Retrospective Study

Development and Validation of a Prognostic Model for the Risk of Recurrent Lumbar Disc Herniation After Percutaneous Endoscopic Transforaminal Discectomy

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Background: Recurrence of lumbar disc herniation (LDH) is an adverse event after percutaneous endoscopic transforaminal discectomy (PETD). Accurate prediction of the risk of recurrent LDH (rLDH) after surgery remains a major challenge for spine surgeons.

Objectives: To develop and validate a prognostic model based on risk factors for rLDH after PETD.

Study Design: Retrospective study.

Setting: Inpatient surgery center.

Methods: Clinical data were retrospectively collected from 645 patients with LDH who underwent PETD at the Affiliated Hospital of Xuzhou Medical University from January 1, 2017 to January 1, 2021. Predictors significantly associated with rLBH were screened according to least absolute shrinkage and selection operator (LASSO) regression, and a prognostic model was established, followed by internal model validation using the enhanced bootstrap method. The performance of the model was assessed using receiver operating characteristic (ROC) curves and calibration curves. Finally, the clinical usefulness of the model was analyzed using decision curve analysis (DCA) and clinical impact curves (CICs).

Results: Among the 645 patients included in this study, 56 experienced recurrence of LDH after PETD (8.7%). Seven factors significantly associated with rLDH were selected by LASSO regression, including age, type of herniation, level of herniation, Modic changes, Pfirrmann classification, smoking, and history of high-intensity physical work. The bias-corrected curve of the model fit well with the apparent curve, and the area under the ROC curve was 0.822 (95% confidence interval, 0.76-0.88). The DCA and CIC confirmed that the prognostic model had good clinical utility.

Limitations: This is a single-center study, and we used internal validation only.

Conclusions: The prognostic model developed in this study had excellent comprehensive performance and could well predict the risk of rLDH after PETD. This model could be used to identify patients at high risk for rLDH at an early stage to individualize the patient's treatment modality and postoperative rehabilitation plan.

Key words: Recurrent lumbar disc herniation, prognostic model, percutaneous endoscopic transforaminal discectomy, individualized treatment

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With the aging of the population and increases in work stress in recent years, lumbar disc herniation (LDH) has become increasingly common in clinical work (1,2). At the individual level, patients experience leg pain with sensory or motor loss, leading to impairment or even disability in activities of daily living. At the societal level, LDH imposes a significant economic burden on society due to costs associated with sick leave and hospitalization (3,4). Most LDHs can be resolved by conservative treatment, but if this cannot provide effective relief, symptomatic LDHs should be treated surgically. With surgery, an important area of uncertainty is the accurate prediction of the risk of recurrent LDH (rLDH) after surgery.

Percutaneous endoscopic transforaminal discectomy (PETD) is a minimally invasive spine surgery that involves removal of the herniated disc, hypertrophic ligamentum flavum, hyperplastic tuberosity, and bony bulge and enlarges the intervertebral foramen, lateral saphenous fossa, and even the central canal. Currently, PETD is a routine, minimally invasive surgical procedure for the treatment of LDH. However, some patients continue to be unsatisfied with the postoperative outcome because of rLDH (5), defined as a DH in the same segment after initial discectomy with a recurrence interval of more than 6 months (6). Previous studies (7-9) have shown that the incidence of postoperative rLDH varies from 3% to 11%, making rLDH an important issue that spine surgeons need to address. In previous retrospective studies (10,11), researchers have reported several possible risk factors, including advanced age, gender, obesity, diabetes, smoking, discitis, and degree of disc degeneration, for rLDH. However, to date, there are no reports of any predictive models using least absolute shrinkage or selection operator (LASSO) regression to screen for rLDH risk factors.

This retrospective study was performed to analyze the clinical and imaging data of patients who underwent PETD, and age, type of herniation, level of herniation, Modic changes, Pfirrmann classification, smoking, and history of high-intensity physical work were screened as predictors. The prediction model was established based on the 7 predictors, and the results of internal validation showed that the model has excellent comprehensive performance and can well predict the risk of rLDH after PETD in a high-risk group at an early stage in order to individualize both the treatment modality and postoperative rehabilitation plan of the patients, thus effectively preventing the recurrence of LDH after surgery and promoting the functional recovery of patients. Moreover, health care costs are reduced.

This report was drafted in accordance with the Transparent Reporting of a Multivariate Prediction Rule for Individual Prognosis or Diagnosis guidelines. Additional details are presented in the Supplementary Material.

Methods

Patient Selection

We collected clinical data of 782 patients diagnosed with LDH and treated with PETD between January 1, 2017 and January 1, 2021.

The inclusion criteria were as follows: (1) diagnosis of single-segment LDH based on clinical presentation and imaging data; (2) complete imaging data, including x-ray, computed tomography, and magnetic resonance imaging (MRI); (3) no contraindications to surgery and obvious surgical indications; and (4) postoperative follow-up lasting more than 1 year.

The exclusion criteria were as follows: (1) previous open lumbar spine surgery; (2) severe liver and kidney dysfunction, coagulation dysfunction, or mental disorders; (3) LDH due to lumbar instability, lumbar spondylolisthesis, or idiopathic scoliosis; or (4) incomplete clinical data or loss to follow-up.

We eventually included 645 patients for the construction of the prognostic model. All surgeries were performed by the same group of experienced and highly qualified chief surgeons. All patients were informed about the steps of the procedure and signed the Informed Consent Form for Surgery. This study was approved by the Institutional Ethics Committee of the Affiliated Hospital of Xuzhou Medical University.

Data Collection

Basic patient information, general information, and follow-up records were retrospectively collected using the Xuzhou Medical University Hospital medical record system. An image archiving and communication system was used to collect patient imaging information.

Specifically, patient gender, age, body mass index (BMI), preoperative Visual Analog Scale (VAS) score, type of herniation, level of herniation, disease duration, Modic changes, Pfirrmann classification, smoking, alcohol consumption, diabetes, hypertension, and history of high-intensity physical work were included. A history of high-intensity physical work was defined as work with a physical work intensity classification (GB 3869-1997) greater than grade III.

Patient Grouping

The patients were divided into rLDH and nonrLDH groups according to whether LDH recurred after PETD. The rLDH was diagnosed mainly by clinical manifestations and imaging data. The clinical manifestations are remission for more than a few weeks after PETD, followed by clinical symptoms dominated by neurogenic pain.

Statistical Analysis

Analyses were performed using R® (version 4.0.3). Unlike in randomized controlled trial studies, there is no clear standard for calculating the sample size for prognostic models. In this paper, we used the "pmsampsize" package in R 4.0.3 for the 4-step sample size calculation. The sample size for the prediction study was calculated from each of the 4 aspects, and the largest sample size was finally taken as the final sample size.

Data were compiled according to patients' gender, age, BMI, preoperative VAS score, location of medullary prominence, level of herniation, disease duration, Modic changes, Pfirrmann classification, smoking, history of alcohol consumption, history of diabetes mellitus, history of hypertension, history of high-intensity physical work, and postoperative recurrence and were statistically analyzed using SPSS Version 26.0 (IBM Corporation, Armonk, NY). Count data are presented in the form of numbers and percentages. Measurement data are expressed as the mean ± standard deviation. The t test was used for comparisons between groups for normally distributed measurement data, and the Mann-Whitney U test was used for nonnormally distributed measurement data. The χ^2 test was used for the comparison between groups for count data. $P < 0.05$ was considered to indicate a significant difference.

LASSO regression analysis was performed with the "glmnet" package for variable selection. A multifactorial logistic regression analysis was performed using the "gtsummary" package in R 4.0.3, with the occurrence of rLDH after PETD as the dependent variable and risk factors as independent variables. The predictors selected by the LASSO regression analysis were incorporated into the prognostic model for rLDH recurrence after percutaneous endoscopic lumbar discectomy, developed with the "rms" package in R 4.0.3. The calibration curve and receiver operating characteristic (ROC) curve were plotted using the enhanced bootstrap method for internal validation. The area under the curve (AUC) and calibration curve were used to evaluate the model performance.

The prognostic model developed in this study cannot be easily used in the clinic due to the complexity of its calculations, so we generated a nomogram in R for routine use.

Decision curve analysis (DCA) and clinical impact curve (CIC) plotting were performed with the "rmda" package to calculate the net benefit of predicting rLDH after PETD with different threshold probabilities and to confirm the clinical utility of the model.

Results

Sample Size Calculation

The sample size was calculated in 4 steps in R using the "pmsampsize" package, and the results are shown in Table 1. The final calculated sample size we need is 516.

Patient Characteristics

A total of 645 patients diagnosed with single-segment LDHs and treated with PETD were included, with a mean age of 48.55 ± 11.17 years. Among them, 56 patients experienced rLDHs after PETD, with an incidence of 8.7%.

The mean follow-up time in this study was 24.21 ± 8.22 months. We compared the baseline information and associated rLDH risk factors between the 2 groups and found that Modic changes ($P < 0.001$) and the Pfirrmann classification ($P = 0.024$) had a significant effect on the incidence of rLDH. Smoking and history of high-intensity physical work were also significantly different between the 2 groups, with P values < 0.001 and 0.010, respectively.

Table 1. *Sample size calculation.*

	Sample_Size	Shrinkage	Parameter	Rsq	Max_Rsq	Nag_Rsq	EPP
Criteria 1	364	0.900	14	0.288	0.454	0.634	2.34
Criteria 2	516	0.927	14	0.288	0.454	0.634	3.32
Criteria 3	126	0.927	14	0.288	0.454	0.634	0.81
Final	516	0.927	14	0.288	0.454	0.634	3.32

Abbreviations: Rsq, R-squared; Max Rsq, maximum R-squared; Nag Rsq, Nagelkerke R-squared; EPP, endplate perforation.

In contrast, gender, age, level of herniation, BMI, preoperative VAS score, duration of disease, alcohol consumption, diabetes, and hypertension did not differ significantly between the 2 groups ($P > 0.05$).

The descriptive statistical comparisons of the clinical data and associated risk factors between the 2 groups are shown in Table 2.

Table 2. *Comparison of the clinical data and associated risk factors between the 2 groups.*

Characteristic	rLDH (56/645)	nonrLDH (589/645)	*P* value
Gender			0.947
Women, n	26	293	
Men, n	30	296	
Age (y)	51.82 ± 15.19	48.32 ± 11.26	0.112
< 45, n	8	128	
≥ 45, n	25	204	
BMI (kg/m^2)	24.15 ± 2.53	23.83 ± 2.58	0.446
Preoperative VAS score	5.88 ± 1.78	5.36 ± 2.38	0.298
1, n	2	35	
2, n	9	195	
3, n	13	119	
4, n	13	31	
5, n	4	38	
6, n	11	41	
7, n	4	61	
8, n	0	34	
9, n	0	35	
Type of Herniation			0.926
Central, n	4	50	
Paracentral, n	26	360	
Lateral or Extreme Lateral, n	11	179	
Level of Herniation			0.250
L2/L3, n	4	6	
L3/L4, n	6	22	
L4/L5, n	29	412	
L5/S1, n	17	149	
Disease Duration (mo)	7.33 ± 2.13	7.07 ± 2.01	0.216
Modic Changes			< 0.001
0, n	12	366	
1, n	11	60	
2, n	33	163	
Pfirrmann Classification			0.024
III, n	24	172	
IV, n	29	352	

LASSO Regression Analysis

Fourteen predictor variables, including patient gender, age, BMI, preoperative VAS score, type of herniation, level of herniation, disease duration, Modic changes, Pfirrmann classification, smoking, alcohol consumption, diabetes, hypertension, and history of high-intensity physical work, were included in the LASSO regression model to select predictors associated with rLDH. A total of 19 predictors were included in the LASSO regression analysis because of the classification of some of the included predictors. After the LASSO regression analysis, a total of 12 risk factors were eliminated. The remaining 7 predictors were age, type of herniation, level of herniation, Modic changes, Pfirrmann classification, smoking, and history of high-intensity physical work. When the partial likelihood deviation reaches the minimum value, it indicates that the model obtains the best performance with 7 predictors, as shown in Fig. 1.

Multivariate Logistic Regression Analysis

Multivariate logistic regression analysis showed that age, type of herniation, level of herniation, Modic changes, Pfirrmann classification, smoking, and history

Table 2 (cont). *Comparison of the clinical data and associated risk factors between the 2 groups.*

Characteristic	rLDH (56/645)	nonrLDH (589/645)	*P* value
V, n	3	65	
Smoking			< 0.001
No, n	27	396	
Yes, n	29	193	
Alcohol Consumption			0.761
No, n	38	377	
Yes, n	18	212	
Diabetes			0.636
No, n	52	535	
Yes, n	4	54	
Hypertension			0.780
No, n	39	401	
Yes, n	17	188	
History of High-Intensity Physical Work			0.010
No, n	39	506	
Yes, n	17	83	

Abbreviations: rLDH, recurrent lumbar disc herniation; nonrLDH, nonrecurrent lumbar disc herniation; n, number; y, year(s); BMI, body mass index; VAS, visual analog scale; mo, month(s).

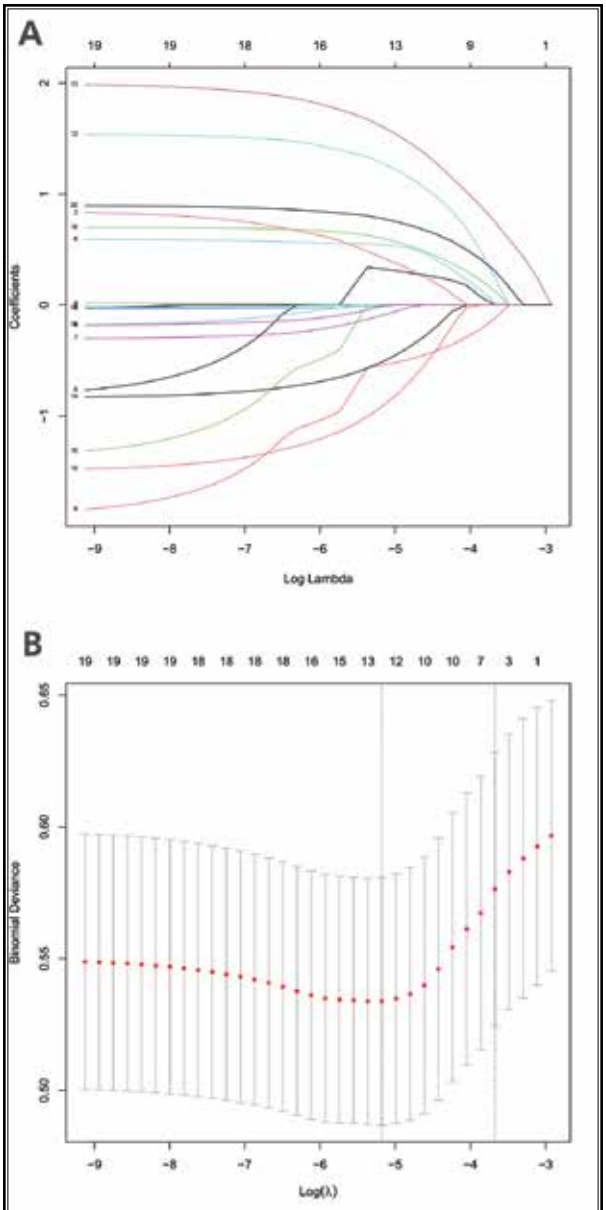

Fig. 1. *The rLDH variable selection with LASSO regression.*

of high-intensity physical work were independent predictors of rLDH, as shown in Table 3.

Development of the Prognostic Model

After 1,000 rounds of enhanced bootstrap validation, the calibration curves of the prognostic model were plotted. The apparent curves of the model fit well with the bias-corrected curves, indicating that the prognostic model fit well to the actual data (Fig. 2A). After 1,000 bootstrap resamplings, the AUC of the prognostic model was 0.822 (95% confidence interval, 0.76 to 0.88), demonstrating the good discriminability of the model (Fig. 2B).

Table 3. *Multivariate logistic regression analysis for the risk factors for rLDH.*

Characteristic	Odds Ratio	95% Confidence Interval	*P* value
Age (y)			
< 45	-	-	REF
≥ 45	2.17	1.12, 4.43	0.026
Type of Herniation			
Central	-	-	REF
Paracentral	2.41	1.27, 4.62	0.007
Lateral or Extreme Lateral	1.39	0.37, 4.13	0.6
Level of Herniation			
L2/L3	-	-	REF
L3/L4	0.44	0.07, 2.80	0.4
L4/L5	0.15	0.03, 0.74	0.016
L5/S1	0.26	0.05, 1.33	0.1
Modic Changes			
0	-	-	REF
1	4.60	1.81, 11.6	0.001
2	7.30	3.58, 15.9	< 0.001
Pfirrmann Classification			
III	-	-	
IV	0.42	0.21, 0.81	0.010
V	0.21	0.05, 0.50	0.021
Smoking			
No	-	-	REF
Yes	2.06	1.12, 3.81	0.020
History of High-Intensity Physical Work			
No	-	-	REF
Yes	2.44	1.19, 4.88	0.013

Abbreviations: y, year(s); REF, reference standard.

Visualization of the Prognostic Model

The prognostic model was visualized using R to predict the risk of rLDH (Fig. 3).

Clinical Utility of the Prognostic Model

DCA and CIC plotting are widely used methods for assessing the clinical utility of prognostic models. The DCA curve shows that a threshold of 0.12-0.81 has the greatest net clinical benefit, as shown in Fig. 4A.

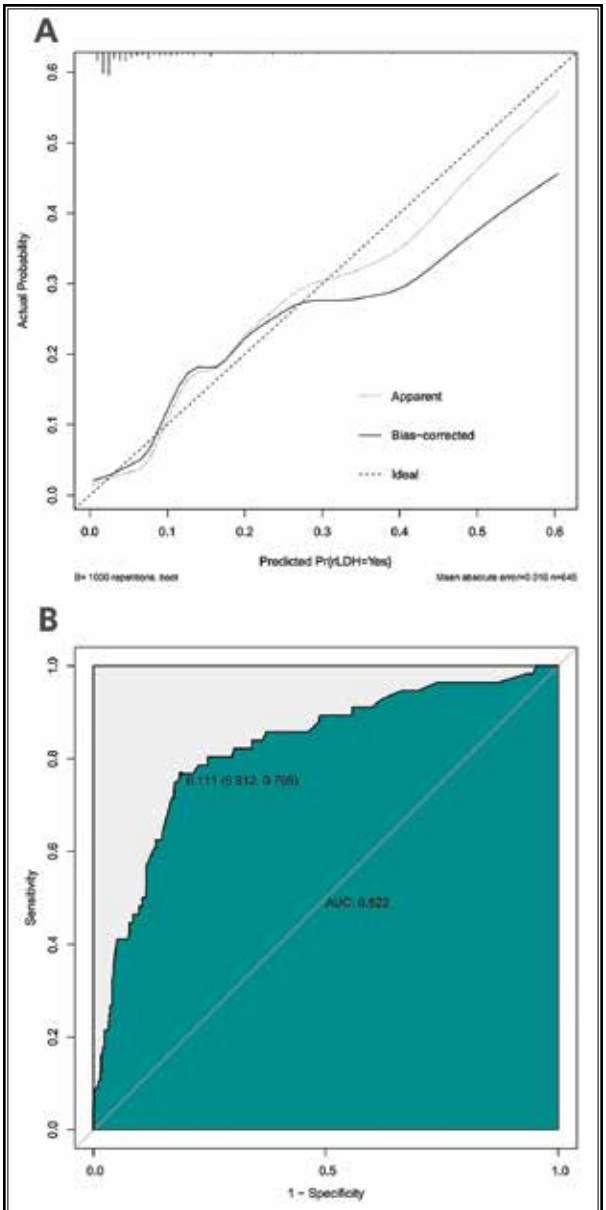

Fig. 2. *Calibration plot and ROC curve of the prognostic model.*

A simulation using the prognostic model predicted the risk stratification for 1,000 people, shown on the "loss:benefit" axis in Fig. 4B. The red curve shows the number of people classified as high risk by the model at each threshold probability; the blue curve shows the true number of people at each threshold probability of the event. The CICs (Fig. 4B) also show that within the threshold probabilities, there are always more expected recurrences than actual recurrences.

Discussion

PETD allows patients to get out of bed and perform functional exercises as early as possible after surgery, reducing the incidence of the multiple complications caused by long-term bed rest and improving the patient's quality of life (12-14). However, any new clinical technique is often accompanied by a series of unique complications. Minimally invasive, nonfusion-based PETD has a number of postoperative complications, including postoperative LDH recurrence, nerve root injury, and dural tears (15). Because rLDH not only increases patient suffering but also increases their financial burden, it has been the subject of several previous studies (6,9,16). LASSO regression selected age, location of nucleus pulposus prominence, surgical segment, Modic changes, Pfirrmann classification, smoking, and history of high-intensity physical work as predictors to build a prognostic model for rLDH, which was then visualized with a nomogram that can be used to predict the probability of LDH recurrence.

Among the predictors screened by LASSO regression, advanced age is often considered a risk factor for rLDH (16). Kim et al (17) reported advanced age as an independent risk factor for rLDH. The results of a meta-analysis study on risk factors associated with rLDH showed that the recurrence rate of LDH was higher in elderly patients (4.3%) than in younger people (2.7%) (8). Given that elderly patients often have severe disc degeneration, circumferential incision during surgery can make the remaining nucleus pulposus fragments more susceptible to prolapse due to mechanical overload. The discs of older individuals are often accompanied by changes and tears in the fibrous annulus that make the disc more susceptible to deformation, which subsequently leads to ineffective healing of the outer fibrous annulus after PETD. When dealing with patients of advanced age, conservative treatment options are often a reasonable solution.

This study shows that rLDH often occurs when the nucleus pulposus protrudes laterally or extremely laterally. Theoretically, PETD can cure almost all types of LDH. However, the herniated nucleus pulposus may not always be located in the same location. This makes it difficult to adequately remove lateral or extreme lateral discs intraoperatively. Adequate removal of the herniated nucleus pulposus tissue presupposes that the intervertebral foramen is sufficiently dilated to create sufficient space for surgical manipulation. Subsequently, the contralateral nerve roots are explored to achieve "unilateral access and bilateral decompression." When

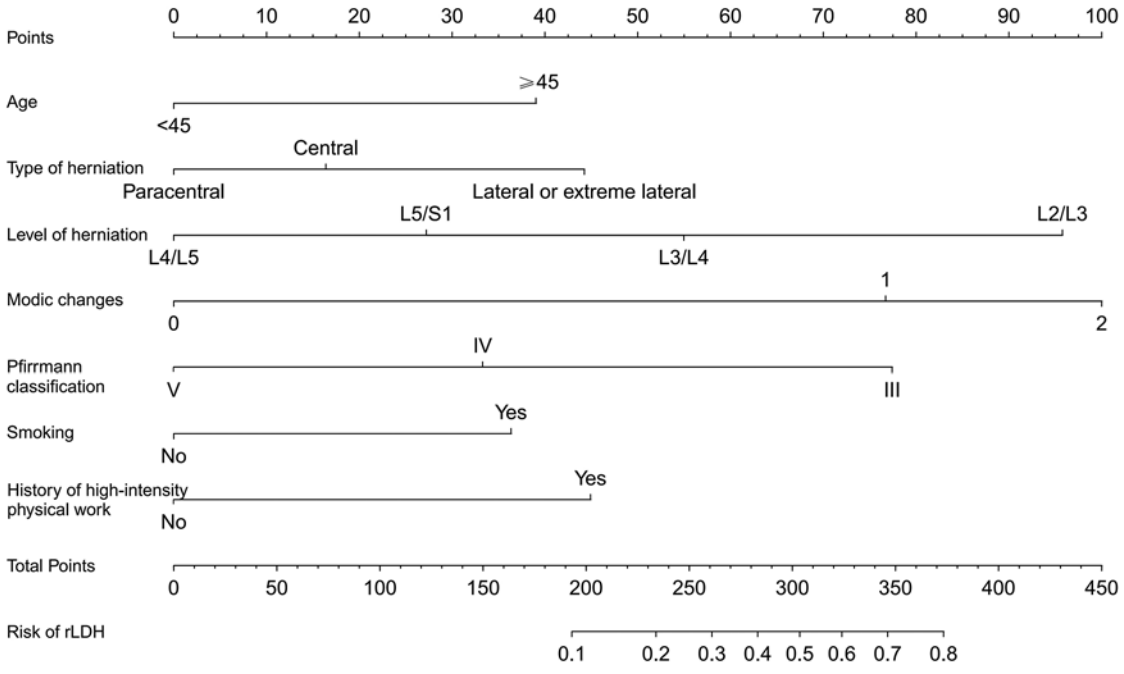

Fig. 3. *Nomogram for predicting rLDH.*

the herniated disc is located in the extreme lateral position, the puncture target is further from the posterior midline. For this type of LDH, the skin entry point is closer to the interior, and the angle of entry is steeper. The target area is usually located at the outer edge of the intervertebral foramen, and the tip of the working trocar is placed posterior and medial to the herniated nucleus pulposus and the compressed nerve. Notably, the initial working trocar on the sagittal image is positioned at the posterosuperior edge of the inferior vertebral body, and smooth removal of the herniated disc is facilitated by gradually moving the trocar upward during the procedure.

The results of a previous meta-analyses (8) has shown that the incidence of rLDH in the upper lumbar spine is significantly higher than that in L4/L5 and L5/S1. This is consistent with the results of our study. The exact reason for this is unknown; however, it can be speculated that PETD may lead to nerve injury or lumbar instability in the upper lumbar segment because of the smaller spinal canal and larger dural sac, dense nerve accompaniment, and the presence of spinal cones in the dural sac, resulting in a higher likelihood of nerve injury during discectomy for upper lumbar spine herniation. In addition, the tendency for segmental instability in the upper lumbar spine may be due to the short distance between the 2 vertebral bodies as well as the smaller interlaminar space. Therefore, due to the unique anatomical features of the upper lumbar spine, the smaller spinal canal, larger dural sac, and higher technical demands may account for the greater recurrence of LDH in the upper lumbar segment.

Modic changes are changes in signal intensity in the vertebral endplates and adjacent vertebral bone marrow on MRI, are commonly associated with disc degeneration and LDH, and represent different stages of the degenerative process of the vertebral body. Type 1 and type 2 Modic changes can be interchanged over time and will eventually become type 3. Although the etiology of Modic changes is unknown, endplate changes are thought to be a key link in the development of Modic changes. Endplate injury leads to a series of degenerative changes in the vertebral body and disc. Endplate injury increases intraosseous pressure and leads to stress concentrations within the disc, both of which may worsen cellular metabolism and promote degenerative changes. Yao et al (18) identified Modic changes as an independent risk factor for the development of rLDH after surgery, which is consistent with our follow-up results. When prophylactic discectomy is performed for discs close to the spinal canal during PETD, damage to the endplate cartilage of the vertebral body

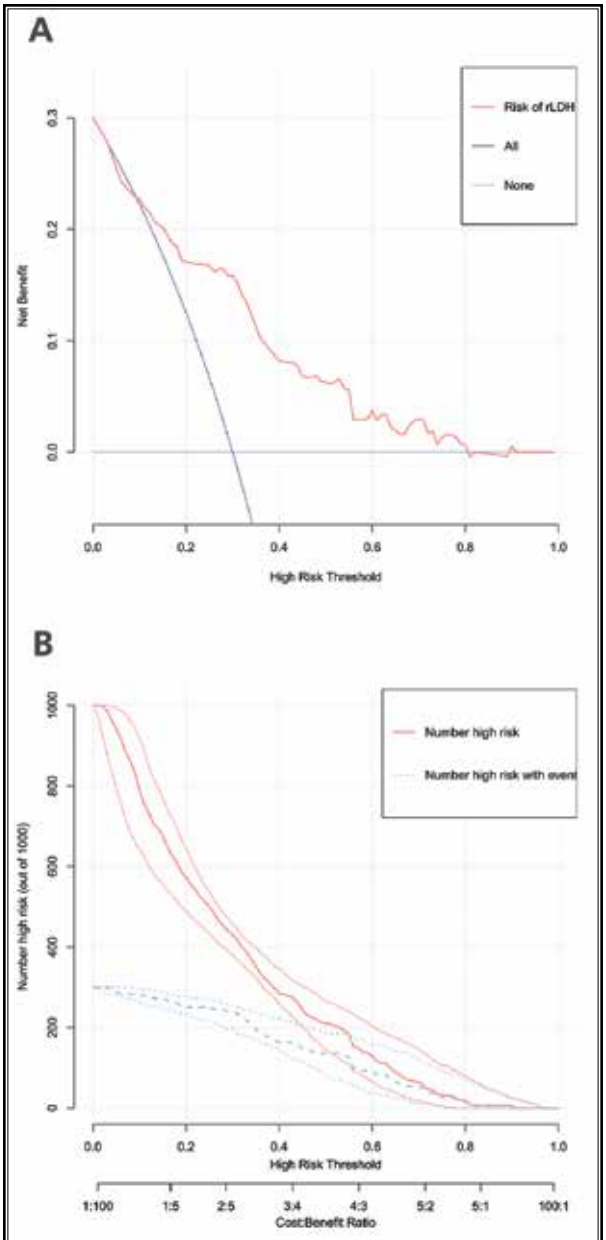

Fig. 4. *DCA and CIC plots of the prognostic model.*

is inevitable. Endplate damage increases the degree of Modic changes; thus, the deterioration of the microecological environment associated with Modic changes leads to more severe disc destruction and an increased recurrence rate of LDH.

Pfirrmann devised a grading system for disc degeneration based on MRI signal intensity, disc structure, disc height, and distinction of the nucleus pulposus. The classification of disc degeneration using Pfirrmann grading has now become the preferred method for assessing disc degeneration in clinical work. In the current study, we found that the incidence of rLDH was significantly higher in patients with Pfirrmann grade III than in those with grades IV and V. A biomechanical study of disc degeneration models showed that only one disc herniation occurred in moderately and severely degenerated discs; however, in mildly degenerated discs, all specimens showed herniation of the lumbar disc. When a disc is severely degenerated, intervertebral motion is reduced, resulting in localized stability of the intervertebral space; and thus, a reduction in the risk of rLDH (19). By comparing the biomechanical parameters of normal vs degenerated segments, Hasegawa et al (20) concluded that degenerated segments with preserved disc height may be less stable than segments with collapsed discs. Severely degenerated discs have reduced segmental motion compared to moderately degenerated discs, making the discs more biomechanically stable and reducing the incidence of rLDH.

Our prognostic model identified smoking as a predictor of rLDH, which is consistent with the results of a previous study. In this study, a significant correlation between smoking and the incidence of rLDH was found. Smoking is thought to affect disc oxygenation, cellular recovery, and nutrient uptake by the annulus fibrosus (21). Nicotine is a small molecule that can enter the disc by diffusion and has a direct toxic effect on the disc, leading to disc degeneration. Especially during early recovery after surgery, proteoglycans are induced by the nicotine inhaled during smoking, which affects the nutrient uptake and oxygenation of the intervertebral disc and inhibits disc healing. Whether smoking cessation reduces the recurrence of postoperative LDH remains an interesting question for future research.

The occurrence of LDH is usually associated with prolonged high-intensity physical work, and continuous pressure on the lumbar region during prolonged repetitive lifting or exercise will make the disc more susceptible to herniation. In a finite element study, Sharifzadeh-Kermani et al (22) presented the first internal disc strains under various complex loading conditions, and they found that the maximum fiber strain at the posterior lateral annulus during flexion and compression loading increased with increasing axial rotation and lateral bending. However, to further validate these 3-dimensional finite element results, in vitro internal disc strains need to be measured in human lumbar spine segments under repetitive complex loading. Thus, by performing simulated measurements

of internal disc strains during repetitive lifting in a hydrated and temperature-controlled environment, Amin et al (23) concluded that repetitive bending, lifting, and weight-bearing movements during high-intensity physical work can produce high stresses on the disc. This stress is significantly higher in the posterior lateral aspect of the disc, and shear stress in the posterior lateral region further increases the risk of nucleus pulposus prolapse.

Conservative treatment is usually the preferred option in elderly patients, but when conservative treatment is not effective, PETD may not be as effective in the long term as posterior lumbar interbody fusion or transforaminal lumbar interbody fusion. When imaging indicators suggest that the patient has herniation of the lateral or extreme lateral, Modic changes type 3, or Pfirrmann classification III, PETD must be chosen with caution for the treatment of LDH. In addition, postoperative lifestyle changes are important. A healthy lifestyle can reduce the probability of recurrence of LDH after surgery.

Randomized controlled trials remain the gold standard for determining surgical efficacy to identify those procedures that are more likely to have higher clinical benefit and efficacy. Another emerging approach, as demonstrated in this study, is the development and validation of clinical prognostic models. Thanks to well-established electronic medical record systems, the development of prospective multicenter databases, and increased awareness of machine learning and statistical learning methods, predictive analysis in clinical medicine is possible, providing patients with specific risk probabilities and expected outcomes. Our model was built using 7 easily accessible predictor variables, and its predictive probabilities were visualized through a nomogram, a practical and effective visual statistical model that is increasingly used in clinical work. The nomogram is concise and easy to use, and with just 7 predictors, the probability of rLDH can be accurately assessed. Considering the ease with which the variables used to obtain the results of the nomogram can be obtained in clinical practice, our model could see widespread clinical application. We included the predictors screened by LASSO regression in the prognostic model and assessed their accuracy by using ROC curve analysis. The high AUC values suggest that the nomogram can be reliably applied in clinical work. We then further evaluated the benefit of PETD in patients with rLDH by DCA, which analyzes the risk of under- and overtreatment and assists clinicians in selecting appropriate treatments. CICs generated using this model predicted risk stratification in 1,000 individuals and demonstrated the high utility of the model for predicting rLDH.

This study has several limitations. First, this was a single-center study, and all patients were from the Department of Spine Surgery, Xuzhou Medical University Hospital, thus reducing the reliability of this prognostic model. Second, although internal validation with the enhanced bootstrap method was effective in assessing the performance of the model in this study, an additional, large clinical cohort is still needed for external validation. Therefore, to further improve the predictive power of the model, the inclusion of more relevant risk factors, increased sample size, and reliable external validation are essential in future studies.

Conclusions

The model has excellent comprehensive performance and can well predict the risk probability of rLDH after PETD. We can identify the high-risk group of rLDH at an early stage so that we can individualize the treatment modality and postoperative rehabilitation plan of patients. However, no matter how accurate a prediction model is, it cannot replace the clinical judgment of physicians. Our goal is to construct a prognostic model that can help physicians provide a more accurate and individualized assessment of a specific patient's risk/benefit profile and effectively prevent the recurrence of LDH after surgery.

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