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Multifidus fat infiltration negatively influences the postoperative outcomes in lumbar disc herniation following transforaminal approach percutaneous endoscopic lumbar discectomy

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Abstract

Purpose This study aims to investigate the influence of multifidus muscle fat infiltration on clinical outcomes in lumbar disc herniation (LDH) undergoing percutaneous endoscopic lumbar discectomy (PELD).

Methods A retrospective analysis was conducted on 224 patients who underwent lateral PELD, with complete one-year follow-up data. Patients were divided into two groups based on preoperative MRI evaluation of L4 multifidus muscle fat infiltration: a mild group (< 25%) and a severe group (≥ 25%). Baseline characteristics and postoperative outcomes were recorded and compared.

Results At the final follow-up, significant improvements in VAS scores for back and leg pain, ODI scores, and EQ-5D scores were observed in both groups. There were no statistically significant differences in preoperative VAS scores for back and leg pain, ODI scores, and EQ-5D scores between the two groups. However, significant differences were found in VAS scores for back pain, ODI scores, and EQ-5D scores at 3, 6, and 12 months postoperatively ($P < 0.05$), while no significant difference was noted in VAS scores for leg pain during follow-up. The total recurrence rate was 6.7% (15 out of 224 cases), with 12 cases in the severe group and 3 cases in the mild group, showing a statistically significant difference ($P < 0.05$).

Conclusion The effectiveness of postoperative PELD in patients with LDH is impacted by severe multifidus muscle fat infiltration. Multifidus muscle fat infiltration represents a risk factor for recurrent LDH after PELD.

Keywords Percutaneous endoscopic lumbar discectomy, Multifidus muscle fat infiltration, Lumbar disc herniation

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Introduction

Lumbar disc herniation (LDH) is emerging as a critical public health issue, with prevalence rates ranging from 13 to 40%. It poses a significant threat to both the physical and psychological health of patients, resulting in dual impacts on their families, both mentally and economically. Furthermore, the substantial expenses associated with treatment place significant burdens on healthcare systems [1–3]. LDH cases among those younger than 20 years old are infrequent, primarily seen in middle-aged individuals around 50 years old who are sedentary or involved in activities requiring prolonged sitting, bending, or twisting of the body, or vigorous physical exertion. With advancing age, the incidence of LDH gradually diminishes [4]. Due to the gradual degeneration of spinal structures, such as the fibrous ring and nucleus pulposus of the lumbar intervertebral disc, loss of elasticity and strength occurs. Under various factors, especially external forces, the fibrous ring may rupture, causing the nucleus pulposus to protrude into the spinal canal. This can lead to clinical syndromes characterized by irritation or compression of the nerve roots [5, 6]. The main clinical manifestations of LDH include lower back pain and radiating pain in the lower extremities, accompanied by varying degrees of restriction in lumbar spine movement. Currently, it is believed that the majority of LDH cases can be effectively improved through non-surgical treatments such as physical therapy, medication, and traditional Chinese medicine. However, approximately 10–20% of patients undergoing conservative treatment experience treatment failure and require surgical intervention [7, 8]. The conventional approach to surgery involves significant tissue damage, slow recovery of function postoperatively, and a higher likelihood of complications. As minimally invasive endoscopic techniques in spinal surgery progress, PELD is becoming increasingly favored by spine surgeons. PELD has been established as having advantages over open surgery, including reduced surgical trauma and faster postoperative recovery. However, a subset of patients, ~ 8–12%, remain unsatisfied with the treatment outcome [9–11]. Postoperative complications and recurrence rates following PELD have attracted considerable attention, influenced by numerous factors. Reasons cited in the literature include age, smoking habits, duration of illness, postoperative weight-bearing duration, and the presence of Modic changes [12, 13]. Recent studies have revealed that paraspinal muscle fat infiltration is associated with postoperative outcomes in a variety of degenerative lumbar spine conditions [14–16]. The multifidus muscle, a major paraspinal muscle in the lumbar spine, plays a critical role in stabilizing the lumbar vertebrae. Research suggests that fat infiltration in the multifidus muscle could potentially predict postoperative functional improvement in patients with degenerative lumbar spinal stenosis [17]. Increasingly, studies have utilized 25% fat infiltration in the multifidus muscle as a delineating threshold [18]. Yet, there is a lack of literature discussing the impact of multifidus muscle fat infiltration exceeding 25% on postoperative outcomes following PELD. This study aims to explore the influence of multifidus muscle fat infiltration on the efficacy of PELD, providing valuable insights for spine surgeons in preoperative evaluation of surgical outcomes.

Methods

Study population

This retrospective study included 224 patients diagnosed with single-segment LDH who underwent PELD treatment from January 2019 to December 2021 (age range: 24–66 years). Inclusion criteria were as follows: (1) primary diagnosis of LDH; (2) underwent single-segment lateral PELD surgery; (3) MRI findings consistent with clinical symptoms and signs, with ineffective conservative treatment. Exclusion criteria were as follows: (1) spinal tumors, spinal infections, lumbar instability; (2) history of previous lumbar spine surgery or trauma; (3) neurological, muscular, or endocrine system disorders, or long-term use of steroid medications; (4) incomplete clinical data or loss to follow-up. Baseline characteristics (age, gender, BMI) and surgical parameters (operative level, surgical duration, time to ambulation, hospital stay duration) were documented. Clinical outcomes (VAS score, ODI score, and EQ-5D score) were evaluated, alongside the incidence rates of complications (infection, dural tear, nerve injury) and disc re-herniation.

Radiological assessment

The radiological assessment involved positioning axial slices of MRI at the level just below the upper endplate of L4 using the hospital's Picture Archiving and Communication System (PACS). Measurements were taken for both the total cross-sectional area (CSA) of the multifidus muscle and the area of fat infiltration at this level (Fig. 1). Two radiologists with specialized training conducted all measurements. Image J software (U.S. National Institutes of Health, Bethesda, MD, USA) was utilized to process MR images and calculate the proportion of multifidus muscle fat infiltration. Using a threshold of 25% fat infiltration, patients were categorized into two groups: mild (< 25%) and severe (≥ 25%) fat infiltration.

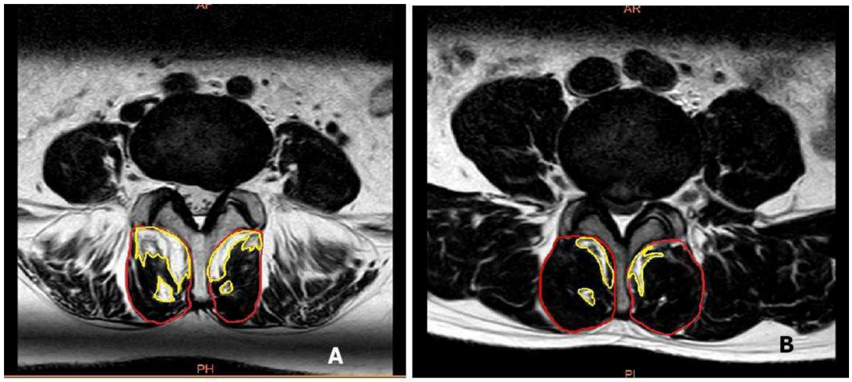

Fig. 1 The calculation of MF FI rate = [right FI CSA + left FI CSA (yellow zone)]/[right MF CSA + left MF CSA (red zone)]. **A** The representative case of severe group (≥ 25%). **B** The representative case of mild group. CSA indicates cross-sectional area, FI indicates fat infiltration

Surgical technique

The surgical procedures were conducted by the same surgeon. Patients were positioned in a prone position after standard surgical preparation. Local anesthesia was administered using 1% lidocaine hydrochloride for the puncture site and pathway. Under fluoroscopic guidance ("C-arm"), an 18-gauge puncture needle was inserted to the anterior inferior edge of the lower vertebra facet joint of the affected segment. Local anesthesia was then administered around the facet joint. A guide wire was passed through the puncture needle and subsequently removed. An 8 mm incision was made around the guide wire, and a dilation channel was created along it. Dilation tubes were gradually inserted along the guide rod. A ring saw was introduced under a protective sleeve to partially remove the lateral edge of the upper facet joint. Following the removal of the ring saw, a working channel was inserted along the guide rod. Proper positioning was confirmed using fluoroscopy in both anteroposterior and lateral views. A spinal endoscope was inserted through the working channel. Under endoscopic guidance, the protruding nucleus pulposus was excised using a nucleus pulposus forceps. Nerve roots were explored and decompressed, and bipolar radiofrequency was applied for hemostasis and annular reshaping. Normal status of the dural sac and nerve roots was confirmed under the endoscope. The working channels were sequentially removed, and the surgical incisions were closed.

Postoperative management

Following the procedure, patients were encouraged to begin lower limb mobilization exercises in their rooms as soon as possible. Three days post-surgery, they were permitted to wear a lumbar belt for ambulation, and starting from one week post-surgery, they commenced lumbar muscle functional exercises, performing 15 repetitions three times a day. Within the initial three months following surgery, patients were advised to refrain from excessive activity and lifting heavy objects.

Statistical analysis

Statistical analysis was conducted using SPSS 23.0 software. Normality testing of patients' general data, including age, BMI, surgery-related parameters (operative time, time to ambulation, length of hospital stay, and surgical segments), and clinical outcomes (VAS score, ODI score, and EQ-5D score), was performed using the Shapiro–Wilk test. Variables with a normal distribution were expressed as mean ± standard deviation, while non-normally distributed variables were expressed as median and interquartile range. The Kruskal–Wallis test was applied for variables that did not meet the normality assumption. For within-group comparisons, paired t-tests were used for normally distributed data, and the Wilcoxon signed-rank test was applied for non-normally distributed data. Between-group differences were analyzed using analysis of variance (ANOVA). Categorical variables, such as gender, were reported as proportions and analyzed using the Chi-square test. A multivariate regression model was employed to adjust for potential confounding factors. Clinical significance was considered alongside statistical results, with statistical significance set at $P < 0.05$.

Results

A total of 224 patient records were retrospectively analyzed. Baseline characteristics, including age, sex, BMI, operative time, time to ambulation, and length of hospital stay, showed no statistically significant differences between the mild fatty infiltration group (< 25%) and the severe fatty infiltration group (≥ 25%) ($P > 0.05$; Table 1). Similarly, no significant differences were

Table 1 Comparisons of baseline data and perioperative parameter

	Severe group n = 95	Mild group n = 129	P value
Baseline data			
Age at surgery (year)	50.6 ± 10.4	53.2 ± 8.8	0.673
Gender (male/female)	38(M)/57(F)	52(M)/77(F)	0.083
BMI	25.6 ± 6.2	22.4 ± 7.8	0.229
Perioperative parameter			
Operation time (min)	65.2 ± 15.8	62.7 ± 14.2	0.092
Time to first ambulation (d)	3.0 ± 0.5	2.9 ± 0.3	0.471
Hospital stays (d)	5.3 ± 3.9	5.5 ± 2.3	0.366
Recurrent lumbar disc herniation	12	3*	0.022
Complication	3	2	0.096
Number of surgical segments			
L2–3	1	2	0.412
L3–4	5	5	0.236
L4–5	76	106	0.234
L5–S1	13	16	0.564

observed between the groups in preoperative back pain VAS (6.7 ± 0.7 vs. 6.3 ± 1.6), leg pain VAS (7.4 ± 0.9 vs. 7.5 ± 1.2), ODI (66.4 ± 11.3 vs. 63.6 ± 14.6), or EQ-5D scores (0.51 ± 0.5 vs. 0.52 ± 0.6) ($P > 0.05$). Postoperatively, both groups demonstrated significant improvements in VAS scores for back and leg pain, ODI scores, and EQ-5D scores at final follow-up. However, significant differences were noted between the groups in back pain VAS, ODI, and EQ-5D scores at 3, 6, and 12 months postoperatively ($P < 0.05$). For instance, at 12 months, the back pain VAS score was 1.7 ± 1.4 in the severe group compared to 0.9 ± 1.7 in the mild group, and the ODI score was 18.4 ± 12.4 versus 12.7 ± 13.6, respectively. The severe group also reported lower EQ-5D scores (0.80 ± 0.5 vs. 0.85 ± 0.7; $P < 0.05$). These differences exceeded the established thresholds for minimal clinically important differences (MCID), supporting their clinical relevance.

There were no significant differences in leg pain VAS scores between the two groups at any follow-up point ($P > 0.05$), suggesting comparable efficacy of PELD in relieving neurological symptoms (Table 2). The overall recurrence rate was 6.7% (15 out of 224 cases), with a significantly higher recurrence rate in the severe group (12.6%, 12/95) compared to the mild group (2.3%, 3/129; $P < 0.05$). Multivariate regression analysis, adjusted for confounding factors such as age, BMI, and sex, revealed that severe multifidus fatty infiltration was independently associated with a 3.4-fold increased risk of recurrence (odds ratio [OR]: 3.41; 95% confidence interval [CI] 1.01–11.54; $P = 0.046$) (Table 3). Complications, such as dural tears, were rare and showed no significant differences between the groups ($P > 0.05$). No cases of infection or neurological injury were reported. A typical case is shown in Fig. 2.

Discussion

The functionality of back muscles is crucial in the biomechanics of degenerative lumbar spine diseases [19]. The multifidus muscle plays a critical role in spinal stability

Table 2 Comparisons of surgical outcomes

Group	Preoperative	Postoperative 3 months	Postoperative 6 months	Postoperative 12 months	MCID
Back pain VAS score					
Severe group	6.7 ± 0.7	4.2 ± 1.9	3.1 ± 1.2	1.7 ± 1.4	7/88
Mild group	6.3 ± 1.6	2.9 ± 1.5	1.5 ± 0.8	0.9 ± 1.7	6/123
P value	0.128	0.041	0.001	0.037	0.024
Leg pain VAS score					
Severe group	7.4 ± 0.9	2.6 ± 1.3	1.6 ± 1.4	0.6 ± 1.1	2/93
Mild group	7.5 ± 1.2	2.5 ± 1.5	1.8 ± 1.5	0.4 ± 1.5	4/125
P value	0.259	0.775	0.468	0.810	0.238
ODI score					
Severe group	66.4 ± 11.3	38.8 ± 11.1	25.1 ± 12.1	18.4 ± 12.4	8/87
Mild group	63.6 ± 14.6	29.4 ± 10.7	21.8 ± 11.5	12.7 ± 13.6	7/122
P value	0.846	0.035	0.001	0.017	0.046
EQ-5D score					
Severe group	0.51 ± 0.5	0.62 ± 0.5	0.71 ± 0.5	0.80 ± 0.5	10/85
Mild group	0.52 ± 0.6	0.68 ± 0.9	0.80 ± 0.8	0.85 ± 0.7	10/119
P value	0.681	0.022	0.041	0.010	0.018

Table 3 Univariate analysis for recurrence

Parameters	Recurrence, $n = 15$	No recurrence, $n = 209$	*P* value
Age	51.2 ± 9.8	52.9 ± 12.1	0.212
Gender (female)	6(M)/9(F)	74(M)/135(F)	0.139
BMI	26.3 ± 4.6	21.7 ± 5.2	0.024
Time to first ambulation	3.1 ± 0.2	3.0 ± 0.7	0.456
Operation time	65.7 ± 14.2	64.0 ± 15.9	0.384
VAS back preoperative	6.3 ± 1.1	6.5 ± 1.9	0.041
ODI preoperative	64.6 ± 12.7	66.6 ± 13.9	0.190
MF severe group/mild group	12/3	83/126	0.011
Multivariable analysis (OR, 95% CI)			
Parameters	**OR**	**CI**	***P* value**
BMI	1.06	0.32–3.68	0.431
VAS back preoperative	1.77	0.55–4.82	0.249
MF severe group/mild group	3.41	1.01–11.54	0.046

by controlling intersegmental motion. Fatty infiltration reduces muscle density and function, thereby compromising its stabilizing capacity. This instability may result in abnormal loading of spinal structures postoperatively, potentially leading to adverse outcomes such as recurrent disc herniation or persistent back pain [20]. Among patients with lower back pain, 80% were found to exhibit multifidus muscle atrophy. Some studies suggest that the degree of atrophy and fatty infiltration may correlate with the severity of lower back pain [14, 21, 22]. Research findings suggest that the total area of the multifidus muscle notably impacts the effectiveness of lumbar decompression surgery, with an area less than 8.5 cm^2 often indicating poor surgical outcomes [23]. For the first time, this study provides a quantitative assessment of the reduction in multifidus muscle area. While clinical measurements are straightforward, notable individual and racial variations may challenge their reliability as clinical benchmarks. Another research study indicated that the mean level of multifidus muscle fat infiltration in patients suffering from lumbar spine diseases was close to 25%, providing a quantified measure of multifidus muscle atrophy that bears significant clinical relevance [18]. Recently, there has been growing attention in the literature towards the influence of multifidus muscle fat degeneration on the outcomes of PELD surgery. We utilized the ratio of multifidus muscle fat infiltration to assess the effectiveness of PELD surgery, a process that is both simple and convenient. To the best of our knowledge, this study represents the first of its kind. By comparing data from two distinct patient cohorts, we identified a significant correlation between the degree of multifidus muscle fat degeneration and post-PELD efficacy assessments. Earlier studies have indicated that patients exhibiting poorer multifidus muscle quality tend to have worse baseline back pain and/or ODI scores [24]. Nonetheless, significant controversy persists regarding its impact, with some researchers suggesting that the quality of the multifidus muscle may not consistently correspond with the severity of chronic back pain and could potentially undergo changes due to age [25]. The results of our study indicate that there were no differences in baseline back pain and ODI scores between the two patient groups prior to surgery. Upon analysis by our team, it was observed that patients in both groups experienced more severe pain due to direct nerve compression caused by lumbar disc herniation, whereas multifidus muscle fat infiltration tends to be associated with a chronic disease course, potentially resulting in a lesser impact on the condition for such patients. Therefore, there were no significant differences in preoperative data between the two groups. However, this study did not investigate whether multifidus muscle fat infiltration contributes to an increased incidence of disc herniation. Other studies have suggested a relationship between preoperative MRI multifidus muscle area and ODI scores, which does not correlate with improvements in low back pain. Nevertheless, there is a notable correlation between the extent of multifidus muscle fat infiltration and postoperative back pain and ODI scores [26]. Another potential explanation is that fatty infiltration of the multifidus muscle is often associated with a chronic inflammatory state. Adipose tissue serves as a source of pro-inflammatory cytokines, such as IL-6 and TNF-α, which may sustain local inflammation, thereby delaying postoperative healing and recovery. The inflammatory process can also impair surrounding neural structures, exacerbating

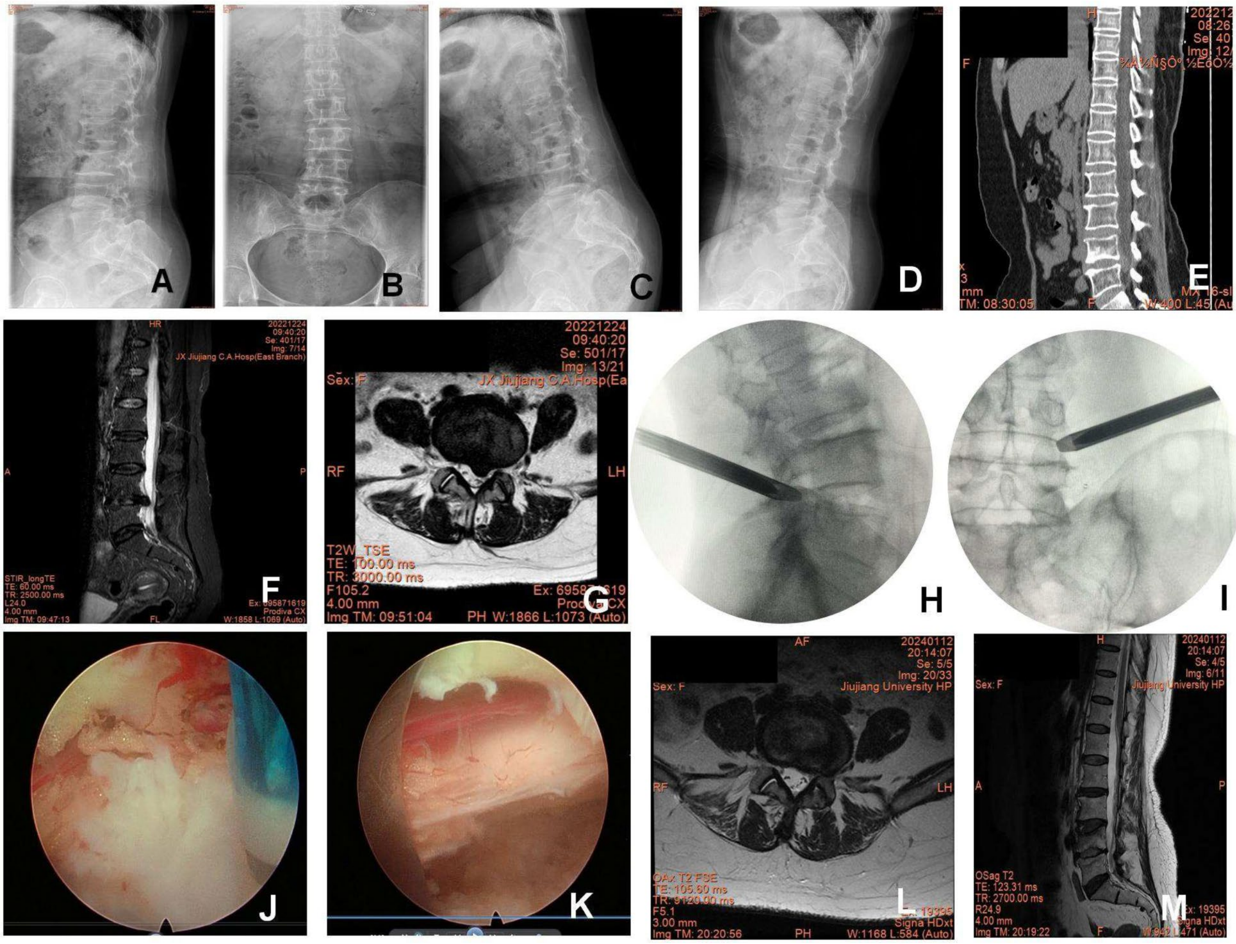

Fig. 2 Typical LDH case, a 57-year-old female. Recurrent low back pain and left lower limb pain for 3 months, and then DR (**A**–**D**), CT (**E**) and MRI (**F**, **G**) were performed. After admission, PELD was performed (**H**–**K**), and the symptoms gradually improved after surgery, back pain and leg pain disappeared completely 12 months after surgery. But 14 months later, due to the back pain after the injury caused by the car accident, the re-examination of MRI showed that the L4–5 intervertebral disc nucleus pulposus was removed and the nerve was fully loosened, but the L4 vertebral body was fractured (**L**, **M**)

postoperative pain and functional limitations [27, 28]. Studies have documented that PELD is highly effective in treating leg pain associated with disc herniation, achieving a success rate of over 90% [29]. By comparing four LDH surgical procedures (MD, PELD, PEID, and UBED) in terms of iatrogenic muscle injury and surgical invasiveness, scholars have confirmed that PELD is the least invasive approach. This technique has been shown to reduce hospital stay and postoperative back pain [30]. Significant improvements were noted in the VAS scores for lower back pain, leg pain, as well as ODI and EQ-5D scores during the final follow-up after surgery in both patient groups. These improvements are likely linked to multifidus muscle function and the decompression of the dorsal branches of the spinal nerves innervating the multifidus muscle. There is ongoing debate regarding the ability of lumbar muscle exercises to reverse the morphology of the multifidus muscle. Some argue that while motor control exercises may lead to an increase in the size of the multifidus muscle in chronic low back pain patients, such changes might not be clinically relevant [31]. Studies have highlighted the role of the multifidus muscle in stabilizing the lumbar spine and controlling excessive movement in the facet joints, potentially contributing to the reduction of lower back pain [32]. In our investigation of postoperative cases undergoing follow-up MRI, we found that implementing lumbar muscle functional exercises may reverse multifidus muscle fatty infiltration, leading to an improvement in the fatty infiltration ratio and potentially enhancing muscle function. Furthermore, another study's findings suggest a relationship between LDH and paraspinal muscle degeneration, as the severity of paraspinal muscle fatty infiltration increases due to denervation associated with compressed nerve roots [33, 34]. Thus, for individuals with LDH and concomitant radiculopathy, it is vital to prevent and correct severe multifidus muscle fatty infiltration. Employing appropriate medical interventions to rectify nerve root compression is essential. In cases where relief is not achieved, considering suitable surgical interventions to alleviate pressure becomes necessary.

The increasing utilization of PELD can be attributed to its minimally invasive nature, minimal blood loss, and quick recovery. Nonetheless, compared to open discectomy procedures, PELD appears to be linked to a higher frequency of postoperative complications, particularly recurrence, with rates reported in a substantial body of literature ranging from ~ 5–15%. Recurrence typically occurs within the first 6 months postoperatively, with the primary manifestations being recurrent back and leg pain or simultaneous recurrence of both [35, 36]. The determinants of postoperative recurrence following PELD are multifactorial. Previously suggested predictive factors include gender, smoking, intervertebral disc degeneration, morphological changes, and the surgeon's skill level, although their specific impacts remain contentious. Current evidence suggests that age, gender, smoking status, extent of protrusion, and duration of symptoms are not associated with recurrence rates [12, 37–39]. Reports in the literature indicate that early postoperative activity or loading is a factor contributing to the reduced short-term effectiveness of PELD. Premature engagement in such activities could lead to the re-herniation of the nucleus pulposus through the ruptured annulus, causing symptoms to recur [40]. As a result, our surgical team has standardized the time for postoperative ambulation to 3 days after surgery, consistent with the timeframe reported in the majority of literature. The results of this study suggest that PELD is associated with an increased risk of recurrence in patients with severe multifidus muscle fat infiltration, likely due to the destabilizing effect of multifidus muscle fat infiltration on spinal stability, leading to a higher recurrence rate. With fatty infiltration, the mechanical properties of the multifidus muscle are compromised, resulting in reduced resilience to biomechanical stress during daily activities. This functional impairment can lead to abnormal segmental motion, increasing the likelihood of recurrence. According to a study, multifidus muscle fat infiltration was classified into four grades based on fat infiltration: 0% to 10% (normal), 10% to 30% (mild), 30% to 50% (moderate), and over 50% (severe). The data revealed that the recurrence rate for moderate to severe multifidus muscle fat infiltration was approximately 3.414 times higher than that for normal to mild multifidus muscle fat infiltration [41]. Our study highlights the importance of preoperative MRI assessment of multifidus fatty infiltration. Incorporating this evaluation into clinical algorithms could enhance patient management. For instance, patients with severe multifidus fatty infiltration could be provided with tailored rehabilitation programs focused on core muscle strengthening, potentially mitigating the negative impact of fatty infiltration on postoperative outcomes.

There are several limitations to this study. Firstly, the small sample size limits the generalizability of the findings. Future research efforts should focus on recruiting a larger number of patients to investigate the association between multifidus muscle fat infiltration and the incidence of disc herniation, as well as its effects on the outcomes of endoscopic spinal surgery. Extended follow-up periods are necessary to evaluate the long-term effectiveness. Additionally, proactive education on back muscle functional exercises and extensive follow-up assessments with a larger cohort of patients are required to determine the potential reversibility of fatty infiltration.

Conclusion

The proportion of multifidus fatty infiltration is a reliable predictor of postoperative outcomes and recurrence rates following PELD. Preoperative detailed MRI evaluation of the multifidus muscle should be performed for all PELD patients, categorizing them into "mild" and "severe" fatty infiltration groups based on the established 25% threshold. For patients with severe fatty infiltration, it is essential to communicate the potential risks, including poorer postoperative outcomes and higher recurrence rates. Implementing targeted rehabilitation programs postoperatively provides an objective and scientific basis for enhancing therapeutic efficacy.

Author contributions

Jun Li, Guoliang Chen, Genlong Jiao and Kai Sun designed and supervised the experiments. Guoliang Chen, Genlong Jiao and Guodong Sun acquired fundings. Kai Sun, Renjie Qin and Wenzhuo Wang acquired analyzed the data. Kai Sun wrote the draft of the manuscript. Jun Li revised the manuscript. All authors read and approved the final version of the manuscript.

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Data availability

The data that support the findings of this study are not openly available due to reasons of sensitivity and are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
This research protocol was approved by the Institutional Review Board of Jiujiang University Affiliated Hospital and The First Affiliated Hospital of Jinan University. The clinical procedures adhered to the principles of the declaration of Helsinki. An exemption for informed consent was applied and approved by the Ethics Committee, because this retrospective study only involved the clinical data and completed test results without any intervention in the diagnosis and treatment of the patients. All authors read and approved the final manuscript, and agreed the publication.

Consent for publication
Informed consent was obtained from all individual participants included in the study.

Competing interests
The authors declare no competing interests.

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