Risk Stratification for Endovascular Treatment in Acute Anterior Circulation Occlusive Stroke

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Objective: To develop and validate a novel scoring system for risk stratification in acute anterior circulation large vessel occlusion stroke patients undergoing endovascular treatment. *Methods:* Subjects were included from a multicenter registry on acute ischemic stroke undergoing thrombectomy in China. Two thirds of the patients were used as the derivation group and the other one third of the patients as the validation group. Multivariable logistic regression was used to generate the scoring system. The area under the receiver operating characteristic curve and Hosmer-Lemeshow goodness-of-fit test were used to assess model discrimination and calibration, respectively. *Results:* The Risk strAtification for eNdovascular treatment in acute anterior circulation occlusive stroKe (RANK) scale (total score ranges from −11 to 14) showed good discrimination in the derivation cohort (AUC = .79; 95% confidence interval [CI], .74-.84) and validation cohorts (AUC = .74; 95% CI, .68-.81), as well as good calibration (Hosmer-Lemeshow test) in the validation cohort ($P = .54$). We categorized the RANK score into 5 predictive groups for an unfavorable functional outcome, less than or equal to −8 (very low risk), −7 to −4 (low risk), −3 to 0 (intermediate), 1-5 (high risk), and greater than or equal to 6 (very high risk). In the very high risk group, only 3.3% (1 of 30, 95% CI: .08%-.2%) of patients in the derivation group and 5.5% (1 of 18, 95% CI: .1%-.3%) of patients in the validation group achieved a good functional outcome at day 90. *Conclusions:* The novel scale is a valid tool for risk stratification for endovascular stroke treatment in anterior circulation large vessel occlusions.

Key Words: Stroke—thrombolysis—endovascular treatment—scale

Introduction

Recent clinical trials have demonstrated that intravenous thrombolysis bridging to thrombectomy is the first-line treatment for acute ischemic stroke due to anterior circulation proximal large artery occlusion.[1-7] Based on 5 randomized clinical trials,[1-5] the AHA/ASA acute stroke guideline recommended that a patient with a prestroke mRS score 0-1, an occlusion of the internal carotid artery or proximal MCA (M1), NIHSS score of greater than or equal to 6, Alberta Stroke Program Early CT Score (ASPECTS) of greater than or equal to 6, and onset to groin puncture within 6 hours should have a

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thrombectomy (*Class I; Level of Evidence A*).[8] However, thrombectomy for patients with ASPECTS less than 6 and/or an NIHSS score less than 6 may be reasonable in some patients, but needs more evidence. The HERMES Collaborators' meta-analysis revealed that the time window may be extended to 7.3 hours with continued benefit with thrombectomy.[9] Based on the DAWN[10] and DEFUSE 3[11] trials, the guideline also stated that selected patients with a tissue time window with a small to moderate sized ischemic core using CT perfusion or diffusion weighted MRI within 6-24 hours of last known normal who have large artery occlusion in the anterior circulation also benefit from thrombectomy.

In real world practice, patients are diverse and decision-making is quite difficult for those patients who do not fulfill the requirements for thrombectomy according to guidelines. The Pittsburgh Response to Endovascular therapy (PRE),[12] Houston Intra-Arterial Therapy 2 (HIAT2),[13] and Totaled Health Risks in Vascular Events (THRIVE)[14] scales were developed for patient risk stratification for endovascular therapy with large vessel occlusion strokes based on cohorts using the Merci, or Penumbra devices. The development of the third generation thrombectomy devices (Solitaire or Trevo device) that can achieve higher recanalization rates and better functional outcomes than the Merci and Penumbra devices was a major advance. Although PRE and THRIVE were validated in cohorts using the third generation thrombectomy devices,[15-17] currently no scale has been derived from cohorts of patients using the Solitaire or Trevo devices. Moreover, the 3 scales did not include collateral status as part of the scale, which is considered to be a very critical predictor of outcome.[18]

Therefore, we developed and validated a scoring system for risk stratification in a large cohort of acute anterior circulation large vessel occlusion stroke patients undergoing endovascular treatment using the third generation thrombectomy devices in an Asian population. We also compared our new scale with the PRE, HIAT2, and THRIVE scales for predicting functional outcome at day 90.

Methods

Study Population

Patients were derived from a multicenter retrospective registry — the Endovascular Treatment For Acute Anterior Circulation Ischemic Stroke Registry (ACTUAL). Details of the ACTUAL study were previously published.[19] For the current study, we included patients who fulfilled the following inclusion criteria: (1) adult patients (age $\geq$ 18 years), (2) anterior circulation large vessel occlusion (ICA, MCA M1, and M2, ACA) confirmed by CT angiography (CTA), magnetic resonance angiography, or digital subtracted angiography (DSA), (3) thrombectomy with a retrievable stent device, (4) mRS at day 90 was documented, and (5) patients with onset to puncture time less than or equal to 7.3 hours.[9] To ensure the homogeneity of the study, patients with an extended time window more than 7.3 hours who definitely need imaging selection by CT perfusion or MRI perfusion or diffusion weighted imaging (DWI) evaluation were excluded from the current study. The use of data from the ACTUAL registry was approved by a central institutional review board at Nanjing Jinling Hospital and the ethics committee of each participating center. Because of retrospective reviewing of the medical notes and images, the patient consents were waived by the central institutional review board of Nanjing Jinling Hospital.

Data Collection and Measurements

We retrieved patient's demographic data, clinical history, laboratory tests (blood glucose at admission, neutrophil to lymphocyte ratio [NLR], etc.), and stroke severity (NIHSS score at admission) from the ACTUAL registry. Time delays were separated into stroke onset time to emergency department arrival (onset to ED), and door to groin puncture time. All angiography, CT, and magnetic resonance imaging were sent to the core imaging laboratory at the Jinling Hospital and were reviewed by an expert group who were blinded to clinical outcomes. Two physicians reviewed the results independently for imaging determinations. In case of a disagreement, a third physician was asked to provide a final decision. ASPECTS was evaluated on the noncontrast head CT. Collateral status was assessed by the American Society of Interventional and Therapeutic Neuroradiology/Society of Interventional Radiology (ASITN/SIR) grading on DSA.[20] Successful recanalization was defined as a modified Thrombolysis in Cerebral Ischemia (mTICI) score of 2b to 3 after the completion of endovascular treatment.[21] sICH was defined by using the criteria of the Heidelberg Bleeding Classification.[22] ICH was classified as one of the following subtypes: hemorrhagic infarction 1: scattered small petechiae, no mass effect or hemorrhagic infarction 2: confluent petechiae, no mass effect or parenchymal hematoma (PH) 1: hematoma within infarct tissue that occupied less than 30% of the infarct volume with no substantial mass effect; PH2: hematoma that occupied greater than or equal to 30% of the infarct volume, with obvious mass effect; remote PH: PH remote from the region of infarction intraventricular hemorrhage; subarachnoid hemorrhage; subdural hemorrhage. sICH was diagnosed if the new observed ICH was associated with any of the following conditions: (1) NIHSS score that increased greater than 4 points than that seen before worsening; (2) NIHSS that score increased greater than 2 points in 1 category; and (3) deterioration that led to intubation, hemicraniectomy, external ventricular drain placement, or any other major interventions. In addition, the symptom associated with deterioration could not be explained by causes other than the observed ICH. Asymptomatic ICH was diagnosed if the new ICH was not accompanied by any of the above conditions. For hemorrhage classified as PH 2, even if the neurological deterioration could be attributed to infarction per se, the hemorrhage was classified as sICH. However, for hemorrhage classified as hemorrhagic infarction 1, hemorrhagic infarction 2, PH1, remote PH, intraventricular hemorrhage, subarachnoid hemorrhage, or subdural hemorrhage, if the neurological deterioration could be attributed to infarction per se, the hemorrhage was classified as asymptomatic.

The mRS at day 90 after endovascular treatment was assessed by a clinical visit or telephone follow-up by an experienced investigator. mRS 0-2 and mRS 3-6 were considered as good and unfavorable functional outcomes, respectively.

Calculation of PRE, THRIVE, and HIAT2

The PRE score was calculated according to a formula: PRE score = age (years) +2 × NIHSS + 10 × ASPECTS.[12] HIAT2 score ranges from 0 to10: age (≤59 = 0, 60-79 = 2, ≥80 years = 4), glucose (<150 = 0, ≥150 mg/dl = 1), NIHSS (≤10 = 0, 11-20 = 1, ≥21 = 2), and ASPECTS (8-10 = 0, ≤7 = 3).[13] The THRIVE score ranges from 0 to 9: age (≤59 = 0, 60-79 = 1, ≥80 years = 2), NIHSS (≤10 = 0, 11-20 = 2, ≥21 = 4), hypertension (yes = 1, no = 0), diabetes mellitus (yes = 1, no = 0), and atrial fibrillation (yes = 1, no = 0).[14]

Statistical Analysis

NIHSS score and NLR were dichotomized according to median of the whole population, and glucose at admission was dichotomized according to the 75% quartile of the whole population. The study population were randomly divided into derivation (60%) and validation (40%) groups using a computer generated random sequence. In the derivation group, univariate analyses (student T tests or Mann-Whitney U tests for continuous variables and χ^2 tests or trend tests for categorical variables) were utilized to detect the variables differences between mRS 0-2 and mRS 3-6. Those statistically significant preprocedural variables with *P* less than .05 were further put into a multivariable logistic regression model with stepwise method to determine the preoperative predictive factors. Then continuous variables in the final model were transformed into separate categories and β coefficient of individual predictors was used to calculate the corresponding points in the scale and, finally, to derive the scoring system.[23] To evaluate the internal validation of this scoring system, we evaluated the discrimination and calibration of the scoring system in the validation group. Discrimination was assessed by Receiver Operating Characteristic Curve (ROC) analysis with the area under the curve (AUC). Cutoff was determined by the maximum Youden index, and the corresponding sensitivity, specificity, positive predictive values (PPV), and negative predictive values (NPV) were calculated. We also calculated the corresponding cutoff, sensitive, PPV, and NPV values at specificity of .99. Calibration was evaluated by the Hosmet-Lemeshow goodness-of-fit test, which was graphically described in the plot of observed versus predicted mRS 3-6 risk on the basis of ten deciles of the predicted risk. Statistical analysis was performed using the SPSS version 22 software package (SPSS Inc, Chicago, IL) and SAS 9.3 (SAS Institute Inc., Cary, NC).

Results

Patient Characteristics

Patients were randomly classified as the derivation group (N = 345) and the validation group (N = 230). Table 1 shows the baseline characteristics and clinical

Table 1. *Baseline characteristics and clinical outcomes between derivation and validation groups*

	Derivation group (n = 345)	Validation group (n = 230)	*P* value
Age, mean (SD), y	64.4 (12.7)	65.2 (11.9)	.361
Sex, male, n (%)	206 (59.7)	123 (53.5)	.139
Coronary heart disease	82 (23.8)	59 (25.7)	.621
Atrial fibrillation	150 (43.6)	106 (46.1)	.558
Hypertension	216 (62.6)	149 (64.8)	.596
Diabetes mellitus	60 (17.4)	46 (20.0)	.429
Hyperlipidemia	30 (8.7)	20 (8.7)	1.000
SBP > 140 mm Hg	178 (51.6)	138 (60.0)	.047
NLR > 7.07	156 (49.5)	110 (51.9)	.595
Glucose > 8.6 mmol/L	66 (20.7)	62 (28.8)	.031
Baseline NIHSS score > 16	171 (49.6)	120 (52.2)	.540
Baseline ASPECTS > 7	259 (77.5)	174 (78.7)	.741
Stroke etiology, n (%)			
Atherosclerotic	145 (42.0)	91 (39.6)	.651
Cardioembolic	178 (51.6)	127 (55.2)	
Other and undetermined	22 (6.4)	12 (5.2)	
Collateral status (ASITN/SIR), n (%)			
0-1	177 (51.8)	112 (48.9)	.505
2-3	165 (48.2)	117 (51.1)	
Prior intravenous rtPA, n (%)	104 (30.1)	91 (39.6)	.019
mTICI, n (%)			
0-2a	49 (14.2)	39 (17.0)	.369
2b-3	296 (85.8)	191 (83.0)	
ICH, n (%)			
No ICH	178 (51.6)	111 (48.3)	.365
Asymptomatic ICH	119 (34.5)	77 (33.5)	
Symptomatic ICH	48 (13.9)	42 (18.3)	
mRS at 90 days, n (%)			
0-2	147 (42.6)	94 (40.9)	.679
3-6	198 (57.4)	136 (59.1)	

Abbreviation: ASITN/SIR, the American Society of Interventional and Therapeutic Neuroradiology/Society of Interventional Radiology; ASPECTS, the Alberta Stroke Program Early Computed Tomography Score; ICH, intracerebral hemorrhage; mRS, modified Rankin Scale; NIHSS, National Institute of Health Stroke Scale; NLR, neutrophil to lymphocyte ratio; rtPA, recombinant tissue-type plasminogen activator; SBP, systolic blood pressure.

outcomes of the 2 groups. Compared with the validation group, patients in the derivation group had a lower proportion of patients with a systolic blood pressure greater than 140 mm Hg (51.6% [178 of 345] for the derivation group versus 60.0% [138 of 230] for the validation group), $P = .047$) and a lower proportion of intravenous recombinant tissue-type plasminogen activator (rtPA) (30.1% [104 of 345] use for the derivation group versus 39.6% [91 of 230] for the validation group), $P = .019$). There were no significant differences regarding age, sex, medical history, glucose, NLR, stroke etiology, collateral status, mTICI, ICH, and mRS at day 90 between the groups.

Predictors for Unfavorable Functional Outcome

In the derivation group, to determine the preprocedural predictors for an unfavorable functional outcome (mRS 3-6), univariate analysis found that age, male sex, history of atrial fibrillation, blood glucose, NLR, baseline NIHSS score, baseline ASPECTS, a proximal occlusion site, and collateral status were significantly different between the mRS 3-6 and mRS 0-2 groups (**Table e-1** in the data supplement). Although onset to ED presentation time had borderline significance, considering its importance for functional outcome, we still included this variable in the regression model. Preprocedural factors were further put into a binary logistic regression model with a stepwise method, which revealed that age (odds ratio [OR] 1.04, 95% confidence interval [CI] 1.02-1.08, $P = .001$), onset to ED presentation (OR 1.00, 95% CI 1.00-1.01, $P = .04$), blood glucose at admission (OR 2.36, 95% CI 1.13-4.93, $P = .02$), baseline NIHSS score (OR 2.13, 95% CI 1.23-3.69, $P = .007$), baseline ASPECTS (OR .36, 95% CI .18-.75, $P = .006$) on initial CT scan, and collateral status (1 versus 0: OR .42, 95% CI .18-1.01, $P = .05$; 2 versus 0: OR .22, 95% CI .09-.53, $P = .001$; 3 versus 0: OR .14, 95% CI .06-.36, $P < .001$) were independent predictors for an unfavorable functional outcome (Table 2).

Derivation of the Risk strAtification for eNdovascular treatment in acute anterior circulation occlusive stroKe (RANK) score

Based on the β-coefficients from the multivariable regression model, the independent predictors were translated into a point scoring system. Table 3 shows the scoring system, with the whole score ranging from −11 to 14. Discrimination of the Risk strAtification for eNdovascular treatment in acute anterior circulation occlusive stroKe (RANK) scale was good, with the AUC .79 (95% CI: .74-.84) in the derivation group (Fig e-1 in the data supplement) and .74 (95% CI, .68-.81) in the validation group (Fig e-2 in the data supplement). According to the largest Youden index, the cutoff was −3 in both the derivation and the validation groups for an unfavorable functional outcome. The cutoff for corresponding 99% specificity was 6 in both groups for predicting an unfavorable functional outcome. Sensitivity, specificity, PPV, and NPV values are summarized in Table e-2 in the data supplement. Calibration of the regression model was satisfactory in the derivation cohort (Hosmer-Lemeshow test $P = .54$). Very strong positive correlations were observed between predicted and observed probabilities of an unfavorable functional outcome in the derivation group ($r = .968$, $P < .001$) and validation group ($r = .952$, $P < .001$) (Figs e-3 and e-4 in the data supplement, respectively).

We categorized the scoring system into 5 predictive groups for an unfavorable outcome, less than or equal to −8 (very low risk), −7 to −4 (low risk), −3 to 0 (intermediate), 1-5 (high risk), and greater than or equal to 6 (very high risk). The corresponding rates of an unfavorable functional outcome in each rank are shown in Fig 1 with error bars showing 95% confidence interval. In patients with very low and low risk (35.7% [205 of 575] of the entire population), 70.5% (79 of 112, 95% CI: 61.2%-78.8%) of the patients in the derivation group, and 65.5% (61 of 93, 95% CI: 55.0%-75.1%) of patients in the validation group achieved mRS 0-2 at day 90. In patients with high and very high risk (30% [173 of 575] of the entire cohort),

Table 2. *Logistic regression model of functional dependence (mRS 3-6) in the derivation group*

				95% CI for OR		
	β	SE	OR	Lower	Upper	*P* value
Age (y)	.038	.012	1.04	1.02	1.08	.001
Onset to ED presentation	.003	.002	1.00	1.00	1.01	.04
Glucose (>8.6 mmol/L)	.857	.377	2.36	1.13	4.93	.02
Baseline NIHSS score (>16)	.755	.281	2.13	1.23	3.69	.007
Baseline ASPECTS (>7)	−1.009	.367	.36	.18	.75	.006
ASITN/SIR grading						<.001
0			1	Reference		
1	−.863	.447	.42	.18	1.01	.05
2	−1.536	.458	.22	.09	.53	.001
3	−1.948	.475	.14	.06	.36	<.001

Abbreviations: CI, confidence interval; ED, emergency department; OR, odds ratio; SE, standard error.

Table 3. *The risk stratification for acute anterior circulation occlusive stroke (RANK) scale*

Items	Categories	Points
Age (years)		
	<50	0
	50-59	1
	60-69	3
	70-79	4
	80-89	5
Time (Onset to ED presentation) (min)		
	<120	0
	120-179	1
	180-299	2
	≥300	3
Blood glucose (mmol/L)		
	≤8.6	0
	>8.6	3
NIHSS score		
	≤16	0
	>16	3
ASPECTS		
	≤7	0
	>7	−4
Collateral status (ASITN/SIR grading)		
	0	0
	1	−3
	2	−6
	3	−7
Total points		−11 to 14

13.6% (14 of 103, 95% CI: 7.6%-21.2%) of patients in the derivation group, and 14.3% (10 of 70, 95% CI: 7.1%-24.7%) in the validation group achieved mRS 0-2 at day 90. In particular in the very high group (8.3% [48 of 575] of the entire cohort), only 3.3% (1 of 30, 95% CI: .08%-.2%) of patients in the derivation group, and 5.5% (1 of 18, 95% CI: .1%-.3%) of patients in the validation group achieved mRS 0-2 at day 90.

Sensitivity Analysis by Recanalization Status

The RANK score was consistently an independent predictor for an unfavorable functional outcome in patients with successful recanalization (mTICI 2b-3) (OR 1.30, 95% CI 1.07-1.58, $P = .009$) and in patients with poor recanalization (mTICI 0-2a) (OR 1.27, 95% CI 1.20-1.34, $P < .001$).

The RANK Score Risk for sICH

The RANK score is associated with sICH (OR 1.16, 95% CI: 1.10-1.22). The ROC for RANK score predicting sICH was acceptable (AUC .70 [95% CI: .64-.76]). The best cutoff with a maximal Youden index was 0 (sensitivity 64.8%, specificity 67.9%), the corresponding cutoff for 99% specificity was 8 with a sensitivity of 4.2%. Logistic regression found that the sICH risk was the highest in patients with RANK score greater than or equal to 8

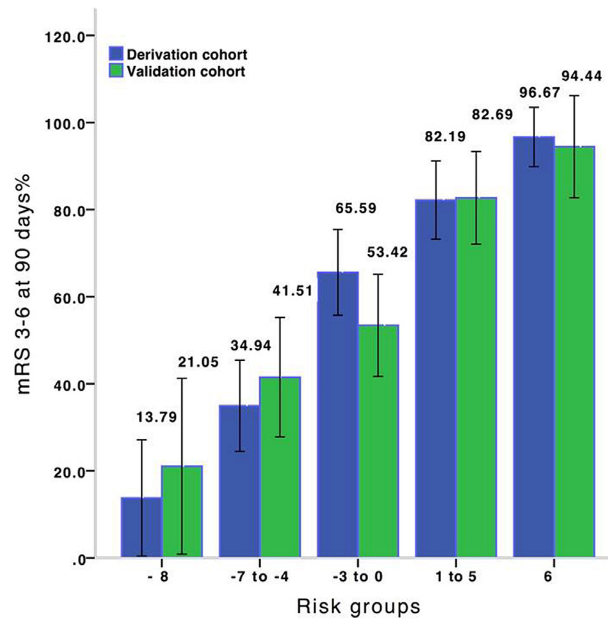

Figure 1. *The proportion of unfavorable outcome after endovascular treatment according to the RANK score in the derivation and internal validation cohorts. The potential risk of an unfavorable outcome after endovascular treatment increased steadily with a higher RANK score. Error bars indicated 95% confidence interval for the proportion of unfavorable outcome after endovascular treatment in each category.*

(RANK ≥ 8 versus RANK < 0, OR 5.40 [2.13-13.68]); RANK 0-8 versus RANK < 0, OR 3.67 [2.24-6.00]).

Comparisons of Rank with THRIVE, HIAT2, and PRE

Using the entire cohort, Fig 2 shows the ROCs of RANK, THRIVE, HIAT2, and PRE for predicting mRS 3-6 at day 90. The RANK (AUC = .77, 95% CI .73-.81) was better than THRIVE (AUC = .68, 95% CI .64-.73, $P < .0001$) and HIAT2 (AUC = .72, 95% CI .68-.77, $P = .004$). The RANK was not statistically superior to PRE although a trend was observed (RANK AUC = .77 versus PRE AUC = .75, $P = .15$) in predicting an unfavorable outcome.

Discussion

The AHA/ASA guideline[8] for endovascular treatment recommends thrombectomy for a small group of patients, however, a large number of patients may not meet the criteria for endovascular treatment in clinical practice. How to treat these patients is still unclear. Our ACTUAL registry included all patients undergoing endovascular treatment for an anterior circulation large vessel occlusion in Chinese patients, and offers a good opportunity to analyze the probabilities of patients having an unfavorable functional outcome at day 90 in real world clinical practice. Based on the ACTUAL registry, we derived and validated the RANK scale.

Our study demonstrated that the RANK score had good discrimination for unfavorable functional outcome at day 90, and good validation in our internal cohort.

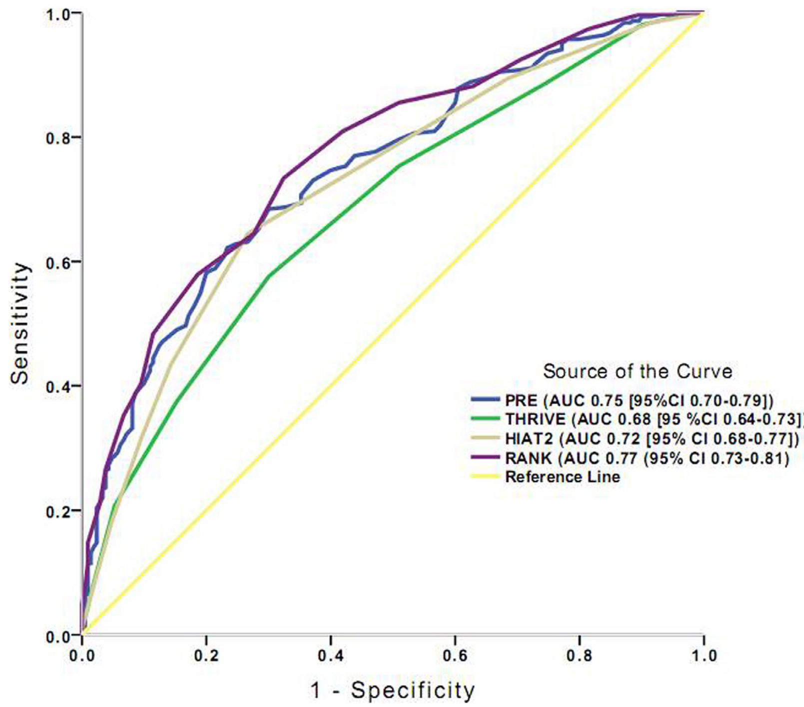

Figure 2. *Comparison of RANK with other prediction scores by ROC curve analysis. The RANK scale had the best ROC value among the 4 rating scales.*

Patients with RANK greater than or equal to 6 (very high risk) had a very limited (3%-5%) probability for mRS 0-2 at day 90. It also predicts the risk for sICH, with the high-risk RANK group having the highest risk for sICH. Compared with previous prediction scales, the RANK score was better than the THRIVE score and the HIAT2 score for predicting patients' functional outcomes.

The RANK scale incorporates previously reported predictive variables including age,[24] baseline blood glucose,[25] baseline NIHSS score,[24] baseline ASPECTS[26], and baseline collateral flow.[18] Collateral flow was the most important protective predictor, having the most weight in the scoring system, followed by age and the ASPECTS score. DSA is the gold standard for collateral flow evaluation,[21] whereas CTA, a noninvasive alternative is a more practical choice for preprocedural collateral evaluation. DSA collateral flow assessment was well correlated with CTA collateral flow evaluation.[27] There were 3 main reasons to utilize DSA as collateral evaluation tool in our study: First, there were limited patients undergoing noninvasive angiography (186 patients with CTA and 50 patients with MRA) preoperatively in our database. When CTA or MRA was not available, DSA was the only alternative in many centers in China. If we only included patients with noninvasive angiography examinations in the study, the sample size would be too small to derive and internally validate a scoring system. The CTA collateral grading system is consistent with the DSA, so it is feasible that the calculation of collateral status by DSA can be substituted by CTA in future pre-thrombectomy-evaluations. Further studies are needed to validate the RANK score using CTA as the method of collateral flow assessment.

In our study, we found that stroke onset time to ED arrival was an independent predictor for functional outcome. With considerable effort, the door to puncture time has been shortened in China. Most thrombectomy centers have increased the procedure performance speed and have a more efficient workflow within the ED.

The significant relationship of stroke onset time to ED arrival and not ED arrival to puncture time to functional outcome indicated that in hospital delays were a less important to patient outcome than prehospital delays.

Consistent with PRE[12] and HIAT2,[13] RANK also includes NIHSS, ASPECTS, and age components. Additionally, RANK included a collateral flow assessment, which has proven to be the most important protective factor for functional outcome,[28,29] and time from onset to ED presentation, which was associated with better clinical outcome after revascularization.[30] Table e-3 in the data supplement shows the comparisons of items in each scale. Compared with previously published scales, the discrimination ability of RANK scale was better than THRIVE[14] and HIAT2. However, the RANK scale had numerically higher AUC than the PRE scale. Moreover, the PRE scale used continuous NIHSS and ASPECTS values, and the calculation of PRE score was determined by the exact NIHSS and ASPECTS score, which may be affected by the experience of the raters.

Recanalization was another important predictor for functional outcome. In our study, because we mainly focused on the prethrombectomy predictors, we did not include recanalization status in the scoring system. However, in the subgroup analysis, a high RANK score was consistently an independent predictor for an unfavorable functional outcome irrespective of recanalization status.

Our novel scoring system identified the probability of an unfavorable functional outcome in different risk groups. Patients with very low and low risk, patients are good candidates for endovascular treatment those would achieve favorable 90 days mRS. For patients with higher scores, endovascular treatment does not appear to have much benefit. For patients with a very high score RANK ≥ 6), endovascular treatment is likely to have no benefit. The RANK score provides quantitative data to guide patients and their families, and doctors regarding the probabilities of an unfavorable functional outcome from endovascular treatment. It will aid doctors-patients communication and help decision-making.

Limitations of our study include its retrospective nature, lack of external validation, and using DSA to assess collateral flow. Further studies are needed to elaborate CTA collateral flow assessment as a predictor of outcome. The validities of the RANK score in a prospective external cohort and non-Asian cohort are needed.

Conclusion

The RANK scale is a valid tool for risk stratification for endovascular stroke treatment in anterior circulation large vessel occlusions.

Declaration of Competing Interest

The authors declare no conflict of interest.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.jstrokecerebrovasdis.2019.104442.

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