Short-Term Prognostic Risk Factors and Nomogram Predictive Model Construction for Acute Ischaemic Stroke after Endovascular Treatment

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ABSTRACT

Objective: To investigate the factors influencing the severity of acute ischaemic stroke (AIS) and short-term prognosis after endovascular treatment.

Study Design: Observational study.

Place and Duration of the Study: Department of Cerebrovascular Diseases, The First People's Hospital of Qujing City, Yunnan Province, China, from June 2020 to December 2022.

Methodology: An analysis was conducted on 160 AIS patients undergoing endovascular treatment, classified into atherosclerosis subtype (AS) and cardioembolic subtype (CE) based on the Trial of ORG 10172 in Acute Stroke Treatment (TOAST) classification, each comprising 80 cases. The association among baseline and endovascular treatment parameters, clinical characteristics, postoperative complications, and short-term outcomes (risks of mortality and poor prognosis) was tested.

Results: Univariate analysis revealed significant positive correlations between increased fasting glucose, diastolic pressure, and the number of thrombectomy procedures with the frequency of cerebral haemorrhage in CE-type stroke. The time from femoral artery puncture to vessel opening was positively associated with the degree of brain oedema. In the AS subtype, univariate regression analysis demonstrated a significant association between heart rate, fasting glucose, cholesterol, time from femoral artery puncture to vessel opening, and degree of brain oedema with short-term prognosis. Fasting glucose and the number of thrombectomy procedures were significantly linked to short-term prognosis in CE-type AIS. A predictive model using line charts was developed for factors associated with postoperative complications and short-term prognosis, achieving predictive accuracies of 95.5% for the risk of death and 92.7% for poor prognosis (mRS >2), notably surpassing traditional prediction methods.

Conclusion: Clinical characteristics and endovascular treatment-related factors are important for the short-term prognosis of AIS patients. Development of predictive models can efficiently identify high-risk patients at an early stage.

Key Words: *Acute ischaemic stroke, Atherosclerosis, Cardioembolic, Severity, Prognosis.*

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INTRODUCTION

Acute ischaemic stroke (AIS) remains one of the leading causes of disability and mortality worldwide.[1,2] The establishment of stroke centres / units, together with the standardisation of diagnostic and treatment procedures and advancements in endovascular treatment techniques, has significantly improved vascular recanalisation rates and reduced ischaemic duration. However, nearly half of all patients still experience poor short-term outcomes.[3,4]

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Numerous clinical studies have demonstrated associations between traditional risk factors (e.g., age, BMI, blood glucose, HDL-C, and heart rate variability) and adverse outcomes in AIS.[5-7] Additionally, stroke severity (e.g., ASPECT score, infarct size, and infarct location), early complications (e.g., severe cerebral oedema and cerebral haemorrhage), and treatment strategies (e.g., intravenous thrombolysis, endovascular treatment, mechanical thrombectomy, and frequency of interventions) can, to some extent, predict short-term mortality risk.

However, current domestic and international research on the short-term prognosis assessment of ischaemic stroke remains limited by issues such as sample heterogeneity, retrospective study designs, and limited external validity. Additionally, regional variations in the incidence and progression of AIS arise from factors such as education, societal influences, and healthcare resource availability. This study aimed to examine the association between disease severity, short-term prognosis, and clinical characteristics in AIS patients who underwent endovascular treatment. The rationale is to provide more accurate guidance for clinical decision-making, medical resource allocation, and related fields.

METHODOLOGY

This retrospective study included patients with AIS who underwent endovascular treatment at the First People's Hospital of Qujing City between June 2020 and December 2022. The inclusion criteria were age ≥30 years; National Institutes of Health Stroke Scale (NIHSS) score[8] of ≥5 at admission, with suspected acute anterior circulation large-vessel occlusion stroke; and confirmation of acute anterior circulation large-vessel occlusion causing ischaemic stroke through imaging examinations, such as CT angiography and digital subtraction angiography. The procedure followed the 2018 Chinese Early Vascular Intervention Diagnosis and Treatment Guidelines for Acute Ischaemic Stroke and was performed by experienced neurologists specialising in interventional treatment. Patients met the indications for endovascular treatment and had no contraindications. Complete clinical data and a willingness to undergo telephone or outpatient follow-up for prognosis assessment; immediate post-treatment angiography showing a modified Thrombolysis in Cerebral Infarction (mTICI) grade of 2b or 3;[9] symptom onset within 6 hours, or 6-16 hours for patients meeting strict imaging criteria was also considered in the selection of subjects. Informed consent for endovascular treatment was signed by the patient or their relatives. The exclusion criteria were: CT indicating cerebral haemorrhage, active systemic bleeding, or a known bleeding tendency, or extensive cerebral infarction (>1/3 of the middle cerebral artery supply area), and clear diagnosis of secondary cerebral infarction due to other conditions, such as vasculitis and coagulation disorders; severe cardiac, hepatic, and renal dysfunction; and expected time from symptom onset to femoral artery puncture greater than 16 hours.

Baseline patient data were collected using the electronic medical record system. This included demographic details such as age, gender, height, weight, and medical history (hypertension, diabetes, hyperlipidaemia, coronary heart disease, atrial fibrillation, and other vascular occlusive diseases). Clinical indicators, including vital signs (systolic blood pressure, diastolic blood pressure, and heart rate), lipid profile (triglycerides, total cholesterol, low-density lipoprotein cholesterol, high-density lipoprotein cholesterol, and lipoprotein(a)), and fasting blood glucose, were also recorded. Preoperative condition scores, including the NIHSS, ASPECTS,[10] and mRS scores,[11] were documented. Data related to endovascular treatment were also gathered, such as the time from femoral artery puncture to vessel recanalisation, the number of thrombectomy procedures, and whether a stent was implanted, along with other relevant parameters. Postoperative CT scans at 24 hours were used to evaluate bleeding and brain oedema. Patients' mRS scores and survival status were reassessed at the 90-day mark through outpatient visits or telephone interviews.

The Trial of ORG 10172 in Acute Stroke Treatment (TOAST) classification of stroke aetiology primarily includes large artery atherosclerosis (AS) stroke, cardioembolic (CE) stroke, and strokes due to other causes.[12] Atrial fibrillation rhythm and heart rate were obtained from electrocardiograms. Hypercholesterolaemia was defined as total cholesterol levels exceeding 5.2 mmol/L, and elevated LDL cholesterol (LDL-C) was defined as LDL-C levels exceeding 3.4 mmol/L. The time from femoral artery puncture to vessel recanalisation refers to the duration taken during endovascular treatment, from femoral artery puncture to the successful opening of the vessel. Prognostic indicators included postoperative symptomatic intracranial haemorrhage assessed within 24 hours postoperatively based on clinical manifestations and head CT evaluations of intracranial bleeding, within 24 hours postoperatively, brain oedema was categorised into three levels based on CT scan results as Grade I: No significant brain oedema; Grade II: Marked parenchymal oedema without herniation; and Grade III: Brain oedema with herniation. Prognostic indicators at 90 days included mortality rate within 90 days postoperatively, 90-day mRS score through outpatient or telephone follow-up with 0-2 points indicating a good prognosis and 3–6 points indicating a poor prognosis.

Statistical analysis was conducted using R 4.2.0 statistical software. Chi-square tests were applied to analyse intergroup differences in categorical data, with percentages representing these data. Independent sample t-tests were used to assess intergroup differences in continuous data. For continuous response variables, linear regression models were employed to analyse the correlation between predictor variables, with statistics reported as estimate ± standard error, and p-values indicating significance. For categorical response variables, logistic regression models were used to examine the association between predictor variables, with statistics presented as OR (95% CI), and p-values indicating significance. A p-value of <0.05 was considered statistically significant.

RESULTS

The study included 160 AIS patients who underwent endovascular treatment for ischaemic stroke, with equal representation of AS and CE stroke types (80 cases each). Out of these, 72 (45%) were males and 88 (55%) were females, with a mean age of 69.09 ± 11.74 years. The average BMI was 22.72 ± 3.48 Kg/m^2. Sixteen (10%) patients had a history of diabetes, 56 (35%) had hypertension, and 2 (1.3%) had hyperlipidaemia. Laboratory results showed that 46 (28.75%) patients had hypercholesterolaemia, 30 (18.8%) had elevated LDL-C, and 50 (31.3%) had low HDL cholesterol (HDL-C). Preoperatively, the average NIHSS score was 15.03 ± 8.23, and the Alberta Stroke Programme Early Computed Tomography Score (ASPECTS) was 8.73 ± 1.05. The mean time from femoral artery puncture to vessel recanalisation was 76.60 ± 39.62 minutes. Thrombectomy was performed an average of 1.73 ± 1.06 times, and stent placement occurred in 50 (31.3%) cases. Postoperative complications included symptomatic intracranial haemorrhage in 16 (10%) cases, significant brain oedema in 88 (55%) cases, and brain herniation in 21 (13.1%) cases. Forty-two (26.3%) patients died within 90 days, and 86 (53.8%) patients had a poor prognosis (mRS score >2) at 90 days.

Table I: Differences in clinical features and prognosis of AIS with different TOAST classifications.

Category	Clinical Characteristics	AS	CE	Statistics	p-value
Baseline Characteristics	Age	67.05 ± 12.06	71.13 ± 11.10	-2.22	0.0276
	Male, gender (%)	40 (50.0%)	32 (40.0%)	1.24	0.266
	BMI (kg/m²)	22.02 ± 3.35	23.57 ± 3.47	-2.51	0.0133
	SBP (mmHg)	146.1 ± 23.85	144.15 ± 22.59	0.53	0.5962
	DBP (mmHg)	88.25 ± 16.42	83.40 ± 14.57	1.98	0.04998
	HR (bpm)	79.58 ± 13.50	82.18 ± 17.70	-1.04	0.2978
	Triglyceride (mmol/L)	1.36 ± 0.73	0.95 ± 0.29	4.52	1.51E-05
	Total cholesterol(mmol/L)	4.58 ± 1.04	4.16 ± 0.91	2.70	0.0079
	HDLC (mmol/L)	1.12 ± 0.19	1.17 ± 0.23	-0.69	0.4939
	LDLC (mmol/L)	2.87 ± 0.72	2.67 ± 0.72	1.72	0.0867
	Lp (a)(mg/dL)	301.12 ± 384.77	226.42 ± 214.61	1.46	0.1462
	Fasting glucose (mmol/L)	8.06 ± 4.25	7.58 ± 3.29	0.77	0.442
Severities	NIHSS	13.95 ± 8.33	16.10 ± 8.03	-1.66	0.0985
	ASPECT	8.79 ± 0.84	8.68 ± 1.24	0.66	0.5124
	mRS	3.84 ± 0.71	4.03 ± 0.66	-1.67	0.0979
Operation factors	Puncture to vascular opening time (min)	69.95 ± 36.97	83.25 ± 41.26	-2.15	0.0333
	Times of embolectomy operations	1.40 ± 0.87	2.05 ± 1.14	-4.05	8.34E-05
	Stenting	22 (27.5%)	28 (35%)	0.73	0.3938
Complications	Cerebral haemorrhage	2 (2.5%)	14 (17.5%)	8.40	0.0037
	Cerebral oedema grade II-III	33 (41.3%)	55 (68.8%)	11.14	0.0008
	Grade III	13 (16.3%)	8 (10.0%)	0.88	0.349
Prognosis	Death in 90 days	20 (25.0%)	22 (27.5%)	0.03	0.8574
	mRS >2 in 90 days	44 (55.0%)	42 (52.5%)	0.29	0.5932

Chi-square tests were used in count data. Independent sample t-tests were used in measurement data. Abbreviations: AS, atherosclerosis subgroup; CE, cardioembolic subgroup; BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; HR, heart rate; HDLC, high-density lipoprotein cholesterol; LDLC, low-density lipoprotein cholesterol; Lp (a), lipoprotein(a); NIHSS, National Institutes of Health Stroke Scale; ASPECT, Alberta stroke programme early CT score; mRS, modified Rankin scale.

Table II: Regression analysis between clinical features and complications in AIS patients.

Prognosis	Risk factors	AS OR (95% CI)	AS p-value	CE OR (95% CI)	CE p-value
Cerebral oedema	Puncture to vascular opening time	1.02 (1.00 - 1.04)	0.0177	1.03 (1.00 - 1.06)	0.0254
Symptomatic cerebral Haemorrhage	Times of embolectomy operations	1.97 (0.50 - 7.78)	0.3307	3.44 (1.70 - 6.95)	0.0006
	DBP	0.96 (0.87 - 1.07)	0.4673	1.06 (1.02 - 1.11)	0.0043
	Fasting glucose	3.38 (0.44 - 25.85)	0.2412	0.57 (0.33 - 0.99)	0.0448

OR, odds ratio; CI, confidence interval; DBP, diastolic blood pressure.

Table III: Regression analysis between clinical features and short-term prognosis of AIS patients.

Prognosis	Risk factors	AS OR (95% CI)	AS p-value	CE OR (95% CI)	CE p-value
Death in 90 days	NIHSS	1.18 (1.08 - 1.27)	9.26E-05	1.19 (1.09 - 1.30)	9.83E-05
	mRS	7.72 (2.19 - 27.27)	0.0015	2.51 (1.04 - 6.07)	0.0408
	ASPECT	0.28 (0.13 - 0.59)	0.0008	0.46 (0.29 - 0.74)	0.0013
	HR	1.06 (1.01 - 1.10)	0.0082	0.95 (0.92 - 0.99)	0.0093
	Fasting glucose	1.49 (1.22 - 1.82)	8.40E-05	1.14 (0.98 - 1.32)	0.0861
	Puncture to vascular opening time	1.03 (1.01 - 1.05)	0.0032	1.00 (0.98 - 1.01)	0.6110
	Times of embolectomy operations	1.42 (0.80 - 2.51)	0.2356	4.27 (2.18 - 8.38)	2.45E-05
	Cerebral oedema	4.97 (2.29 - 10.79)	4.99E-05	2.78 (1.14 - 6.78)	0.0243
mRS >2 in 90 days	NIHSS	1.20 (1.10 - 1.32)	6.39E-05	1.20 (1.10 - 1.31)	2.23E-05
	mRS	5.04 (1.79 - 14.19)	0.0022	3.50 (1.46 - 8.40)	0.0049
	Fasting glucose	1.61 (1.16 - 2.24)	0.0046	1.23 (0.99 - 1.53)	0.0662
	Total cholesterol	1.73 (1.04 - 2.89)	0.0356	0.80 (0.48 - 1.31)	0.3758
	Times of embolectomy operations	1.50 (0.83 - 2.69)	0.1757	2.38 (1.47 - 3.87)	0.0005
	Cerebral oedema	2.26 (1.12 - 4.54)	0.0224	1.35 (0.65 - 2.81)	0.9432

AS: atherosclerosis subgroup; CE, cardioembolic subgroup; DBP, diastolic blood pressure; NIHSS, National Institutes of Health Stroke Scale; ASPECT, Alberta stroke programme early CT score; mRS. modified Rankin scale; OR, odds ratio; CI, confidence interval; HR, heart rate.

Differences in baseline parameters between AS and CE stroke types revealed that AS patients had lower age, BMI, and preoperative diastolic pressure, but higher triglycerides and total cholesterol ($p < 0.05$). In contrast, CE patients exhibited a longer femoral artery puncture to vessel recanalisation time and a higher incidence of postoperative symptomatic intracranial haemorrhage and brain oedema ($p < 0.05$). No significant differences in mortality or poor prognosis were found between AS and CE stroke types. Detailed distributions and group differences are presented in Table I, with $p < 0.05$ indicating statistical significance.

In the analysis of the relationship between clinical characteristics and complications (degree of brain oedema and symptomatic intracranial haemorrhage), a prolonged time from femoral artery puncture to vessel recanalisation (POT) was significantly associated with a higher degree of brain oedema in both CE and AS stroke types ($p < 0.05$). Baseline parameters did not show a significant correlation with the degree of brain oedema. In the analysis of symptomatic intracranial haemorrhage, only baseline parameters (lower fasting blood glucose and higher diastolic pressure) and procedural parameters (increased thrombectomy procedures) demonstrated a significant association with the occurrence of symptomatic intracranial haemorrhage in CE type stroke ($p < 0.05$) Table II. In the analysis of baseline parameters and short-term prognosis, heart rate showed a significant positive correlation with the risk of death in both groups ($p < 0.05$).

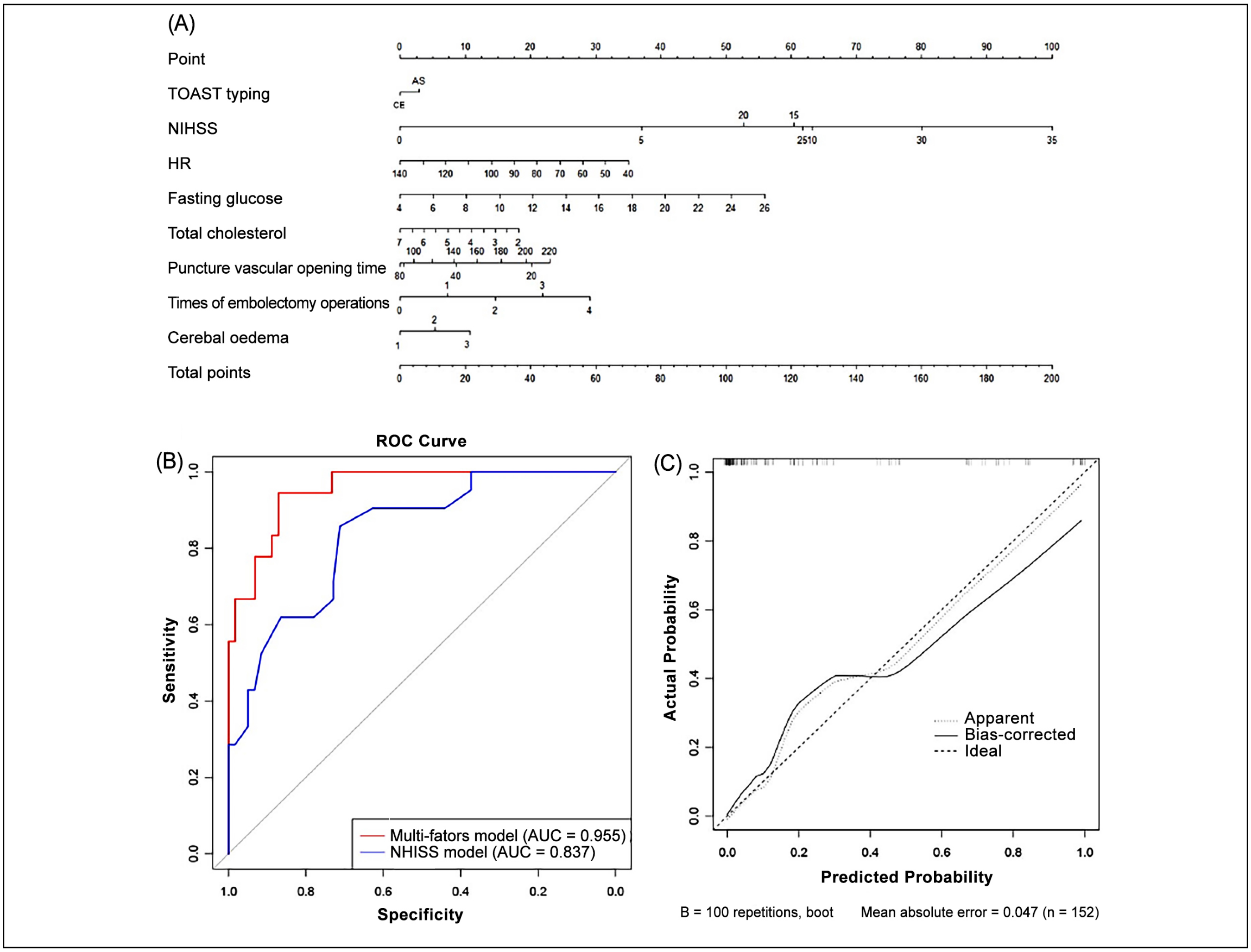

Figure 1: Multi-factor nomogram model to predict mortality risk of AIS. (A) Nomogram predictive model for AIS mortality risk. (B) ROC curve for AIS mortality prediction. (C) Internal validation errors for AIS mortality prediction.

Fasting blood glucose demonstrated a significant association with the risk of death and poor prognosis in the AS group ($p < 0.05$) and showed nominal significance in the CE group analysis ($p = 0.086$). Furthermore, the time from femoral artery puncture to vessel recanalisation in the AS group and the number of thrombectomy procedures in the CE group exhibited significant positive correlations with the risk of death and poor prognosis ($p < 0.05$). Regarding complications, the occurrence of brain oedema in the AS group was significantly associated with the risk of death and poor prognosis. Detailed results are presented in Table III.

Significant differences were observed in short-term prognostic factors between AS and CE subtypes. Nomogram predictive models were developed to visually and systematically assess the influence of various risk factors on short-term prognosis in AIS, incorporating variables associated with complications and prognosis ($p < 0.05$). To mitigate collinearity bias among severity scores, only the most significant NIHSS score was included in the nomogram model. The scoring systems for mortality risk and poor prognosis risk in the nomogram predictive models are depicted in Figure 1A and 2A. ROC curves were subsequently generated to evaluate the prognostic prediction value (Figure 1B and 2B). The model, incorporating multiple factors, demonstrated prediction accuracies of 95.5% and 92.7% for AIS mortality and short-term poor prognosis risks, respectively, significantly outperforming predictions based solely on the NIHSS score. Furthermore, internal validation was performed through random sampling to evaluate the model's robustness. The model exhibited prediction errors of 0.039 for short-term AIS mortality risk and 0.048 for poor prognosis risk, indicating that the multi-factor model was relatively robust in predicting both mortality and poor prognosis risks (Figure 1C and 2C).

DISCUSSION

Current research suggests that early relief of large vessel occlusion in anterior circulation stroke patients through endovascular treatment significantly improves prognosis. However, despite these advancements, nearly 50% of patients continue to experience poor outcomes.[4,13] This study aimed to analyse the correlation between short-term prognosis and clinical characteristics in AIS patients undergoing endovascular treatment in Qujing, addressing a research gap in the local context.

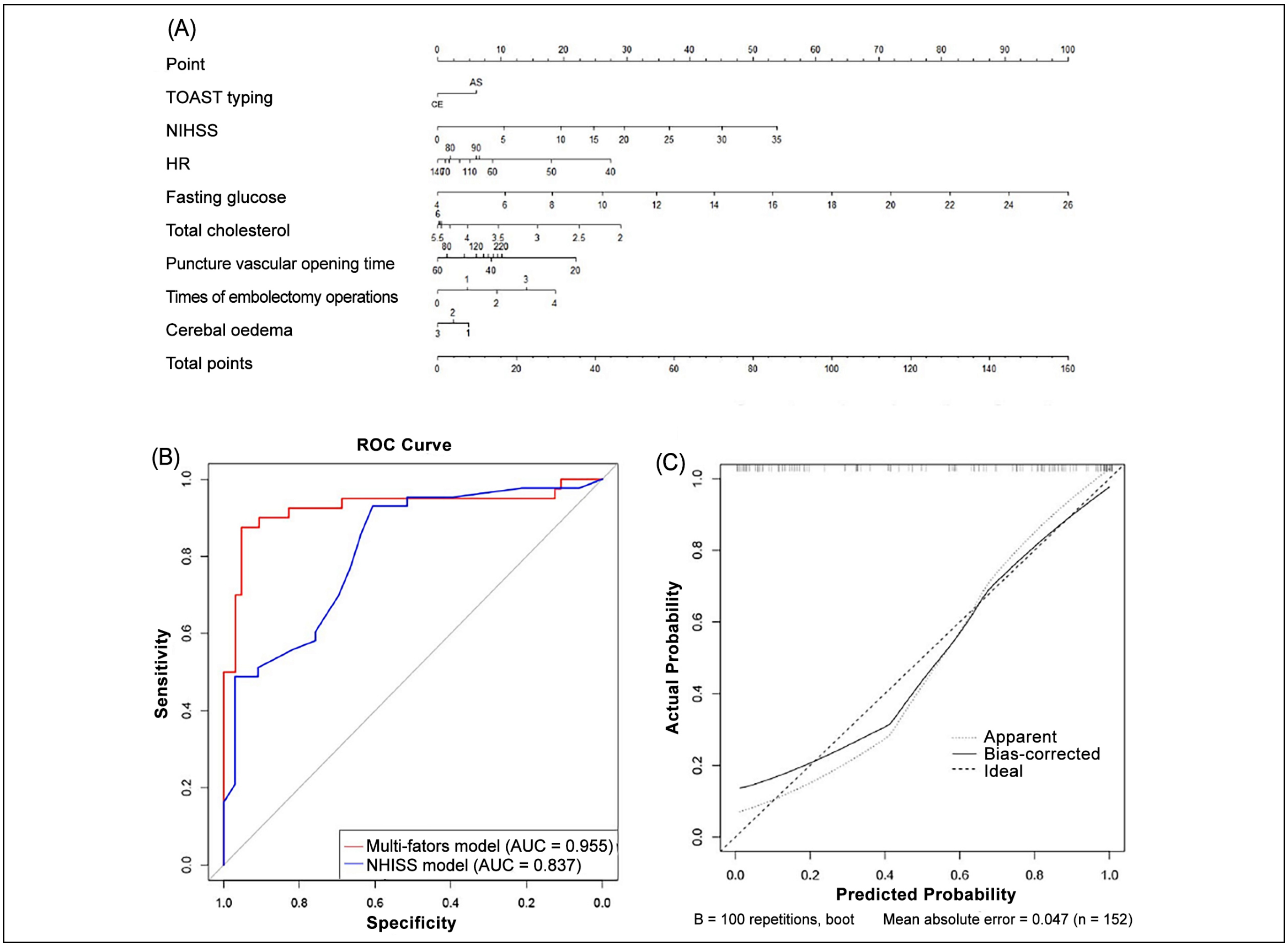

Figure 2: Multi-factor nomogram model predicted the risk of poor prognosis in AIS. (A) Nomogram predictive model for AIS poor prognosis risk. (B) ROC curve for AIS poor prognosis prediction. (C) Internal validation errors for AIS poor prognosis prediction.

The findings provide valuable insights and evidence to support the standardisation of stroke diagnosis and treatment, as well as future developments in this field.

In this study cohort, both types of acute ischaemic stroke, AS and CE, had a poor prognosis rate exceeding 50% and a mortality rate exceeding 25% within 90 days after endovascular treatment, consistent with reports in the literature. This highlights the urgency of stroke prevention and improving prognosis as a significant public health concern. The analysis of the association between clinical characteristics and AIS severity and prognosis revealed a significant correlation between lipid characteristics (high total cholesterol), fasting blood glucose, and AIS prognosis, consistent with previous research.[14-16] Despite increased awareness of cardiovascular disease and the widespread use of statins in the population, the intervention rate for hyperlipidaemia in China averages around 37.8%.[17] However, regional variations persist: 20% of ischaemic stroke patients in Qujing had lipid abnormalities, but only 1% were aware of their lipid disorders. This indicates a need for improved health education and more widespread health examinations in the region. Additionally, the association between diabetes and ischaemic stroke, as well as other cardiovascular diseases, has long been a focus. This study's findings once again emphasise the close connection between elevated blood glucose levels and stroke. High blood glucose may lead to atherosclerosis and endothelial damage, while post-ischaemic stroke fasting blood glucose levels may reflect the body's stress response,[18] which can, to some extent, indicate disease severity.[19] Studies have shown that high blood glucose can trigger inflammation, oxidative stress, and endothelial damage, promote the formation of atherosclerotic plaques, and increase the risk of thrombosis upon plaque rupture.[20-22] Therefore, glucose control is crucial for stroke prevention, disease progression, and improving prognosis. The conclusions drawn from this study provide theoretical support for local public health management and medical resource allocation. Early identification of high-risk individuals and widespread implementation of secondary prevention treatments could significantly reduce the disability and mortality rates of stroke in the region, thereby alleviating the economic burden on families and healthcare systems.

Many studies suggest that postoperative symptomatic intracranial haemorrhage is a significant risk factor for poor prognosis in AIS patients undergoing endovascular treatment.[23,24] Mechanical thrombectomy is one of the most important iatrogenic risk factors for symptomatic intracranial haemorrhage. This study also found that the number of thrombectomy procedures, particularly in cardiogenic embolic stroke, was significantly correlated with an increased risk of symptomatic intracranial haemorrhage and poor prognosis. However, an increase in the number of thrombectomy procedures often indicates a heavy and complex thrombus burden in the affected area, making it difficult to exclude the impact of disease severity on prognosis. This highlights the need to further optimise treatment strategies for cardiogenic embolic stroke and to develop safer and more effective techniques. Furthermore, this study combined traditional risk factors with procedural parameters to construct a nomogram predictive model, which significantly improved the predictive accuracy of the disease compared to traditional methods.

This study has certain limitations, including its retrospective design, small sample size, lack of external validation, and limited exploration of underlying mechanisms, which should be addressed in future research.

CONCLUSION

This study identified key risk factors associated with disease severity and prognosis in AIS patients, including blood glucose, lipid levels, and endovascular treatment parameters. While interventional therapy has significantly improved the prognosis of stroke patients, there is an association with adverse complications with a need for optimised treatment strategies.

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ETHICAL APPROVAL:
This retrospective study was approved by the Ethics Committee of the First People's Hospital of Qujing for a waiver of informed consent.

PATIENTS' CONSENT:
The study was retrospective and did not require patients' written informed consent.

COMPETING INTEREST:
The authors declared no conflict of interest.

AUTHORS' CONTRIBUTION:
BC: Performed the analysis and wrote the manuscript.
RD, SL: Edited the manuscript.
YC: Performed the result visualisation.
XM, GJ, SL: Collected the data.
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