Research Square

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Analysis of Risk Factors and Establishment of a Predictive Model for Endplate Collapse After Posterior Short-Segment Fixation Combined with Screw Placement at the Injured Vertebra in Thoracolumbar Fractures

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Abstract

Purpose

To identify the risk factors for endplate collapse in patients with thoracolumbar fractures undergoing posterior short-segment fixation combined with intermediate screw placement, and to develop and validate a clinical prediction model to aid in early risk stratification and prognosis optimization.

Materials and methods

Clinical data from 135 patients with thoracolumbar fractures treated with posterior short-segment fixation and screw placement at the injured vertebra were retrospectively analyzed. Based on postoperative imaging findings, patients were stratified into an endplate collapse group (n = 57) and a non-collapse control group (n = 78). Variables collected included demographic and fracture characteristics (age, gender, BMI, fracture location, fracture pattern, mechanism of injury, osteoporotic status), radiographic parameters (screw length at the injured vertebra, severity of endplate and intervertebral disc injury, extent of anterior and posterior complex injury, postoperative mean vertebral body height [MVBH] and Cobb angle [CA]), and postoperative outcomes (fixation duration, postoperative Pfirrmann grade). Univariate analysis identified variables with significant between-group differences. Independent risk factors for postoperative endplate collapse were determined by multivariable logistic regression analysis. A predictive model was constructed incorporating these factors, and its performance was evaluated using receiver operating characteristic (ROC) curve analysis with calculation of area under the curve (AUC), sensitivity, and specificity.

Results

Univariate analysis revealed significant differences in BMI, osteoporotic status, screw depth, endplate injury grade, intervertebral disc injury severity (Sander classification), load-sharing classification (LSC) score, postoperative Pfirrmann grade, and postoperative Cobb angle between groups (all $P < 0.05$). Multivariable logistic regression identified osteoporosis, screw depth, and endplate injury grade as independent risk factors for postoperative endplate collapse (all $P < 0.05$), with screw depth demonstrating the largest odds ratio and thus the strongest association. A predictive model incorporating these three factors was constructed. Receiver operating characteristic curve analysis demonstrated an area under the curve (AUC) of 0.888 (95% CI: 0.826–0.943), with sensitivity of 78.9% and specificity of 89.7%, indicating favorable predictive performance.

Conclusion

Postoperative endplate collapse following posterior short-segment fixation with injured vertebra screw placement for thoracolumbar fractures is multifactorial, with osteoporosis, screw depth, and endplate injury grade serving as major independent risk factors. The predictive model developed in this study effectively stratifies the risk of postoperative endplate collapse and may provide a valuable tool for preoperative risk assessment, intraoperative technical optimization, and postoperative individualized rehabilitation planning, thereby potentially reducing the incidence of endplate collapse and improving functional outcomes.

INTRODUCTION

Thoracolumbar spine fracture is one of the most common injuries in spinal surgery, with an incidence exceeding 70% of all spinal fractures[1]. Short-segment posterior fixation combined with fractured vertebra instrumentation has become the preferred surgical approach for treating thoracolumbar spine fractures owing to its advantages of rigid fixation, minimal invasiveness, and preservation of spinal mobility[2, 3]. This technique restores vertebral height and corrects spinal deformity by inserting pedicle screws into the fractured vertebra and adjacent levels, thereby re-establishing spinal stability and providing favorable conditions for fracture healing. However, severe thoracolumbar fractures with concomitant endplate damage may develop postoperative complications such as “shell-like” changes and vertebral body height loss due to bone deficiency, leading to upper endplate collapse[4–6]. Notably, endplate collapse is a major causative factor of late complications in thoracolumbar spine fractures[7–9].

Multiple factors contribute to endplate collapse, including severe endplate injury in burst fractures, underlying osteoporosis, and suboptimal endplate reduction. However, current clinical understanding of risk factors for postoperative endplate collapse remains incomplete, with most studies focusing on single-factor analysis and limited investigation into the interplay among multiple factors. Moreover, systematic clinical data are lacking to support comprehensive risk stratification.

This study retrospectively analyzed clinical data from patients with thoracolumbar spine fractures treated with short-segment posterior fixation combined with fractured vertebra instrumentation. We aimed to identify risk factors associated with postoperative endplate collapse, elucidate correlations between individual factors and collapse development, and stratify high-risk populations. By establishing targeted preventive and intervention measures, we sought to reduce the incidence of postoperative endplate collapse, improve long-term patient outcomes, and provide reliable clinical evidence to optimize surgical strategies and enhance rehabilitation protocols for thoracolumbar spine fractures.

MATERIALS AND METHODS

1. Study Population

This retrospective study enrolled patients with neurologically intact thoracolumbar spine fractures treated surgically between March 2018 and October 2025. This study was approved by the Ethics

Committee of the Affiliated Hospital of Hebei University of Engineering in July 2023 (Ethics No.: 2023[K]096). Written informed consent was waived by the ethics committee because of the retrospective nature of this study. All methods were performed in accordance with the relevant guidelines and regulations.All surgeries were performed by a single surgeon, with intraoperative reduction of fractured and fragmented endplates in all cases. Postoperative rehabilitation was conducted under medical supervision with commitment to long-term follow-up.

1.1 Inclusion Criteria

- Age 18–65 years with confirmed thoracolumbar spine fracture (T11–L2) documented on imaging studies (radiographs, computed tomography, or magnetic resonance imaging);Fracture involving the superior endplate with intraoperative endplate reduction;Neurologically intact burst fractures of the thoracolumbar spine;Treatment with short-segment posterior fixation combined with fractured vertebra instrumentation performed by the same orthopedic surgical team;Postoperative follow-up duration ≥ 12 months with complete clinical and radiological documentation.

1.2 Exclusion Criteria

History of spinal deformity, vertebral malformation, spinal myelopathy, prior spinal infection, or tuberculosis;Unstable fractures with neurological injury or multiple vertebral fractures requiring long-segment fusion;Intraoperative or postoperative complications;Poor postoperative compliance with inadequate follow-up imaging documentation.

2. Data Collection

Patient demographic and baseline characteristics were collected and documented, including sex, age, body mass index (BMI), bone mineral density, mechanism of injury, fracture level, and timing of internal fixation. Radiological parameters included fracture type, pedicle screw insertion depth, severity of endplate damage, posterior ligamentous complex injury, intervertebral disc injury grade before and after surgery, postoperative relative vertebral body height (MVBH) of the fractured vertebra, and postoperative local kyphotic angle (CA).

2.1 Grouping and Scoring Criteria

Intervertebral disc degeneration Pfirrmann grading[10].: Grade I: homogeneous disc structure with high signal intensity and normal disc height; Grade II: mild signal heterogeneity with small areas of low signal and normal disc height; Grade III: heterogeneous signal with reduced intensity, disrupted disc structure, and mildly reduced disc height; Grade IV: low signal intensity with markedly reduced disc height and indistinct disc-endplate boundary; Grade V: markedly decreased signal intensity with severely reduced disc height and disc collapse.

Criteria for endplate collapse assessment: Endplate injury is a common concomitant finding in thoracolumbar spine fractures, though its classification lacks unified standardization and criteria for assessing endplate healing morphology remain undefined. Su et al.[11]. analyzed the relationship between endplate healing patterns and disc degeneration and identified three categories of endplate healing: increased endplate curvature, irregular healing, and traumatic Schmorl's node. Further investigation demonstrated that irregular healing and traumatic Schmorl's node are important factors influencing disc degeneration. Based on this framework, we applied a modified classification: endplate collapse was defined as the presence of either irregular healing or traumatic Schmorl's node. For patients with increased endplate curvature, endplate collapse was defined as a reduction in vertebral body MVBH at final follow-up by > 5% compared to immediate postoperative imaging (MVBH is defined as the ratio of average midline height of adjacent upper and lower vertebral bodies to midline height of the fractured vertebra[12].) (Fig. 1).

Figure 1A:Increased endplate curvature; B:irregular healing traumatic; C:Schmorl nodes

3. Statistical Analysis

Data were analyzed using SPSS version 26.0 statistical software. Continuous variables were expressed as mean ± standard deviation (x ± s), with between-group comparisons performed using independent samples t-tests. Categorical variables were presented as frequencies and percentages [n (%)], with between-group comparisons conducted using chi-square tests or Fisher's exact probability test as appropriate. Univariate analysis was performed to identify potential risk factors, and variables with $P < 0.05$ were subsequently entered into multivariate logistic regression analysis to calculate odds ratios (OR) and corresponding 95% confidence intervals (CI) for independent risk factors. Receiver operating characteristic (ROC) curve analysis was employed to evaluate model discrimination, with calculation of area under the curve (AUC), optimal cutoff value, sensitivity, and specificity. Model calibration was assessed using calibration curves and the Hosmer-Lemeshow goodness-of-fit test. Decision curve analysis (DCA) was performed to evaluate clinical utility of the model. A P-value < 0.05 was considered statistically significant.

RESULTS

1. Comparison of Baseline Characteristics Between Groups

Comparative analysis of baseline characteristics between the two groups revealed no statistically significant differences in sex, fracture level, fracture type, or mechanism of injury (all $P > 0.05$). Regarding continuous variables, no significant differences were observed between groups in age, PLC injury score, fixation timing, postoperative MVBH, or postoperative CA (all $P > 0.05$). However, statistically significant differences were found between groups in BMI, osteoporosis status, screw insertion depth, endplate

injury grade, Sander classification of disc injury, LSC score, and postoperative Pfirrmann grade (all P < 0.05). (Table 1).

Table 1
Comparison of general information between the two groups

Variables	Collapse group (n = 57)	Non-collapse group (n = 78)	Statistic	*P* value
Sex (male/female)	37/20	50/28	χ^2=0.000	1.000
Fracture level (T11/T12/L1/L2)	9/8/24/16	7/15/33/23	χ^2=3.820	0.431
Fracture type (A1/A2/A3)	3/31/23	1/37/40	χ^2=2.921	0.232
Cause of injury (traffic accident/fall from height/others)	27/23/7	42/28/8	χ^2=0.565	0.754
Osteoporosis (yes/no)	37/20	17/61	χ^2=23.746	< 0.001
Screw insertion depth (0.4/0.6)	45/12	21/57	χ^2=33.620	< 0.001
Endplate injury grade (Grade 1/2/3)	5/32/20	36/35/7	χ^2=27.225	< 0.001
Intervertebral disc injury (Sander´s classification)	6/15/34/2	5/46/24/3	χ^2=14.862	0.002
Age (years)	52.00(41.00–57.00)	46.50(32.00–54.00)	Z=-1.850	0.064
BMI (kg/m^2)	23.50(23.20–24.50)	23.40(22.32–23.85)	Z=-2.292	0.022
LSC score	3.00(2.00–4.00)	2.00(2.00–3.00)	Z=-3.012	0.003
Postoperative Pfirrmann grade	3.00(2.00–4.00)	3.00(2.00–4.00)	Z=-2.124	0.034
PLC injury score	1.00(1.00–2.00)	2.00(1.00–2.00)	Z=-1.238	0.216
Fixation duration, months	18.00(16.00–22.00)	18.00(16.00–22.00)	Z=-0.273	0.785
Postoperative MVBH	0.96(0.96–0.98)	0.97(0.96–0.98)	Z=-0.537	0.591
Postoperative CA,(°)	7.60(4.10–11.40)	6.60(4.50-9.00)	Z=-1.635	0.102

2. Univariate Logistic Regression Analysis

Univariate logistic regression analysis was performed for all variables. The results revealed that BMI (OR = 1.456, P = 0.011), osteoporosis (OR = 6.638, P < 0.001), screw insertion depth (OR = 10.179, P < 0.001), endplate injury grade (OR = 4.526, P < 0.001), intervertebral disc injury Sander classification (OR = 1.676, P = 0.049), LSC score (OR = 1.358, P = 0.005), postoperative Pfirrmann grade (OR = 1.408, P = 0.036), and postoperative CA (OR = 1.095, P = 0.037) were risk factors for endplate collapse. (Table 2).

Table 2
Univariate Logistic Regression Analysis of Endplate Collapse

Variable	**OR**	**95%CI**	***P* value**
Sex	1.036	0.507–2.116	0.923
Age	1.028	1.000-1.058	0.054
Fracture level	0.924	0.436–1.960	0.838
Fracture type	0.611	0.327–1.144	0.124
Cause of injury (traffic accident/fall from height/others)	1.201	0.728–1.983	0.474
BMI	1.456	1.089–1.946	0.011
Osteoporosis	6.638	3.090-14.262	< 0.001
Screw insertion depth	10.179	4.529–22.876	< 0.001
Endplate injury grade	4.526	2.419–8.466	< 0.001
PLC injury score	0.792	0.458–1.368	0.402
Endplate injury grade	1.676	1.002–2.804	0.049
LSC score	1.358	1.095–1.684	0.005
Postoperative Pfirrmann grade	1.408	1.023–1.938	0.036
Fixation duration, months	0.983	0.911–1.061	0.664
Postoperative MVBH	0.000	0.000-18961.848	0.361
Postoperative CA	1.095	1.006–1.193	0.037

3. Multivariate Logistic Regression Analysis

Eight variables with P < 0.05 from the univariate analysis were included in multivariate logistic regression. Results showed that osteoporosis (OR = 3.799, 95% CI: 1.386–10.413, P = 0.010), screw insertion depth (OR = 9.479, 95% CI: 3.136–28.648, P < 0.001), and endplate injury grade (OR = 4.486, 95% CI: 1.950–10.318, P < 0.001) were independent risk factors for endplate collapse, with screw insertion depth being the most significant (highest OR value). (Table 3) (Fig. 2).

Table 3
Multivariate Logistic Regression Analysis of Endplate Collapse

Variables	β	SE	Wald χ^2	OR	95%CI	*P* value
BMI	0.172	0.211	0.662	1.188	0.785–1.797	0.416
Osteoporosis	1.335	0.515	6.729	3.799	1.386–10.413	0.010
Screw insertion depth	2.249	0.564	15.886	9.479	3.136–28.648	< 0.001
Endplate injury grade	1.501	0.425	12.472	4.486	1.950-10.318	< 0.001
Intervertebral disc injury (Sander´s classification)	0.253	0.382	0.439	1.288	0.609–2.721	0.508
LSC score	0.141	0.148	0.907	1.152	0.861–1.540	0.341
Postoperative Pfirrmann grade	0.105	0.234	0.201	1.111	0.702–1.758	0.654
Postoperative CA,	0.046	0.065	0.514	1.047	0.923–1.189	0.473
Note: The AIC of the multivariate Logistic regression model was 123.14, and the Pseudo R^2 was 0.428, indicating an excellent overall model fit.						

Figure 2 Forest Plot of Multivariate Logistic Regression Analysis

4. Predictive Model Construction

A predictive model for endplate collapse was constructed based on three independent risk factors identified from multivariate logistic regression (osteoporosis, screw insertion depth, and endplate injury grade). The logistic regression equation was established as follows: Logit(P) = -5.347 + 1.426 × osteoporosis + 2.446 × screw insertion depth + 1.638 × endplate injury grade. Notably, screw insertion depth demonstrated the largest regression coefficient (β = 2.446), further underscoring its critical role in predicting endplate collapse. (Table 4).

Table 4
Regression Coefficients of the Endplate Collapse Prediction Model

Variables	β	OR	95%CI	*P*
Constant	-5.347	-	-	< 0.001
Osteoporosis	1.426	4.164	1.564–11.084	0.004
Screw insertion depth	2.446	11.537	4.191–31.756	< 0.001
Endplate injury grade	1.638	5.147	2.395–11.059	< 0.001

5. Receiver operating characteristic (ROC) curve analysis

The discriminative ability of the predictive model was evaluated using receiver operating characteristic (ROC) curves. The combined model achieved an area under the curve (AUC) of 0.888 (95% CI: 0.826–0.943), indicating favorable discriminatory power. At the optimal cut-off value of 0.593, the corresponding sensitivity and specificity were 0.789 and 0.897, respectively.

When evaluated individually, the AUCs were 0.649 for osteoporosis, 0.781 for screw insertion depth, and 0.755 for endplate injury grade. The combined predictive model yielded a significantly higher AUC than any single predictor, demonstrating superior predictive performance over individual parameters (Table 5; Figs. 3, 4).

Table 5
Performance Indicators of the Prediction Model

Metrics	Value
AUC	0.888
95%CI	0.826–0.943
Optimal cut-off value	0.593
Sensitivity	0.789
Brier score	0.123
AIC	116.45
Pseudo R^2	0.410

Figure 3 ROC Curve of the Endplate Collapse Prediction Model

Figure 4 Comparison of ROC Curves of Each Variable and the Combined Model

6. Calibration curve analysis

Calibration curves were generated to evaluate the agreement between the predicted probabilities and actual observed outcomes. The calibration curve showed close alignment with the ideal 45-degree diagonal reference line. The model yielded a Brier score of 0.123, and the Hosmer–Lemeshow goodness-of-fit test demonstrated no statistically significant deviation (P = 0.337; P > 0.05), indicating favorable model calibration (Fig. 5).

Figure 5 Calibration Curve of the Endplate Collapse Prediction Model

2.4 Decision curve analysis

Decision curve analysis (DCA) was performed to assess the clinical utility of the predictive model. The DCA curve showed that the model yielded a higher net benefit compared with both the “treat-all” and “treat-none” strategies across a wide threshold probability range of 0.05 to 0.90, indicating favorable practical value in assisting clinical decision-making (Fig. 6).

Figure 6 Decision Curve Analysis (DCA) of the

Endplate Collapse Prediction Model

DISCUSSION

Thoracolumbar fractures represent the most frequent spinal injuries in clinical practice [13]. Posterior short-segment fixation combined with intermediate screw placement in the fractured vertebra has become the predominant surgical approach. By placing pedicle screws into both the fractured vertebra and adjacent levels, this “three-point fixation” construct effectively mitigates the parallelogram effect inherent in conventional short-segment constructs, thereby reducing reduction loss associated with the suspension effect [14–16]. Despite its widespread utility and confirmed clinical efficacy, postoperative complications persist, among which endplate collapse is particularly debilitating [17, 18]. This retrospective study was conducted to identify these risk factors, optimize surgical execution, guide postoperative rehabilitation, and prevent long-term adverse sequelae.

1. Risk factor analysis of endplate collapse

1.1 Impact of osteoporosis on endplate collapse

Osteoporosis, characterized by decreased bone mass and microarchitectural deterioration, significantly compromises skeletal biomechanical properties and heavily influences fracture healing and surgical prognosis. In this study, 54 patients were diagnosed with osteoporosis (37 in the collapse group and 17 in the non-collapse group, The mechanisms by which osteoporosis exacerbates collapse involve three main aspects:Compromised load-bearing architecture: Finite element analysis [19] demonstrates that trabecular bone dissipates axial spinal loads through elastic deformation. In osteoporotic vertebrae,

trabecular thinning and rarefaction markedly reduce load-bearing and energy absorption capacities, leaving the endplate susceptible to microfractures and gradual invagination under physiological stress.

Reduced screw–bone purchase: Osteoporotic bone significantly degrades screw holding strength (pullout force and torsional rigidity), facilitating construct micromotion and adverse stress redistribution. This unstable mechanical milieu during the critical reparative phase amplifies the collapse risk.Impaired biological repair: The negative bone remodeling balance (diminished osteoblastic activity relative to osteoclastic resorption) delays callus formation and mineralization. Consequently, the injured vertebra remains unable to support loads transferred from internal hardware, substantially extending the vulnerable temporal window for endplate collapse. Prolonged protected recumbency and aggressive anti-osteoporotic therapy are therefore imperative for these patients.

1.2 Screw insertion depth and structural support

In our cohort, 69 patients received long intermediate screws and 66 received short screws. Significant differences were observed between the collapse and non-collapse groups The optimal insertion depth for intermediate pedicle screws remains controversial. Several investigators argue that the pedicle provides approximately 60% of pullout resistance, with cancellous bone contributing only 15%–20%, suggesting that engagement within the pedicle alone suffices without risking further anterior vertebral disruption [20–22]. Conversely, our findings support the premise that when the anterior column is severely disrupted, shorter screws fail to provide adequate anchorage, leading to focal stress concentration and subsequent screw loosening. Longer screws engage denser cancellous bone or the anterior cortex, enhancing construct stiffness and load redistribution. Biomechanically, longer screws:Extend the lever arm, shifting the construct mechanics from a cantilever beam toward a more stable bridging configuration;

Disperse stress across the anterior and middle columns, preventing peak focal stresses and screw loosening;Provide direct buttressing beneath the central endplate defect, bridging the sub-endplate bone void created by distraction reduction and imparting primary stability to fracture fragments. This aligns with findings in cement augmentation studies, where intimate contact between bone cement and the endplate prevents biomechanical failure and secondary collapse [23].Objections to long screws often cite risks of further fragment displacement into the spinal canal. However, recent biomechanical data confirm that an insertion depth of at least 60% is essential to sustain vertebral height maintenance without displacing canal fragments [24–26]. In our series, none of the 69 patients receiving long intermediate screws suffered intraoperative fragment retropulsion or neurovascular injury. With current intraoperative 3D navigation and robotic guidance, the trajectory and depth of pedicle screws can be controlled with extreme precision, redefining the safety margins of screw length.

1.3 Endplate injury grade

Endplate injuries were categorized as grade I (41 cases), grade II (67 cases), and grade III (27 cases). The collapse group comprised 5 grade I, 32 grade II, and 20 grade III injuries, whereas the non-collapse

group had 36 grade I, 35 grade II, and 7 grade III injuries .Severe traumatic energy directly crushes subchondral trabeculae, generating macroscopic voids between the cartilaginous endplate and cancellous bone, which abolishes sub-endplate mechanical support. Furthermore, extensive endplate rupture disrupts disc–vertebral nutrient diffusion, accelerating disc dehydration and functional degeneration. The degraded disc loses its viscoelastic damping capacity, simultaneously transmitting higher axial impact loads to the endplate while providing less hydrostatic support. Additionally, severely comminuted endplates frequently leave persistent intraoperative step-offs or bony gaps, predisposing the localized interface to excessive stress concentration and collapse.

2. Predictive model performance and clinical translation

The developed nomogram demonstrated robust discriminatory ability, with an AUC of 0.888 (95% CI: 0.826–0.943). At the optimal cut-off value of 0.593, the sensitivity and specificity reached 0.789 and 0.897, respectively. Calibration was favorable, with a Brier score of 0.123 and an insignificant Hosmer–Lemeshow test ($P = 0.337$; $P > 0.05$), reflecting close concordance between predicted and observed risks. Decision curve analysis verified that the nomogram conferred net clinical benefit across a wide threshold probability span (0.05–0.90).

This model provides a practical tool for risk stratification. By integrating readily accessible clinical and radiographic variables—osteoporosis status, endplate injury severity, and intermediate screw depth—surgeons can calculate individual risk probabilities. For high-risk patients, proactive modifications, such as utilizing cement augmentation, increasing screw length/diameter, or extending anterior/posterior bone grafting, can be implemented perioperatively. Postoperatively, risk scoring can guide personalized rehabilitation protocols, including prolonged bracing and tailored bone health management.

4. Study limitations

Study design: This was a single-center retrospective study with a modest sample size, which inevitably introduces potential selection bias.Follow-up duration: The relatively short follow-up period restricted assessment to early-to-mid-term collapse; long-term endplate remodeling patterns and model performance remain to be evaluated.Modeling methodology: The model was constructed using multivariable logistic regression. More advanced machine learning algorithms (e.g., support vector machines or random forests) may yield higher predictive precision in future iterations.

Declarations

1.Ethics approval and consent to participate

This retrospective study was performed in accordance with the Declaration of Helsinki. Ethical approval was obtained from the Ethics Committee of Affiliated Hospital of Hebei University of Engineering (Ethics No.: 2023 [K] 096). Written informed consent was waived due to the retrospective nature of this study.

2.Consent for publication

Not applicable.

3.Availability of data and materials

The datasets supporting the conclusions of this study are available from the corresponding author on reasonable request, subject to approval by the institutional ethics committee and de-identification of patient information to protect patient confidentiality.

4.Competing interests

The authors declare that they have no competing interests.

5. Funding

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6.Authors' contributions

H. Feng and Y.N. Chen contributed equally to this work.

H. Feng: Conceptualization, Data curation, Formal analysis, Writing – original draft.

Y.N. Chen: Conceptualization, Methodology, Investigation, Writing – original draft.

D.J. Kan: Investigation, Resources, Visualization.

D. Zhao: Investigation, Validation.

F. Chen: Resources, Data curation.

J.H. Wang: Supervision, Funding acquisition, Writing – review & editing.

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Figures

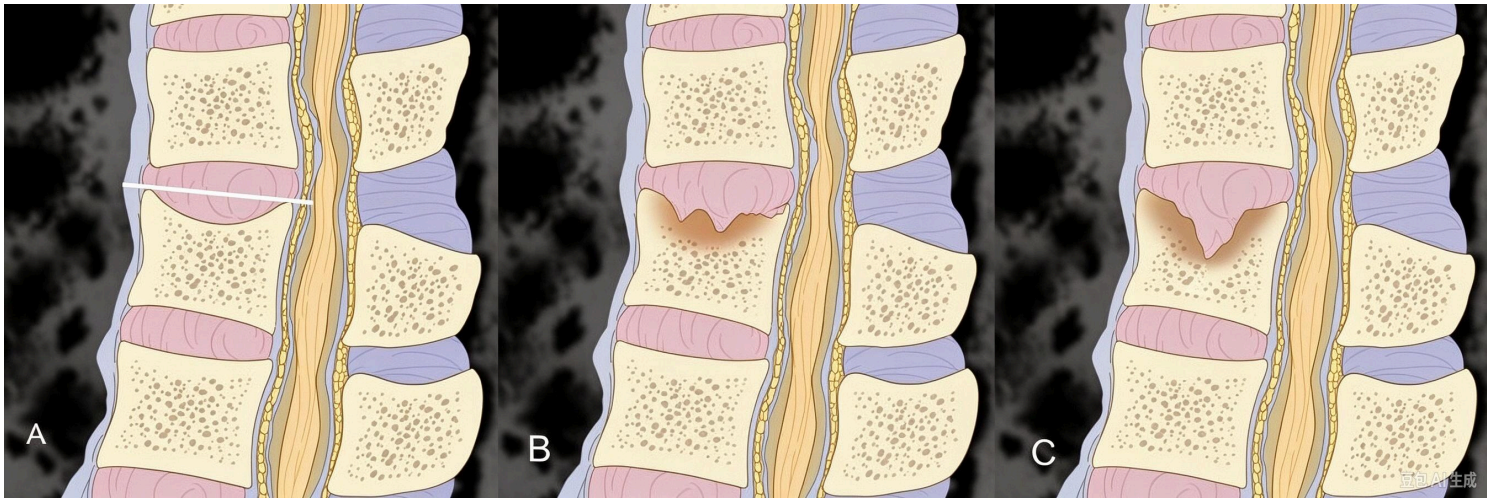


Figure 1

A:Increased endplate curvature; B:irregular healing traumatic; C:Schmorl nodes

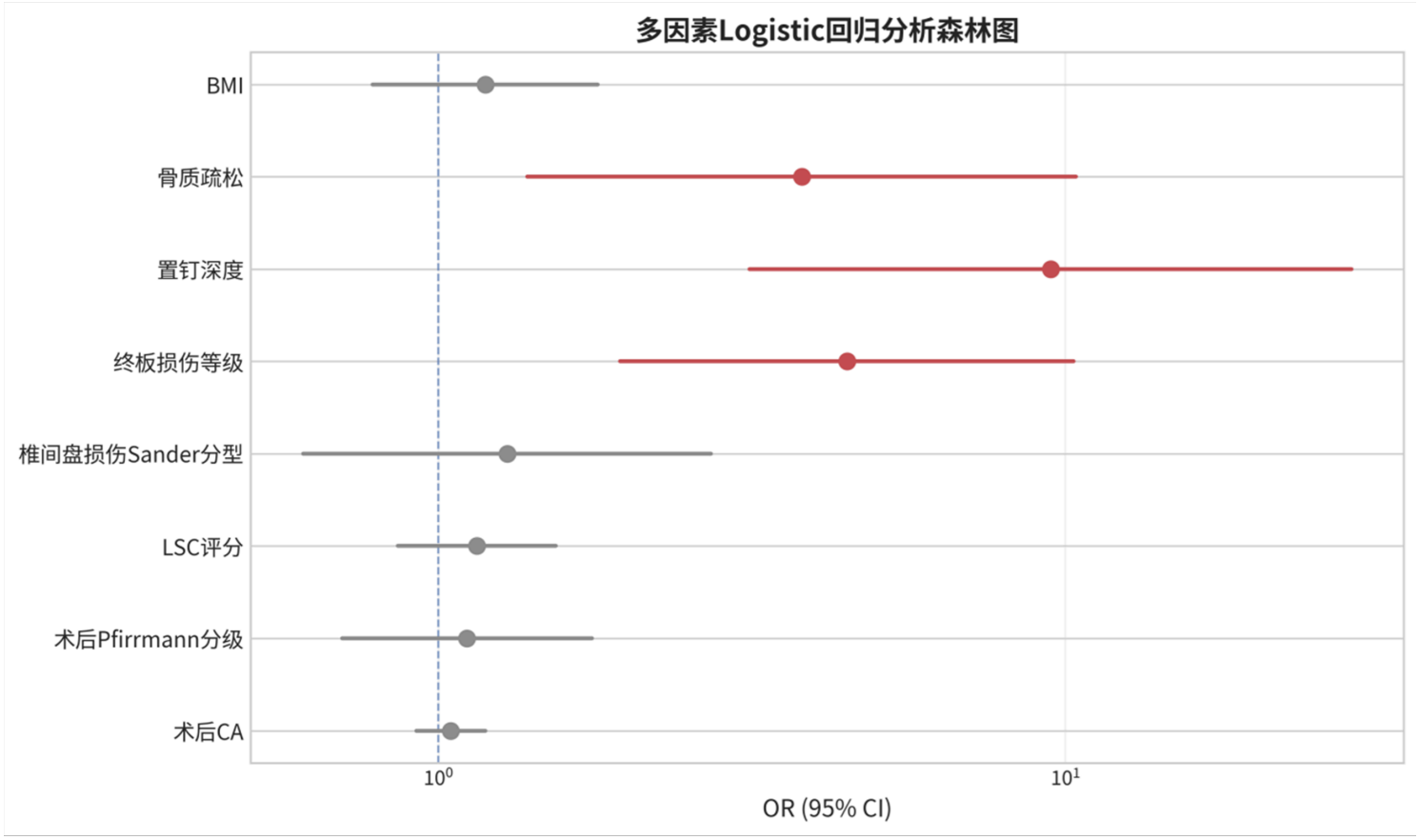


Figure 2

Forest Plot of Multivariate Logistic Regression Analysis

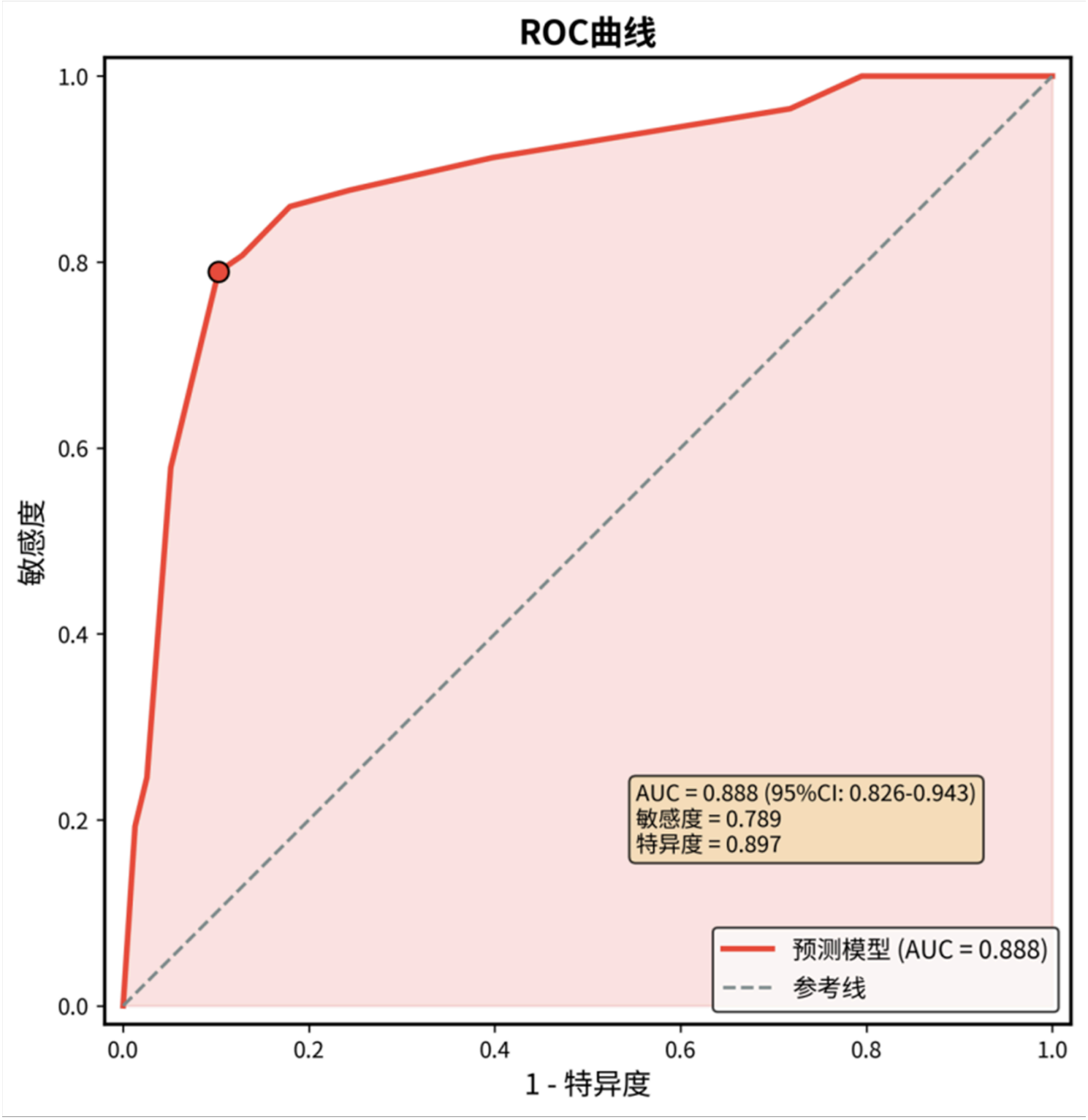


Figure 3

ROC Curve of the Endplate Collapse Prediction Model

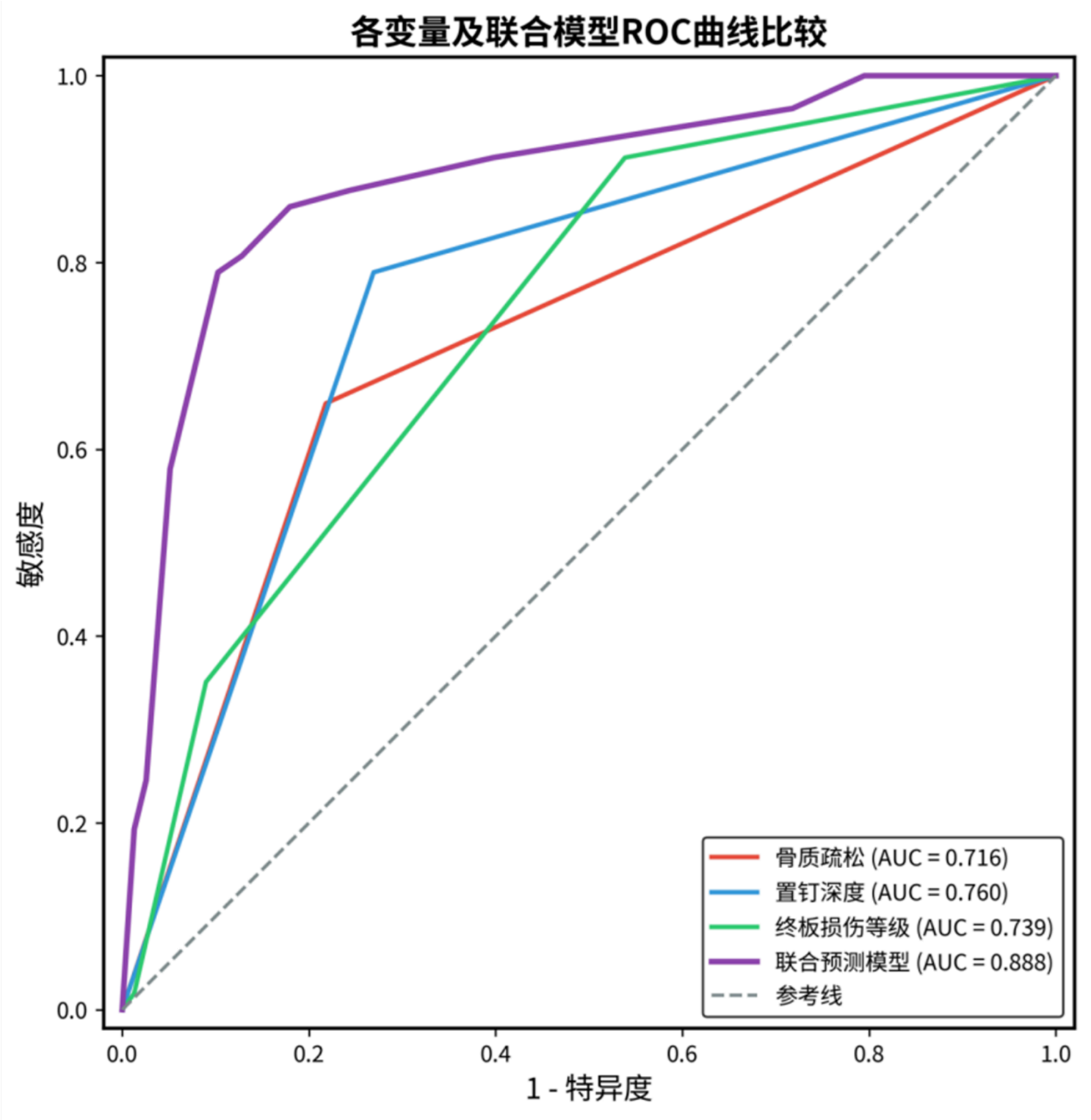


Figure 4

Comparison of ROC Curves of Each Variable and the Combined Model

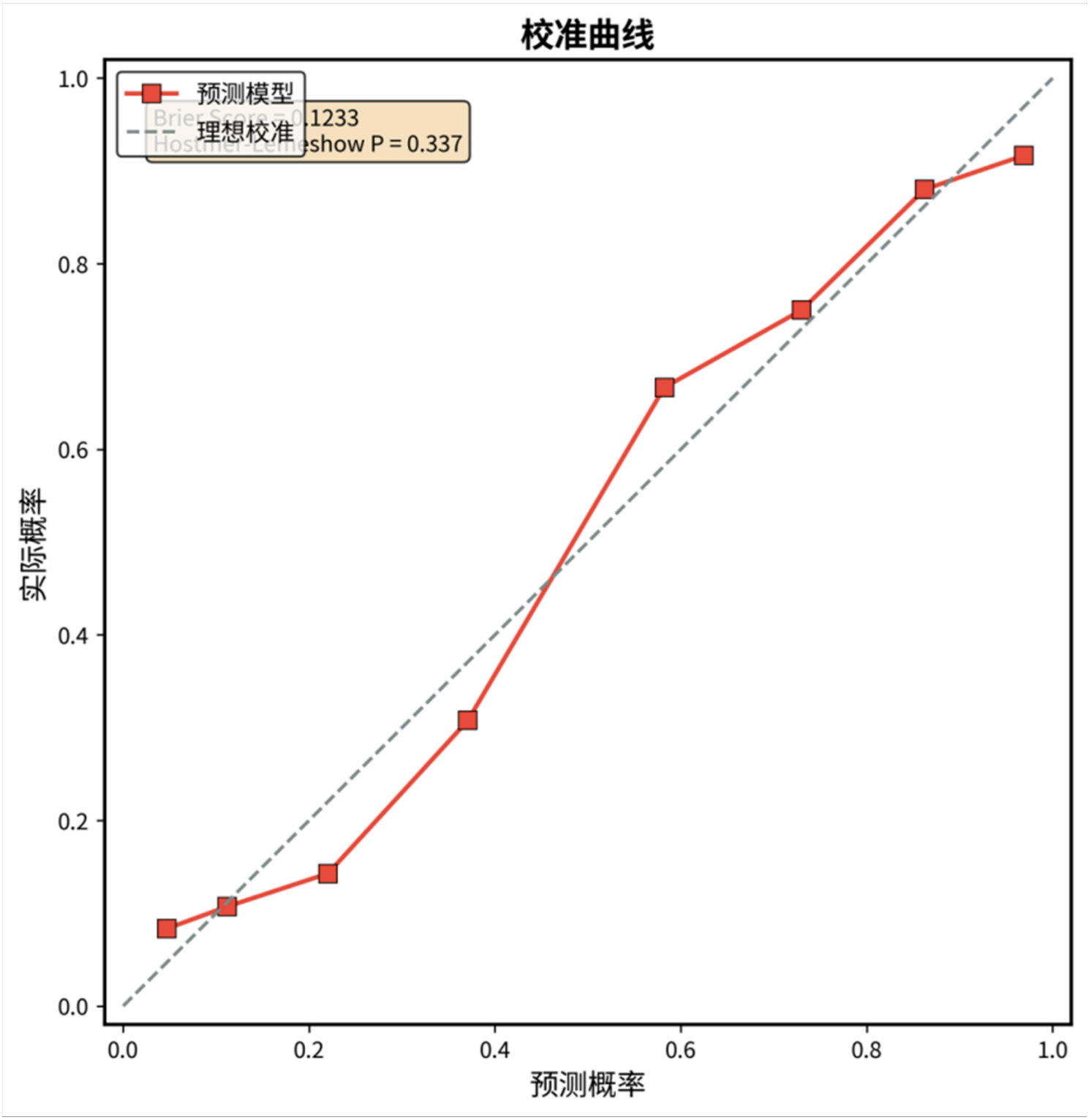


Figure 5

Calibration Curve of the Endplate Collapse Prediction Model

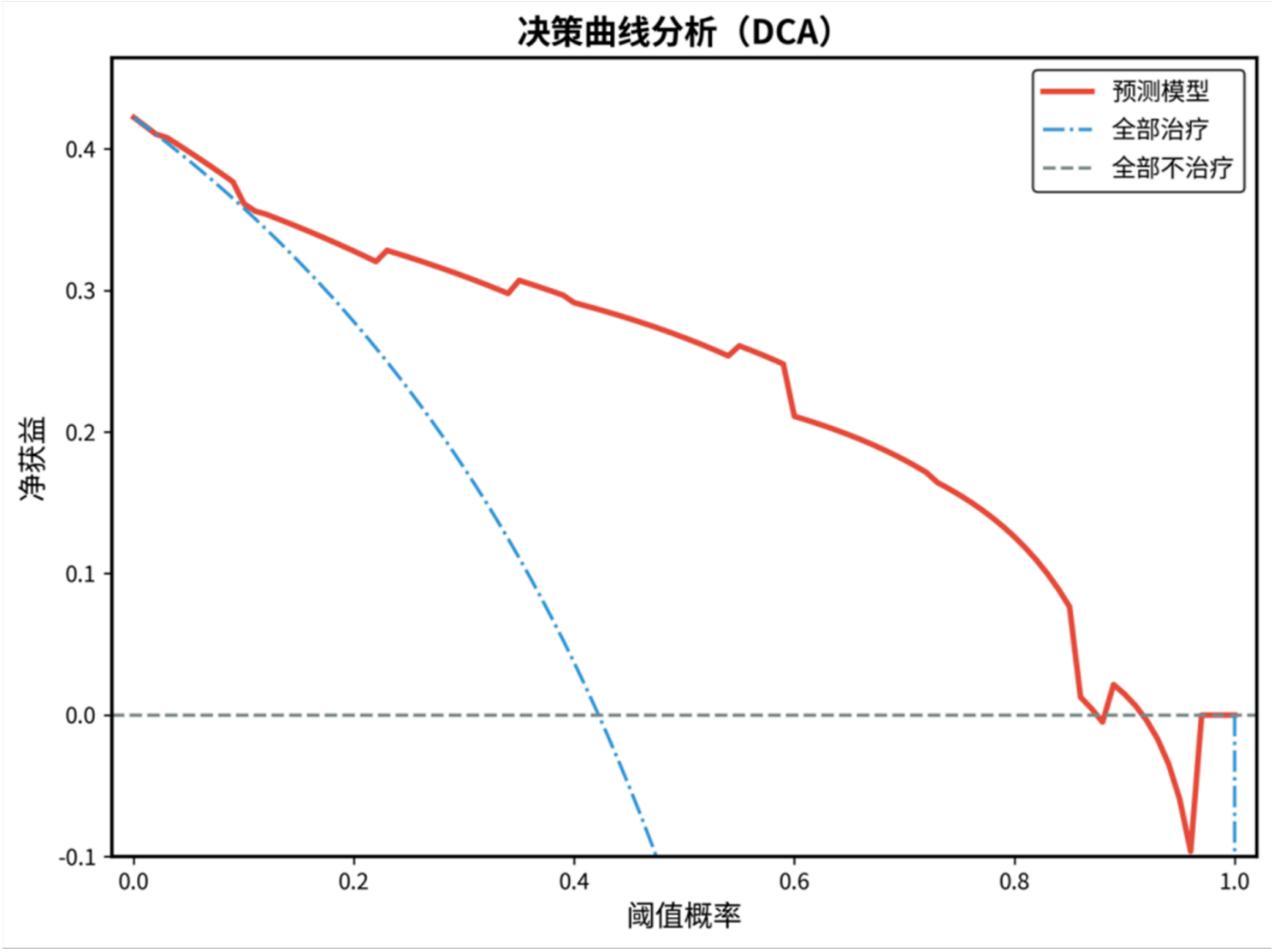


Figure 6

Decision Curve Analysis (DCA) of the Endplate Collapse Prediction Model