Risk Assessment for Reoperation After Surgery for Lumbar Degenerative Disease Based on Preoperative Clinical Characteristics and Imaging Parameters: A Retrospective Cohort Study

Ann. Ital. Chir., 2026 97, 11: 2081–2090
https://doi.org/10.62713/aic.4827

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AIM: To explore the relevant clinical and radiological risk factors for reoperation in patients with lumbar degenerative diseases, and to inform preoperative risk stratification.

METHODS: This was a single-center retrospective cohort study. A total of 653 patients with lumbar degenerative diseases who underwent initial surgical treatment at Nanchang Hongdu Hospital of Traditional Chinese Medicine Affiliated to Jiangxi University of Chinese Medicine between June 2018 and June 2022 were included. All patients completed a 36-month follow-up. Demographic characteristics, comorbidities, perioperative parameters, and preoperative imaging parameters were collected, including the degree of intervertebral disc degeneration (Pfirrmann classification), the degree of paraspinal muscle fat infiltration (Goutallier classification), facet joint effusion distribution, and facet joint angles. Patients were divided into a reoperation group (n = 41) and a non-reoperation group (n = 612) based on whether they underwent reoperation for complications related to the index surgical segment during the follow-up period. Univariate and multivariable logistic regression analyses were performed to identify independent factors associated with postoperative reoperation, and their discriminative ability was evaluated using receiver operating characteristic (ROC) curves.

RESULTS: The reoperation rate within 36 months postoperatively was 6.28% (41/653). Final multivariable logistic regression analysis showed that age (Odds Ratio [OR] = 1.11, 95% Confidence Interval [CI] 1.06~1.15, $p < 0.001$), preoperative visual analog scale (VAS) score (OR = 1.82, 95% CI 1.48~2.23, $p < 0.001$), and Pfirrmann grade 5 (OR = 3.52, 95% CI 1.51~8.21, $p = 0.004$) were independent risk factors for reoperation. Compared with patients with bilateral effusion or synovial cysts, patients with unilateral effusion had a significantly lower risk of reoperation (OR = 0.03, 95% CI 0.00~0.23, $p < 0.001$). The area under the ROC curve for the combination of these factors was 0.89 (0.84–0.94), with a sensitivity of 78.0% and a specificity of 86.0%.

CONCLUSIONS: Age, preoperative pain level, intervertebral disc degeneration grade, and facet joint effusion status (bilateral effusion or synovial cyst vs. unilateral effusion) may be closely related to the risk of reoperation after lumbar degenerative disease surgery. Patients with these characteristics should be thoroughly evaluated preoperatively to inform the development of individualized treatment strategies.

Keywords: lumbar degenerative diseases; imaging parameters; reoperation; risk factors

Introduction

With the accelerating pace of population aging, the prevalence of lumbar degenerative diseases (LDD) has continued to rise globally [1]. These diseases mainly include pathological conditions such as lumbar disc degeneration, lumbar spondylolisthesis, lumbar spinal stenosis and degenerative scoliosis, and are often manifested as chronic low back pain, radiating pain in the lower extremities, numbness, intermittent claudication and varying degrees of functional limitation, which significantly affect the quality of life of patients [2]. Although these conditions are often categorized as distinct clinical entities, they share a common pathological foundation rooted in progressive intervertebral disc degeneration and facet joint arthrosis. From a biomechanical perspective, disc height loss and annular incompetence initiate a cascade of structural alterations that may lead to disc herniation, segmental instability, or ligamentous hypertrophy, ultimately resulting in central or lateral recess stenosis. It is well recognized that these degenerative processes frequently coexist within the same patient, and the affected spinal motion segment may exhibit overlapping features of multiple pathological conditions. This shared degenerative pathway provides a rationale for evaluating preoperative risk factors for reoperation across a combined cohort of LDD, while acknowledging that the relative influence of specific predictors may differ across diagnostic subgroups. For patients with an inadequate response

Submitted: 11 June 2026 Revised: 6 August 2026 Accepted: 13 August 2026 Published: 10 November 2026
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Editor: Roberto Gazzeri

to conservative treatment, persistent symptoms or significant neurological impairment, surgical intervention is generally considered an effective treatment option. In recent years, with continuous advances in spinal surgical technology, perioperative management, and medical resources, the number of patients undergoing surgical treatment has gradually increased, and various surgical procedures, such as decompression, discectomy and vertebral fusion, have been widely used in the clinical treatment of LDD [3]. Meanwhile, minimally invasive spinal techniques, particularly endoscopic decompression, have been increasingly applied for degenerative lumbar spinal stenosis because of their potential advantages in reducing paraspinal muscle injury, intraoperative blood loss, and hospitalization duration while achieving comparable neurological decompression outcomes [4]. Recent systematic reviews and clinical studies have demonstrated that full-endoscopic decompression can provide clinical outcomes comparable to microscopic decompression, with lower perioperative morbidity in selected patients with lumbar spinal stenosis [5,6]. However, despite these advances, postoperative symptom recurrence and subsequent reoperation remain important concerns, particularly considering the progressive nature of degenerative spinal pathology and the potential for residual or recurrent stenosis.

However, as the number of patients choosing surgical treatment increases, postoperative complications and reoperation have gradually attracted attention. Reoperation refers to the surgical intervention performed after the initial spinal surgery for various reasons, such as persistent or recurrent nerve compression, fusion failure, adjacent segment degeneration, infection, and persistent pain [7]. Compared with the initial surgery, reoperation is usually more complex, more invasive, and has a higher risk of perioperative complications, as well as higher medical costs and worse clinical outcomes. Therefore, identifying the relevant factors affecting the occurrence of reoperation is of great significance for optimizing patient selection, improving preoperative assessment, and developing individualized treatment strategies.

Previous studies have explored risk factors for reoperation after spinal surgery from multiple perspectives, including patient demographics, comorbidities, lifestyle, and the initial surgical procedure [7,8]. However, current research conclusions are not entirely consistent, and significant differences remain across studies. Furthermore, most studies lack systematic assessments of specific imaging characteristics and surgical details, which limits the explanatory power of the results. With the development of medical imaging technology, imaging examinations play an increasingly important role in the diagnosis and treatment decision-making for spinal diseases. Quantitative analysis of preoperative imaging parameters may help to more accurately assess the patient's pathological characteristics and potential risks. However, current research on the relationship between preoperative imaging parameters and the risk of reoperation is still limited, and relevant evidence is insufficient. Against this background, this study aims to retrospectively analyze a cohort of patients with LDD consecutively admitted to a teaching hospital, incorporating preoperative clinical characteristics and imaging measurements to assess their associations with the risk of reoperation and to identify factors relevant to preoperative risk assessment. By identifying potential high-risk factors, this study may provide a more objective basis for preoperative clinical decision-making, thereby optimizing patient management strategies and reducing the risk of reoperation.

Methods

Study Design and Patients

This study is a single-center retrospective cohort study. The study participants were patients with LDD who underwent surgical treatment at Nanchang Hongdu Hospital of Traditional Chinese Medicine Affiliated to Jiangxi University of Chinese Medicine between June 2018 and June 2022. All clinical data were obtained from the hospital's electronic medical record system, and imaging data were retrieved from the picture archiving and communication system (PACS). The study protocol followed the Declaration of Helsinki and was approved by the Ethics Committee of Nanchang Hongdu Hospital of Traditional Chinese Medicine Affiliated to Jiangxi University of Chinese Medicine (ethics approval number: KYKS-2026043). As this is a retrospective study, only previously anonymized medical records were extracted, so written informed consent from patients was waived. Inclusion criteria were: (1) age ≥18 years; (2) undergoing primary lumbar surgery for LDD (including lumbar disc herniation, lumbar spinal stenosis, degenerative spondylolisthesis, or degenerative scoliosis); and (3) having complete preoperative clinical baseline data and imaging examination data. Exclusion criteria were: (1) patients with non-degenerative diseases such as spinal infection, primary or metastatic spinal tumors, or acute spinal trauma; (2) patients with missing key preoperative imaging data or severely incomplete clinical data; (3) patients lost to follow-up or with a follow-up period of less than 36 months after surgery. Based on the above criteria, a total of 756 patients with LDD underwent surgical treatment at Nanchang Hongdu Hospital of Traditional Chinese Medicine Affiliated to Jiangxi University of Chinese Medicine between June 2018 and June 2022. After screening according to the exclusion criteria, 653 patients were ultimately included in the analysis. All included patients completed the 36-month follow-up and had complete follow-up records. The primary outcome measure was defined as patients who underwent lumbar surgery again during the follow-up period due to complications related to the index surgical segment, including recurrence, instability, or restenosis in the same segment. Reoperation events were identified through review of the hospital electronic medical

record system, outpatient follow-up records, and telephone interview records. For patients who reported undergoing reoperation at an outside institution, operative notes and discharge summaries were requested to confirm the indication and procedure. The indications for reoperation were adjudicated by two spine surgeons based on a review of clinical records and imaging studies. Reoperations for adjacent segment disease, wound infection, fusion-related complications (such as hardware failure or nonunion), or persistent pain without objective radiographic abnormalities were not included in the primary outcome definition. Based on whether the above endpoint events occurred during the 36-month follow-up period, the included patients were divided into a reoperation group and a non-reoperation group.

Data Collection

This study retrospectively extracted clinical data from all included patients through the hospital's electronic medical record system, image archiving and communication system and surgical database. General demographic information, such as age, sex, smoking history and body mass index of patients, was collected, and the type of lumbar degenerative disease (lumbar disc herniation, lumbar spinal stenosis, degenerative spondylolisthesis, or degenerative scoliosis) was recorded based on the primary surgical indication. The underlying disease status (cardiovascular disease, diabetes, digestive disease, lung disease and osteoporosis) was also recorded. Osteoporosis was diagnosed based on the World Health Organization's recommended criteria, with a bone mineral density T-score ≤ -2.5 as the diagnostic threshold [9]. In addition, the duration of symptoms and baseline pain intensity were recorded, with the latter assessed using the visual analog scale (VAS). The VAS uses a straight line about 10 cm long, with "0" and "10" marked at the two ends. "0" represents no pain and "10" represents the most severe pain that is unbearable. Patients marked the corresponding positions on the line according to their own pain level, and the physician measured the distance from the starting point to the marked point as the score [10]. Perioperative data included operation time, estimated intraoperative blood loss, surgical strategy (fusion/non-fusion), surgical technique (minimally invasive/open), surgical approach (anterior, posterior, or others). The "others" category included approaches that could not be clearly classified as purely anterior or posterior, such as combined or lateral approaches.

The imaging parameters were measured based on the patient's routine preoperative imaging examination. The evaluation indicators included the degree of intervertebral disc degeneration (Pfirrmann grade), the degree of paraspinal muscle fat infiltration (Goutallier grade), and the morphological characteristics of the facet joints (facet joint angles). Paraspinal muscle fat infiltration was assessed on axial T2-weighted MRI images at the index level. The multifidus and erector spinae muscles were evaluated bilaterally, and fatty infiltration was graded according to the Goutallier classification: grade 0, normal muscle without fat; grade 1, few fatty streaks within the muscle; grade 2, less fat than muscle within the muscle; grade 3, equal amounts of fat and muscle within the muscle; and grade 4, more fat than muscle within the muscle. The degree of intervertebral disc degeneration was evaluated using the Pfirrmann grading system, and Grade 3–4 and Grade 5 were classified separately for subsequent analysis [11]. Facet joint effusion was interpreted on axial T2-weighted magnetic resonance imaging (MRI) images. A joint capsule high-signal thickness >2 mm was used as the positive standard, and joint effusion was divided into three groups according to its distribution: no effusion, unilateral effusion, and bilateral effusion or synovial cyst [12]. Facet joint angles were measured on axial computed tomography (CT) or MRI images. The line connecting the posterior margins of the vertebral bodies was used as the reference line. The angle between the bilateral facet joint surfaces and the reference line was measured, and the mean of both sides was taken as the facet joint angle value of that segment [13]. The facet joint angles were categorized according to their deviation from the normal values for the corresponding lumbar levels into three groups: $\leq 10°$, $>10°$ to $\leq 20°$, and $>20°$. The normal reference values were derived from previously published data on asymptomatic individuals [10], and the deviation was calculated as the absolute difference between the measured angle and the segment-specific normal value. All imaging parameters were assessed at the operated segment. For patients who underwent single-level surgery, the index level was defined as the surgically treated segment. For those who underwent multi-level surgery, the index level was defined as the segment corresponding to the primary symptomatic level or the main decompression/fusion level as documented in the operative record. All measurements were performed independently by two spinal surgeons who were blinded to the patient's follow-up outcomes, and any discrepancies were resolved by consensus.

Statistical Analysis

All statistical analyses were performed using SPSS 24.0 (IBM Corp., Armonk, NY, USA) and R 4.2.2 (R Foundation for Statistical Computing, Vienna, Austria). First, the normality of continuous variables was assessed using the Shapiro–Wilk test to determine data distribution. Variables conforming to a normal distribution were expressed as the mean ± standard deviation, and differences between groups were compared using the independent samples *t*-test; variables not conforming to a normal distribution were expressed as the median and interquartile range [M (Q1, Q3)], and the Mann–Whitney U test was used. Categorical variables were expressed as number of cases and percentages, and the χ^2 test, continuity-corrected χ^2 test, or Fisher's exact test was applied as appropriate. Interobserver reliability for imaging measurements was assessed using the

intraclass correlation coefficient (ICC) for the continuous variable (facet joint angle) and weighted kappa (κ) for categorical variables (Pfirrmann grade, Goutallier grade, and facet joint effusion). Facet joint effusion was treated as an ordinal variable, with the categories ordered as no effusion, unilateral effusion, and bilateral effusion or synovial cyst, reflecting the increasing extent of facet joint involvement. Weighted kappa was used to account for the degree of disagreement between observers, with greater weight assigned to disagreements between adjacent categories than to disagreements between the most distant categories. To explore the factors associated with reoperation after surgery in patients with LDD, univariate logistic regression analysis was first performed. Variables with $p < 0.05$ in the univariate analysis were subsequently included in a multivariable logistic regression model, and backward stepwise regression was used to identify independent factors associated with postoperative reoperation. Before including variables in multivariable regression, multicollinearity was assessed for continuous and binary variables using the variance inflation factor (VIF). For categorical variables with more than two levels, the generalized variance inflation factor (GVIF) was used, and its adjusted value was calculated. A VIF/GVIF <5 was used as the criterion for excluding severe collinearity among candidate variables. Results were reported as Odds Ratios (ORs) and 95% Confidence Intervals (95% CIs). This study further used receiver operating characteristic (ROC) curves to assess the discriminative power of the above combination of independent factors for postoperative reoperation, and the area under the curve was calculated.

Results

Comparison of Clinical Data of Study Participants

This study included 653 patients who underwent surgery for LDD, with 612 in the non-reoperation group and 41 in the reoperation group, resulting in a reoperation rate of 6.28%. The interobserver reliability was excellent for all imaging parameters. The ICC for facet joint angle measurement was 0.92. The weighted kappa values were 0.88 for Pfirrmann grading, 0.85 for Goutallier classification, and 0.91 for facet joint effusion assessment. Baseline clinical data analysis showed statistically significant differences between the reoperation group and the non-reoperation group in age, preoperative VAS pain score, Pfirrmann grade, and facet joint effusion (all $p < 0.05$).

Other variables, including type of degenerative disease, body mass index, symptom duration, operation time, intraoperative blood loss, surgical strategy, surgical technique, surgical approach, gender, smoking history, cardiovascular disease, diabetes, digestive system disease, lung disease, osteoporosis, Goutallier classification, and facet joint angles, showed no statistically significant differences between the two groups (all $p > 0.05$; Table 1).

Results of Univariate Logistic Regression Analysis

With postoperative reoperation as the dependent variable, baseline variables were included in the univariate logistic regression analysis. The results showed that age, preoperative VAS score, Pfirrmann grade 5 (compared with grades 3–4), lumbar spinal stenosis (compared with degenerative scoliosis), Goutallier grade 3–4 (compared with grades 0–1), and unilateral facet joint effusion (compared with bilateral effusion or synovial cysts) were significantly associated with the risk of postoperative reoperation (all $p < 0.05$). Degenerative spondylolisthesis ($p = 0.062$), lumbar disc herniation ($p = 0.070$), Goutallier grade 2 ($p = 0.107$), and absence of facet joint effusion ($p = 0.286$) were not significantly associated with reoperation in the respective comparisons. Specifically, patients with Pfirrmann grade 5 had a significantly higher risk of reoperation than those with grades 3–4. Regarding facet joint effusion, patients with unilateral effusion had a significantly lower risk of reoperation compared with those with bilateral effusion or synovial cysts. The remaining variables, including sex, body mass index, smoking history, comorbidities, osteoporosis, surgical strategy, surgical technique, surgical approach, facet joint angle, duration of symptoms, operative time, and intraoperative blood loss, showed no statistically significant association with the risk of reoperation (all $p > 0.05$; Table 2).

Multivariable Logistic Regression Analysis

Variables with $p < 0.05$ in the univariate analysis were included in a multivariable logistic regression model, and independent factors associated with postoperative reoperation were screened using backward stepwise regression. The results of the multicollinearity assessment showed that the adjusted variance inflation factor (VIF) or generalized variance inflation factor for each variable was less than 5, indicating no significant multicollinearity among the included variables. The results showed that age, preoperative VAS score, Pfirrmann grade 5, and facet joint effusion were independent factors associated with postoperative reoperation for postoperative reoperation (all $p < 0.05$). After adjusting for other factors, increased age was significantly associated with increased reoperation risk; higher preoperative VAS scores were associated with greater reoperation risk; patients with Pfirrmann grade 5 had a significantly increased reoperation risk compared to those with grades 3–4; regarding facet joint effusion, the reoperation risk was significantly lower in patients with unilateral effusion compared to those with bilateral effusion or synovial cysts (Table 3).

Discriminative Ability of Combined Independent Factors for Postoperative Reoperation Risk

A receiver operating characteristic (ROC) curve was used to assess the discriminative ability of the combination of independent factors for postoperative reoperation. The re-

Table 1. Comparison of baseline clinical data between the two groups of patients.

Variables	Non-reoperation group (n = 612)	Reoperation group (n = 41)	Statistic	*p*
Age (years)	53.22 (44.65, 60.74)	62.27 (54.19, 69.25)	Z = –4.67	<0.001
BMI (kg/m^2)	24.45 (21.94, 26.18)	24.23 (20.96, 26.34)	Z = –0.40	0.687
Duration of symptoms (years)	8.16 (5.16, 11.67)	7.72 (5.90, 10.35)	Z = –0.73	0.464
Operation time (min)	67.00 (50.00, 122.25)	61.00 (47.00, 80.00)	Z = –1.38	0.167
Blood loss (mL)	103.50 (53.48, 156.40)	110.50 (60.00, 133.90)	Z = –0.05	0.964
VAS	4.70 (3.44, 6.36)	7.00 (4.79, 8.19)	Z = –5.17	<0.001
Type of degenerative disease, n (%)			—	0.178
Degenerative scoliosis	12 (1.96)	3 (7.32)		
Degenerative spondylolisthesis	101 (16.50)	6 (14.63)		
Lumbar disc herniation	251 (41.01)	18 (43.90)		
Lumbar spinal stenosis	248 (40.52)	14 (34.15)		
Surgical strategy, n (%)			χ^2 = 0.02	0.895
Fusion surgery	170 (27.78)	11 (26.83)		
Non-fusion surgery	442 (72.22)	30 (73.17)		
Surgical technique, n (%)			χ^2 = 1.77	0.184
Minimally invasive	450 (73.53)	34 (82.93)		
Open surgery	162 (26.47)	7 (17.07)		
Surgical approach, n (%)			χ^2 = 0.23	0.890
Anterior approach	116 (18.95)	9 (21.95)		
Others	14 (2.29)	1 (2.44)		
Posterior approach	482 (78.76)	31 (75.61)		
Gender, n (%)			χ^2 = 1.44	0.229
Female	400 (65.36)	23 (56.10)		
Male	212 (34.64)	18 (43.90)		
Smoking history, n (%)			χ^2 = 0.09	0.765
No	404 (66.01)	28 (68.29)		
Yes	208 (33.99)	13 (31.71)		
Cardiovascular disease, n (%)			χ^2 = 0.71	0.398
No	272 (44.44)	21 (51.22)		
Yes	340 (55.56)	20 (48.78)		
Diabetes, n (%)			χ^2 = 1.36	0.243
No	492 (80.39)	36 (87.80)		
Yes	120 (19.61)	5 (12.20)		
Digestive system diseases, n (%)			χ^2 = 1.41	0.236
No	520 (84.97)	32 (78.05)		
Yes	92 (15.03)	9 (21.95)		
Lung diseases, n (%)			χ^2 = 1.41	0.235
No	578 (94.44)	41 (100.00)		
Yes	34 (5.56)	0 (0.00)		
Osteoporosis, n (%)			χ^2 = 0.06	0.814
No	516 (84.31)	34 (82.93)		
Yes	96 (15.69)	7 (17.07)		
Pfirrmann, n (%)			χ^2 = 8.59	0.003
Grade 3–4	278 (45.42)	9 (21.95)		
Grade 5	334 (54.58)	32 (78.05)		
Goutallier, n (%)			χ^2 = 4.43	0.109
Grade 0–1	38 (6.21)	6 (14.63)		
Grade 2	166 (27.12)	11 (26.83)		
Grade 3–4	408 (66.67)	24 (58.54)		
Effusion, n (%)			χ^2 = 21.85	<0.001
Bilateral effusion or synovial cysts	364 (59.48)	36 (87.80)		
No	22 (3.59)	4 (9.76)		

Table 1. Continued.

Variables	Non-reoperation group (n = 612)	Reoperation group (n = 41)	Statistic	*p*
Unilateral	226 (36.93)	1 (2.44)		
Facet angulation, n (%)			—	0.698
>10 to ≤20 difference from normal	70 (11.44)	3 (7.32)		
>20 difference from normal	4 (0.65)	0 (0.00)		
≤10 difference from normal	538 (87.91)	38 (92.68)		

BMI, body mass index; VAS, visual analog scale; "—" indicates that Fisher's exact test was used.

sults showed an area under the curve (AUC) of 0.89 (0.84–0.94), indicating good discriminative power. When the Youden index reached its maximum value, the sensitivity was 78.0%, the specificity was 86.0%, and the cutoff value was 0.11 (Fig. 1).

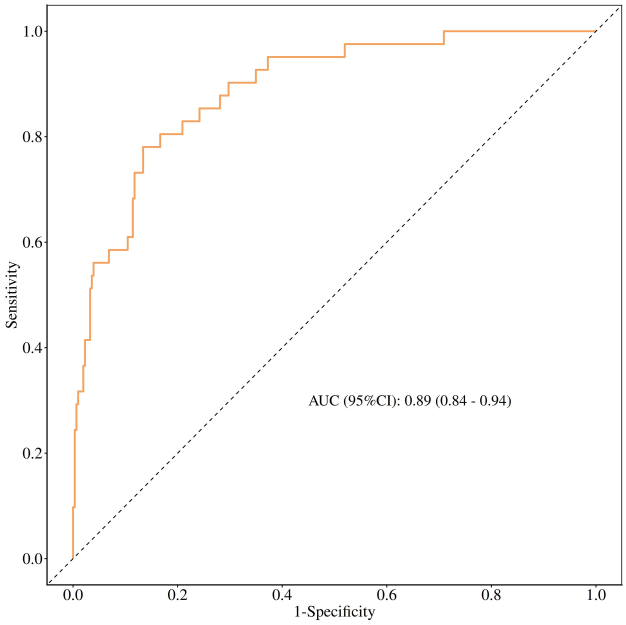


Fig. 1. ROC curves for discriminating postoperative reoperation using combinations of independent factors. AUC, area under the curve; ROC, receiver operating characteristic.

Discussion

While surgical treatment for LDD can effectively relieve symptoms, some patients still require reoperation for various reasons. This study retrospectively analyzed the clinical and imaging data of 653 patients and found that age, preoperative pain intensity, intervertebral disc degeneration grade, and facet joint effusion were associated with the risk of reoperation. These factors are all routinely obtainable preoperative indicators, suggesting that comprehensive evaluation before surgical decision-making may have practical clinical value.

Age is one of the factors associated with reoperation, and the underlying mechanism may be understood in the context of the natural course of spinal degeneration. With increasing age, the proteoglycan content of the intervertebral disc gradually decreases, along with its hydrophilicity, leading to water loss in the nucleus pulposus and reduced elasticity of the annulus fibrosus [2]. The decrease in intervertebral disc height and the weakening of load-bearing capacity result in a significant increase in the load on the posterior facet joints, followed by degenerative remodeling [14]. These cascading structural changes together weaken the stability of the spinal motion segment. At the same time, age-related declines in bone quality and soft tissue repair capacity may further complicate postoperative recovery in older patients [14]. In this study, the median age of patients in the reoperation group was significantly higher than in the non-reoperation group, and this trend remained independent in the multivariable analysis. It is worth noting that age itself is not a contraindication to surgery, but rather suggests that for elderly patients, the surgical benefits and long-term reintervention risks should be more carefully weighed before surgery. The study by Noh et al. [15] also showed that age is an important risk factor for reoperation after lumbar spine surgery, which is consistent with the findings of the present study.

Preoperative pain severity also showed a stable association with reoperation risk in this study. Patients with higher VAS scores may have severe nerve root compression or a wider range of degenerative lesions, and may already have advanced degenerative changes at the time of initial surgery. Although simple decompression can temporarily relieve neural compression, if the structural basis causing the pain is not completely corrected, or if there is potential instability in adjacent segments, the probability of long-term symptom recurrence may increase. Therefore, preoperative pain assessment is not only a quantification of symptom severity, but also an indirect indicator of disease burden. Imaging parameters provided an important objective assessment dimension for this study. In this study, the proportion of Pfirrmann grade 5 in the reoperation group was significantly higher than in the non-reoperation group, and multivariable analysis showed that high-grade degeneration was an independent risk factor for reoperation. Severely degenerated intervertebral discs have lost their normal biomechanical buffering function, and stress distribution in the affected and adjacent segments may become further imbalanced after surgery, thereby promoting the progression of degeneration [16,17]. This finding suggests that patients

Table 2. Univariate logistic regression analysis of factors associated with postoperative reoperation.

Variables	β	S.E	Z	*p*	OR (95% CI)
Surgical strategy					
Fusion surgery					1.00 (Reference)
Non-fusion surgery	0.05	0.36	0.13	0.896	1.05 (0.51 ~ 2.14)
Type of degenerative disease, n (%)					
Degenerative scoliosis					1.00 (Reference)
Degenerative spondylolisthesis	–1.44	0.77	–1.87	0.062	0.24 (0.05 ~ 1.08)
Lumbar disc herniation	–1.25	0.69	–1.81	0.070	0.29 (0.07 ~ 1.11)
Lumbar spinal stenosis	–1.49	0.70	–2.12	0.034	0.23 (0.06 ~ 0.89)
Surgical technique					
Minimally invasive					1.00 (Reference)
Open surgery	–0.56	0.42	–1.31	0.189	0.57 (0.25 ~ 1.32)
Surgical approach					
Anterior approach					1.00 (Reference)
Others	–0.08	1.09	–0.08	0.940	0.92 (0.11 ~ 7.82)
Posterior approach	–0.19	0.39	–0.48	0.633	0.83 (0.38 ~ 1.79)
Gender					
Female					1.00 (Reference)
Male	0.39	0.33	1.20	0.232	1.48 (0.78 ~ 2.80)
Smoking history					
No					1.00 (Reference)
Yes	–0.10	0.35	–0.30	0.765	0.90 (0.46 ~ 1.78)
Cardiovascular disease					
No					1.00 (Reference)
Yes	–0.27	0.32	–0.84	0.400	0.76 (0.40 ~ 1.43)
Diabetes					
No					1.00 (Reference)
Yes	–0.56	0.49	–1.15	0.248	0.57 (0.22 ~ 1.48)
Digestive system diseases					
No					1.00 (Reference)
Yes	0.46	0.39	1.18	0.239	1.59 (0.73 ~ 3.44)
Lung diseases					
No					1.00 (Reference)
Yes	–14.92	678.48	–0.02	0.982	0.00 (0.00 ~ Inf)
Osteoporosis					
No					1.00 (Reference)
Yes	0.10	0.43	0.24	0.814	1.11 (0.48 ~ 2.57)
Pfirrmann					
Grade 3–4					1.00 (Reference)
Grade 5	1.08	0.39	2.81	0.005	2.96 (1.39 ~ 6.31)
Goutallier					
Grade 0–1					1.00 (Reference)
Grade 2	–0.87	0.54	–1.61	0.107	0.42 (0.15 ~ 1.21)
Grade 3–4	–0.99	0.49	–2.03	0.043	0.37 (0.14 ~ 0.97)
Effusion					
Bilateral effusion or synovial cysts					1.00 (Reference)
No	0.61	0.57	1.07	0.286	1.84 (0.60 ~ 5.63)
Unilateral	–3.11	1.02	–3.05	0.002	0.04 (0.01 ~ 0.33)
Facet angulation					
10 to ≤20 difference from normal					1.00 (Reference)
>20 difference from normal	–12.42	727.70	–0.02	0.986	0.00 (0.00 ~ Inf)
≤10 difference from normal	0.50	0.61	0.81	0.415	1.65 (0.50 ~ 5.48)
Age	0.07	0.02	4.77	<0.001	1.08 (1.04 ~ 1.11)

Table 2. Continued.

Variables	β	S.E	Z	*p*	OR (95% CI)
BMI	–0.01	0.05	–0.29	0.773	0.99 (0.89 ~ 1.09)
Duration of symptoms	–0.02	0.04	–0.58	0.564	0.98 (0.90 ~ 1.06)
Surgical duration	–0.00	0.00	–1.55	0.121	1.00 (0.99 ~ 1.00)
Blood loss	–0.00	0.00	–0.21	0.836	1.00 (1.00 ~ 1.00)
VAS	0.49	0.09	5.28	<0.001	1.64 (1.36 ~ 1.96)

OR, Odds Ratio; CI, Confidence Interval; S.E, Standard Error.

Table 3. Multivariable logistic regression analysis of factors associated with postoperative reoperation.

Variables	β	S.E	Z	*p*	VIF/GVIF	OR (95% CI)
Pfirrmann					1.008	
Grade 3–4						1.00 (Reference)
Grade 5	1.26	0.43	2.91	0.004		3.52 (1.51 ~ 8.21)
Effusion					1.018	
Bilateral effusion or synovial cysts						1.00 (Reference)
No	0.51	0.66	0.77	0.441		1.67 (0.45 ~ 6.13)
Unilateral	–3.50	1.05	–3.35	<0.001		0.03 (0.00 ~ 0.23)
Age	0.10	0.02	4.92	<0.001	1.005	1.11 (1.06 ~ 1.15)
VAS	0.60	0.11	5.63	<0.001	1.001	1.82 (1.48 ~ 2.23)

OR, Odds Ratio; CI, Confidence Interval; VIF, ariance inflation factor; GVIF, generalized variance inflation factor.

with significant loss of intervertebral disc height or severe signal reduction on preoperative imaging should be alert to the possibility of postoperative symptom recurrence or new structural problems. Tang's team [18] also reported that higher preoperative Pfirrmann grades were associated with a higher reoperation rate in patients undergoing percutaneous endoscopic lumbar discectomy.

Facet joint effusion has received increasing attention in recent years as an imaging marker of segmental instability [19]. This study found that the distribution of facet joint effusion was significantly associated with the risk of reoperation after surgery. Compared with unilateral effusion, patients with bilateral effusion or synovial cysts had a significantly higher risk of reoperation. From a biomechanical perspective, bilateral effusion or cyst formation usually indicates more severe facet joint capsule laxity and more significant segmental mobility abnormalities, whereas unilateral effusion may reflect a localized inflammatory response or early degenerative changes, with a relatively limited degree of instability [20,21]. However, the markedly low odds ratio for unilateral effusion should be interpreted with caution, as only one patient in the reoperation group had unilateral effusion. This small number of events may render the effect estimate unstable, and the protective association of unilateral effusion requires validation in larger cohorts. The study by Dimitriou et al. [22] suggested that facet joint effusion is associated with poor treatment outcomes after lumbar spine surgery. This result also reminds clinicians to pay attention to the distribution characteristics of facet joint effusion when reading images, which may help to more accurately identify unstable segments. These findings, taken together, suggest that preoperative imaging features may be integrated with clinical characteristics to inform surgical planning for LDD. Recent evidence has highlighted that in patients with complex degenerative spinal stenosis, specific imaging markers such as advanced disc degeneration and facet joint effusion may help identify individuals at elevated risk for adverse postoperative outcomes [23]. Incorporating these imaging parameters into preoperative risk stratification, together with patient age and symptom severity, could assist surgeons in determining the optimal surgical strategy, including the extent of decompression, the need for fusion, and the intensity of postoperative surveillance. Such an individualized approach, informed by both clinical and radiological risk profiles, may contribute to reducing reoperation rates and improving long-term outcomes in this population. In this study, some clinical factors such as gender, body mass index and comorbidities did not show statistical differences between the two groups. This may be related to the baseline characteristics of this patient group and also suggests that, for the specific outcome of postoperative reoperation for lumbar degenerative disease, the degree of structural degeneration reflected by imaging may provide additional information for assessing the risk of reoperation when considered alongside demographic and clinical factors. Surgical parameters such as fusion status and surgical technique (minimally invasive vs. open) were not significantly associated with the risk of reoperation in this study. This does not mean that the aforementioned factors lack clinical value, but rather that greater weight should be given to objective indicators that directly reflect the extent of spinal degeneration during comprehen-

sive evaluation. The probability threshold derived from the ROC analysis may serve as a reference for identifying patients at elevated risk of reoperation in the current cohort. For patients with a predicted probability above this threshold, closer postoperative surveillance could be considered to facilitate early detection of recurrent symptoms or structural deterioration. However, this threshold should not be interpreted as a rigid criterion for clinical decision-making, as it was derived from a single-center retrospective cohort without external validation.

This study has several limitations. The AUC reported in this study was derived from the same dataset used for model development without internal validation such as bootstrapping or cross-validation, and may therefore overestimate the discriminative performance when applied to external populations. However, the primary aim of this study was to identify risk factors rather than to develop a clinical prediction tool, and the AUC was reported to provide a descriptive summary of the combined discriminative ability of the identified factors. The single-center retrospective design makes it difficult to eliminate selection bias, while the limited sample size and small number of events in some subgroups may affect the stability of effect estimates. Although the interobserver reliability for imaging measurements was excellent in this study, all assessments were performed by two surgeons from the same institution, which may reflect shared training and interpretation habits. Future studies involving independent readers from multiple centers would further strengthen the generalizability of these imaging-based predictors. Although all patients completed the 36-month follow-up, some reoperations performed at outside institutions may not have been fully captured if patients did not report them during follow-up contacts or if relevant records could not be obtained. Future multicenter prospective cohort studies incorporating more comprehensive biomechanical parameters and postoperative rehabilitation information may help further elucidate the mechanisms underlying reoperation.

Conclusions

In conclusion, the results of this study suggest that age, preoperative pain intensity, disc degeneration grade, and facet joint effusion may be significantly associated with the risk of reoperation after lumbar degenerative disease. Patients with these characteristics may warrant more attention during preoperative evaluation and postoperative follow-up. Given the exploratory nature of this single-center analysis, the generalizability of these findings remains to be established in larger, multicenter cohorts.

Availability of Data and Materials

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions

JJ and ZQT designed the research study. JJ, JX and LBX performed the research. ZQT, LDZ and JX analyzed the data. JJ and LBX drafted the article. All authors contributed to the critical revision of the manuscript for important intellectual content. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

The study protocol followed the Declaration of Helsinki and was approved by the Ethics Committee of Nanchang Hongdu Hospital of Traditional Chinese Medicine Affiliated to Jiangxi University of Chinese Medicine (approval number: KYKS-2026043). As this was a retrospective study involving only anonymized medical records, the requirement for written informed consent was waived by the Ethics Committee.

Acknowledgment

Not applicable.

Funding

This research received no external funding.

Conflict of Interest

The authors declare no conflict of interest.

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