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The Effect of Endovascular Thrombectomy on Clinical Outcomes in Large Ischemic Stroke Varies by Collateral Status and Stroke Etiology

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Abstract

Background

Endovascular thrombectomy (EVT) improves outcomes compared with standard medical therapy (SMT) in patients with large ischemic stroke; however, factors modifying its effect remain unclear. This study aimed to evaluate whether the benefits of EVT vary according to collateral status and stroke etiology.

Methods

This subanalysis of a prospective cohort study included patients with large vessel occlusion and ASPECTS 0–5, recruited from 38 stroke centers across China between November 2021 and February 2023. Collateral status was graded on single-phase CT angiography (sCTA) images using the Tan score and dichotomized into unfavorable (grades 0–1) and favorable (grades 2–3). The primary outcome was the shift in the 90-day modified Rankin Scale (mRS).

Results

Among 460 eligible patients, 120 had favorable collaterals and 340 had unfavorable collaterals. In the favorable collateral group, EVT was associated with a significant shift toward better 90-day functional outcomes on the mRS (adjusted common odds ratio [acOR], 2.70; 95% CI, 1.23–5.93), whereas no such benefit was observed in the unfavorable collateral group (acOR, 1.08; 95% CI, 0.69–1.68). Subgroup analyses indicated that EVT generally outperformed SMT in the favorable collateral group, with a significant interaction between treatment modality and stroke etiology (P = 0.013), demonstrating greater benefit in patients with non-atherosclerotic stroke (OR, 10.68; 95% CI, 3.91–29.14).

Conclusion

In patients with large ischemic stroke, EVT was associated with improved 90-day functional outcomes in those with favorable collaterals, especially in non-atherosclerotic stroke. Assessment of both collateral status and stroke etiology may help guide optimal patient selection for EVT.

Introduction

Large ischemic strokes account for approximately 20% of anterior circulation large vessel occlusion (LVO) strokes and are associated with high rates of disability and mortality [1]. Recent randomized controlled trials have consistently demonstrated that patients with large ischemic stroke achieve better functional outcomes following endovascular thrombectomy (EVT) compared with standard medical therapy (SMT) alone [2–6]. However, despite EVT, the rates of functional independence remain low (14–30%), and the incidence of bedridden states or death remains high (33–50%) [7]. Therefore, optimizing

patient selection strategies is crucial to maximize the therapeutic benefit of EVT in large ischemic stroke.

Collateral circulation plays a critical role in providing compensatory blood flow to ischemic brain regions, thereby preserving tissue viability in patients with LVO. Consequently, favorable baseline collaterals confer a protective effect on outcomes following EVT. Previous studies have demonstrated that favorable collaterals are associated with higher reperfusion rates, improved functional outcomes, and lower incidences of symptomatic intracranial hemorrhage (sICH) and mortality after EVT [8–10]. Moreover, several clinical factors, including age, comorbidities, stroke severity, time from onset, and stroke etiology, are thought to influence both collateral status and outcomes[11–12]. However, most previous studies have focused on patients with small to medium infarct cores, and data on large ischemic strokes remain limited. A recent study reported that favorable collaterals are associated with improved functional outcomes in patients with large ischemic stroke following EVT, whereas patients with moderate collaterals may benefit from bridging therapy [13]. Nonetheless, there is uncertainty regarding the efficacy of EVT in patients with unfavorable collaterals and the clinical factors that may modify treatment effect across different collateral statuses, since these patients with large ischemic stroke often develop malignant brain edema and hemorrhage, which may limit clinical benefit.

This study aimed to evaluate whether EVT provides superior outcomes compared with SMT in patients with large ischemic stroke across different collateral statuses, and to identify clinical factors that may modify the treatment effect.

Methods

Study population

Data were obtained from a prospective multicenter cohort study that enrolled patients with large ischemic stroke following EVT at 38 stroke centers across China between November 2021 and February 2023. Details of the study protocol have been published previously[14]. The study was approved by the ethics committees of all participating centers, with informed consent obtained from all patients or their legally authorized representatives. This study followed the ethical principles of the Helsinki Declaration.

The main inclusion criteria were as follows: age ≥ 18 years; acute ischemic stroke (AIS) due to anterior circulation LVO, defined as occlusion of the internal carotid artery (ICA) or the M1 or M2 segment of the middle cerebral artery (MCA); large ischemic stroke, defined as an Alberta Stroke Program Early CT Score (ASPECTS) of 0–5; high-quality CTA images at admission; within 24 hours of stroke onset or last known well. The main exclusion criteria included a premorbid modified Rankin Scale (mRS) > 2, absence of 90-day follow-up or essential baseline data, and/or a serious, advanced, or terminal illness unrelated to AIS.

Variables and Imaging Analysis

Stroke etiology was assessed based on patients' medical history, clinical presentation, and imaging features, and classified into large-artery atherosclerosis (LAA), cardioembolism (CE), and other/undetermined etiologies according to the TOAST classification[15]. In the subgroup analysis, atherosclerotic-related stroke included LAA, while nonatherosclerotic stroke included CE, other/undetermined etiology. All collected data were centralized, reviewed, and audited by full-time study coordinators.

Collateral status was assessed using the Tan score derived from single-phase CT angiography (sCTA) images at admission, which ranged from 0 (absence of collateral supply to the occluded MCA territory) to 3 (complete collateral supply to the occluded MCA territory). Based on the modified Tan grading scale, a Tan score of 0–1 was classified as favorable, while a score of 2–3 was classified as unfavorable[16]. All imaging data were evaluated by an independent core imaging laboratory, where two experienced investigators (Dr Lai and Deng), blinded to clinical outcomes, independently reviewed sCTA. In cases of discrepancies, a third investigator (Dr. Tian) assessed and confirmed the results.

Outcomes measurements

The primary outcome was the modified Rankin Scale (mRS) score at 90 days, analyzed as a shift toward better functional outcomes. Secondary outcomes included the proportions of patients achieving mRS scores of 0–2, 0–3, and 0–4 at 90 days, as well as the National Institutes of Health Stroke Scale (NIHSS) score at discharge. Safety outcomes comprised symptomatic intracranial hemorrhage (sICH) within 48 hours, any intracranial hemorrhage, and mortality at 90 days.

Statistical analysis

Statistical analyses were performed using R software, version 4.4.2 (R Foundation for Statistical Computing, Vienna, Austria). Continuous variables were summarized as mean ± standard deviation (SD) or median with interquartile range (IQR), and categorical variables as counts and percentages. For univariate comparisons, the Kruskal–Wallis or Mann–Whitney U test was applied to continuous variables, and the χ^2 test or Fisher’s exact test to categorical variables.

Ordinal logistic regression was performed to evaluate the shift toward better functional outcomes on the mRS in patients with large ischemic stroke, with effect sizes reported as adjusted common odds ratios (acOR) and 95% confidence intervals (CIs). For binary outcomes, the effect of EVT was assessed using binary logistic regression, with results reported as relative risks (RRs) and 95% confidence intervals (CIs). For continuous outcomes, generalized linear regression models were used, and results were expressed as β coefficients. All regression analyses were adjusted for clinically relevant potential confounders, including age, sex, diabetes, hypertension, prior stroke, baseline NIHSS score, ASPECTS, onset to imaging time, intravenous thrombolysis (IVT), and occlusion site. Furthermore, the heterogeneity of EVT effects across collateral status categories was assessed by including an interaction term between treatment modality and collateral status in the regression models. Additionally,

to identify clinical factors that may influence outcomes across different collateral statuses, subgroup analyses were performed using ordinal logistic regression, with odds ratios (ORs) and 95% confidence intervals (CIs) reported without adjustment for confounders. A two-tailed p-value < 0.05 was considered statistically significant.

Results

Baseline Characteristics

A total of 460 eligible patients with large ischemic stroke were included in the final analysis (Figure S1). Of these, 120 had favorable collateral status (SMT, n = 50; EVT, n = 70), and 340 had unfavorable collateral status (SMT, n = 123; EVT, n = 217). Baseline characteristics were compared between EVT and SMT, stratified by collateral status (Table 1). In the favorable collateral group, patients who underwent EVT were younger, had lower systolic blood pressure (SBP) and a lower prevalence of atrial fibrillation, but were more frequently male and had higher ASPECTS scores ($P < 0.05$). In the unfavorable collateral group, patients who underwent EVT were also younger and had lower SBP. Moreover, significant differences were observed in TOAST etiology and occlusion site ($P < 0.05$). Specifically, cardioembolism (CE) and internal carotid artery (ICA) occlusion were more frequent in patients who underwent EVT, whereas large artery atherosclerosis (LAA) and ICA-M1 occlusion were more common in patients who received SMT. Other baseline characteristics were well balanced between the groups.

Table 1
Baseline characteristics of the patients stratified by collateral status

Characteristics	Favorable collaterals (n = 120)			Unfavorable collaterals (n = 340)		
	SMT(n = 50)	EVT(n = 70)	*P* value	SMT(n = 123)	EVT(n = 217)	*P* value
Age, y, median (IQR)	73 (65–81)	65 (55–77)	0.006	72 (65–78)	67 (58–77)	0.003
Sex, male, n (%)	23 (46.0)	46 (65.7)	0.049	64 (52.0)	122 (56.2)	0.527
History, n (%)						
Prior stroke	11 (22.0)	7 (10.0)	0.120	21 (17.1)	32 (14.7)	0.680
Smoking	9 (18.0)	24 (34.3)	0.078	41 (33.3)	70 (32.3)	0.934
Hypertension	35 (70.0)	41 (58.6)	0.276	91 (74.0)	128 (59.0)	0.008
Hyperlipidemia	8 (16.0)	18 (25.7)	0.294	15 (12.2)	43 (19.8)	0.100
Diabetes	11 (22.0)	14 (20.0)	0.970	23 (18.7)	32 (14.7)	0.425
Atrial fibrillation	24 (48.0)	18 (25.7)	0.020	54 (43.9)	94 (43.3)	1.000
SBP, mmHg, median (IQR)	156 (143–178)	145 (128–160)	0.005	152 (135–176)	144 (125–160)	0.001
DBP, mmHg, median (IQR)	92 (81–100)	86 (79–95)	0.197	86 (76–101)	84 (73–96)	0.076
Glucose, mmol/l, median (IQR)	6.8 (5.9-8.0)	6.6 (5.7–8.3)	0.794	7.1 (6.0-8.6)	7.5 (6.1–9.5)	0.137
Baseline NIHSS, median (IQR)	17 (12–21)	15 (13–18)	0.144	17 (14–22)	18 (14–21)	0.841
ASPECTS, median (IQR)	3 (1–5)	4 (3–5)	< 0.001	3 (1–5)	4 (2–5)	0.115
TOAST etiology, n (%)			0.068			0.006
LAA	22 (44.0)	25 (35.7)		57 (46.3)	60 (27.6)	
CE	25 (50.0)	30 (42.9)		54 (43.9)	123 (56.7)	

Abbreviations: SMT, standard medical therapy; EVT, endovascular thrombectomy; SBP, systolic blood pressure; DBP, diastolic blood pressure; NIHSS, National Institutes of Health Stroke Scale; ASPECTS, Acute Stroke Prognosis Early Computed Tomography Score; TOAST, Trial of Org10172 in Acute Stroke Treatment; LAA, large-artery atherosclerosis; CE, cardioembolism; ICA, internal carotid artery; MCA, middle cerebral artery; IVT intravenous thrombolysis; IQR, interquartile range.

Characteristics	Favorable collaterals (n = 120)			Unfavorable collaterals (n = 340)		
	SMT(n = 50)	EVT(n = 70)	*P* value	SMT(n = 123)	EVT(n = 217)	*P* value
Others	3 (6.0)	15 (21.4)		12 (9.8)	34 (15.7)	
Occlusion site, n (%)			0.275			0.001
ICA	7 (14.0)	18 (25.7)		33 (26.8)	98 (45.2)	
MCA-M1	29 (58.0)	37 (52.9)		81 (65.9)	99 (45.6)	
MCA-M2	14 (28.0)	15 (21.4)		9 (7.3)	20 (9.2)	
Tandem occlusion, n (%)	5 (10.0)	6 (8.6)	1	7 (5.7)	17 (7.8)	0.602
Onset to imaging time, min, median (IQR)	340 (219–573)	344 (204–568)	0.649	308 (182–484)	327 (171–523)	0.742
IVT, n (%)	19 (38.0)	21 (30.0)	0.471	35 (28.5)	54 (24.9)	0.554

Abbreviations: SMT, standard medical therapy; EVT, endovascular thrombectomy; SBP, systolic blood pressure; DBP, diastolic blood pressure; NIHSS, National Institutes of Health Stroke Scale; ASPECTS, Acute Stroke Prognosis Early Computed Tomography Score; TOAST, Trial of Org10172 in Acute Stroke Treatment; LAA, large-artery atherosclerosis; CE, cardioembolism; ICA, internal carotid artery; MCA, middle cerebral artery; IVT intravenous thrombolysis; IQR, interquartile range.

Outcomes

Outcomes stratified by treatment modality and collateral status are summarized in Table 2. The effect of EVT on the primary outcome was significantly modified by collateral status (P for interaction = 0.012). In the favorable collateral group, EVT was associated with a significant shift toward better outcomes on the mRS compared with SMT (adjusted common odds ratio [acOR], 2.70; 95% CI, 1.23–5.93), whereas no significant effect was observed in patients with unfavorable collaterals (acOR, 1.08; 95% CI, 0.69–1.68).

Table 2
Clinical outcomes and EVT treatment effect stratified by collateral status

Primary outcome[b]	**SMT**	**EVT**	**Effect size (95% CI)**[a]	***P* value**	***P* for interaction**
mRS score at 90 d, M (IQR)					0.012
Favorable	4.70 (1.58)	3.26 (1.59)	2.70 (1.23–5.93)	0.013	
Unfavorable	4.79 (1.42)	4.62 (1.66)	1.08 (0.69–1.68)	0.737	
Secondary outcomes					
mRS 0–2 at 90 d, n (%)[c]					0.187
Favorable	4 (8.0)	28 (40.0)	5.39 (1.54–18.79)	0.008	
Unfavorable	10 (8.1)	34 (15.7)	2.25 (0.99–5.08)	0.052	
mRS 0–3 at 90 d, n (%)[c]					0.227
Favorable	12 (24.0)	40 (57.1)	2.72 (1.04–7.13)	0.042	
Unfavorable	22 (17.9)	61 (28.1)	1.82 (0.99–3.38)	0.055	
mRS 0–4 at 90 d, n (%)[c]					0.003
Favorable	18 (36.0)	54 (77.1)	3.53 (1.27–9.80)	0.016	
Unfavorable	48 (39.0)	89 (41.0)	1.03 (0.60–1.76)	0.919	
NIHSS at discharge, median (IQR)[d]					0.035
Favorable	15 (10–25)	10 (6–15)	-3.33 (-6.80-0.15)	0.061	
Unfavorable	14 (11–35)	17 (10–36)	0.63 (-1.80-3.06)	0.61	
Safety outcomes, n/total n (%)[c]					
sICH at 48 h, n (%)					0.353

Primary outcome[b]	SMT	EVT	Effect size (95% CI)[a]	*P* value	*P* for interaction
Favorable	5 (10.4)	17 (25.8)	2.69 (0.75–9.60)	0.127	
Unfavorable	9 (7.5)	57 (31.7)	6.26 (2.81–13.92)	< 0.001	
Any intracranial hemorrhage, n (%)					0.137
Favorable	7 (14.0)	21 (30.0)	2.16 (0.75–6.26)	0.156	
Unfavorable	12 (9.8)	94 (43.3)	7.54 (3.74–15.18)	< 0.001	
Mortality, n (%)					0.002
Favorable	23 (46.0)	10 (14.3)	0.31 (0.10–0.98)	0.046	
Unfavorable	58 (47.2)	112 (51.6)	1.31 (0.78–2.19)	0.302	

Abbreviations: mRS, modified Rankin Scale; EVT, endovascular thrombectomy; SMT, standard medical therapy; NIHSS, National Institutes of Health Stroke Scale; sICH, symptomatic intracranial hemorrhage.

[a]Adjusted for age, sex, diabetes, hypertension, previous stroke, baseline NIHSS, ASPECTS, onset to imaging time, IVT, and occlusion site.

[b]The common OR values were calculated using an ordinal logistic regression model and indicated the odds of improvement of 1 point on 90-day mRS scores.

[c]Relative risks were estimated by binary logistic regression with robust error variance.

[d]The β coefficients were estimated using a generalized linear model

For secondary outcomes, our analysis showed that the effect of EVT on mRS 0–4 and NIHSS at discharge was significantly modified by collateral status (*P* for interaction = 0.003 and 0.035, respectively). Patients with with favorable collaterals were associated with better functional outcomes after EVT, including mRS 0–2, 0–3, and 0–4, except for NIHSS at discharge. However, secondary outcomes were comparable between EVT and BMT in patients with unfavorable collaterals (all $P > 0.05$).

In terms of safety outcomes, a significant interaction between treatment modality and collateral status was observed for 90-day mortality (*P* for interaction = 0.002), except for sICH and any intracranial hemorrhage. In the favorable collateral group, sICH and any intracranial hemorrhage were comparable

between EVT and BMT. The 90-day mortality rate was 14.3% (10/70) in patients who underwent EVT, compared with 46% (23/50) in those who received SMT (relative risk [RR], 0.31; 95% CI, 0.10–0.98). In the unfavorable collateral group, sICH occurred in 31.7% (57/217) of patients who underwent EVT, and any intracranial hemorrhage in 43.3% (94/217), compared with 7.5% (9/123) and 9.8% (12/123) in those who received SMT, respectively. Significant differences between EVT and SMT were observed for sICH (RR, 6.26; 95% CI, 2.81–13.92) and any intracranial hemorrhage (RR, 7.54; 95% CI, 3.74–15.18). However, no significant difference in 90-day mortality was found between EVT and SMT (RR, 1.31; 95% CI, 0.78–2.19).

Subgroup analysis

To explore clinical factors that may modify outcomes across different collateral statuses, subgroups were stratified by the following factors: age (≤ 65 years vs > 65 years), sex, baseline NIHSS score (0–24 vs > 25), ASPECTS (0–2 vs 3–5), stroke etiology (atherosclerotic-related stroke vs non-atherosclerotic stroke), IVT (no vs yes), and occlusion status (ICA, MCA-M1, or MCA-M2). The results of the subgroup analysis are shown in Fig. 1, and basically support the primary analysis. In the favorable collateral group, EVT was significantly associated with the primary outcome compared to SMT, except for patients with NIHSS > 25, non-atherosclerotic stroke, and MCA-M2 occlusion. However, no clear benefit was observed across subgroups in the unfavorable collateral group. A significant interaction between treatment modality and stroke etiology was observed in the favorable collateral group (*P* for interaction = 0.013). Among the non-atherosclerotic stroke subgroup, 61.6% (45/73) of those who underwent EVT achieved favorable outcomes, compared with 53.2% (25/47) of those who received SMT (RR, 10.68; 95% CI, 3.91–29.14). However, in the atherosclerotic-related stroke subgroup, no significant difference in the primary outcome was observed between EVT and SMT (RR, 2.45; 95% CI, 0.86–6.97). Additionally, to further visualize the relationship between treatment modality, collateral status, and stroke etiology on clinical outcomes in patients with large ischemic stroke, the distribution of 90-day mRS scores is presented in Fig. 2.

Discussion

In this prospective, multicenter cohort study, patients with favorable collaterals demonstrated superior 90-day outcomes with EVT compared with SMT, whereas no evidence supported the superiority of EVT over SMT in patients with unfavorable collaterals. Subgroup analysis revealed a significant interaction between treatment modality and stroke etiology in the favorable collateral group. EVT was associated with improved 90-day outcomes in patients with non-atherosclerotic stroke, but not in those with atherosclerotic stroke. Thus, patients with favorable collaterals, particularly those with non-atherosclerotic stroke, derived greater benefit from EVT.

Previous studies have primarily focused on patients with small to medium infarct cores, in whom the benefit of EVT was greatest among those with favorable collaterals on baseline CTA [8–10, 17].

Consistent with these findings, our study demonstrates that in patients with large ischemic strokes, favorable collaterals are associated with superior 90-day outcomes following EVT compared with SMT. Favorable collaterals help maintain blood flow in the affected vascular territory, delaying the progression from penumbra to ischemic core, thereby extending the therapeutic time window and enhancing the benefits of EVT in patients with LVO [18–19]. Beyond penumbral salvage, they may confer additional clinical advantages by reducing cerebral edema relative to infarcted brain volume, thus mitigating the extent of tissue damage [20]. In contrast, among patients with unfavorable collaterals, EVT was associated with a higher incidence of sICH and any intracranial hemorrhage compared with BMT, without improving functional outcomes. This is consistent with previous studies indicating that unfavorable collaterals are associated with a smaller ischemic penumbra and a larger infarct core, limiting the potential for tissue recovery despite successful reperfusion [17, 21].

Furthermore, this study demonstrated that the effect of EVT on most outcomes was significantly modified by collateral status, underscoring its prognostic significance. Nevertheless, debate persists regarding how collateral status influences the efficacy of EVT in patients with LVO. In a post hoc analysis of the Multicenter Randomized Clinical Trial of Endovascular Treatment for Acute Ischemic Stroke in the Netherlands (MR CLEAN), baseline CTA collateral status was found to modify the effect of EVT, whereas the Highly Effective Reperfusion Using Multiple Endovascular Devices (HERMES) meta-analysis reported no significant modification of treatment effect by collateral status in EVT-eligible patients [17, 22]. In patients with large ischemic stroke, a recent secondary analysis of the Efficacy and Safety of Thrombectomy in Stroke with Extended Lesion and Extended Time Window (TENSION) trial reported that EVT reduced 90-day functional disability and mortality compared with SMT, without a significant interaction between collateral status and treatment modality [23]. These discrepancies in findings may be attributable to several factors. On one hand, differences in infarct core size may be an important factor, as studies such as MR CLEAN and HERMES primarily focused on small to medium infarct cores, thereby excluding many patients with poor collaterals. On the other hand, variations in the treatment time window and baseline clinical severity, exemplified by the TENSION trial, which included only patients with onset within 11 hours (ASPECTS 3–5, NIHSS ≤ 26), may also contribute to these discrepancies. Future research is warranted to comprehensively investigate how collateral status influences the efficacy of EVT in patients with LVO.

Subgroup analysis demonstrated that, in the favorable collateral group, patients with non-atherosclerotic stroke derived significantly greater benefit from EVT compared with SMT, likely reflecting differences in collateral recruitment mechanisms across stroke etiologies. Although patients with non-atherosclerotic stroke are less likely to have robust collaterals prior to LVO, a subset can rapidly recruit collaterals and subsequently preserve the penumbra, thereby increasing their likelihood of benefiting from EVT [24–25]. In contrast, patients with atherosclerotic-related stroke experience chronic hypoperfusion prior to LVO, which allows more time for collateral recruitment and metabolic adaptation, potentially enhancing tolerance to ischemia [26]. However, this extended duration may also lead to exhaustion of these collateral pathways upon sudden vessel occlusion. This notion is supported by a post hoc analysis of the ATTENTION study, which strongly recommends EVT for patients with basilar artery occlusion who have

good collateral circulation, particularly those with a non-atherosclerotic stroke etiology [27]. Additionally, in the favorable collateral group, our findings indicated that patients with a very large ischemic core (ASPECTS 0–2) had higher odds of achieving a favorable functional outcome after EVT compared with SMT, providing preliminary evidence to support EVT in this patient population [28]. Moreover, patients with MCA-M2 occlusion did not derive significant benefit from EVT, which may be attributable to the localized nature of ischemia in M2 occlusions, reducing EVT efficacy compared with M1 or ICA occlusions, as well as the technical challenges of recanalization in smaller vessels, resulting in lower reperfusion success rates [29–30].

Several limitations of this study should be acknowledged. First, as an observational study, certain biases were unavoidable, and the relatively small sample size may have inflated statistical power in some subgroup analyses, particularly within the favorable collateral group. Second, imaging data were acquired using different CTA systems with varying parameters, which could potentially lead to overestimation or underestimation of the impact of collateral status on clinical outcomes. Finally, the use of sCTA in this study may have limited the ability to fully capture the dynamic nature of collateral flow.

In conclusion, our results indicate that patients with favorable collaterals who underwent EVT achieved superior 90-day outcomes compared with those receiving SMT, particularly among patients with non-atherosclerotic stroke. In contrast, no significant benefit was observed in patients with unfavorable collaterals. These findings underscore the importance of considering both collateral status and stroke etiology when selecting patients for EVT in large ischemic strokes.

Declarations

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Contributor

P.Y. Z. and W. D. conducted the literature review and conceived the study. P.Y. Z., Y.L. S., and W. D. were responsible for the planning, design, and execution of the study. W. D. supervised and coordinated the project and wrote the initial manuscript draft. F.Y. Z., Z.Q. B., and Z.H. C. contributed to data acquisition, processing, and analysis. This manuscript complies with all instructions to authors. The authorship requirements have been met and the final manuscript was approved by all authors. This manuscript has not been published elsewhere and is not under consideration by another journal.

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Data sharing statement

Data generated or analyzed during the study are available from the corresponding author by request.

Ethics approval

The study was approved by the ethics committees of the Second Affiliated Hospital of the Army Medical University and participating hospitals (ChiCTR2100051664). All enrolled patients or their legally authorized representatives provided written informed consent before enrollment.

Consent for publication

Not applicable.

Clinical trial number

Not applicable.

Competing interests

All authors declare no conflict of interest.

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Figures

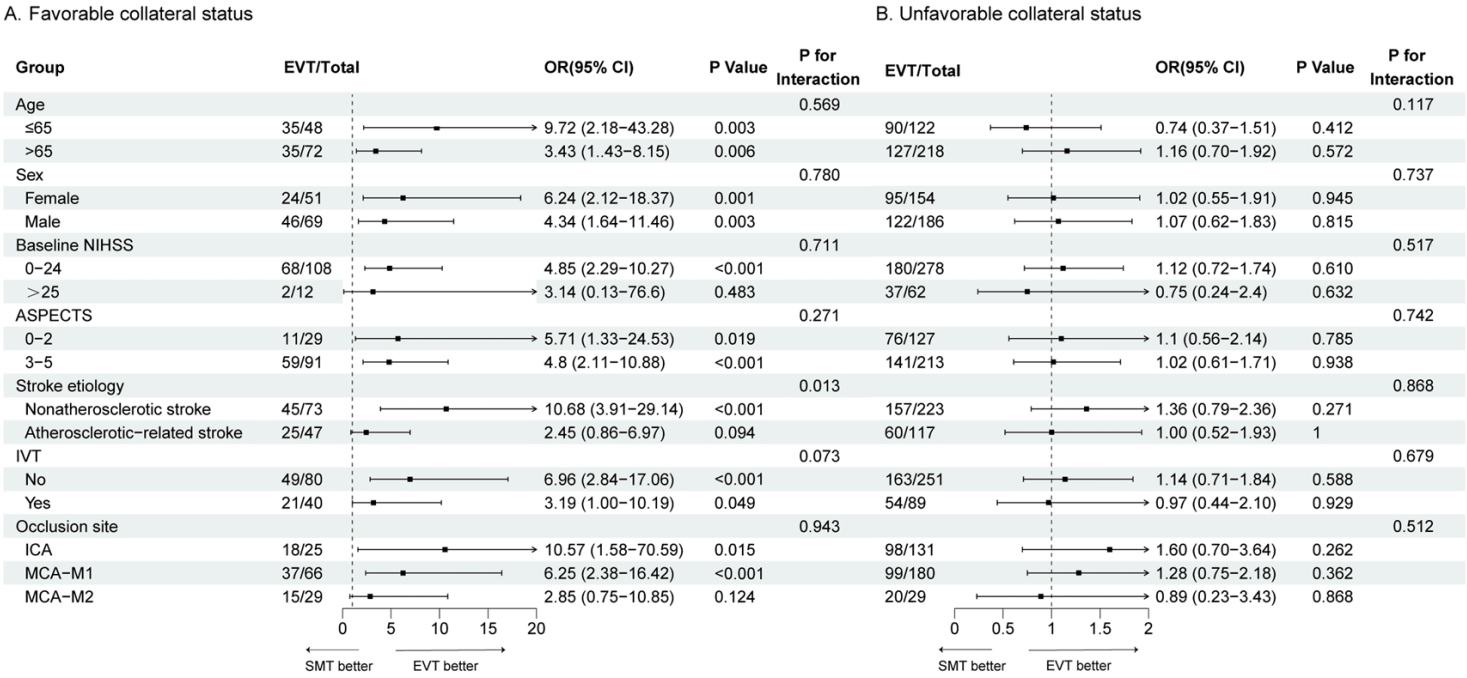


Figure 1

Subgroup analyses of 90-day mRS scores in patients with favorable or unfavorable collateral status. (A) In the favorable collateral group, EVT was significantly associated with the primary outcome compared to SMT, except for patients with baseline NIHSS >25, non-atherosclerotic stroke, and MCA-M2 occlusion. (B) In the unfavorable collateral group, no clear treatment benefit was observed across subgroups.

Abbreviations: EVT, endovascular thrombectomy; SMT, standard medical therapy; NIHSS, National Institutes of Health Stroke Scale; ASPECTS, Acute Stroke Prognosis Early Computed Tomography Score; IVT intravenous thrombolysis; ICA, internal carotid artery; MCA, middle cerebral artery; OR, odds ratio.

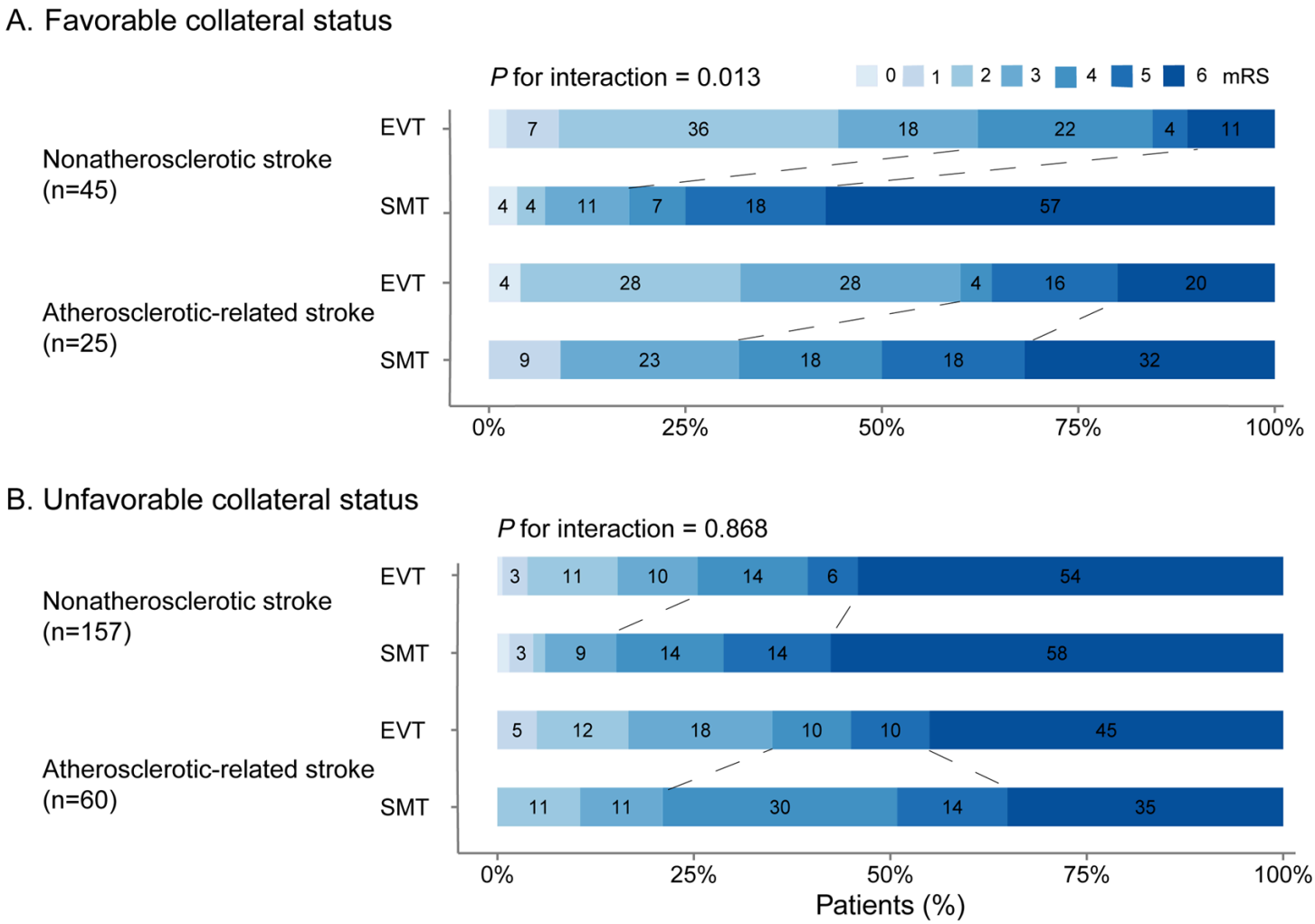


Figure 2

Distribution of 90-day mRS scores stratified by treatment modality and stroke etiology in patients with favorable or unfavorable collateral status. (A) In the favorable collateral group, there was a significant interaction between treatment modality and stroke etiology for the primary outcome (*P* for interaction = 0.013). (B) In the unfavorable collateral group, no significant interaction was observed (*P*for interaction = 0.868).

Abbreviations: EVT, endovascular thrombectomy; SMT, standard medical therapy.

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