Am J Transl Res 2025;17(3):2283-2292
www.ajtr.org /ISSN:1943-8141/AJTR0157384

Original Article

Clinical observation of percutaneous transforaminal endoscopic discectomy for lumbar disc herniation and analysis of influencing factors for recurrence

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Received April 23, 2024; Accepted December 30, 2024; Epub March 15, 2025; Published March 30, 2025

Abstract: Objective: To investigate the clinical effects of percutaneous transforaminal endoscopic discectomy (PELD) in treating lumbar disc herniation (LDH) and analyze the related factors for postoperative recurrence. Methods: A retrospective analysis was conducted on 168 patients with lumbar disc herniation who underwent percutaneous transforaminal endoscopy at the Second Hospital of Tangshan from January 2017 to January 2021. The patients were followed up for 1 year. The Oswestry disability index (ODI) and visual analog scale (VAS) for low back pain/radicular pain were recorded before the operation and at the final follow-up. The patients' overall responses were evaluated according to Stauffer-Coventry's response evaluation criteria. Univariate analysis and multivariate logistic regression were used to analyze the relationship between basic data indicators and postoperative recurrence. Results: Compared with preoperative values, the postoperative VAS scores and ODI indices were significantly reduced at different time points (both $P < 0.05$). During the final follow-up, the efficacy was rated as excellent in 55 cases, good in 59 cases, fair in 35 cases, and poor in 19 cases, with an overall excellent and good rate of 67.86%. Among them, 12 patients had postoperative recurrence, with a recurrence rate of 7.14%. Univariate analysis indicated that age ≥ 49 years, BMI ≥ 24.62 kg/m^2, partition of disc herniation location, intraoperative annulus fibrosus damage, and incomplete removal of nucleus pulposus during surgery were independent risk factors for postoperative recurrence (all $P < 0.05$). Conclusion: PELD surgery for LDH can achieve favorable clinical efficacy. However, intraoperative annulus fibrosus injury and incomplete removal of the nucleus pulposus during surgery may lead to secondary recurrence in patients.

Keywords: Lumbar disc herniation, percutaneous transforaminal endoscopy, efficacy, recurrence, risk factors

Introduction

Lumbar disc herniation (LDH), a major contributor to low back and leg pain in daily life, exhibits a high incidence rate in the population. With social advancement and changes in lifestyle patterns, the prevalence of LDH has been increasing annually [1]. LDH typically stems from the dehydration of the nucleus pulposus following intervertebral disc degeneration. Under continuous external stimulation, the pressure equilibrium within and outside the intervertebral disc is disrupted, causing the nucleus pulposus to compress and herniate towards the surface of the annulus fibrosus. This, in turn, impacts the nerve roots within the intervertebral disc space, and nerve root impairment leads to radiating pain in the lower back or lower limbs [2]. Besides pain in the lumbar region, groin, inner thigh, and coccyx, complications such as numbness, cauda equina syndrome, lumbar spondylolisthesis, and lumbar spinal stenosis may arise. Among these, incontinence and neurological deficits resulting from cauda equina nucleus injury are the most severe, significantly impairing patients' quality of life [3, 4]. Research indicates that most LDH patients experience symptom improvement within 6 weeks of conservative treatment. Generally, the natural course of LDH is favorable, and in the absence of severe neurological deficits, most patients show amelioration after 6 weeks of conservative management [5].

The selection of treatment modalities hinges on the patient's specific condition. Conservative

https://doi.org/10.62347/AAIH8947

approaches encompass bed rest, lumbar traction, physical factor therapy, Western manual therapy, massage therapy, percutaneous block therapy, and pharmacotherapy. Notably, percutaneous endoscopic lumbar discectomy (PELD) is frequently employed for LDH treatment [6]. PELD features a smaller incision and precludes intraoperative traction manipulation of nerve roots and dural sac, effectively minimizing the risk of damage to surrounding normal tissues. This surgical technique causes less harm to patients' facet joints, expedites recovery, curtails hospitalization time and costs, and alleviates the economic burden on patients [7, 8]. By utilizing a foraminoscope, PELD affords surgeons a clear view of the surgical field, facilitating more thorough removal of the diseased nucleus pulposus and reducing the secondary recurrence rate [9, 10]. This surgical method can reduce local nerve root compression and pain mediators that are secreted due to neurometabolic imbalance in patients with low back pain and radicular neuralgia caused by disc herniation, thereby relieving pain symptoms [11]. Although PELD has a relatively extensive range of indications and can be applied to patients of diverse ages, numerous objective factors can interfere with its therapeutic efficacy. Hence, we performed logistic regression to explore the relationship between patients' basic data indicators and postoperative recurrence, as well as to analyze and evaluate the factors influencing patients' physical function recovery and recurrence after treatment, aiming to attain the optimal therapeutic outcome.

The aim of this study was to comparatively analyze the lumbar disc function of LDH patients before and after PELD treatment by Oswestry disability index (ODI) and visual analogue scale (VAS) scores for low back pain/lower limb radicular pain. Additionally, we recorded and evaluated the treatment efficacy, presented relevant cases, and performed case image analysis, providing a scientific foundation for assessing the clinical effectiveness of PELD in treating LDH patients.

Materials and methods

General data

A retrospective analysis was conducted on 168 patients with lumbar disc herniation who underwent percutaneous transforaminal endoscopy at the Second Hospital of Tangshan from January 2017 to January 2021. Their gender, age, body mass index (BMI), disease duration, smoking and drinking histories, underlying diseases, operation time, herniation location, type of disc herniation during surgical decompression, as well as intraoperative annulus fibrosus injury and incomplete removal of the nucleus pulposus were recorded. This study was approved by the Ethics Committee of the Second Hospital of Tangshan.

Criteria for patient selection

Inclusion criteria: ① According to the "LDH Diagnosis and Treatment Guidelines" [12], the diagnosis was made through evaluation: collecting the patient's medical history, symptoms, signs, and imaging findings consistent with LDH, along with lumbar MRI or CT imaging examination and nerve localization. ② There were changes in muscle strength and sensory disorders in the innervated areas, and the straight leg raising test was positive. ③ Non-surgical treatments such as drugs and physiotherapy were ineffective. ④ Patients had no serious pulmonary, cardiovascular, and cerebrovascular diseases, liver and kidney dysfunction, or other organic lesions. ⑤ There were no neurogenic and myogenic diseases. ⑥ Patients agreed to receive treatment and cooperate with the completion of relevant examinations.

Exclusion criteria: ① History of mental illness. ② Patients with other lower limb dysfunctions and diseases affecting normal walking (such as cerebrovascular disease sequelae, knee arthritis, lower limb trauma, etc.). ③ Patients with visual impairment or vestibular dysfunction and other diseases affecting standing balance. ④ Patients with spinal deformities such as clefts, spondylolisthesis, and scoliosis. ⑤ Spinal tuberculosis and spinal tumors. ⑥ Patients with severe osteoporosis or recent traumatic fractures.

Treatment procedures

The patient was placed in a prone position on the fluoroscopy "U" pad operating bed. Protective pads were placed on both shoulders, bilaterally along the anterior superior iliac spine, and bilaterally on the ankles. Local anesthesia was administered for the abdominal suspension localization puncture at the surgical

segment. After C-arm guided puncture, the guide wire was inserted from shallow towards depth to the intervertebral foramen position. The double-level dilatation catheter was inserted through the guide wire to dilate the upper facet position, and the placement of the channel endoscope was completed. The detection field of intraspinal nerves and tissues was clear. As needed, the bone in the ventral part of the superior facet was trimmed to the intervertebral foramen molding using a multi-level trephine and a microscopic dynamic bone drill to identify and remove the nucleus pulposus tissue. The degree of nerve root release was observed in real time under the endoscope. When the patient's symptoms were significantly improved, the channel could be withdrawn. After the endoscope was removed, a bipolar radiofrequency machine was used in an auxiliary way to perform disc annuloplasty and ablation decompression. Bipolar low-temperature radiofrequency hemostasis was carried out on the incision, and no significant bleeding requiring suturing was observed. All patients underwent MRI or CT examination 1 day after surgery.

Outcome evaluation measures

ODI is composed of 9 questions related to pain perception, self-care, lifting, walking, sitting, stable standing posture, depth of sleep, social life, and traveling, a higher score indicates a more severe degree of lumbar dysfunction [13]. Low back pain and lower limb pain were evaluated using the visual analogue scale (VAS) [14]. A 10-cm horizontal line was drawn on paper, with one end marked as 0, representing no pain, and the other end marked as 10, representing severe pain. Different scores corresponded to different degrees of pain. The Stauffer-Coventry (SC) efficacy evaluation criteria were used as the efficacy evaluation index [15].

Statistical analysis

SPSS 26.0 statistical software was employed to analyze the obtained data statistically. All data conformed to the normal distribution and were expressed as mean ± standard deviation. Paired sample t-test was used to compare the conditions before and after surgery. The χ^2 test was used to statistically analyze the clinical efficacy of patients at the final follow-up. Variables with a univariate analysis result of $P < 0.05$ were incorporated into multivariate analysis and analyzed using the logistic regression equation, where $P < 0.05$ signified a significant difference.

Results

Comparison of general data between the two groups

The general data of the 168 patients included in this study are shown in **Table 1**. After a one-year follow-up, the patients were categorized into a recurrence group (n = 12) and a non-recurrence group (n = 156) based on recurrence status.

Changes in VAS score and ODI index in LDH patients treated with PELD

The ODI and VAS scores of LDH patients one year after PELD treatment were lower than those before treatment ($P < 0.05$). See **Table 2**.

Analysis of clinical efficacy at the final follow-up

According to SC response evaluation criteria, 32.74% (55/168) of the patients exhibited an excellent overall response, 35.12% (59/168) had a good response, 20.83% (35/168) had a fair response, and 11.31% (19/168) had a poor response. The excellent and good rate was 67.86%, while 32.14% had a fair or poor efficacy.

Typical case presentation

Example Case: A 40-year-old female, was admitted due to "lumbar pain with radiating pain in the right lower limb for over half a month". Upon admission, she presented with lumbar pain and radiating pain in the right lower extremity, which intensified during exercise and could be alleviated by rest, without significant intermittent claudication. Physical examination revealed no obvious spinal deformity, with a physiological curvature present. There was percussion pain in the right spinous process and paraspinous pressure at L5 and S1, tenderness in the right piriformis muscle, a positive right straight leg raising test at 45°, a positive strengthening test, and a negative left side. The bilateral femoral nerve traction test and

Table 1. General data of patients

Characteristic	Value
Total cases	168
Gender	
Male	102 (60.71%)
Female	66 (39.29%)
Age (years)	49.25 ± 15.12
BMI (kg/m^2)	24.62 ± 3.21
Disease duration (years)	5.63 ± 3.12
Smoking history	73 (43.45%)
Alcohol history	82 (48.81%)
Underlying diseases	
Diabetes	65 (38.69%)
Hypertension	72 (42.86%)
Hyperlipidemia	55 (32.74%)
Operative Time	
< 60 min	98 (58.33%)
≥ 60 min	70 (41.67%)
Herniation location*	
1a	9 (5.36%)
1b	3 (1.79%)
1c	8 (4.76%)
2a	26 (15.48%)
2b	42 (25.00%)
2c	2 (1.19%)
2ab	39 (23.21%)
3a	5 (2.98%)
3b	22 (13.10%)
3ab	12 (7.14%)
Types of herniated disc	
Prominent	70 (41.67%)
Expulsion	78 (46.43%)
Free	20 (11.90%)
Intraoperative annulus fibrosus breakage	22 (13.10%)
Incomplete removal of nucleus pulposus	24 (14.29%)

Data are presented as mean ± standard deviation or n (%). BMI, Body Mass Index. *Herniation location: The first digit (1, 2, 3) represents the vertical position (1 = upper, 2 = middle/foraminal, 3 = lower), and the letter(s) (a, b, c) represent the horizontal position (a = central, b = paracentral, c = lateral). Combined letters (e.g., ab) indicate herniation spanning multiple areas.

Table 2. Comparison of VAS score and ODI index

Time	Low back pain VAS	Lower limb pain VAS	ODI
Before surgery	6.85 ± 1.75	7.95 ± 1.86	73.11 ± 5.94
1 year post-op	1.92 ± 0.82	1.64 ± 0.56	14.96 ± 3.95
T	528.500	552.000	172.000
P	< 0.001	< 0.001	< 0.001

VAS, visual analogue scale; ODI, Oswestry Disability Index.

bilateral piriformis tension test were negative, and the bilateral "4" word test was negative. The superficial sensation of the skin on the lateral aspect of the right lower leg and dorsum of the right foot was diminished compared to the contralateral side. Muscle strength and tone were normal in both lower limbs, physiological reflexes were symmetrically present, and no pathological signs were elicited.

Figure 1 presents the imaging examinations of a typical case of recurrent lumbar disc herniation (rLDH) treated with PELD. The preoperative anteroposterior and lateral X-ray images (**Figure 1A**) and the hyperextension and hyperflexion position images (**Figure 1B**) indicated no obvious abnormalities in the lumbar spine alignment or stability. The preoperative MRI before the first PELD surgery (**Figure 1C**) disclosed a herniated disc, which was completely removed as confirmed by the postoperative MRI (**Figure 1D**). However, the patient experienced symptom recurrence, and the preoperative MRI before the second PELD surgery (**Figure 1E**) demonstrated a recurrent herniation at the same level. The recurrent herniation was successfully managed by a second PELD surgery, as validated by the postoperative MRI (**Figure 1F**). The postoperative anteroposterior and lateral X-ray images (**Figure 1G**) and the hyperextension and hyperflexion position images (**Figure 1H**) confirmed that there were no changes in spinal alignment or stability after the second PELD surgery, demonstrating the minimally invasive nature of the procedure and its favorable effect on maintaining spinal biomechanics. This case exemplifies the effectiveness of PELD in treating rLDH while also emphasizing the importance of identifying and mitigating the risk factors for recurrence to enhance the long-term outcomes of PELD.

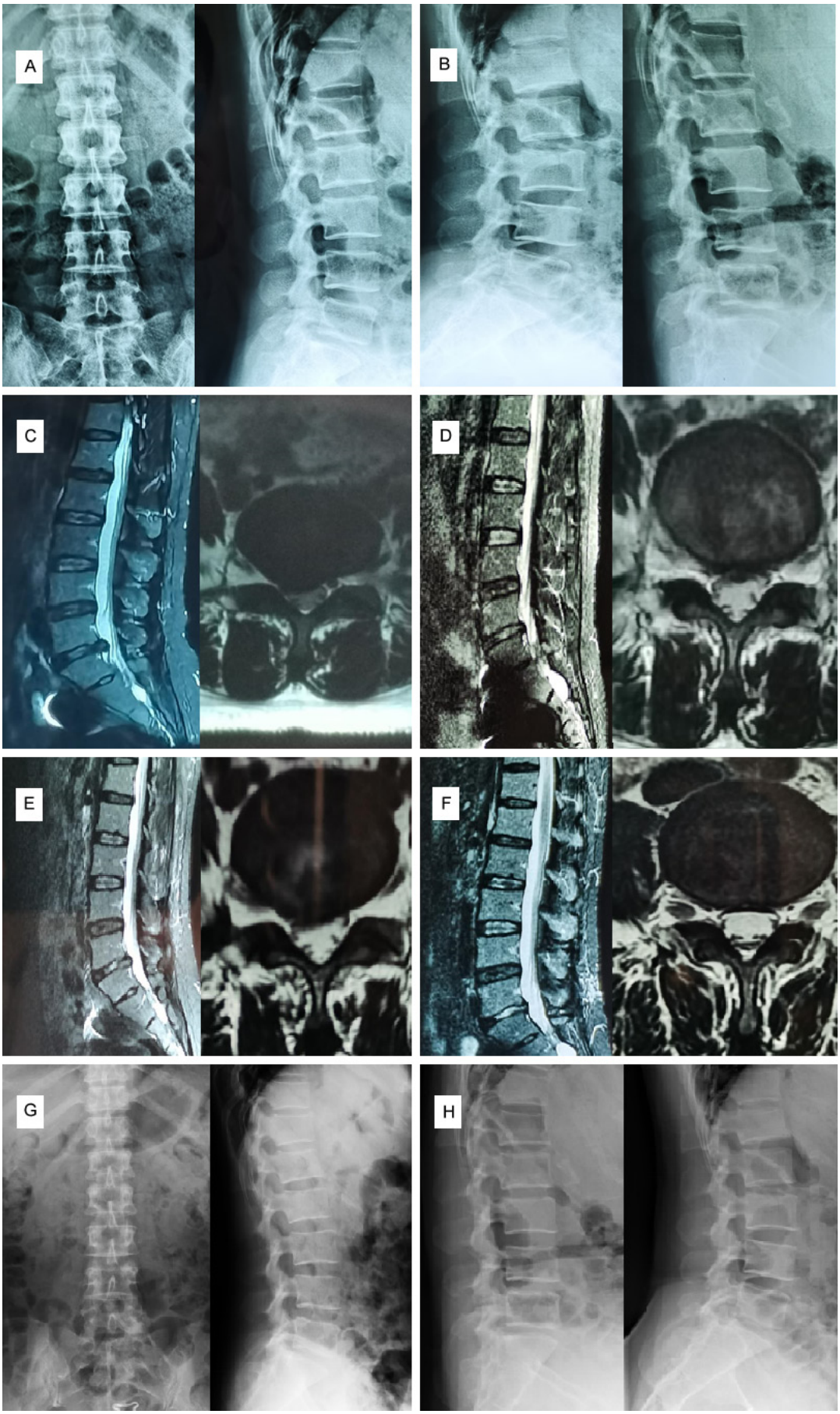
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Figure 1. Imaging examinations of a typical case with recurrent lumbar disc herniation (rLDH) treated by PELD. A. Preoperative X-ray images of the lumbar spine in the anteroposterior and lateral views. B. Preoperative X-ray images of the lumbar spine in the hyperextension and hyperflexion positions. C. Preoperative MRI before the first PELD surgery, showing a herniated disc. D. Postoperative MRI after the first PELD surgery, demonstrating complete removal of the herniated disc. E. Preoperative MRI before the second PELD surgery for rLDH, revealing a recurrent herniation at the same level. F. Postoperative MRI after the second PELD surgery, confirming successful removal of the recurrent herniation. G. Postoperative X-ray images of the lumbar spine in the anteroposterior and lateral views. H. Postoperative X-ray images of the lumbar spine in the hyperextension and hyperflexion positions. PELD, percutaneous transforaminal endoscopic discectomy; rLDH, recurrent lumbar disc herniation; MRI, magnetic resonance imaging.

Table 3. Univariate analysis of postoperative recurrence

Factor	Non-rLDH group (n = 156)	RLDH group (n = 12)	X^2	P
Gender (case)			0.031	0.861
Male	95 (60.90%)	7 (58.33%)		
Female	61 (39.10%)	5 (41.67%)		
Age (years)			4.060	0.044
< 49	86 (55.13%)	3 (25.00%)		
≥ 49	70 (44.87%)	9 (75.00%)		
BMI (kg/m^2)			6.179	0.013
< 24.62	87 (68.59%)	4 (33.33%)		
≥ 24.62	69 (31.41%)	8 (66.67%)		
Disease duration (years)			0.017	0.897
< 5.63	88 (56.41%)	7 (58.33%)		
≥ 5.63	68 (43.59%)	5 (41.67%)		
Smoking history (case)			2.834	0.092
Yes	65 (41.67%)	8 (66.67%)		
None	91 (58.33%)	4 (33.33%)		
Alcohol history (n)			1.649	0.199
Yes	74 (47.44%)	8 (66.67%)		
None	82 (47.44%)	4 (33.33%)		
Underlying disease (case)				
Diabetes			2.102	0.147
Yes	58 (37.18%)	7 (58.33%)		
None	98 (62.82%)	5 (41.67%)		
Hypertension			0.007	0.931
Yes	67 (42.95%)	5 (41.67%)		
None	89 (57.05%)	7 (58.33%)		
Hyperlipidemia			0.002	0.964
Yes	51 (32.69%)	4 (33.33%)		
None	105 (67.31%)	8 (66.67%)		
Operative Time (min)			0.320	0.572
< 60	90 (57.69%)	8 (66.67%)		
≥ 60	66 (42.31%)	4 (33.33%)		
Prominent position			17.229	0.045
1a	8 (5.13%)	1 (8.33%)		
1b	3 (1.92%)	0		
1c	6 (3.85%)	2 (16.67%)		
2a	26 (16.67%)	0		
2b	38 (24.36%)	4 (33.33%)		
2c	2 (1.28%)	0		
2ab	38 (24.36%)	1 (8.33%)		

3a	3 (1.92%)	2 (16.67%)		
3b	20 (12.82%)	2 (16.67%)		
3ab	12 (7.69%)	0		
Types of herniated disc at surgical decompression			0.174	0.917
Prominent	65 (41.67%)	5 (41.67%)		
Expulsion	72 (46.15%)	6 (50.00%)		
Free	19 (12.18%)	1 (8.33%)		
Intraoperative annulus fibrosus breakage			38.901	< 0.001
Yes	15 (9.62%)	9 (75.00%)		
None	141 (90.38%)	3 (25.00%)		
Incomplete removal of nucleus pulposus during surgery			43.521	< 0.001
Yes	13 (8.33%)	9 (75.00%)		
None	143 (91.67%)	3 (25.00%)		

rLDH, recurrent lumbar disc herniation; BMI, body mass index.

Univariate analysis of postoperative recurrence

After 168 patients underwent PELD treatment, 12 developed rLDH (rLDH group), yielding a recurrence rate of 7.14%, and 156 did not experience recurrence (non-rLDH group, 92.86%). Univariate analysis revealed significant differences between the rLDH group and the non-rLDH group in terms of age ≥ 49 years, BMI ≥ 24.62 kg/m^2, disc herniation location partition, intraoperative annulus fibrosus damage, and incomplete removal of the nucleus pulposus during surgery (all $P < 0.05$). There were no significant differences in gender, disease duration, smoking history, drinking history, underlying diseases, operation time, and type of disc herniation between the rLDH group and the non-rLDH group (all $P > 0.05$), as detailed in **Table 3**.

Multivariate logistics regression analysis of postoperative recurrence in LDH patients

We assigned values to the indicators that differed in the univariate analysis, and the assignment sheets are detailed in **Table 4**. Logistic regression analysis was performed on the aforementioned variables to calculate the odds ratio (OR) and 95% confidence interval (95% CI) of the risk factors, where $P < 0.05$ signified a significant difference. The results indicated that age ≥ 49 years, BMI ≥ 24.62 kg/m^2, prominent location partition (2ab, 3a, 3b, 3ab), intraoperative annulus fibrosus injury, and incomplete removal of the nucleus pulposus during surgery were the influencing factors for rLDH after PELD, as shown in **Table 5**.

Conclusion

Currently, the treatment of LDH follows the principle of minimizing physical trauma and safeguarding the complete structure as well as mechanical stability of the lumbar anatomy, provided that the therapeutic effect is guaranteed. Based on this principle, non-surgical conservative treatment is predominantly adopted in the early stage of the disease. Nevertheless, relevant clinical data [16] indicate that approximately 10%-20% of LDH patients with severe conditions still necessitate surgical intervention for diverse reasons. These patients are mostly middle-aged and elderly individuals, often accompanied by various underlying diseases, and thus exhibit poor physical tolerance. Minimally invasive techniques, such as collagenase dissolution, ozone ablation, percutaneous aspiration, laser vaporization, and radiofrequency thermocoagulation, have demonstrated favorable efficacy through decompression therapy and have been widely utilized in the treatment of LDH patients. However, their decompression modalities exert indirect effects, failing to entirely preclude the continuous compression of neural tissue by the protrusion. Moreover, the damaged annulus fibrosus cannot be promptly repaired, which contributes to the unsatisfactory recovery time and recurrence rate [17, 18]. Given that minimally invasive techniques for spinal diseases still require further refinement, we conduct research and analysis on the advantages and influencing factors of foraminoscopy in LDH patients, aiming to surmount the drawbacks of existing minimally invasive techniques for spinal diseases and offer innovative ideas.

Table 4. Value assignment sheet

Factor	Assigned Value
Age	≥ 49 years = 1, < 49 = 0
BMI	≥ 24.62 kg/m^2 = 1, < 24.62 kg/m^2 = 0
Protrusion zone	2ab, 3a, 3b, 3ab = 1, 1a, 1b, 1c, 2a, 2b, 2c = 0
Intraoperative annulus fibrosus breakage	Yes = 1, No = 0
Incomplete removal of nucleus pulposus during surgery	Yes = 1, No = 0
Recurrence	Recurrence = 1, No recurrence = 0

BMI, body mass index.

Table 5. Survival multivariate analysis

Factor	B	S.E.	Wals	Sig.	Exp (B)	95% C.I. of EXP (B)	
						Lower Limit	Upper Limit
Age ≥ 49 years	0.930	0.353	6.954	0.009	2.523	1.275	5.032
BMI ≥ 24.62 kg/m^2	1.325	0.362	13.195	< 0.001	3.775	1.845	7.749
Protrusion zone (2ab, 3a, 3b, 3ab)	0.679	0.332	4.105	0.042	1.969	1.029	3.769
Intraoperative annulus fibrosus breakage	1.932	0.532	12.986	< 0.001	6.946	2.415	19.910
Incomplete removal of nucleus pulposus during surgery	0.792	0.332	5.512	0.018	2.215	1.142	4.312

BMI, body mass index; B, regression coefficient; S.E., standard error; Sig., significance; Exp (B), odds ratio; C.I., confidence interval.

The results of this study indicated that 168 patients successfully underwent PELD surgery, and the postoperative VAS score and ODI index were significantly decreased. Previous studies have demonstrated that during PELD surgery, the anatomical structure is distinctly presented on the screen [19, 20]. The surgical field allows for a clear differentiation of the spinal canal, nerves, local adhesive tissues, and small scar tissues, preventing damage to the paravertebral muscles and ligaments and eliminating the need to resect the lamina, thus having minimal impact on spinal stability. The surgical wound is small, and no antibiotics are required during the perioperative period, with a short recovery time. It is evident that the clear visual field during PELD surgery can avert injury to the peripheral nerve roots and enhance both the surgical success rate and the rehabilitation level of lumbar function. An analysis of the overall efficacy evaluation revealed that at the final follow-up, the overall excellent and good rate of efficacy was 67.86%, and the recurrence rate was 7.14%. Literature reports have stated that PELD can effectively relieve nerve compression and promote the improvement of lumbar function in patients, with relatively broad indications, and is capable of addressing a variety of lumbar diseases (such as disc herniation, foraminal stenosis, spinal stenosis) [21, 22]. These results imply that PELD is efficacious in alleviating nerve compression in LDH patients in both the short and long term, albeit with a certain recurrence probability. Therefore, we conducted univariate and multivariate analyses of the basic data of the included patients. The results showed that age ≥ 49 years, BMI ≥ 24.62 kg/m^2, disc herniation location partition, intraoperative annulus fibrosus damage, and incomplete removal of the nucleus pulposus during surgery were independent risk factors for postoperative recurrence in patients. Numerous studies have suggested that the damaged annulus fibrosus following lumbar discectomy relies on the slow repair process of annulus fibrosus scar hyperplasia [23, 24]. The annulus fibrosus possesses a special composition and structure, with poor self-repair and healing capabilities, high resistance to nucleus pulposus herniation, and an unbalanced increase in intradiscal pressure caused by incomplete removal of the herniated nucleus pulposus or nucleus pulposus, which may be the main factors contributing to early postoperative recurrence. These results indicate that the relatively low recurrence rate of PELD in patients with LDH might be associated with avoiding dural sac traction and infection and achieving complete removal of the herniated nucleus pulposus during surgery, thereby reducing the occurrence of postoperative complications in patients.

This study has several limitations that merit recognition. Firstly, it was a single-center retrospective study with a relatively small sample size, which potentially restricts the generalizability of the findings. Secondly, the follow-up period was relatively short (1 year), and longer-term outcomes warrant investigation in future studies. Thirdly, certain potential confounding factors, such as the surgeon's experience and learning curve, were not accounted for in this study. Further multi-center prospective studies with larger sample sizes and longer follow-up periods are necessary to validate our results.

In conclusion, PELD treatment can effectively relieve nerve compression in patients with LDH, facilitate the recovery of lumbar function, and significantly reduce the degree of pain and recurrence rate. During the treatment process, individualized treatment plans should be formulated based on the herniation position, and efforts should be made to avoid intraoperative damage to the annulus fibrosus and incomplete removal of the nucleus pulposus, which may enhance the overall treatment efficacy.

Disclosure of conflict of interest

None.

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