Research Square

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Nomogram to predict unfavorable outcomes after mechanical thrombectomy in patients with intracranial atherosclerosis-related large-vessel occlusion

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Research Article

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Abstract

Background: Endovascular treatment (EVT) has emerged as an effective therapeutic option for large-vessel occlusion (LVO) in patients with acute ischemic stroke (AIS). However, there is a paucity of research focusing on factors influencing clinical outcomes in patients with intracranial atherosclerosis-related large-vessel occlusion (ICAS-LVO). Therefore, this study aimed to develop a nomogram to predict 3-month unfavorable outcomes in AIS patients with ICAS-LVO undergoing EVT.

Methods: We retrospectively analyzed data from 183 AIS patients with ICAS-LVO who underwent EVT between January 2022 and December 2023. The primary outcome was a 3-month unfavorable outcome, defined as a modified Rankin Scale (mRS) score of 3–6. A nomogram was constructed based on a multivariable logistic regression model. The calibration of the predictive model was assessed using Spiegelhalter's Z-test.

Results: In the visualized nomogram, age (odds ratio [OR] 3.40; 95% CI, 1.54–7.54), NIHSS score at admission (OR 0.46; 95% CI, 0.28–0.76), and core infarct area (OR 0.06; 95% CI, 0.01–0.50) were identified as independent predictors of 3-month unfavorable outcomes among stroke patients undergoing EVT. Spiegelhalter's Z-test yielded a p-value of 0.843, suggesting satisfactory calibration and good model fit.

Conclusions:

We established a novel nomogram incorporating age, NIHSS score at admission, and core infarct area, which effectively predicts 3-month unfavorable outcomes in AIS patients with ICAS-LVO treated with EVT.

Introduction

Intracranial atherosclerotic stenosis-related large vessel occlusion (ICAS-LVO) is recognized as a leading cause of acute ischemic stroke (AIS), and it is particularly prevalent among Asian populations.[1–3] ICAS-related LVO presents distinct technical challenges compared to other etiologies. These occlusions are often more complex, commonly characterized by dense atherosclerotic plaques and underlying residual stenosis. Such structural characteristics significantly increase the difficulty of achieving successful recanalization with current thrombectomy techniques. Moreover, the paucity of comprehensive data on this specific subset of stroke patients hampers the development of tailored treatment protocols and impedes accurate predictions of clinical outcomes.

Recent studies have, however, demonstrated encouraging results. The clinical outcomes of endovascular treatment (EVT) in patients with ICAS-LVO have been reported to be comparable to those in patients with other etiologies of stroke.[4–13] Furthermore, when adjunctive rescue treatments—such as balloon angioplasty or stenting—are employed to address the underlying stenosis, recanalization rates approach those observed in patients without ICAS-related occlusions.[4, 7, 14] These findings suggest that select

subpopulations of ICAS-LVO patients may derive substantial benefit from EVT when managed appropriately. Therefore, identifying these subgroups and elucidating the factors that contribute to favorable outcomes is crucial for refining treatment strategies.

To date, there remains a paucity of research investigating the determinants of clinical outcomes in the ICAS-LVO population. A critical need exists to identify prognostic factors that can optimize therapeutic approaches and improve overall patient management in this group.

Accordingly, the objective of this study is to investigate the clinical and procedural factors associated with prognosis following EVT in patients with ICAS-LVO. Specifically, we aim to identify predictors of unfavorable outcomes, thereby providing valuable insights that may contribute to the development of individualized treatment strategies and enhanced clinical decision-making.

Methods

Population and Data Collection

This study was a retrospective analysis of prospectively collected data from a comprehensive stroke center at our institution, spanning the period from January 2022 to December 2023. Informed consent was obtained from each patient or their legal representative. The inclusion criteria were as follows: (1) a confirmed diagnosis of ICAS-LVO; (2) stroke onset to treatment time of less than 24 hours; (3) age ≥ 18 years; (4) a baseline National Institutes of Health Stroke Scale (NIHSS) score[15] of ≥ 5; and (5) a premorbid modified Rankin Scale (mRS) score[16] of ≤ 3. Patients were excluded if the lesion etiology was not attributable to ICAS-LVO.

Data collection

We collected baseline clinical information for all patients, including demographic data, medical history, NIHSS score, core infarct volume measured using automated software tools[17,18], and various time metrics (onset-to-groin, puncture-to-recanalization, and total procedure duration). Additional data recorded comprised the location of vessel occlusion, recanalization status, occurrence of symptomatic intracranial hemorrhage (sICH), rescue treatment interventions, and clinical outcomes at 3 months. The etiology of the occlusion was independently evaluated during the procedure by two experienced interventional neurologists, based on patients' medical history, risk factors, and angiographic findings. Intracranial atherosclerotic disease (ICAD)-related occlusion was defined angiographically as (1) fixed stenosis greater than 70% at the site of occlusion, or (2) mild stenosis with impaired distal blood flow or a tendency for re-occlusion, as observed during the endovascular procedure or on final angiography.

Outcome measures

Clinical prognosis was evaluated using the mRS at 3 months post-procedure, with functional independence defined as an mRS score of 2 or less. A favorable outcome was defined as an mRS score of 3 or less. Reperfusion status was assessed according to the modified Thrombolysis in Cerebral Infarction (mTICI) scale[19], with successful reperfusion defined as an mTICI score of 2b, 2c, or 3. Secondary outcomes included 3-month all-cause mortality and the occurrence of sICH within 7 days. The diagnosis of sICH was based on the Heidelberg Bleeding Classification.

Statistical Analysis

Continuous variables were summarized as medians with interquartile ranges (IQR, 25th–75th percentile), and univariate comparisons were performed using the Mann–Whitney U test when appropriate. Categorical variables were presented as frequencies and percentages, with differences assessed using either the chi-square test or Fisher's exact test, as appropriate. The least absolute shrinkage and selection operator (LASSO) logistic regression was employed to identify potential predictive factors. Significant predictors identified in the LASSO analysis were subsequently included in a multivariate logistic regression model, with the odds ratio (OR), 95% confidence interval (CI), and p-value reported for each variable. A nomogram was then constructed to visualize the predictive model. Model calibration was assessed using Spiegelhalter's Z-test. Finally, decision curve analysis (DCA) was conducted to evaluate the clinical utility of the predictive model. All statistical analyses were performed using R software (version 4.4.1; https://www.R-project.org/), and a two-sided p-value of < 0.05 was considered statistically significant.

Results

Demographic and clinical characteristics

A total of 183 patients with AIS were enrolled in this study. Among them, 99 patients achieved a favorable prognosis (mRS score 0–2), while 84 exhibited an unfavorable prognosis (mRS score 3–6). The clinical, demographic, and laboratory characteristics of patients in the favorable and unfavorable outcome cohorts are summarized in Table 1. Compared with those with a favorable prognosis, patients in the unfavorable group were older (66 vs. 62 years), had a higher proportion of females, and demonstrated a greater prevalence of hypertension (51.2% vs. 36.4%) and coronary heart disease (13.1% vs. 4.0%). Additionally, they presented with a higher baseline NIHSS score on admission (19.5 vs. 12), larger infarct core volumes (12.8 ml vs. 10 ml), longer onset-to-groin puncture times (433 minutes vs. 344 minutes), longer puncture-to-recanalization times (95 minutes vs. 80 minutes), longer total operation times (170 minutes vs. 150 minutes), and a higher incidence of sICH (17.8% vs. 7.1%).

Table 1
Characteristics of all patients

Variables	Favorable prognosis (mRS 0–2, n = 99)	Unfavorable prognosis (mRS 3–6, n = 84)	P
Age(years,median ,IQR)	62.0(54.0–70.0)	66.0 (61.3–74)	0.002
Sex(n/%)			0.004
Male	89 (89.9)	62 (73.8)	
Female	10 (10.1)	22 (26.2)	
History of Hypertension(n/%)	36 (36.4)	43 (51.2)	0.044
History of Diabetes(n/%)	13 (13.1)	16 (9.0)	0.275
History of Coronary heart disease(n/%)	4 (4.0)	11 (13.1)	0.026
History of Atrial fibrillation(n/%)	1 (1.0)	2 (2.4)	0.594
History of Cerebrovascular disease(n/%)	9 (9.1)	13 (15.5)	0.186
History of Smoking history	49 (49.5)	45 (53.6)	0.582
IV tPA(n/%)	6 (6.1)	5 (5.9)	0.962
NHISS score(median ,IQR)	12.0 (10.0–16.0)	19.5 (15.0–25.0)	< 0.001
Core infarcted volume(ml, median ,IQR)	10.0 (0–12.0)	12.8 (2.2–41.2)	0.002
Onset-to-groin time(min, median ,IQR)	344.0 (222.0–545.0)	433.0 (318.0–692.8)	0.018
Puncture-to-recanalisation time (min, median, IQR)	80.0 (60.0–110.0)	95.0 (75.0–120.0)	0.046
Operation time(min, median ,IQR)	150.0 (120.0–180.0)	170.0 (130.0–197.5)	0.038
Occlusion site(n/%)			0.633
ICA	51(51.5)	38 (45.2)	
MCA	26(26.3)	27 (32.1)	
VA-BA	22(22.2)	19 (22.6)	
mTICI(n/%)			0.534
0–2a	9 (9.9)	10 (11.9)	
2b–3	90 (90.1)	74 (88.1)	

Variables	Favorable prognosis (mRS 0–2, n = 99)	Unfavorable prognosis (mRS 3–6, n = 84)	P
sICH(n/%)	7(7.1)	15 (17.8)	0.025
Rescue treatment(n/%)			0.585
Tirofiban	20 (20.2)	18 (21.4)	
Balloon angioplasty	17 (17.2)	15 (17.9)	
Stent angioplasty	62 (62.6)	49 (58.3)	

Multivariable logistic regression analysis identified NIHSS score at admission (OR 1.09, 95% CI 1.04–1.14, $p < 0.001$), age (OR 1.04, 95% CI 1.00–1.08, $p = 0.036$), and baseline infarct core volume (OR 1.02, 95% CI 1.00–1.03, $p = 0.033$) as independent predictors of unfavorable outcomes at 3 months (Table 2).

Table 2
Multivariable logistic regression for unfavorable prognosis

Variables	OR	95% CI	p-value
NIHSS score	1.09	1.04, 1.14	< 0.001
Sex			
Male	—	—	
Female	2.13	0.85, 5.59	0.11
Age	1.04	1.00, 1.08	0.036
Hypertension			
Yes	—	—	
No	0.65	0.30, 1.37	0.3
Coronary heart disease			
Yes	—	—	
No	0.56	0.12, 2.28	0.4
Cerebrovascular disease			
Yes	—	—	
No	0.76	0.25, 2.28	0.6
Onset to groin	1.00	1.00, 1.00	0.3
Operation time	1.00	1.00, 1.01	0.059
Core infarcted volume	1.02	1.00, 1.03	0.033
sICH			
Yes	—	—	
No	1.65	0.54, 5.32	0.4
OR = Odds Ratio, CI = Confidence Interval			

Identification of significant predictors for unfavorable outcome following EVT

The LASSO logistic regression algorithm was employed to identify the most significant predictive factors, which were subsequently incorporated into the prediction model. Sixteen variables from Table 1 were included in the LASSO regression analysis, resulting in the selection of 10 factors with non-zero coefficients based on the optimal lambda value of 0.025 (Fig. 1). Ultimately, the final model comprised

the following 10 predictors: NIHSS, sex, age, hypertension, coronary heart disease, cerebrovascular disease, onset-to-groin time, operation time, core infarcted area, and sICH. These variables were further subjected to multivariable regression analysis.

A nomogram was constructed based on the results of the multivariable regression to predict the likelihood of unfavorable outcomes at 90 days. Each independent predictor was assigned a score ranging from 0 to 100 points. The total score, which could range from 0 to 240, corresponds to the cumulative probability of a poor outcome at 90 days (Fig. 2).

Performance and Validation of the Nomogram

In this cohort, the calibration curve of the unfavorable prognosis nomogram for stroke patients demonstrated good agreement between the predicted and observed outcomes (Fig. 3). The p-value for Spiegelhalter's Z-test was 0.843, indicating no significant deviation from perfect model calibration. Furthermore, the Brier score[20] was 0.191, suggesting that the nomogram's predictive probabilities were closely aligned with the ideal values. As shown in Fig. 4, when the risk threshold ranged from 10% to 80% in the training set, the nomogram yielded a greater net benefit in predicting 90-day unfavorable outcomes in stroke patients after mechanical thrombectomy (MT), compared to either treating all AIS patients or treating none.

Discussion

In this study, we developed and validated a nomogram to predict unfavorable outcomes in patients with ICAS-LVO undergoing EVT. The nomogram, which integrates variables such as age, initial NIHSS score, and infarct core volume, demonstrated robust predictive performance, exhibiting excellent discrimination and calibration in the training cohort. Furthermore, DCA confirmed the clinical utility of the model, showing significant net benefit across specific probability thresholds.

Nomograms have proven to be reliable tools for prognostic assessment and the advancement of personalized treatment decisions by combining multiple prognostic factors with key clinical indicators.[21–23] Our study extends this utility to the ICAS-LVO patient population. Notably, the utilization of real-world data in our research enhances the representativeness of the study cohort, thereby providing valuable supplementary evidence for future investigations.

Our single-center-derived nomogram demonstrated strong predictive accuracy for 90-day outcomes following MT. Early prediction of poor prognosis plays a crucial role in optimizing clinical management for patients with ICAS-LVO. The nomogram developed in this study offers clinicians an effective tool to guide treatment decisions and improve outcomes in this patient population.

Previous predictive models have consistently identified age and baseline NIHSS scores as the most significant determinants of 3-month outcomes following EVT.[24–28] These two variables—age and initial

NIHSS score—are closely correlated and serve as critical indicators in predicting clinical prognosis after EVT. Similarly, in our cohort with ICAS-LVO, both factors emerged as robust predictors of unfavorable outcomes at 3 months post MT.

Our findings are consistent with those reported by Ospel et al.[27], who observed that each 1-point increment in NIHSS score approximately corresponds to a 3-year increase in patient age. Given that the NIHSS score reflects the severity of neurological deficit, higher scores are naturally associated with a greater likelihood of poor outcomes following EVT. Furthermore, multiple studies have demonstrated that, even in cases of successful revascularization, both advanced age and elevated NIHSS scores remain independently associated with poor prognosis.[29,30]

Nevertheless, emerging evidence suggests that older patients may still derive greater benefit from EVT compared to conservative treatment strategies.[31] Despite this, increasing age is generally associated with diminished organ function, including compromised intracranial collateral circulation, suboptimal reperfusion, and a decline in immune competence—all of which elevate the risk of post-procedural infections and other complications.[32] Consequently, reversing severe neurological deficits through EVT in elderly patients continues to pose a considerable clinical challenge.

In our study, baseline infarct core volume emerged as an independent predictor of unfavorable outcomes. This finding is consistent with previous research, which has demonstrated that infarct volume serves as a robust predictor of clinical outcomes following EVT.[33–35] For instance, in a retrospective analysis of the Bernese Stroke Registry that utilized MRI-based triage for stroke patients, Gilgen et al.[36] identified diffusion-weighted imaging (DWI) lesion volume as an independent predictor of both unfavorable outcomes and overall survival. Similarly, Xie et al.[35] reported that pretreatment lesion volume was a significant predictor of clinical disability and mortality in their study cohort. Their results showed a strong association between pretreatment lesion volume and functional independence at three months, even after adjusting for age and initial stroke severity. Notably, even among patients who were younger and had mild neurological deficits—two factors traditionally associated with favorable outcomes[26]—the likelihood of achieving functional independence was markedly reduced when larger pretreatment lesion volumes were present.

The primary strengths of our study lie in the development of a user-friendly and rapid tool to facilitate pre-procedural identification of unfavorable outcomes in individual patients. The constructed nomogram demonstrated excellent discrimination and calibration, indicating that its predictive performance closely aligns with actual clinical risks. Furthermore, the robustness of our model was confirmed through validation with Spiegelhalter's Z-test. While several previous studies have investigated the association between risk predictors and stroke outcomes following mechanical thrombectomy[37,38], accumulating evidence suggests that nomograms outperform conventional risk prediction models [39,40]. Unlike traditional methods that categorize patients into risk groups, the use of a nomogram provides a visual,

individualized estimation of the probability of specific outcomes for each patient. This feature renders the nomogram an invaluable instrument for enhancing clinical decision-making.

This study has several limitations. First, it was based on a retrospective analysis of data from a single center with a relatively small sample size, which may restrict the generalizability of the findings to other geographical regions and ethnic populations. To overcome this limitation, future research should include multicenter, prospective studies to further validate the accuracy and applicability of the proposed model. Second, not all potential risk factors were included in our current analysis, meaning that other relevant predictors may need to be considered in future models. In upcoming prospective studies, additional parameters should be incorporated, and the potential benefits of integrating other biomarkers in improving the accuracy of the nomogram should be explored. Finally, although prospectively collected data were used for this retrospective analysis and the model exhibited good discriminative performance, external validation is still necessary to further assess its robustness and generalizability.

Conclusion

A novel nomogram incorporating age, initial NIHSS score, and infarct core volume has been developed to predict 3-month unfavorable outcomes in patients with AIS due to ICAS-LVO treated with EVT. Further large-scale prospective studies are warranted to validate the predictive efficacy of this nomogram.

Abbreviations

Endovascular treatment
EVT acute ischemic stroke-AIS
large
vessel occlusion-LVO
intracranial atherosclerosis
related large-vessel occlusion-ICAS-LVO
modified Rankin Scale
mRS odds ratio-OR
National Institutes of Health Stroke Scale
NIHSS
symptomatic intracranial hemorrhage
sICH
Intracranial atherosclerotic disease
ICAD
modified Thrombolysis in Cerebral Infarction
mTICI
The least absolute shrinkage and selection operator
LASSO
decision curve analysis

DCA mechanical thrombectomy-MT

Declarations

Consent for publication

Not applicable. This manuscript does not contain any individual person's data in any form (including individual details, images, or videos) that would compromise anonymity.

Ethics approval and consent to participate

This study was approved by the Institutional Review Board of Beijing Chao-Yang Hospital, Capital Medical University. Due to the retrospective nature of the study, the requirement for informed consent to participate was waived by the Institutional Review Board of Beijing Chao-Yang Hospital, Capital Medical University. The study was conducted in accordance with the Declaration of Helsinki.

Competing Interests:

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Declaration

Author Contribution

Hongchao Yang: Conceptualization, Methodology, Software, Investigation, Formal Analysis, Resources,Supervision,Writing – Original Draft, Review & Editing.Hongliang Zhong: Data Curation, Investigation.Jianwen Jia: Visualization, Investigation, Validation.Yu Wang: Data Curation, Investigation.Tong Li: Visualization, Investigation, Validation.He Liu: Visualization, Investigation, Validation.Yang Wang: Visualization, Investigation, Validation.All authors have read and approved the final manuscript.

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Data Availability

The datasets generated and/or analysed during the current study are not publicly available due to restrictions imposed by the institutional ethics committee and patient confidentiality requirements. However, anonymized data may be available from the corresponding author upon reasonable request and with permission from the institutional review board.

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Figures

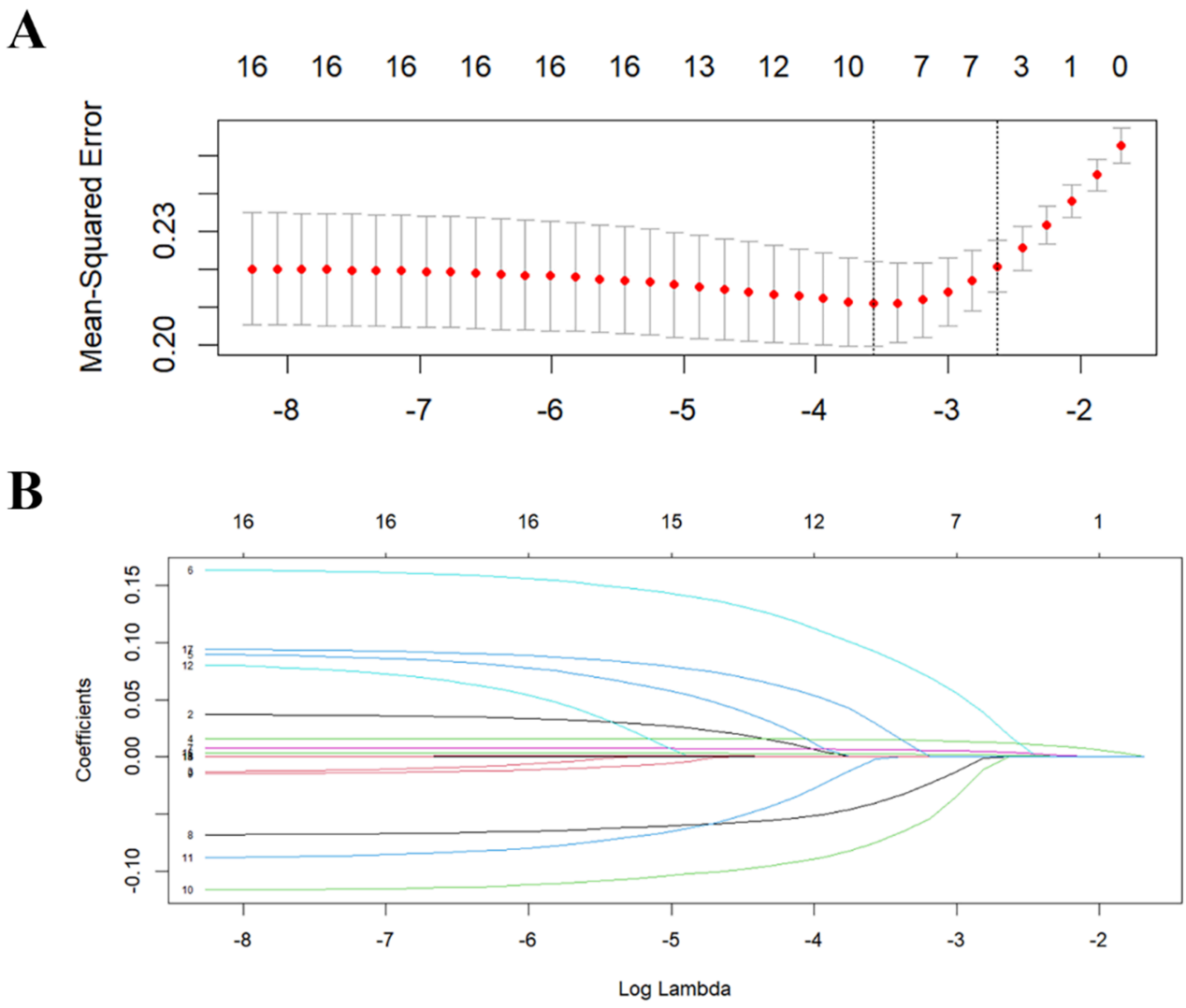


Figure 1

Factor selection using the least absolute shrinkage and selection operator (LASSO) logistic regression. A The LASSO coefcient profles of the 16 candidate variables. B The LASSO regression analysis.

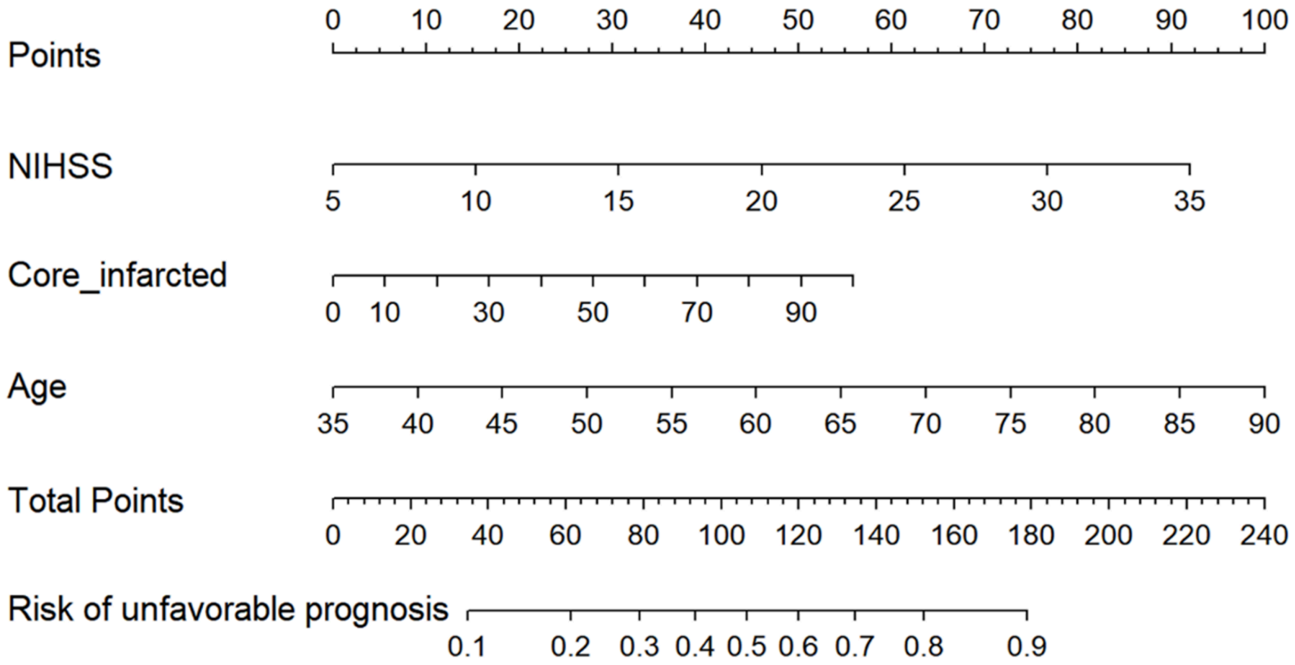


Figure 2

Nomogram for predicting the probability of unfavorable outcome after mechanical thrombectomy. NIHSS: National Institute of Health

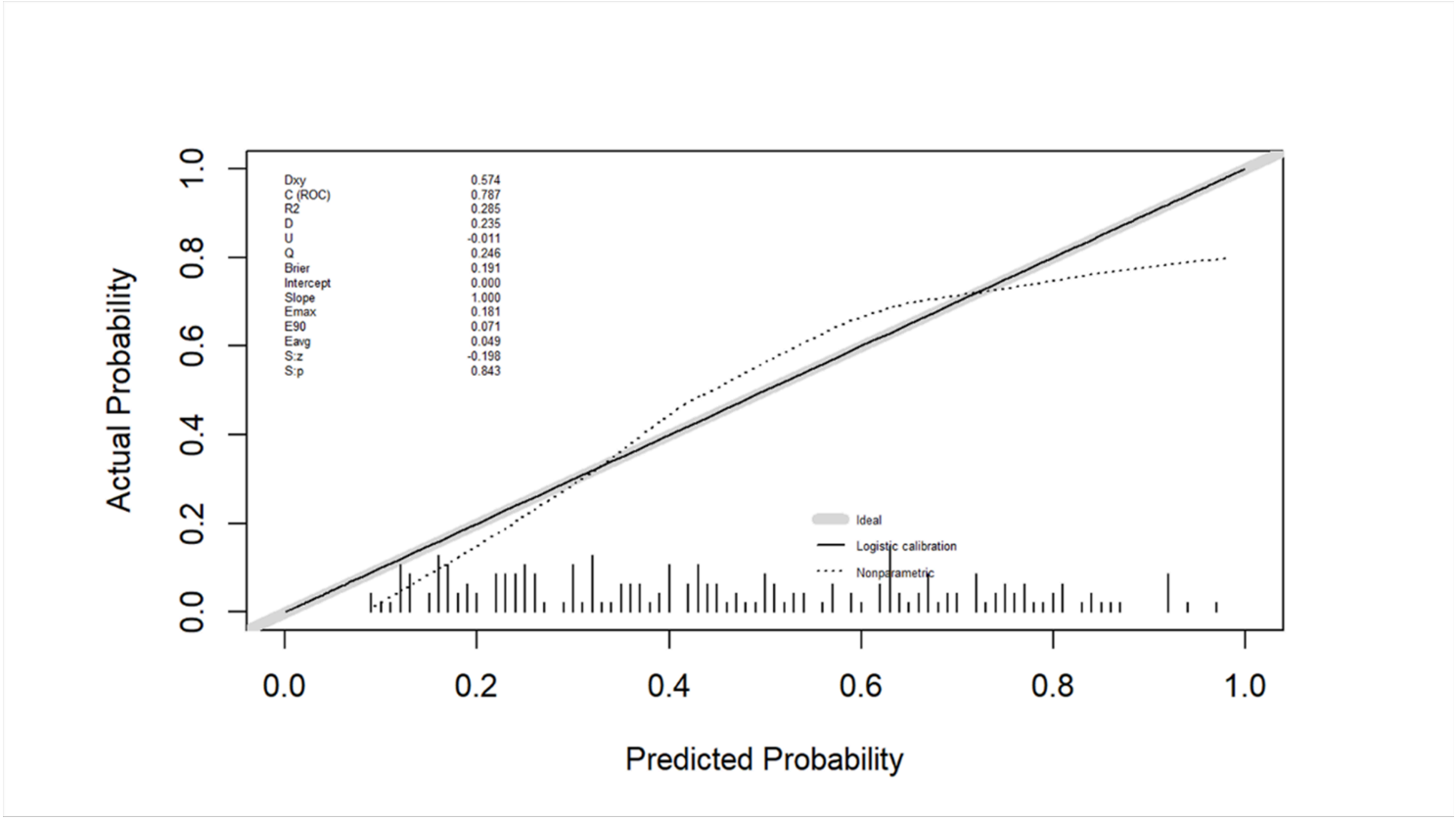


Figure 3

The calibration plot of the nomogram for predicting 3-month unfavorable outcomes of stroke patients undergoing mechanical thrombectomy.

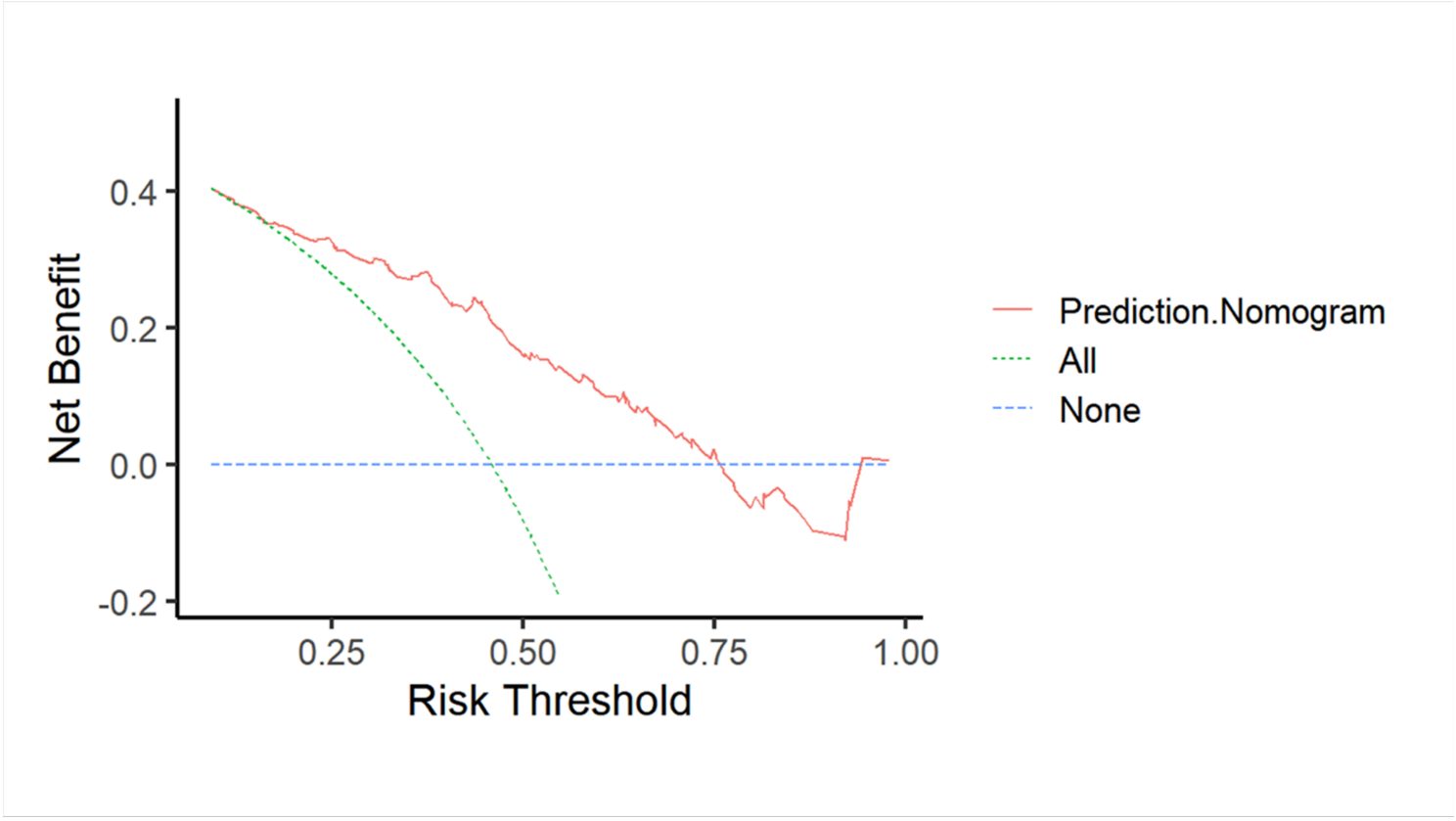


Figure 4

Decision curve analysis (DCA) of the nomogram. x-axis, the threshold probability; y-axis, the net benefit