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A new nomogram for predicting the prognosis based on 24-hour blood pressure variability after intravenous thrombolysis

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Abstract

Background & Objective: There is insufficient research on the use of population data to construct a predictive model of blood pressure variability (BPV) after thrombolysis to estimate the subsequent development of acute ischemic stroke (AIS) patients. The aim of this study is to construct and validate a model that uses BPV 24 hours after thrombolytic therapy to predict outcome in patients with AIS. *Methods:* To construct and validate a model that uses BPV 24 hours after thrombolytic therapy to predict outcome in patients with AIS. *Results:* A total of 503 patients with acute ischemic stroke who received intravenous thrombolytic therapy were enrolled in the study. The multivariate analysis outcomes have delineated several pivotal factors that are significantly prognostic of adverse outcomes in AIS patients post-thrombolysis: The initial National Institutes of Health Stroke Scale score, a recorded history of hypertension, the variability in systolic and diastolic blood pressure as indicated by their standard deviation, and the blood pressure measurements recorded 24 hours subsequent to thrombolytic therapy. These determinants have emerged as substantial predictors, shedding light on the complex interplay of clinical parameters that influence patient prognosis following AIS treatment. Within the development and validation cohorts, the area under the curve for the nomogram, which estimates the probability of an unfavorable prognosis, was determined to be 0.876 (95%CI: 0.84–0.913) and 0.849 (95%CI: 0.784–0.913), respectively. The calibration curve revealed a striking congruence between the predicted probabilities by the nomogram and the actual outcomes observed in the validation set. Furthermore, the decision curve analysis underscored the significant clinical utility and robust applicability of the prognostic model, illustrating its potential to guide clinical decision-making effectively.
Conclusion: Because of its superior predictive accuracy, discriminative power, and clinical utility, the nomogram is an important adjunct tool for the assessment of possible adverse outcomes in patients with AIS following thrombolytic therapy.

Keywords: Acute ischemic stroke, thrombolysis, blood pressure variability, nomogram

INTRODUCTION

Stroke is still one of the most common fatal and disabling diseases in the world.[1] In China, ischemic stroke occupies the first place in all types of stroke. There are many predisposing factors of stroke, the most noteworthy of which is hypertension. Approximately 75% of patients with stroke experience elevated blood pressure (BP) during the acute phase of the disease, and increased intracranial pressure, discomfort, unstable preexisting hypertension, and acute physiological stress are among the causes of increased systolic BP in in acute stroke patients. Furthermore, lower BP is connected with better outcomes, especially in patients receiving intravenous rt-PA treatment.[2] However, BP greatly fluctuates during the acute stage of stroke. Compared with a single BP assessment, a BP model that changes with time may better predict the outcome of stroke.

The degree to which BP varies as a result of the complicated interplay between neurological reactions, humoral factors, physical illnesses, drugs, and lifestyle choices is known as blood pressure variability (BPV).[3] The rate of

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significantly elevated BPV notably increases with age.[4] Even with BP regulation, many patients still experience cerebrovascular disease, and BPV is a better predictor of the development of these conditions.[5]

Intravenous thrombolysis (IVT) is still the recommended treatment of choice for AIS within 4.5 hours of onset.[6] Multiple factors contribute to poor outcomes and mortality after stroke and treatment with thrombolysis. Among these factors, BPV also affects the prognosis of patients who undergo IVT.[7] Patients with a stable BP during thrombolysis have been shown to be more likely to have a good outcome[8], and increased BPV is negatively associated with better recovery of neurological function at 3 months in patients with AIS.[9-11]

Nomograms are graphical models that combine several risk factors to make precise predictions; they are employed as diagnostic tools for a wide range of illnesses. As far as we know, few studies have publicly reported the practice of using nomogram to predict the prognosis of BPV after thrombolysis in patients with AIS. In this study, we aim to use the BPV within 24 hours after thrombolytic therapy to design and validate a nomogram for patients with AIS. We hope that it will help promote the application of BPV to predict the prognosis of patients after thrombolytic therapy.

METHODS

Study design and patients

This research represents a retrospective analysis conducted at a single institution. It involves a review of medical records from patients diagnosed with AIS who received intravenous rt-PA therapy at the Second Affiliated Hospital of Harbin Medical University, capturing data spanning the period from March 2021 to June 2023.

Inclusion criteria were: (1) Received IVT therapy within 4.5 hours of the commencement of AIS; (2) aged > 18 years; (3) brain computed tomography excluded intracranial hemorrhage (ICH); and (4) received a 3-month follow-up evaluation.

Exclusion criteria were: (1) Insufficient baseline data; (2) a lack of 3-month modified Rankin scale (mRS) scores; (3) the presence of brain tumors, aneurysms or arteriovenous malformations, or traumatic brain injury or other brain injuries; (4) dementia or mental illness; and (5) endovascular treatment after intravenous thrombolysis.

Data collection

This study involved acquiring a variety of patient data, that included: patient age and gender, smoking and alcohol consumption history, a review of medical history including hypertension, diabetes, coronary heart disease, and prior stroke incidents. Additionally, hourly blood pressure readings within the initial 24 hours post-thrombolysis were systematically recorded, alongside the mRS scores assessed three months subsequent to the stroke event. The laboratory parameters included total cholesterol levels, triglyceride (TG) levels, high-density lipoprotein levels, low-density lipoprotein levels, homocysteine levels, and the baseline National Institutes of Health Stroke Scale (NIHSS) score. The electronic medical records of patients were extracted from the hospital's health information system.

Outcomes and definitions

Recovery of neurological function in patients with AIS who underwent IVT three months after stroke was evaluated using the mRS score. mRS is the most commonly used index for evaluating neurological function in patients with a stroke, it was assessed at 3 months or later after the stroke. It is graded from 0 to 6.[12,13] Studies have shown that mRS experiences a leap change at 2 and 3 points.[14] We classified patients with mRS scores of 0–2 into the good prognosis group, including those with 0 (no symptoms at all), 1 (symptomatic but with no obvious disability), and 2 (mild disability). Patients with a score of 3–6 were divided into poor prognosis groups, including 3 (moderate disability), 4 (severe disability), 5 (severe disability), and 6 (death).

Various indexes are used to evaluate BPV, including the standard deviation (SD), coefficient of variation, mean true variability, weighted 24-hour standard deviation, and mean independent variability. These indexes can better quantify the extreme changes in blood pressure measurements, and may be more advantageous than the average.[15,16] We collected the BPV data within 24 hours, which is a type of Office Blood Pressure Measurement of short-term BPV. Based on the classification and characteristics of BPV, we adopted the SD as the calculation method for BPV. The formula is provided below:

$$SD = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(BP_i - \overline{BP})^2}.$$

Statistical analyses

Data analysis was carried out using R 4.1.0 and SPSS 25.0 software. The entire collection of sample datasets was meticulously divided into two distinct subsets: one for development and the other for verification, adhering to a proportional ratio of 7:3, ensuring a balanced allocation for robust analysis. Normally distributed measurement data are represented by mean ± SD, and comparisons of these variables between groups were performed using *t* tests. Measured data, non-normally distributed, presented as M (P25, P75). Wilcoxon test was used to compare these variables between groups. Data measurement is demonstrated by examples and analyzed by chi-square test or Fisher's exact probability method. The factors that influence poor prognosis were screened using single-factor logistic regression models. Using regression analysis techniques, multivariate logistic regression analysis was performed to select variables that had a significant effect on adverse outcomes and to construct predictive nomograms accordingly. The bootstrap method (1000 resamples) was used for internal verification. In order to evaluate the resolution and accuracy of the prediction model, receiver operating characteristic (ROC) graphs and calibration graphs were constructed. Subsequently, the application value of the histogram prediction model was evaluated with the help of the clinical decision aid curve. A P value of < 0.05 was considered statistically significant.

RESULTS

Patient's characteristics at baseline

This study included 529 patients with AIS who underwent intravenous thrombolytic treatment, and the 503 patients who completed the three-month follow-up were randomly assigned into modeling (n = 353) and verification (n = 150) samples (Figure 1).

Table 1 reveals the initial attributes of the patients in the development and validation sets. In the development cohort, comprising 353 individuals, the majority were male with 239 individuals (67.71%), while 114 were female (32.29%). The median age for this group was 63 years, with an interquartile range of 57 to 70 years. Among them, 113 patients (32.01%) experienced an unfavorable outcome. The validation cohort consisted of 97 males (64.67%) and 53 females (35.33%), with a median age of 65 years, interquartile ranging from 56 to 71.25 years. Within this cohort, 41 patients (27.33%) had a poor prognosis. A comparative analysis between the development and validation sets revealed no significant disparities regarding demographic profiles or serological parameters ($P > 0.05$), suggesting a commendable level of heterogeneity between the two cohorts.

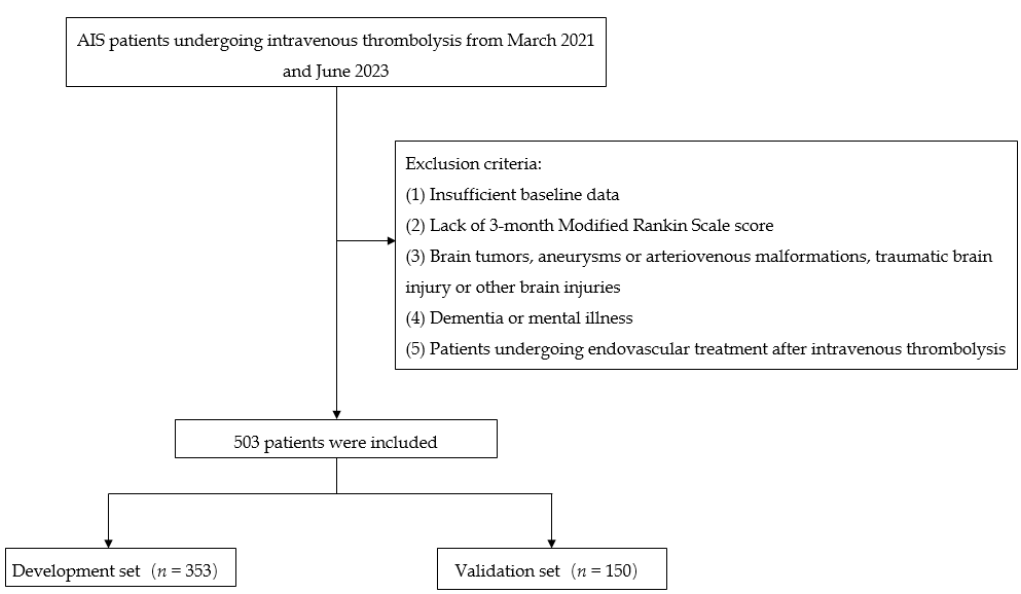

Figure 1. Flow chart of patient inclusion

AIS: Acute ischemic stroke.

Table 1: Patient characteristics in the development and validation sets (n = 503), n (%)

Characteristics	Development set (n = 353)	Validation set (n = 150)	$z/\chi 2/t$	P value
Sex			0.44	0.508
Male	239 (67.71)	97 (64.67)		
Female	114 (32.29)	53 (35.33)		
Age (years)	63 (57, 70)	65 (56, 71.25)	-0.68	0.4985
Smoker			0.12	0.733
No	225 (63.74)	98 (65.33)		
Yes	128 (36.26)	52 (34.67)		
Drinker			0.22	0.6381
No	254 (71.95)	111 (74)		
Yes	99 (28.05)	39 (26)		
Hypertension			1.25	0.2636
No	162 (45.89)	77 (51.33)		
Yes	191 (54.11)	73 (48.67)		
Diabetes			0.16	0.6856
No	281 (79.6)	117 (78)		
Yes	72 (20.4)	33 (22)		
Stroke			3.63	0.0569
No	271 (76.77)	103 (68.67)		
Yes	82 (23.23)	47 (31.33)		
Coronary heart disease			1.39	0.238
No	304 (86.12)	123 (82)		
Yes	49 (13.88)	27 (18)		
Total cholesterol (mmol/L)	4.42 (3.79, 5.09)	4.54 (3.85, 5.14)	-0.79	0.43
Triglyceride (mmol/L)	1.32 (0.98, 1.79)	1.31 (0.98, 2.03)	-0.53	0.5946
HDL (mmol/L)	1.05 (0.9, 1.26)	1.08 (0.92, 1.31)	-0.8	0.4266
LDL (mmol/L)	2.81 (2.21, 3.35)	2.86 (2.26, 3.4)	-0.55	0.5803
Homocysteine (mmol/L)	11.98 (9.38,15.57)	11.51 (8.62,14.49)	1.76	0.0792
Baseline NIHSS	4 (2, 10)	4 (2, 8)	0.69	0.4899
SBP_{SD} (mmHg)	9.08 (7.11, 12.11)	8.93 (6.98, 11.45)	0.48	0.6299
DBP_{SD} (mmHg)	6.55 (5.22, 8.3)	6.19 (5.4, 7.96)	0.27	0.7839
mRS	2 (1, 3)	2 (1, 3)	1.71	0.0867
Prognosis			1.08	0.2977
Good	113 (32.01)	41 (27.33)		
Poor	240 (67.99)	109 (72.67)		

NIHSS: National Institutes of Health Stroke Scale; HDL: High-density lipoprotein; LDL: Low-density lipoprotein; SBP_{SD}: Standard deviation of systolic blood pressure; DBP_{SD}: Standard deviation of diastolic blood pressure; mRS: Modified Rankin scale.

Univariate and multivariate risk factors for poor prognosis

Based on a preliminary statistical analysis of medical information from the patient population, we explored the clinical markers shared by patients who experienced exacerbations after thrombolytic therapy (Table 2). Sex, age, hypertension history, homocysteine level, baseline NIHSS score, and the BPV 24 hours after thrombolysis were significantly associated with a poor prognosis

Table 2: Patient demographics and clinical characteristics in the development cohort, *n* (%)

Characteristics	Good prognosis (*n* = 240)	Poor prognosis (*n* = 113)	*z*/χ2/*t*	*P* value
Sex			6.57	0.0104
Male	173 (72.08)	66 (58.41)		
Female	67 (27.92)	47 (41.59)		
Age (years)	62.53 ± 9.44	65.63 ± 10.85	-2.74	0.0064
Smoker			0	0.9952
No	153 (63.75)	72 (63.72)		
Yes	87 (36.25)	41 (36.28)		
Drinker			0.88	0.3485
No	169 (70.42)	85 (75.22)		
Yes	71 (29.58)	28 (24.78)		
Hypertension			6.18	0.0129
No	121 (50.42)	41 (36.28)		
Yes	119 (49.58)	72 (63.72)		
Diabetes			0.07	0.7875
No	192 (80)	89 (78.76)		
Yes	48 (20)	24 (21.24)		
Stroke			0.22	0.6362
No	186 (77.5)	85 (75.22)		
Yes	54 (22.5)	28 (24.78)		
Coronary heart disease			3.08	0.0795
No	212 (88.33)	92 (81.42)		
Yes	28 (11.67)	21 (18.58)		
Total cholesterol (mmol/L)	4.47 (3.83, 5.03)	4.3 (3.72, 5.13)	0.49	0.624
Triglyceride (mmol/L)	1.31 (0.98, 1.8)	1.33 (0.96, 1.79)	-0.08	0.9336
HDL (mmol/L)	1.06 (0.91, 1.26)	1.04 (0.87, 1.28)	0.36	0.7222
LDL (mmol/L)	2.83 (2.21, 3.32)	2.75 (2.2, 3.37)	-0.08	0.9381
Homocysteine (mmol/L)	10.97 (8.86, 15.17)	13.09 (10.37, 17.98)	-3.07	0.0022
Baseline NIHSS	3 (2,6)	8 (4,13)	-7.07	< 0.0001
SBP_{SD} (mmHg)	7.98 (6.49, 9.91)	12.77 (10.41, 15.06)	-10.19	< 0.0001
DBP_{SD} (mmHg)	6.06 (4.93, 7.44)	8.18 (6.34, 10.61)	-7.01	< 0.0001

NIHSS: National Institutes of Health Stroke Scale; HDL: High-density lipoprotein; LDL: Low-density lipoprotein; SBP_{SD}: Standard deviation of the systolic blood pressure; DBP_{SD}: Standard deviation of the diastolic blood pressure.

after thrombolysis ($P < 0.05$).

In Table 3, the univariate logistic regression analysis shows that female patients have a significantly higher risk of poor prognosis than male patients (OR = 1.84, 95%CI: 1.15–2.94, $P = 0.0108$). As age increases, the risk of poor prognosis in patients correspondingly increases (OR = 1.03, 95%CI: 1.01–1.06, $P = 0.007$). Individuals with a history of hypertension face a significantly increased risk of adverse outcomes compared with those without hypertension (OR = 1.79, 95%CI: 1.13–2.84, $P = 0.0134$). Patients presenting with elevated baseline scores on the NIHSS were found to possess a significantly elevated risk of encountering an unfavorable prognosis. (OR = 1.16, 95%CI: 1.11–1.22, $P < 0.001$; OR = 1.17, 95%CI: 1.12–1.23, $P < 0.001$). The risk of a poor prognosis was significantly higher in patients with high variability of systolic BP (SBP) and diastolic BP (DBP) 24 hours after thrombolysis (OR = 1.54, 95%CI: 1.4–1.7, $P < 0.001$; OR = 1.44, 95%CI:

Table 3: Univariate logistic regression analysis of poor prognosis after thrombolysis in patients with acute ischemic stroke

Variable	β	Se	*z*	*P* value	OR (95%CI)
Sex (female)	0.609	0.239	2.548	0.0108	1.84 (1.15,2.94)
Age (years)	0.032	0.012	2.694	0.0071	1.03 (1.01,1.06)
Smoker	0.001	0.237	0.006	0.9952	1 (0.63,1.59)
Drinker	0.243	0.260	-0.936	0.3491	0.78 (0.47,1.29)
Hypertension	0.580	0.234	2.473	0.0134	1.79 (1.13,2.84)
Diabetes	0.076	0.281	0.269	0.7876	1.08 (0.61,1.86)
Stroke	0.126	0.267	0.473	0.6363	1.13 (0.67,1.9)
Coronary heart disease	0.547	0.315	1.740	0.0819	1.73 (0.92,3.19)
Total cholesterol	0.029	0.110	-0.262	0.7932	0.97 (0.78,1.2)
Triglycerides	0.072	0.104	-0.692	0.4889	0.93 (0.74,1.12)
HDL (mmol/L)	0.092	0.374	0.246	0.8054	1.1 (0.52,2.27)
LDL (mmol/L)	0.007	0.134	0.053	0.9578	1.01 (0.77,1.31)
Homocysteine (mmol/L)	0.011	0.008	1.445	0.1484	1.01 (1,1.03)
Baseline NIHSS	0.149	0.023	6.375	< 0.0001	1.16 (1.11,1.22)
SBP_{SD} (mmHg)	0.430	0.049	8.746	< 0.0001	1.54 (1.4,1.7)
DBP_{SD} (mmHg)	0.363	0.055	6.541	< 0.0001	1.44 (1.29,1.61)

NIHSS: National Institutes of Health Stroke Scale; HDL: High-density lipoprotein; LDL: Low-density lipoprotein; SBP_{SD}: Standard deviation of systolic blood pressure; DBP_{SD}: Standard deviation of diastolic blood pressure.

1.29–1.61, $P < 0.001$).

Upon conducting a rigorous multivariate logistic regression analysis of the aforementioned pivotal variables, it was found that a history of hypertension, the initial NIHSS score, the standard deviation of systolic blood pressure (SBP_{SD}), and the standard deviation of diastolic blood pressure (DBP_{SD}) emerged as independent risk factors, significantly associated with an unfavorable prognosis (Table 4).

Nomogram development and validation

To create a nomogram, the independent risk factors in the multivariate logistic regression model analysis were used (Figure 2). A score was assigned to each subtype of the independent factors, and the overall score was then projected to an outcome's probability.

The metric of the area under the receiver operating characteristic curve (AUC-ROC) served as the benchmark for evaluating the predictive precision of the nomogram model. An AUC value exceeding 0.70 is broadly recognized as a threshold for strong discriminatory capability. The model exhibited an AUC of 0.876 (95%CI: 0.84–0.913) (Table 5) within the development dataset, and a comparable AUC of 0.849 (95%CI: 0.784–0.913) within the validation dataset (Table 6 and Figure 3). These results underscore the model's robust predictive capacity.

In this comprehensive study, the efficacy of

Table 4: Multivariate logistic regression for poor prognosis

Variable	β	Se	*z*	*P* value	OR (95%CI)
Hypertension	0.808	0.312	2.589	0.0096	2.24 (1.23,4.19)
Baseline NIHSS	0.132	0.029	4.552	< 0.0001	1.14 (1.08,1.21)
SBP_{SD} (mmHg)	0.384	0.053	7.189	< 0.0001	1.47 (1.33,1.64)
DBP_{SD} (mmHg)	0.125	0.062	2.004	0.045	1.13 (1,1.29)

NIHSS: National Institutes of Health Stroke Scale; SBP_{SD}: Standard deviation of systolic blood pressure; DBP_{SD}: Standard deviation of diastolic blood pressure.

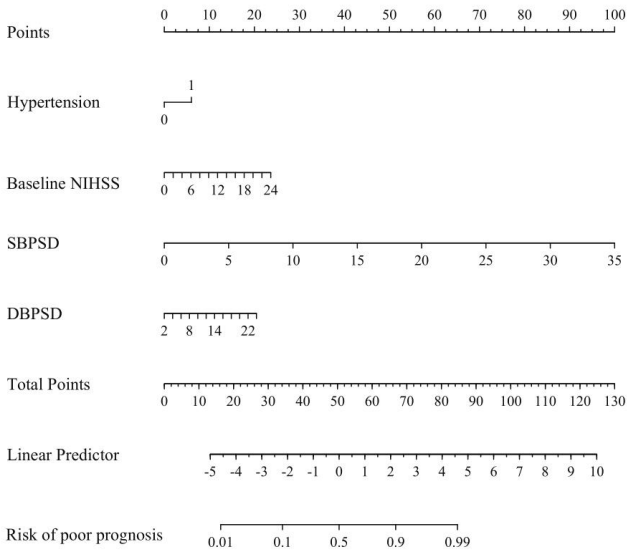

Figure 2. Nomogram for predicting poor prognosis in patients with acute ischemic stroke within three months after thrombolysis.

SBPSD: Standard deviation of systolic blood pressure; DBPSD: Standard deviation of diastolic blood pressure.

the nomogram model in seamlessly adapting to both the development and validation datasets was evaluated *via* the Hosmer–Lemeshow test, yielding definitive results that underscored its impeccable fit and predictive prowess ($P > 0.9999$).

Through the utilization of the calibration curve, the precision and accuracy of the nomogram model's predictions were intuitively and meticulously assessed. This assessment entailed a comparison of the predicted adverse outcomes with their actual counterparts, where the predicted probabilities were juxtaposed against the observed frequencies of adverse events. The resulting calibration curve demonstrated an exceptional alignment, showcasing that the predicted probabilities generated by the nomogram model were in remarkable proximity to the actual probabilities observed in the validation set (Figure 4).

Finally, the clinical applicability of the model was evaluated with the help of decision curve analysis (DCA), which was used to establish a nomogram of poor prognosis for patients with AIS after three months of thrombolysis. The DCA results of the training and verification sets are shown in Figure 5, which demonstrated the great clinical effect and applicability of the prediction model.

DISCUSSION

We developed a new nomogram based on a history of hypertension, the baseline NIHSS score, and the systolic and diastolic BPV 24 hours after thrombolysis and used it to predict the

Table 5: Receiver operating characteristic results for the development set

AUC (95%CI)	Sensitivity	Specificity	Youden index	Accuracy	Cutoff
0.876 (0.84, 0.913)	0.929	0.654	0.583	0.533	38.654

AUC: Area under the curve.

Table 6: Receiver operating characteristic results for the validation set

AUC (95%CI)	Sensitivity	Specificity	Youden index	Accuracy
0.849 (0.784, 0.913)	0.927	0.651	0.578	0.541

AUC: Area under the curve.

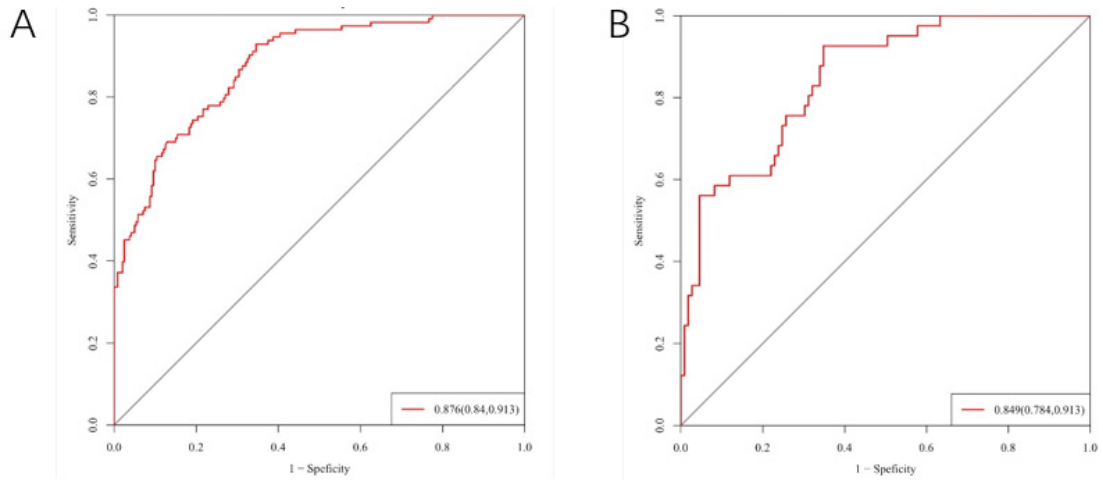

Figure 3. Receiver operating characteristic curves for the clinical model of poor prognosis applied to the development and validation sets.
A: Receiver operating characteristic (ROC) curve in development cohort; B: ROC curve in validation cohort.

prognosis of patients with AIS. The AUC-ROC was used to assess the discriminating power of the nomogram; an AUC-ROC of 0.5 was considered meaningless, 0.5–0.7 was considered fair, 0.7–0.9 was considered acceptable, and > 0.9 was considered exceptional. Our nomogram exhibited commendable discriminatory and calibration properties across both the development and validation cohorts. The AUC for the development set was recorded at 0.876 (95%CI: 0.84–0.913), while the validation set yielded an AUC of 0.849 (95%CI: 0.784–0.913), substantiating the model's efficacy in predictive accuracy and reliability (Figure 3). The DCA indicated that the nomogram was clinically useful (Figure 5).

One well-known risk factor for stroke is high BP[17], and changes in BP are closely related to cardiovascular and cerebrovascular events. A correlation meta-analysis demonstrated that the prognosis of patients with a stroke is significantly affected by BPV, which is a new and clinically important risk factor.[18] According to previous studies, vascular stiffness and elevated BPV are strongly correlated.[19,20] Moreover, increased aortic stiffness and maladaptive carotid artery remodeling are linked to increased BPV.[21] Stiffness of the aortic wall in patients with hypertension weakens the pressure reflex, which leads to greater BPV and exacerbates penumbra perfusion in patients with AIS.[22] Greater BPV is predictive

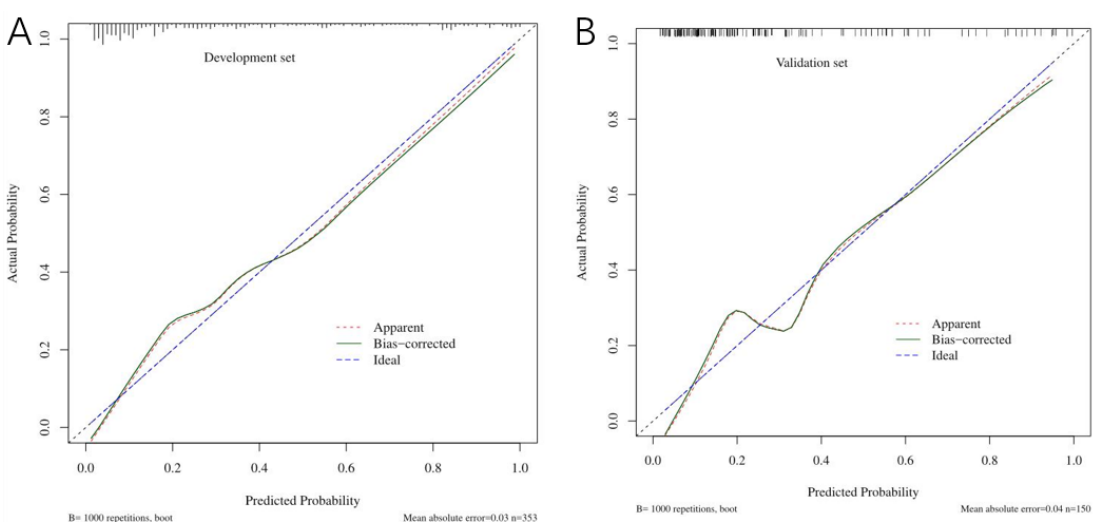

Figure 4. Calibration curves of the nomograms in the development and validation sets.
A: Calibration curve in development cohort; B: Calibration curve in validation cohort.

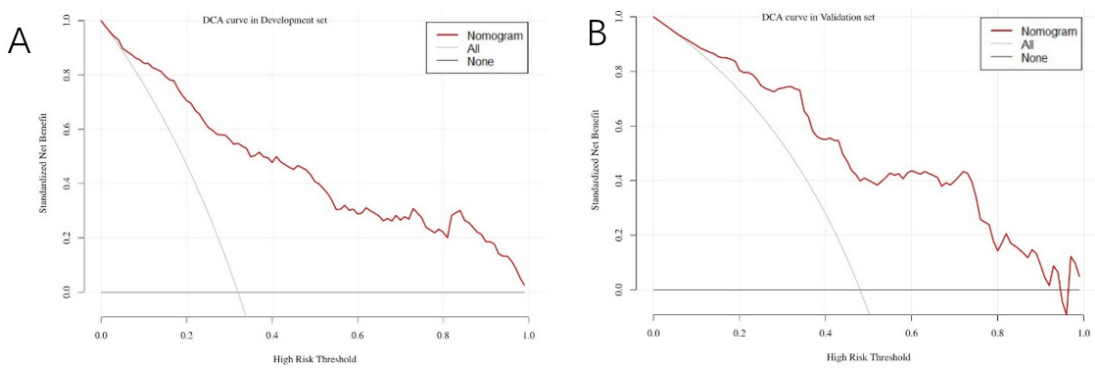

Figure 5. Decision curve analysis of the nomograms in the development and validation sets.
A: Decision curve analysis in development cohort; B: Decision curve analysis in validation cohort.

of poor functional outcomes.[23] As shown in studies on thrombolytic therapy for patients with AIS, BP dynamics are independently related to prognosis.[24,25] Furthermore, relevant research results have demonstrated that a greater BPV within 72 hours after thrombolysis is linked to a greater risk of stroke within 3 months.[26]

The subsequent effects of BPV in patients with cerebral infarction have not been clearly revealed. Relevant findings indicate that patients with significant variations in BP may upregulate endothelial cytokines, which increase the shear force within the vascular system and worsen the prognosis by causing vascular inflammation, breaking down the blood-brain barrier, and encouraging the development of atherosclerotic plaques.[27] Additionally, in the acute ischemic brain region, an increase in BPV disrupts the brain's natural balance. The BP increases in an attempt to compensate for the loss of this function and preserve cerebral blood flow in ischemic meninges. Consequently, changes in BP can affect the brain and cause instability in cerebral perfusion. This instability can manifest as either excessive or insufficient perfusion of the ischemic brain, thereby increasing the risk of bleeding, intracranial pressure, and injury site swelling.[28,29] BPV may have a long-term impact on the prognosis of patients with AIS, but further relevant research is needed. In addition, recent studies have shown that individuals with higher NIHSS scores have poorer neurological outcomes after an ischemic stroke.[30] Our results show that a history of hypertension, the baseline NIHSS score, and the BPV within 24 hours after thrombolysis were independently related to adverse outcomes in patients with a stroke at 3 months and could independently predict the prognosis. Our findings concurred with the conclusions of these earlier studies.

Ningning *et al*.[31] studied the relationship between BPV and initial recovery in patients with AIS. They performed prospective research and collected imaging data besides demographic, clinical, and laboratory data. However, the blood pressure they used to calculate the BPV was only measured six times, and they had fewer data than the data used in our study. They concluded that the prognosis of people with high SBP and DBP variability was poor, which agrees with our findings. In a study on BPV, Li *et al*.[32] used daytime and nighttime blood pressure variability to distinguish the influence of diurnal blood pressure changes on the study. However, in our study, we measured and recorded the BP immediately after thrombolysis because of the randomness of the time of onset of AIS in our patients; therefore, we could not distinguish the BPV from diurnal variations in blood pressure.

This study has several strength. First, according to our knowledge, only a few studies have created a model map to estimate the subsequent status of patients with AIS treated with BPV within 24 hours of thrombolytic therapy. Our predictive model, underpinned by a nomogram derived from multivariate logistic regression analysis, offers not just precision but also accessibility for clinical application. This nomogram serves as a valuable tool for the identification of AIS patients who may face the risk of unfavorable outcomes post-thrombolysis. It enables the prediction and preemptive mitigation of adverse outcomes upon discharge, facilitating a strategy for early intervention and personalized risk assessment. Second, our sample size is moderate, which improves the accuracy of the model. Finally, DCA, a relatively new net benefit analysis method, was applied to our nomogram, and the outcomes demonstrated its strong clinical practicability.

There are several limitations in this study.

First, this study was a retrospective analysis based on a single medical center, which means that the sample of patients selected may not fully reflect the actual situation of all patients with AIS. Second, within 3 months after stroke, a patient's condition may further improve or worsen, and the effects of taking antiplatelet drugs and lipid-lowering drugs cannot be completely ruled out. In addition, there are many other risk factors for stroke, such as the duration of the disease, the types of drugs administered, the body mass index, eating habits, and physical exercise, which are not well recorded in the patient's electronic medical record; therefore, they are not analyzed. Moreover, both cerebral artery stenosis and carotid artery stenosis are important risk factors for stroke. In the future, a multi-center prospective study, which should include imaging examination, should e performed to further evaluate and improve the accuracy of our nomogram.

In conclusion, the nomogram has excellent prediction accuracy, discrimination ability, and clinical practicability. It can be used to assess the probability of possible negative outcomes in patients with AIS after thrombolytic therapy. It will aid clinical practice, help physicians and nurses to evaluate the prognoses of individuals, and serve as an auxiliary tool for decision-making. It will facilitate early intervention or planning for patients with AIS during hospitalization.

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