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Original Article

Effectiveness of transforaminal approach spinal endoscopy in the treatment of patients with lumbar disc herniation and the factors affecting its efficacy

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Abstract: Objective: To compare the surgical metrics, improvement of functional scores, and clinical efficacy of percutaneous endoscopic transforaminal discectomy (PETD) and percutaneous endoscopic interlaminar discectomy (PEID) and to analyze the independent risk factors affecting the therapeutic efficacy of PETD. Methods: The clinical data of LDH (lumbar disc herniation) patients who underwent treatment in Shaanxi Provincial Nuclear Industry 215 Hospital from May 2020 to May 2022 were retrospectively collected, including 70 PEID cases and 74 PETD cases. The two groups were compared in terms of surgical indexes, such as operation time and bleeding volume, as well as changes in functional scores, such as preoperative and postoperative Visual Analogue Scale (VAS) scores and Oswestry Disability Index (ODI). The clinical efficacy was evaluated according to the Macnab criteria, and logistic regression analysis was performed to determine the independent influencing factors of the treatment efficacy of PETD. Results: The differences between the two surgical groups were statistically significant in terms of operation time (P<0.001), bleeding (P=0.005), and C-arm X-ray exposure times (P<0.001), and the above indexes were higher in the PETD group; however, there were no statistical differences in terms of improvement in functional scores (P>0.05) and clinical efficacy (P>0.05) between the two groups. BMI≥25 kg/m^2 (P=0.001), severe disc degeneration (P=0.003), and operation time ≥60 min (P=0.003), severe disc degeneration (P=0.003), and operation time ≥60 min (P=0.036) were independent risk factors for the outcome of PETD. Conclusion: The clinical effectiveness of PEID and PETD in treating LDH is comparable, and each has its own advantages. While PETD is more technically demanding, it does not yield superior results. Obesity, severe disc degeneration, and prolonged surgery are risk factors for the treatment efficacy of PETD.

Keywords: Lumbar disc herniation, spinal endoscopy, transforaminal approach, interlaminar approach, surgical evaluation, risk factors

Introduction

With the aging of society, coupled with unhealthy lifestyle habits, low back pain has generally become a critical health problem that inhibits the quality of life of people [1]. Pain not only reduces a person's ability to function in daily life and work but also may lead to disability, imposing heavy economic burden on the individual and society [2]. Research data suggests that approximately 70% of the population will experience low back pain at least once in their lifetime, with an annual prevalence ranging between 15% and 45% [3]. Approximately, 5% of men and 2.5% of women may experience sciatica [4]. Lumbar disc herniation (LDH), responsible for about 50% of back pain, is a prevalent issue in degenerative spinal disorders [5]. Notably, not only has the incidence of LDH increased dramatically over the past two decades, but the age group of patients has also tended to be younger [6].

The therapeutic landscape for LDH encompasses conservative treatment, traditional open surgical treatment, and minimally invasive interventions, forming the core therapeutic modalities [7]. As the foundation of LDH treatment, conservative treatment provides significant symptomatic relief in more than 90% of patients [8]. However, when prolonged conservative treatment fails to achieve significant symptomatic relief or even exacerbates symptoms such as nerve damage, surgical treatment becomes imperative [9]. Traditional open surgery, as a mainstream surgical method, has the advantages of quickly relieving the compression on the nerve root, significantly reducing pain, and completely removing the herniated areas [10]. However, it may result in anatomical changes in the surgical area, necessitating additional fixation materials to maintain postoperative spinal stability, which is accompanied by more significant trauma, higher costs, and extended hospital stays, as well as new pain caused by adjacent spinal lesions and postoperative scars [11].

With the advancement of technology and rising patient demand, minimally invasive interventions, especially spinal endoscopic techniques, have become a new trend in the treatment of LDH [12]. It not only has the advantages of being capable of being conducted under local anesthesia, minor trauma, and rapid recovery but also provides a more direct view of the herniation and its surrounding nerves and tissues, as well as more thorough removal compared with other minimally invasive techniques [13]. Spinal endoscopic methods are subdivided into percutaneous endoscopic transforaminal discectomy (PETD) and percutaneous endoscopic interlaminar discectomy (PEID) according to the surgical route, of which PETD is widely used in the clinic because of its good decompression effect and low complication rate [14]. Even so, there are still some patients who have poor outcomes after PETD and require further conservative treatment or repeat surgery, which highlights the importance of an in-depth study of the risk factors affecting the outcome of PETD.

In addition, we also identified and evaluated various relevant risk factors affecting the LDH treatment efficacy to elucidate the relationship between these risk factors and the therapeutic effects, to provide more valuable references and guide to future clinical practice.

Methods and materials

Sample sources

Clinical data of LDH patients who underwent treatment at Shaanxi Provincial Nuclear Industry 215 Hospital from May 2020 to May 2022 were retrospectively collected.

Inclusion criteria: ① patients showed typical radicular symptoms in the lower limbs and were diagnosed as single-segment herniation by CT or MRI, and their symptoms were not relieved or did not improve significantly after three months of conservative treatment; ② patients did not have lumbar disc herniation in other segments during their history; ③ the surgeries were performed through the foramen magnum approach; ④ the herniated components of the LDH were limited to L3/4, L4/5, and L5/S1; and ⑤ the same senior surgeon performed all surgeries. The same senior physician performed all surgeries, and the routine surgical procedures were strictly followed.

Exclusion criteria: ① patients lost during follow-up; ② patients with incomplete imaging data; ③ patients with a history of spinal surgery; ④ patients with other spine-related diseases; ⑤ patients with multi-segmental herniation on CT or MRI; ⑥ patients with lumbar spondylolisthesis (degree II or above).

This study initially included 234 cases of eligible samples based on the inclusion criteria, and finally, 144 patients that met the requirements were selected for further analysis. The patients who underwent percutaneous endoscopic transforaminal discectomy were assigned into the PETD group (n=74) and patients who underwent percutaneous endoscopic interlaminar discectomy as the PEID group (n=70) according to different surgical modalities. **Figure 1** illustrates the sample screening process.

Clinical data collection

Patient clinical information, as well as surgical data that included operative time, intraoperative blood loss, number of C-arm X-rays, time to out-of-bed activities, and length of hospitalization, was retrieved from and outpatient review records.

Outcome measurement

The differences in clinical data, including age, gender, body mass index (BMI), duration of illness, American Society of Anesthesiologists (ASA) classification [15], history of smoking and alcoholism, diabetes mellitus, and hyperten-

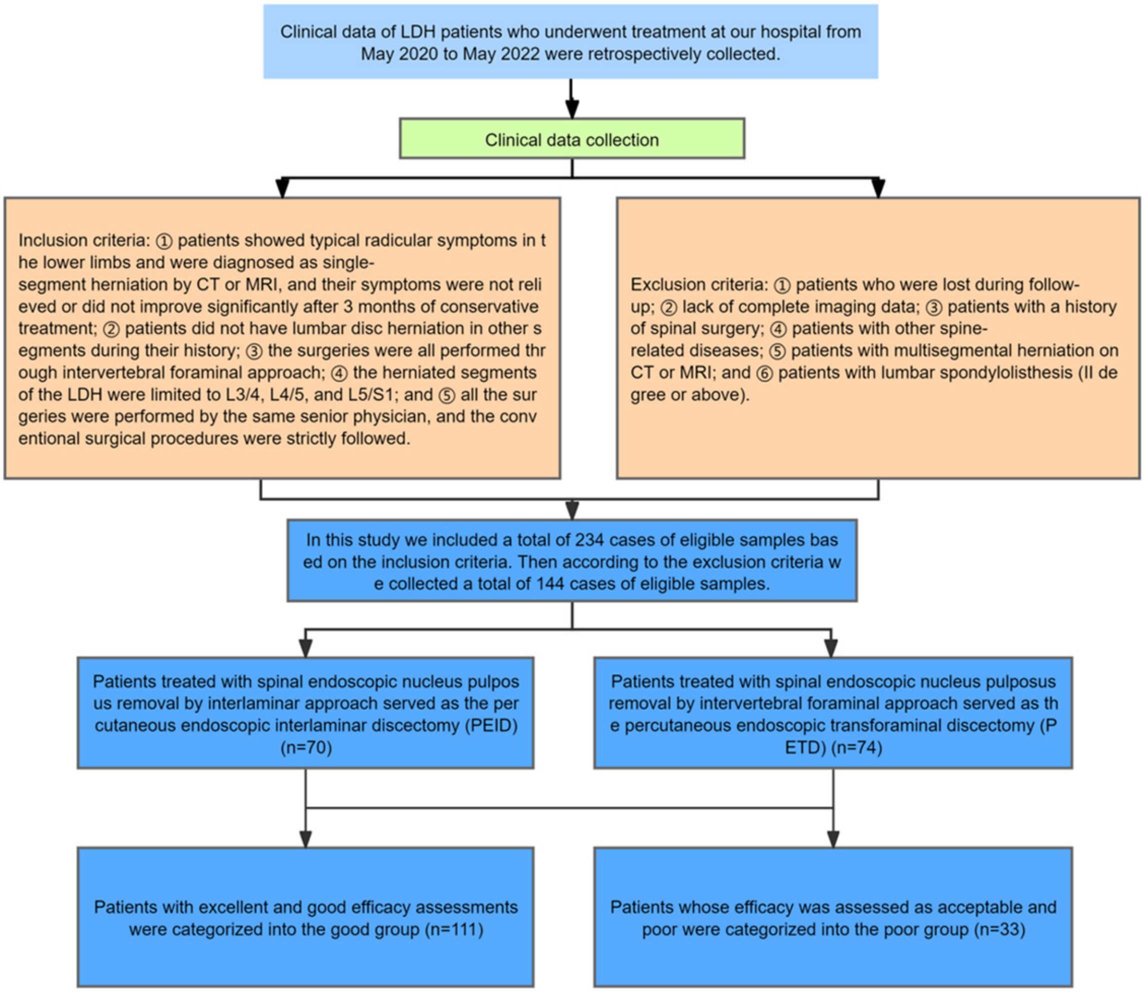

Figure 1. Flowchart of sample sourcing and screening.

sion were compared between the two groups. Additional data, including history of lumbar trauma, lesion segment, Pfirrmann classification, spinal canal morphology, herniation calcification, and lumbar spondylolisthesis, were also compared between the two groups.

Surgery-related data, including operative time, intraoperative blood loss, number of C-arm X-rays, time to out-of-bed activities, and length of hospitalization, were also retrieved from electronic medical records and compared between the two groups.

Functional scores, including Visual Analog Scale (VAS), Joint Orientation Angle (JOA), Oswestry Disability Index (ODI), and Modified MacNab criteria (MacNab) scores, were evaluated and compared between the two groups.

The VAS is a subjective scale for assessing acute and chronic pain. The score is recorded by marking a 10-centimeter line representing a continuum from "no pain" to "worst pain that is unbearable". Higher scores on the VAS indicate greater pain intensity [16].

The JOA score assesses the functional status of patients with spinal disorders, particularly spinal cord lesions, including lower extremity motor, sensory, and bladder functions. In the case of lumbar disorders, higher scores indicate better functional status. However, the exact range of scores and the criteria for defining them needed to be more detailed in the information obtained [17].

The ODI is used to determine a patient's permanent functional disability. The index is scored on a scale from 0 to 100, with 0 indicating no disability and 100 indicating the maximum possible level of disability. The higher the score on the ODI, the more severe the disability due to low back pain [18].

The surgical outcomes were assessed using the modified MacNab efficacy evaluation criteria, which were categorized into four grades. Excellent: the symptoms completely disappeared, and patients resumed normal daily life and work; Good: the signs were largely alleviated, and the activities were mildly limited, which did not affect life and work; Fair: the symptoms were alleviated while the activities were still limited, which affected normal and work life; Poor: no obvious improvement [19].

The patients were subsequently sub-grouped according to their treatment efficacy based on the MacNab score. Those patients with excellent and good prognosis were categorized into the good outcome group (Group G, n=111). Those with fair and poor prognosis were classified into the poor outcome group (Group P, n=33).

Statistical analysis

The data were analyzed using SPSS 26.0 statistical software. Continuous variables, following a normal distribution, were expressed as mean ± standard deviation (SD); an independent paired t-test was applied for inter-group comparisons, while a paired t-test for intra-group comparisons. Multiple-group comparison was conducted with repeated-measures analysis of variance (ANOVA) followed with post-hoc Bonferroni test. Count data were expressed as n (%) and compared using chi-square test. Logistic regression was used to analyze independent risk factors affecting patients' clinical outcomes. P<0.05 was considered as a statistically significant difference.

Results

Comparison of baseline information between the two groups

Comparison of the baseline data between the two groups revealed that there was no statistical difference in age, gender, BMI, disease duration, ASA classification, history of lumbar trauma, lesion segment, Pfirrmann classification, spinal canal morphology, calcification of herniation, lumbar spondylolisthesis, history of smoking, alcohol consumption, diabetes mellitus, and hypertension (all P>0.05, **Table 1**).

Comparison of surgical data between the two groups

Surgery-related data of the two groups of patients were compared. The results showed that the operation time, intraoperative bleeding, and the amount of C-arm X-ray irradiation were significantly lower in the PEID group than those in the PETD group (all P<0.001, **Table 2**). However, there were no significant differences between the two groups in terms of time to out-of-bed activities and the hospitalization time (all P>0.05, **Table 2**).

Comparison of VAS, JOA, and ODI scores between the two groups before and after treatment

Comparisons of pre-operative VAS, JOA, and ODI scores between the two groups of patients revealed that there were no statistical differences in pre-operative VAS, JOA, and ODI scores between the two groups (all P>0.05). After the treatment, the VAS and ODI scores decreased significantly compared with pre-treatment, and JOA scores increased significantly (all P<0.001). However, there were no statistical differences in VAS, JOA, and ODI scores between the two groups after treatment (all P>0.05), as shown in **Figure 2**.

Comparison of patient outcome between the two groups

We compared the clinical efficacy between the two groups of patients, and the results found that there were no statistical differences in the clinical efficacy between the two groups of patients (P>0.05, **Table 3**), and the comparison of the excellent rate between the two groups of patients also revealed no statistical differences (P>0.05, **Table 3**).

Analysis of risk factors affecting patient outcomes

According to the clinical efficacy of the patients after treatment, we divided the patients into a good efficacy group (n=111) and a poor efficacy group (n=33). Clinical data of patients in both

Table 1. Comparison of patients' baseline data

Indices	PEID group (n=70)	PETD group (n=74)	χ^2-value	*P*-value
Age				
≥60 years	19	26	1.070	0.301
<60 years	51	48		
Gender				
Male	42	41	0.311	0.577
Female	28	33		
BMI				
≥25 kg/m^2	17	11	2.038	0.153
<25 kg/m^2	53	63		
Course of disease				
≥6 months	41	37	1.065	0.302
<6 months	29	37		
ASA classification				
Phase I	28	37	1.453	0.228
Phase II	42	37		
History of trauma to the lumbar spine				
Yes	6	7	0.035	0.853
No	64	67		
Diseased segment				
L3/4	4	7	0.367	0.832
L4/5	40	47		
L5/S1	16	20		
Pfirrmann classification				
Mildly	39	36	0.720	0.396
Severe	31	38		
Morphology of the spinal canal				
Trefoil-shaped	21	26	0.431	0.511
Non-trifoliate	49	48		
Calcification of protrusions				
Yes	12	17	0.760	0.383
No	58	57		
Lumbar spondylolisthesis				
Yes	7	10	0.427	0.514
No	63	64		
Smoking history				
Yes	42	41	0.311	0.577
No	28	33		
History of alcohol abuse				
Yes	7	11	0.778	0.378
No	63	63		
History of diabetes				
Yes	14	11	0.661	0.416
No	56	63		
History of hypertension				
Yes	10	9	0.142	0.707
No	60	65		

Note: ASA, American Society of Anesthesiologists; BMI, Body mass index.

Table 2. Comparison of patients' surgical data

Group	Surgical time (min)	Intraoperative bleeding (mL)	C-arm X-rays	Time to out-of-bed activities (d)	Length of hospitalization (d)
PEID group (n=70)	63.24±9.6	177.41±25.82	7.07±2.28	3.96±0.88	6.86±1.53
PETD group (n=74)	81.66±12.27	192.03±34.99	19.61±3.43	4.04±0.82	6.92±1.13
t-value	9.994	2.839	25.692	0.591	0.277
P-value	<0.001	0.005	<0.001	0.556	0.782

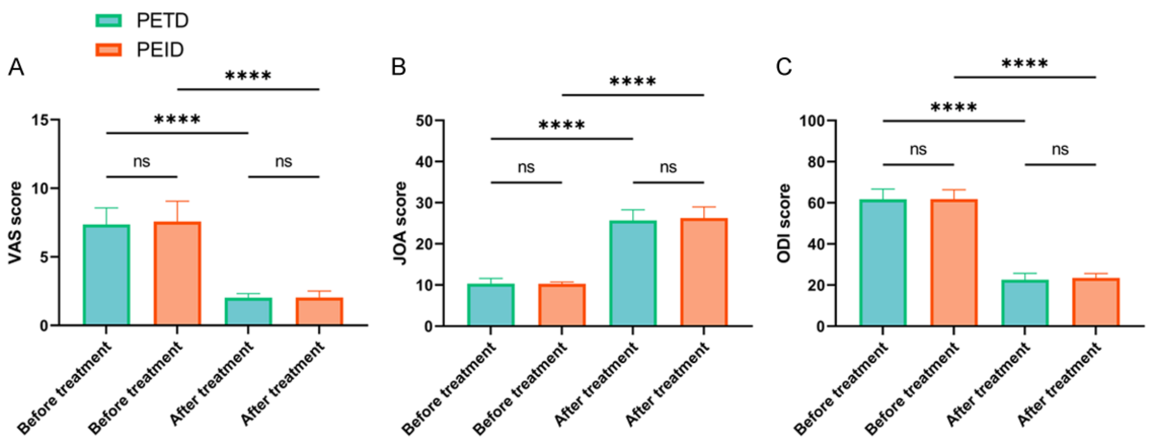

Figure 2. Changes in VAS, JOA, and ODI scores of patients before and after treatment. A. Changes in VAS scores before and after treatment in the two groups. B. Changes in JOA scores before and after treatment in the two groups. C. Changes in ODI scores before and after treatment in the two groups. Note: VAS, Visual Analog Scale; JOA, Joint Orientation Angle; ODI, Oswestry Disability Index; nsP>0.05, ****P<0.0001.

Table 3. Patient outcome assessment

Group	Excellent	Good	Fair	Poor	Excellent rate
PEID group (n=70)	26	30	10	4	56 (80.00%)
PETD group (n=74)	35	20	10	9	55 (74.33%)
χ^2-value		5.144			0.656
P-value		0.162			0.418

groups were collected. By univariate analysis, we found that BMI, Pfirrmann classification, calcification of the protrusion, and surgery time were strongly correlated with patients' clinical outcomes (P<0.05, **Table 4**). After assigning values to these data and utilizing receiver operating characteristic (ROC) curve intercepts for dichotomous grouping (**Table 5**), multifactorial logistic regression analysis revealed that BMI≥ 25 kg/m^2, Pfirrmann classification of severe degeneration, and operative time ≥60 min were independent risk factors for patient outcome (all P<0.05, **Table 6**).

Discussion

With the aging of society and changes in people's lifestyles, LDH has become an increasingly common disease among the elderly, significantly reducing patients' quality of life due to the low back and leg pain [20]. In response, minimally invasive interventions have gradually gained attention due to their high efficiency and less invasiveness, and offer a variety of approaches in the treatment of LDH, including spinal endoscopy, collagenase injections, laser therapy, ozone therapy, and radiofrequency ablation [21]. In particular, spinal endoscopic techniques have become the primary minimally invasive intervention for the treatment of LDH due to their ability for direct visualization and precise removal of disc herniations, as well as the immediate feedback on decompression from patients, which significantly improves the safety and efficacy of the treatment, and therefore has earned wide acceptance and application [22].

Although effective in treating lumbar disc herniation, open laminar decompression and fusion are limited in their application due to surgical trauma and high complication rates [23].

Table 4. One-way analysis of variance

Indices	Group G (n=111)	Group P (n=33)	χ^2/t value	*P*-value
Age				
≥60 years	33	12	0.521	0.470
<60 years	78	21		
Gender				
Male	61	22	1.429	0.232
Female	50	11		
BMI				
≥25 kg/m^2	13	15	18.490	<0.001
<25 kg/m^2	98	18		
Course of disease				
≥6 months	60	18	0.002	0.960
<6 months	51	15		
ASA classification				
Phase I	50	15	0.002	0.967
Phase II	61	18		
History of trauma to the Lumbar spine				
Yes	9	4	0.499	0.480
No	102	29		
Diseased segment				
L3/4	7	4		0.329
L4/5	69	18	2.225	
L5/S1	25	11		
Pfirrmann classification				
Mildly	67	8	13.296	<0.001
Severe	44	25		
Morphology of the spinal canal				
Trefoil-shaped	33	14	1.864	0.172
Non-trifoliate	78	19		
Calcification of protrusions				
Yes	13	16	21.388	<0.001
No	98	17		
Lumbar spondylolisthesis				
Yes	10	7	3.638	0.056
No	101	26		
Smoking history				
Yes	67	16	1.469	0.225
No	44	17		
History of alcohol abuse				
Yes	11	7	2.971	0.085
No	100	26		
History of diabetes				
Yes	17	8	1.413	0.235
No	94	25		
History of hypertension				
Yes	17	2	1.902	0.168
No	94	31		
Surgical time (min)	63.15±24.20	79.91±13.03	3.829	<0.001

Intraoperative bleeding (mL)	4.63±2.23	4.42±0.71	0.535	0.594
C-arm X-rays	13.39±18.50	7.67±0.99	1.772	0.078
Time out of bed (d)	3.99±0.88	4.03±0.68	0.245	0.807
Length of hospitalization (d)	6.94±1.35	6.69±1.28	0.900	0.37
Pre-treatment VAS score	7.47±1.31	7.27±1.51	0.740	0.457
Pre-treatment JOA score	10.3±1.04	10.12±0.96	0.900	0.372
Pre-treatment ODI	61.93±4.74	60.67±5.19	1.340	0.181

Note: ASA, American Society of Anesthesiologists; BMI, Body mass index.

Table 5. Assignment table

Considerations	Assignment
BMI	≥25 kg/m² =1, <25 kg/m² =0
Pfirrmann classification	Mild =0, Severe =1
Calcification of protrusions	Present =1, Absent =0
Surgical time (min)	≥60 min =1, <60 min =0
Treatment efficacy	Good =0, Poor =1

Minimally invasive techniques such as PEID and PETD are favored for their less invasive nature, rapid recovery, and low risk of complications, and their advantages and disadvantages are inconclusive despite their benefits in maintaining lumbar stability. In the present study, we found that the operative time, intraoperative bleeding, and number of C-arm X-rays were significantly lower in the PEID group than in the PETD group. However, there was no significant difference in the time to out-of-bed activities, hospitalization time, post-treatment VAS, JOA, ODI scores, and clinical outcomes between the two groups of patients. This suggests that although PETD may be more technically demanding, it did not lead to better patient recovery or clinical outcomes in a short time. In other words, PEID and PETD may be similar in improving long-term patient recovery and pain management. Therefore, other factors may need to be considered when choosing a surgical option, such as the cost of the procedure, patient preference, technology availability, and physician proficiency. These results emphasize the importance of a holistic evaluation of surgical approaches in clinical decision-making. A previous study by Gao et al. [24] found that PEID and PETD provided similar clinical outcomes in treating L5/S1 disc herniation. Still, PEID had the advantage of shorter surgery time and less radiation exposure, consistent with our findings. In addition, Chen et al. [25] found that although PETD may have a longer operation time, it is more advantageous in reducing bleeding and shortening hospitalization and incision length. In addition, PETD is as safe as PEID and is more effective in treating lumbar disc herniation. Xu et al. [26] found that although PETD and PEID resulted in comparable patient satisfaction in treating LDH, PEID performed better in reducing residual symptoms of low back pain. These findings indicate that both PEID and PETD serve as effective minimally invasive surgical approaches for the management of L5/S1 lumbar disc herniation, significantly mitigating symptoms and enhancing the quality of life for patients. While PEID demonstrates advantages in terms of shorter operative durations, reduced intraoperative radiation exposure, heightened patient satisfaction, and diminished postoperative low back pain, PETD distinguishes itself with lesser intraoperative bleeding, reduced length of hospital stays, and minimal incision lengths. The observed disparities in surgical outcomes between PEID and PETD may stem from inherent differences in the surgical techniques and the anatomical focus of each procedure. For instance, the transforaminal approach in PETD could potentially lead to a higher risk of bleeding due to the proximity to vascular structures, while its technique may allow for a more rapid postoperative recovery and shorter incision due to targeted intervention. Conversely, PEID's interlaminar approach may facilitate a shorter operative time and less radiation exposure due to more straightforward navigation and visibility. These variations underscore the importance of individualized patient assessment, taking into account the specific anatomical and pathological considerations, to optimize the choice of surgical technique for lumbar disc herniation treatment. The two techniques have no significant difference regarding recurrence rates and long-term rehabilitation outcomes.

Table 6. Multi-factor analysis

Considerations	β	Standard error	Chi-square value	*P*-value	OR value	95% CI	
						Lower limit	Higher limit
BMI	1.756	0.526	11.147	0.001	5.791	2.065	16.239
Pfirrmann classification	1.481	0.494	8.975	0.003	4.396	1.669	11.583
Calcification of protrusions	0.65	0.469	1.924	0.165	1.916	0.764	4.805
Surgical time	2.299	1.098	4.38	0.036	9.96	1.157	85.733

Note: BMI, Body mass index.

Surgical selection should consider factors such as surgeon proficiency, individual patient differences, and availability of technology. Therefore, there is no absolute "best" choice but a comprehensive evaluation of the patient's specific situation and medical conditions to choose the most appropriate treatment.

Despite the promising outcomes of PETD in LDH treatment, some patients may not achieve significant pain relief, quality of life improvement, or may face recurrence of LDH [27]. Therefore, it is essential to identify and analyze the risk factors associated with the efficacy of PETD for LDH. At the end of the study, we examined the risk factors affecting the clinical outcome of patients, and regression analysis revealed that BMI≥25 kg/m^2, Pfirrmann classification of severe degeneration, and surgical time ≥60 min were independent risk factors affecting the outcome of patients. Yao et al. [28] showed that BMI≥25 kg/m^2 significantly contributed to the recurrence of LDH after percutaneous endoscopic lumbar discectomy (PELD). Elevated BMI increases the burden on the musculoskeletal system, adversely affecting the lumbar spine and accelerating degeneration of the lumbar discs, leading to rupture of the annulus fibrosus (AF) and herniation of the nucleus pulposus (NP) in the lumbar discs. Severe Pfirrmann grading indicates more severe disc degeneration, which may signal the need for more complex surgery and a poorer prognosis. An operative time exceeding 60 minutes may reflect the technical challenges of the procedure and the risk of complications, which, in combination, may lead to poor postoperative recovery. Identifying these risk factors underscores the need for individualized assessment and careful risk management in surgical treatment planning.

Limitations of this study include a relatively small sample size and insufficient follow-up time, which may not fully reveal the long-term efficacy and recurrence rate. Future studies may validate the findings of this study by expanding the sample size and extending the follow-up time. In addition, the study failed to consider all the risk factors that may affect the efficacy, such as patients' lifestyle habits and psychosocial factors. Meanwhile, the study mainly focused on the immediate postoperative energy, and the long-term impact on patients' quality of life has yet to be fully clarified. Therefore, in-depth studies on the long-term effects on patients' quality of life are warranted.

In conclusion, PEID and PETD offer comparable efficacy in treating LDH, and each has its advantages. PETD is a more delicate procedure but brings better efficacy. Special attention should be paid to patients with obesity, advanced disc degeneration, and those requiring extended surgical time.

Disclosure of conflict of interest

None.

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