lost to follow-up were excluded from the analysis. Following this, a case-control matching process was performed to enhance the comparability between the two groups. Matching was based on age, sex, and surgery level, with age matching defined as having an age difference of less than 10 years between the paired subjects. We required matched patients to have the same surgical level and gender, and then select those with the smallest age difference from the PEID group. After the exclusion of patients who were lost to follow-up and the matching process, the final analysis included 33 UBE patients and 66 PEID patients. Each UBE patient was matched with two PEID patients based on the criteria mentioned above. This approach aimed to reduce the impact of confounding variables and allow for a more accurate comparison of the costs and surgical outcomes between the two groups.

Data were collected from the electronic medical records of patients, including age at procedure, sex, surgery level, follow-up time, ASA classification score, operative time, blood loss, hospital stay duration, and hospitalization costs. In April 2024, we conducted an online survey among the 99 patients to record their preoperative and postoperative VAS scores, ODI scores, and EQ-5D scores. Health outcome was quality-adjusted life-years (QALYs), based on responses from the online questionnaire. EQ-5D evaluates 5 dimensions: mobility, self-care, activities of daily life, pain, and anxiety/depression. Each dimension is described by 3 possible problem levels (no, mild to moderate, and severe problem). Hence, this descriptive system contains 243 combinations, or health states, revised into a healthrelated quality of life (HRQoL) index with a range from −0.59 to 1.00, where 1.00 indicates full health. QALYs were estimated by combining HRQoL index and time, calculating the area under the curve using the trapezoidal method.

Treatment alternative

Our Spine Surgery Center has two minimally invasive spine surgery teams: one specializes in UBE surgery, and the other specializes in PEID surgery. The surgeons at both teams have more than 15 years of spine surgery experience. The surgical procedure depended on the patient's choice between two medical teams. All patients received UBE or PEID procedure under general anesthesia. All surgeries were conducted under general anesthesia with endotracheal intubation. Patients were positioned prone on a radiolucent table, with the hip and knee flexed at 45° and 90°, respectively, to optimize the interlaminar window space. Following standard preparation and draping,

PEID

The surgical procedure for PEID has been described previously [16]. Fluoroscopy is used to identify the center of the interlaminar window. A 7- to 8-mm skin and muscle fascia incision is made, and a dilator is gently inserted dorsoventrally. The working sheath (outer diameter 7.9 mm) is introduced through the dilator with its beveled opening facing the spinous process; its position is confirmed via fluoroscopy. The dilator is removed, and the rod-lens endoscope (outer diameter 6.9 mm, Richard Wolf GmbH) is placed. A low-pressure isosmotic saline solution is continuously used to maintain a clear surgical field. The initial step involve identifying the ligamentum flavum, seen as a smooth ivory-white surface. A micropunch is used to incise the ligamentum flavum (3 to 5 mm) for entry into the spinal canal. A high-speed burr is employed as necessary to remove laminar bone. After ligamentum flavum incision, the nerve root and its axilla are exposed, sometimes necessitating partial removal of sequestrated disc fragments. Bipolar electrocautery ensure hemostasis and soft tissue release along the lateral recess. The neural structures are retracted and protected by rotating the beveled opening inward by 180°. The herniated disc is then exposed and removed using micropituitary instruments. Successful decompression is confirmed by ensuring the nerve root could be mobilized 1 cm laterally to medially, no significant bleeding occurre within the spinal canal, and no free disc fragments are visible. Final confirmation of the target area is done with live fluoroscopy. The instruments are removed, and the incision is closed without the need for drains.

UBE

The target intervertebral space on the left side is identified with C-arm fluoroscopy. Two incisions, each 1.5 cm from the midline and spaced 3 cm apart, are centered over the target intervertebral space. Guide rods are inserted through these incisions, converging at the junction of the upper vertebral lamina and lower articular process, as verified by fluoroscopy. A T-shaped dilator is utilized for blunt soft tissue dilation. The cranial portal facilitate endoscope insertion (Stryker, Kalamazoo, MI, USA) for visualization, while the caudal portal accommodate surgical instruments and radiofrequency (RF) ablation (BONSS, JiangSu, China). RF ablation and pituitary forceps cleare the soft tissue within the visual field, revealing the upper vertebral lamina and articular process. Partial laminectomy is conducted with a grinding drill (Medaidezr, Guizhou, China) and Kerrison punches to uncover the ligamentum flavum attachment. The ligamentum flavum is excised with Kerrison punches, exposing the dura mater and nerve roots. The transverse nerve root is gently retracted medially, and discectomy is performed with pituitary forceps. Absence of residual fragments is confirmed with a neural probing hook. After meticulous hemostasis, the wounds are sutured.

Cost and cost-utility analysis

Total cost contains the direct cost and the indirect cost. The direct cost was gathered from an electronic medical record system and were divided into eight major parts: hospitalization expenses, examination cost, physician cost, surgical expenses, anesthesia expense, surgical equipment and materials costs, drug costs, and other treatment costs. The specific individual costs were summarized in each major item according to the actual conditions of each patient. The indirect cost was a cost to the patient related to miss time from work or decreased productivity due to the intervention, which was not calculated because the employment status of each patient was different. All costs were converted into U.S. dollars ($) at their value during December 2023. The analysis of costs and health outcomes was presented by the cost-utility ratios (CERs) and the incremental cost-utility ratio (ICER) [17].

$$ICER = \frac{COST_{UBE} - COST_{PEID}}{QALY_{UBE} - QALY_{PEID}}$$

Statistical analysis

Statistical analyses were conducted with SPSS version 23.0 (IBM, Armonk, NY, USA). Categorical variables were expressed as absolute numbers and percentages, and their associations were analyzed using Fisher's exact test. Continuous variables with normal distributions were presented as means±standard deviations (SD) and analyzed using independent t-tests. For those did not follow a normal distribution, data were described as medians with interquartile ranges and analyzed using the Mann–Whitney U test. P-value<0.05 was considered significant. For this study the STROBE statement is followed.

Table 1 Patients information for two surgical techniques. Data are means ± SD or median (quartile range) or numbers of subjects and percentages in parentheses

Variable	UBE group *n* = 33	PEID group *n* = 66	*P* value
Age at procedure (y)	43.6 ± 15.8	44.7 ± 12.9	0.710
Sex			
Male	18 (54.5%)	36 (54.5%)	
Female	15 (45.5%)	30 (45.5%)	1.000
Surgery level			
L4/5	11 (33.3%)	22 (33.3%)	
L5/S1	22 (66.7%)	44 (66.7%)	1.000
Follow-up time (m)	8.5 (9.8)	8.4 (12.8)	0.844
ASA classification score			
I	0	3 (4.5%)	
II	28 (84.8%)	46 (69.7%)	
III	5 (15.2%)	17 (25.8%)	0.193

Result

After applying the inclusion and exclusion criteria, 181 patients were enrolled in the study including 38 UBE patients and 143 PEID patients. After matching UBE and PEID in a 1:2 ratio, a total of 99 patients met the inclusion criteria, with 33 in the UBE group and 66 in the PEID group. There were no significant differences between the two groups in terms of age, gender, surgical segment, follow-up time, and ASA scores (Table 1; Fig. 1).

The hospitalization time between the two groups was not significantly different ($p=0.997$). However, compared to the PEID group, the UBE group had significantly increased operation time and intraoperative blood loss ($p<0.05$) (Table 2).

Postoperatively, both surgical groups demonstrated significant improvements in VAS, EQ-5D, and ODI scores compared to their preoperative baselines ($p>0.05$) (Fig. 2); however, the magnitude of these improvements and the gained QALY did not differ significantly between the two groups ($p<0.001$). The median total healthcare costs were comparable between the UBE and PEID groups ($3113.51 vs. $3078.06, $p=0.327$). Notably, nursing and special nursing costs were significantly higher in the UBE group ($p<0.001$), while other cost categories showed no significant differences between the two groups ($p > 0.05$) (Tables 3 and 4).

There were no statistically significant differences between the two groups in terms of cost, utility, and CERs ($p<0.05$) (Table 5). The incremental cost-utility ratio (ICER) of UBE was $354.5/QALY (Fig. 3).

Discussion

Previous study suggested both UBE and PEID procedures have similar efficacy in alleviating pain and improving functional ability in patients with LDH [18]. However, there remains a notable gap in the literature concerning cost-utility of the two surgical methods. This study was a retrospective, single-center study that firstly compare cost-utility of UBE versus PEID for lumbar disc herniation by using matched samples [19, 20].

As shown in Table 2, the operation time and intraoperative blood loss in the UBE group were significantly higher than those in the PEID group, consistent with previous studies [11, 21, 22]. Unlike PEID, UBE represents a combination of open and endoscopic spinal surgery, requiring the creation of an additional channel, partial laminectomy, and drain insertion [18]. Those additional

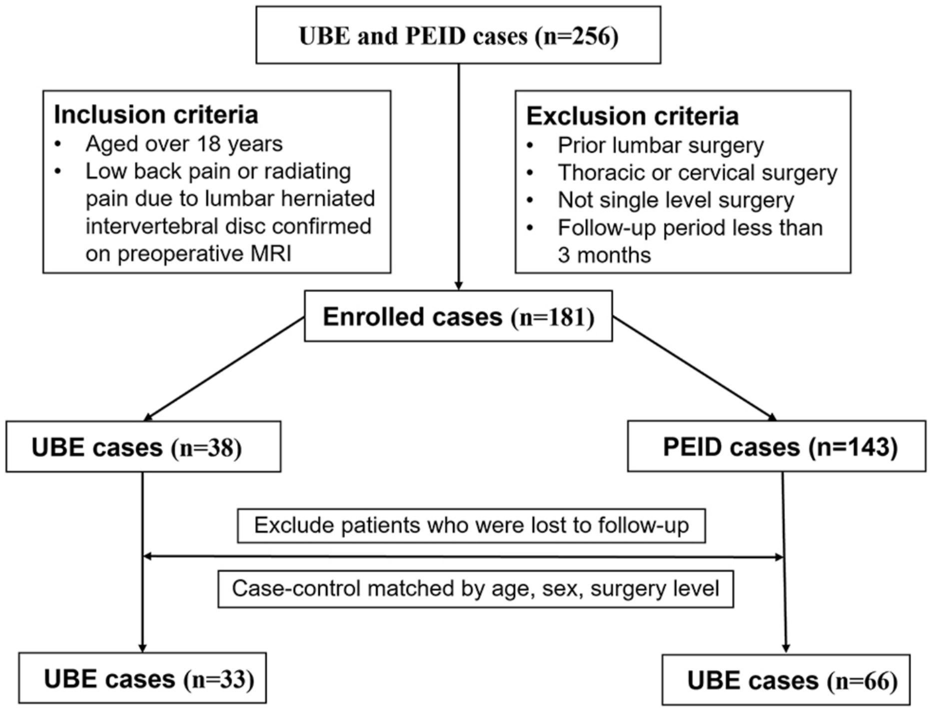

Fig. 1 Inclusion and Exclusion Process of Patients

Table 2 Operative time, blood loss and hospital stay duration for two surgical techniques. Data are means ± SD or median (quartile range)

Variable	UBE group *n* = 33	PEID group *n* = 66	*P* value
Operative time (min)	100.8 ± 36.1	86.0 ± 19.4	**0.034**
Blood loss	9.9 ± 3.4	5.5 ± 2.3	**< 0.01***
Hospital stay duration	7.0 (3.0)	7.0 (2.0)	0.997

*Clinical outcomes showed significant differences before and after surgery ($P<0.05$)

procedures not only cause greater soft tissue damage and bleeding from the cancellous bone, but also cost longer operation time than PEID [11, 23, 24]. Although these additional procedures increase the surgical burden, they indeed provide greater surgical control and wider visualization [18, 25], which is helpful for more comprehensive neural decompression [26]. The hospitalization duration for patients in our center includes the time required to complete preoperative blood tests, electrocardiograms, and necessary imaging and ultrasound examinations, which typically takes about three days. As a result, the hospitalization period is relatively long. According to China's medical insurance policies, these tests are only eligible for insurance reimbursement if the patient is hospitalized. Therefore, patients are admitted in advance to complete the necessary examinations. There was no significant difference in the length of hospital stay between the two groups, suggesting that both PEID and UBE procedures allow for rapid postoperative recovery and a timely return to normal activities [18].

Multiple studies have shown that both UBE and PEID surgeries can achieve good clinical short-term outcomes [27, 28]. In this study, the postoperative scores for Visual Analog Scale (VAS), European Quality of Life-5 Dimensions (EQ-5D), and Oswestry Disability Index (ODI) were significantly improved compared to preoperative scores for both UBE and PEID. The extent of improvement and the increase in Quality-Adjusted Life Years (QALY) showed no significant difference between the two surgical methods, which is consistent with previous studies [27, 29–31]. Regarding hospitalization costs, as shown in Table 4, there were no significant differences in most medical expenses between the two groups. However, nursing costs were significantly higher in the UBE group, likely due to the more complex postoperative care requirements. UBE surgery involves longer operation times and greater muscle trauma [21, 28], necessitating intraoperative catheterization and drainage placement. These complex measures increase postoperative nursing workload and related costs. In contrast, PEID surgery utilizes single-channel endoscopic technology, resulting in less intraoperative trauma and bleeding [26], and relatively simpler postoperative care, leading to lower nursing costs.

The costs, gained QALY, and CER of PEID and UBE showed no significant differences (Table 5). The incremental cost-utility ratio (ICER) of UBE was $354.5/

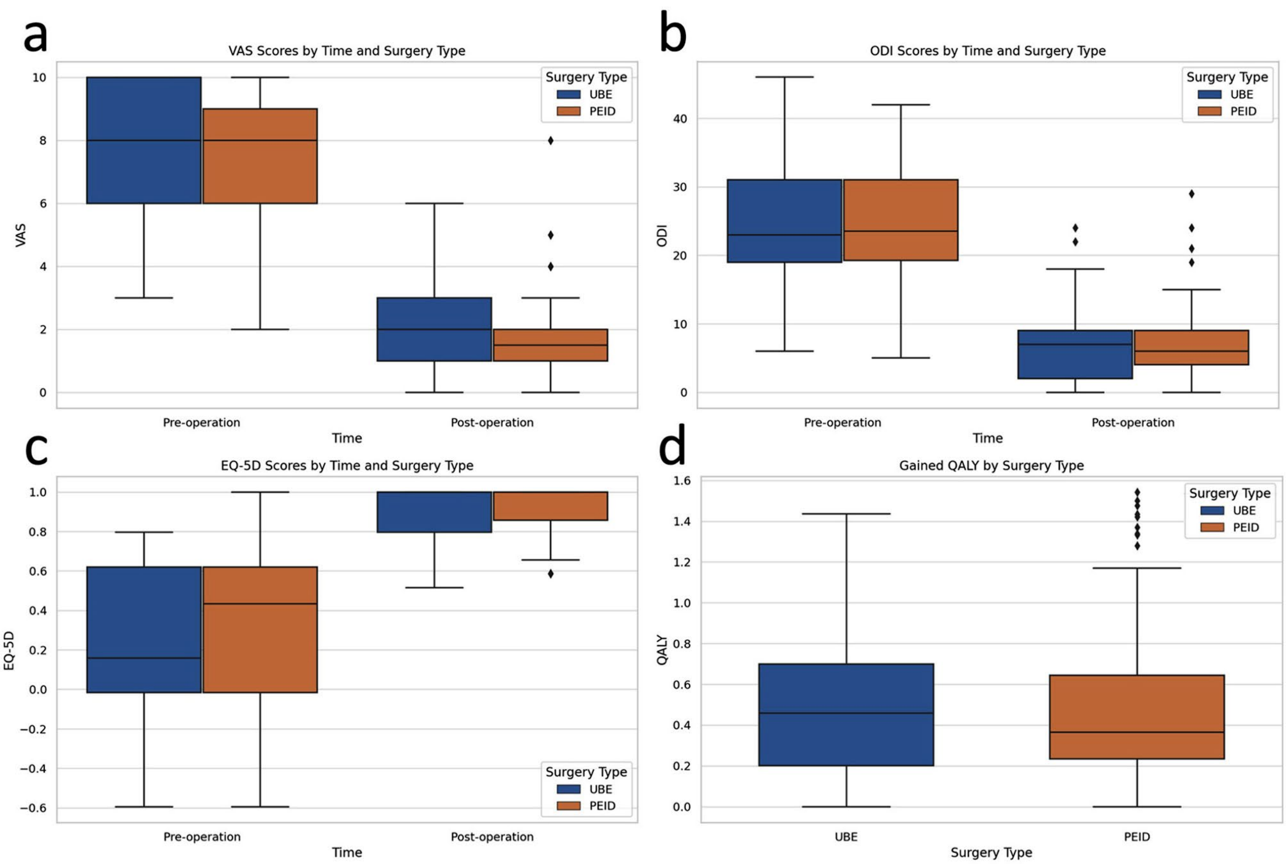

Fig. 2 (a,b,c) Comparison of preoperative and postoperative VAS scores, ODI scores, and EQ-5D scores for two surgical techniques. **(d)** Comparison of gained QALYs for two surgical techniques

Table 3 Clinical outcome. Data are means ± SD or median (quartile range) or numbers of subjects and percentages in parentheses

Variable	UBE group *n* = 33	PEID group *n* = 66	*P* value
Preoperative VAS	8.0 (4)	8.0 (3)	0.664
Postoperative VAS	2.0 (2)**	1.5 (1)**	0.688
Mean improvement	6 (3)	6 (2)	0.665
Preoperative ODI	23.0 (13)	23.5 (12)	0.688
Postoperative ODI	7.0 (9)**	6.0 (5)**	0.876
Mean improvement	17.3 ± 6.3	17.9 ± 8.5	0.705
Preoperative EQ-5D score	0.16 (0.65)	0.43 (0.64)	0.794
Postoperative EQ-5D score	1.0 (0.20)**	1.0 (0.15)**	0.433
Mean improvement	0.80 (0.55)	0.48 (0.62)	0.525
Gained QALY	0.46 (0.50)	0.36 (0.43)	0.643
MacNab criteria (excellent, good)	32 (97.0%)	63 (95.5%)	1.000

*Clinical outcomes showed significant differences before and after surgery ($P<0.05$)

QALY, indicating that each additional quality-adjusted life year (QALY) requires only an extra $354.5 (Fig. 3). ICER is the ratio of the additional cost to the additional benefit. In this study, compared to PEID surgery, each additional QALY gained from UBE surgery costs an extra $354.5. According to the World Health Organization (WHO) definition, we set the willingness-to-pay threshold at three times the per capita GDP of China (USD 30,828 in 2019) [32, 33], The ICER of UBE surgery was significantly below this threshold, demonstrating better cost-utility. The specific reason may be that the dual-channel technology used in UBE provides a wider field of view and greater operational space, enabling more thorough decompression [34, 35]. Additionally, PEID has a steeper learning curve [16], while the operational process of UBE surgery is similar to traditional surgery, with a gentler learning curve that is easier to master [25, 36]. Based on these advantages, UBE surgery can achieve better cost-utility with only a slight increase in cost. Therefore, UBE surgery can be prioritized for younger patients in good overall health. For elderly patients with multiple comorbidities, PEID might be a better choice due to its smaller trauma, less bleeding, and faster recovery.

Limitation

Firstly, the retrospective design of this single-center study in China, along with its relatively small sample size, limits the broader applicability of the findings. Additionally, the average follow-up period of 8 months is insufficient for

Table 4 Healthcare cost. Data are median (25% quartile, 75% quartile). Values represent the mean cost per patient calculated based on the US dollar/RMB exchange rate in December 2023

Variable	UBE group *n* = 33	PEID group *n* = 66	*P* value
Hospitalization	$108.91(97.20, 147.87)	$101.90(87.71, 124.83)	0.067
Bed cost	$58.87(52.98, 92.51)	$64.75(55.50, 80.10)	0.844
Nursing and special nursing	$47.66(41.45, 54.14)	$35.74(29.75, 42.75)	< 0.001*
Examination cost	$349.52(274.74, 434.63)	$360.32(286.16, 464.46)	0.672
Laboratory expense	$173.34(146.43, 197.62)	$173.80(138.55, 207.46)	0.964
Radiography	$144.37(70.08, 185.19)	$136.31(125.09, 199.48)	0.448
Other	$60.27(8.41, 60.27)	$28.85(14.00, 65.86)	0.432
Physician	$75.91(52.07, 105.84)	$73.47(55.79, 89.05)	0.876
Surgery	$1487.33(1321.24, 1487.33)	$1487.33(1319.06, 1487.33)	0.640
Anesthesia	$234.35(203.02, 255.24)	$215.50(200.08, 239.36)	0.102
Surgical equipment and medical materials	$292.99(268.44, 386.97)	$300.43(242.40, 365.65)	0.324
Drugs	$392.19(322.00, 490.35)	$383.38(330.39, 458.13)	0.784
Other treatment	$154.52(140.23, 169.64)	$156.38(129.54, 194.52)	0.841
Total cost	$3113.51(2921.93, 3328.52)	$3078.06(2908.57, 3207.84)	0.327

*Significant difference ($P < 0.05$)

Table 5 Cost-effectiveness ratios (CERs)

Variable	UBE group *n* = 33	PEID group *n* = 66	*P* value
Cost	$3113.51 (406.59)	$3078.06 (299.27)	0.327
Utility (QALY)	0.46 (0.50)	0.36 (0.43)	0.643
CERs	$6402.32 (9688.53)/QALY	$8155.45 (8116.59)/QALY	0.502

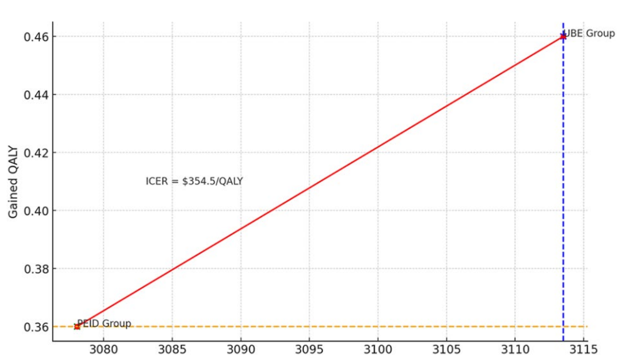

Fig. 3 Cost-utility of UBE versus PEID

a thorough assessment of long-term clinical outcomes. Finally, the surgical procedure is also determined based on the patient's choice, which may introduce a certain degree of bias in the final outcomes. To achieve a more comprehensive and accurate analysis of the costs and clinical outcomes associated with UBE and PEID, future research should involve multi-center, large-sample, and long-term follow-up randomized controlled trials. Moreover, this study only evaluated patients with single-level disc herniation, limiting the applicability of the findings to those with multi-level disc herniations.

Conclusion

This single-center study conducted in China suggests that both the UBE and PEID procedures have demonstrated comparable short term efficacy in alleviating pain and improving functional ability in patients with LDH. UBE procedure demonstrates greater cost-utility than the PEID procedure in cost-utility analysis, despite its longer operative time, higher nursing costs and greater blood loss. Overall, the additional cost associated with the UBE procedure appears to be justified by the increased health utility it provides.

Abbreviations

UBE	Unilateral biportal endoscopy
PEID	Percutaneous endoscopic interlaminar discectomy
LDH	Lumbar disc herniation
QALYs	Quality-adjusted life years
ICER	Incremental cost-utility ratio
HRQoL	Healthrelated quality of life
VAS	Visual Analog Scale
EQ-5D	European Quality of Life-5 Dimensions
ODI	Oswestry Disability Index

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Author contributions
Y.YF. and Y.JC. designed the research; Y.JC. and Z.ZW. collected the data. Y.YF. analyzed the data; Y.JC. and Y.YF. wrote the manuscript. All authors reviewed and approved the submitted manuscript.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethical approval
The study protocol was conducted retrospectively from data obtained for clinical purposes, which was approved by the Institutional Review Board of Second Xiangya Hospital of Central South University, Hunan, China.

Consent for publication
Not applicable.

Informed consent
Written informed consent was obtained from each patient for publication of this study.

Statement of human and animal rights
There are no experimental procedures involving animals or humans and statement of human or animal rights is not applicable.

Competing interests
The authors declare no competing interests.

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