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ORIGINAL RESEARCH

Endovascular Treatment in Stroke Patients of Working Age: A Multicenter Observational Study of Real-World Outcomes

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Purpose: The prevalence of acute ischemic stroke (AIS) is increasing among people of working age, posing socioeconomic and healthcare challenges. Inability to return to work can have significant negative consequences and contribute to the economic burden of stroke. Endovascular treatment (EVT) has been established as the standard of care for large vessel occlusion AIS patients. In this study, we aimed to identify factors predicting favorable outcome among working age AIS patients undergoing EVT.

Patients and Methods: We analyzed data from 309 patients from five comprehensive stroke centers between 2019 and 2023. All patients were working age (18<59) with symptoms onset of within 24 hours. Modified thrombolysis in cerebral infarction (mTICI) score of 2b-3 was considered as successful recanalization. We used 3-months mRS post-EVT to evaluate the outcome; mRS of 0–2 was defined as favorable outcome, whereas mRS of 3–6 was considered unfavorable outcome.

Results: The unfavorable outcome group consisted of 150 patients, and 159 patients were in the favorable outcome group. More people in the unfavorable outcome group had diabetes (29.33% vs 15.72%, p=0.004) and hypertension (61.33% vs 40.88, p<0.001). A multivariable regression analysis demonstrated that several factors, including successful recanalization (odds ratio (OR) 5.298, 95% confidence interval (CI) 1.735–16.174, p=0.003), pre-EVT NIHSS (OR 0.892, 95% CI 0.852–0.934, p=0.000), baseline Alberta stroke program early CT score (ASPECTS) (OR 1.609, 95% CI 1.274–2.032, p=0.000), hypertension (OR 0.477, 95% CI 0.270–0.845, p=0.011), diabetes mellitus (OR 0.413, 95% CI 0.208–0.820, p=0.011), and symptomatic intracerebral hemorrhage (sICH) (OR 0.045, 95% CI 0.006–0.359, p=0.003) can predict the outcome of patients undergoing EVT.

Conclusion: Favorable outcome of working age patients with AIS undergoing EVT can be predicted using multiple factors, including hypertension, diabetes mellitus, successful recanalization, pre-EVT NIHSS, baseline ASPECTS, and sICH.

Keywords: acute ischemic stroke, endovascular treatment, thrombectomy, China, working age, patient outcome

Introduction

Stroke has been the leading cause of mortality in China, with increasing prevalence.[1–4] It has been estimated that Chinese citizens have the highest risk of stroke within the next 25 years globally, posing a significant burden on the country.[5]

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Multiple factors, including increased prevalence of comorbidities such as obesity, diabetes, hypertension, and lack of adequate physical activity, have been reported as reasons for this upward trend.[6–8]

Endovascular thrombectomy (EVT) has been firmly established as the standard treatment for acute ischemic stroke (AIS) caused by large vessel occlusion, as demonstrated by several pivotal trials, including MR CLEAN,[9] ESCAPE,[10] REVASCAT,[11] SWIFT PRIME,[12] and EXTEND IA.[13] These studies showed that EVT significantly outperforms medical therapy alone, with some reporting a number needed to treat as low as three to achieve better functional outcomes. Nonetheless, the initial trials predominantly included broad adult populations, with limited emphasis on outcomes in individuals of working individuals.

The China Stroke Prevention Project Committee Stroke Program has been initiated by the Chinese government since 2011 aiming to reduce the burden of stroke in the country by raising awareness with publicity and education, conducting screening and physical examinations, and providing comprehensive and effective interventions for residents above the age of 40.[14] On a global scale, stroke is also the second leading cause of death and a leading cause of disability. Indeed, the incidence of stroke has been increasing in developing countries.[15–17] Therefore, experiences and challenges from China can provide valuable lessons for other developing countries and international regions. In China, the adoption of EVT has grown substantially since 2015.[2] However, limited research has focused specifically on outcomes among working-age individuals. The ANGEL-ACT registry (n=1793) offered valuable insights into EVT practices nationwide,[18] yet it did not examine age-specific outcomes in detail. Our study extends this work by concentrating on the working-age population, for whom return to employment and economic productivity are especially pertinent considerations.

A significant cohort of patients who are affected by stroke are people of working age. A lack of complete return to work can negatively affect the affected patients, their families, and society.[19] Not being able to work can cause isolation and mental health problems for the affected patient, reduce the family's income, and cause significant problems for employers.[14] The ability to work after stroke is a major factor in the life satisfaction of stroke patients, especially men who reported a 2.5 times higher risk of life dissatisfaction when they were not able to return to work.[20] Therefore, understanding outcomes among working-age people can support developing and implementing evidence-based policies. In China, the retirement age for both males and females is 60 years old.[21] The aim of this study was to identify factors affecting the outcome of working-age patients with AIS following EVT.

Materials and Methods

Patients Populations

We conducted a retrospective analysis of data from patients who underwent EVT in five comprehensive stroke centers in China between 2019 and 2023. The inclusion criteria were as follows: 1) AIS patients who underwent EVT; 2) patients older than 18 years old and younger than 59 years old; 3) patients within 24 hours from last know well time (LKW). The exclusion criteria were as follows: 1) patients with missing 3-months modified Rankin scale (mRS) follow-up data 2) patients with pre-EVT National Institute of Health Stroke Scale (NIHSS) score less than 6, 3) patients with premorbid mRS of over 2.

We excluded patients with pre-EVT NIHSS <6 because: (1) current guidelines limit EVT recommendations primarily to NIHSS ≥6 cases; (2) mild strokes demonstrate fundamentally different pathophysiology and treatment responses; and (3) our focus on working-age outcomes required a population where functional impairment was substantial enough to assess return-to-work potential meaningfully. This approach aligns with recent working-age specific studies (eg, the WORK-STROKE cohort analysis[22]) that similarly focused on NIHSS ≥6 patients when evaluating employment outcomes.

Data Collection

We collected the following data in our study: sex, age, diabetes, coronary artery disease, hypertension, atrial fibrillation, prior stroke, hyperlipidemia, smoking status, pre-treatment NIHSS, baseline Alberta stroke program early CT score (ASPECTS), thrombolysis, LKW time, door-to-puncture time (DPT), successful recanalization, symptomatic intracerebral hemorrhage (sICH).

Outcome Evaluation

Successful recanalization was defined as a modified thrombolysis in cerebral infarction (mTICI) score of 2b-3.[21,22] We used 3-months mRS after EVT to evaluate patient outcomes. mRS of 0–2 after 3-months was defined as favorable outcome and mRS of 3–6 was considered unfavorable outcome.[23–25]

Statistical Analysis

The nonparametric Mann–Whitney *U*-test was performed analyze non-normally distributed continuous data, reported as medians along with the interquartile range (IQR). Categorical data were described as frequencies and percentages. Multivariable regression was performed to assess the factors associated with patient outcome. Results were considered statistically significant if the p-value was less than 0.05. IBM SPSS version 26 (IBM-Armonk, NY) was used for completing all statistical tests.

Sample size was determined by both feasibility considerations and statistical requirements. Based on participating centers' annual EVT volumes, we anticipated 300–350 eligible cases during the study period. A priori power analysis indicated 267 patients would provide 80% power to detect medium effect sizes (OR=1.8) for our primary predictors in multivariable analysis. Our final cohort (n=309) achieved 82–99% power for the observed effect sizes.

Ethics

The Institutional Review Board of all hospitals (Huadu District People's Hospital of Guangzhou, Guangdong Province, Guangzhou, China; First People's Hospital of Foshan, Foshan, Guangdong Province, China; The Affiliated Yuebei People's Hospital of Shantou University Medical College, Shaoguan, China; Foshan Sanshui District People's Hospital, Foshan, Guangdong Province, China; Guangdong Provincial Hospital of Integrated Traditional Chinese and Western Medicine (Nanhai District Hospital of Traditional Chinese Medicine of Foshan City), Foshan, Guangdong Province, China) in the study approved the protocol. All procedures in the study involving human participants were performed following the ethical standards of the institutional and/or national research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. Written informed consents from the participants' legal guardian/next of kin were obtained to perform the EVT. Informed consent for inclusion in the study was waived due to its retrospective nature and minimal patient risk according to the national and institutional guidelines.

Results

A total of 323 consecutive AIS patients were screened for this study. After the application of inclusion and exclusion criteria, 14 patients were excluded for the following reasons: two patients were excluded due to missing 3-months follow-up data; eleven patients were excluded due to pre-EVT NIHSS of lower than 6, and one patient was excluded due to a premorbid mRS of over 2. Figure 1 demonstrates a summary of patients selection criteria.

The baseline characteristics of patients are demonstrated in Table 1. The unfavorable outcome group consisted of 150 patients, whereas 159 patients were in the group with favorable outcome. There were statistically significant differences between the two groups in diabetes, hypertension, hyperlipidemia, pre-treatment NIHSS, baseline ASPECTS, successful recanalization, and sICH. There were more patients in the unfavorable outcome group with diabetes (29.33% vs 15.72%, p=0.004) and hypertension (61.33% vs 40.88%, p<0.001). In contrast, hyperlipidemia was higher in the group with favorable outcome (29.56% vs 19.33%, p=0.037). More successful recanalization was achieved in the group with favorable outcome (96.23% vs 78.67%, p<0.001). Pre-treatment NIHSS was higher in the group with unfavorable outcome (18.0 interquartile range (IQR) (13.0–22.3) vs 13.0 (9.0–17.0), p<0.001), whereas higher baseline ASPECTS was noted in the group with favorable outcome (IQR 9.0 (8.0–9.0) vs 8.0 (7.0–9.0), p<0.001). There were 25 (16.67%) sICH cases among unfavorable outcome group, but only one case (0.63%) in the favorable outcome group had sICH (p<0.001).

Figure 2 demonstrates the 3-months mRS distribution of patients. Overall, 51.5% of patients achieved favorable outcomes 3-months post-EVT, and 22.7% of patients died even after EVT intervention.

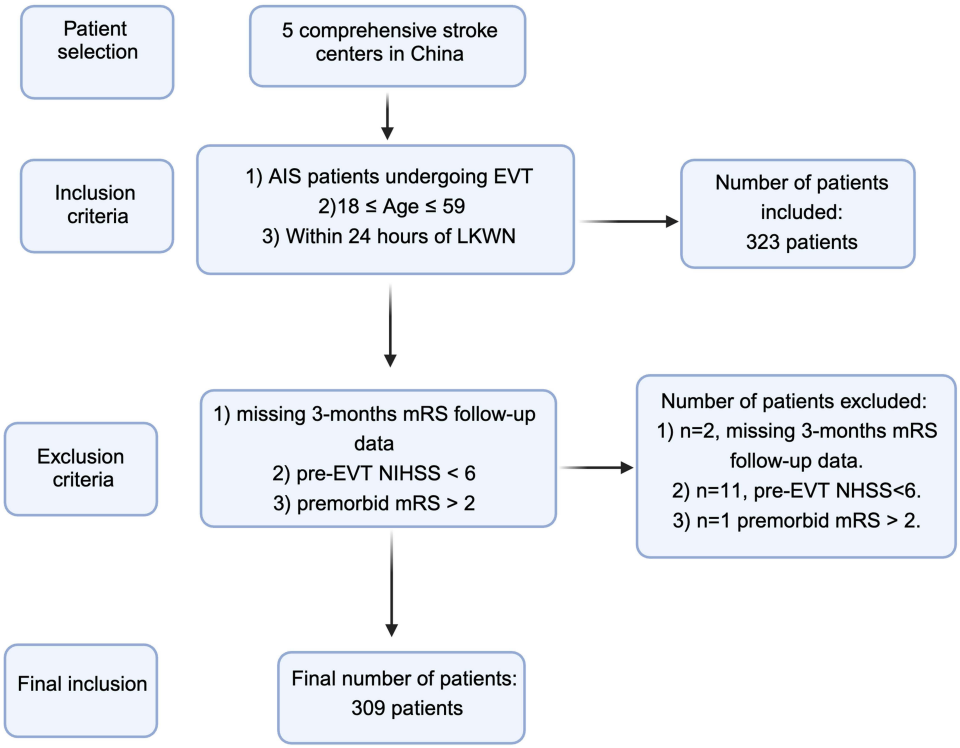

Figure 1 A summary of patient selection criteria in the current study.

Multivariate regression analysis revealed that multiple factors, including hypertension (p=0.011), diabetes mellitus (p=0.011), sICH (p=0.003), successful recanalization (p=0.003), pre-EVT NIHSS (p=0.000), and baseline ASPECTS (p=0.000), were independently associated with outcome after EVT (Table 2).

Table 1 Baseline Characteristics of Patients

	Unfavorable Outcome	Favorable Outcome	P value
Number	150	159	
Female sex (n, %)	31 (20.67%)	27 (16.98%)	0.407
Age year (IQR)	53 (50–56)	52 (47–56%)	0.062
Diabetes (n, %)	44 (29.33%)	25 (15.72%)	0.004*
Coronary artery disease (n, %)	15 (10.00%)	16 (10.06%)	0.985
Hypertension (n, %)	92 (61.33%)	65 (40.88%)	<0.001*
Atrial fibrillation (n, %)	23 (15.33%)	20 (12.58%)	0.484
Stroke history (n, %)	25 (16.67%)	17 (10.69%)	0.126
Hyperlipidemia (n, %)	29 (19.33%)	47 (29.56%)	0.037*
Smoker (n, %)	54 (36.00%)	58 (36.48%)	0.930
Successful recanalization (n, %)	118 (78.67%)	153 (96.23%)	<0.001*
Pre-treatment NIHSS (IQR)	18.0 (13.0–22.3)	13.0 (9.0–17.0)	<0.001*

(*Continued*)

Table 1 (Continued).

	Unfavorable Outcome	Favorable Outcome	P value
Baseline ASPECTS	8.0 (7.0–9.0)	9.0 (8.0–9.0)	<0.001*
Thrombolysis (n, %)	41 (27.33%)	55 (34.59%)	0.168
DPT (IQR), min	130.0 (83.5–185.3)	117.0 (83.0–170.0)	0.423
LKWT (IQR), min	357.5 (243.8–582.3)	320.0 (185.0–570.0)	0.118
sICH (n, %)	25 (16.67%)	1 (0.63%)	<0.001*

Notes: *Denotes significance.
Abbreviations: ASPECTS, Alberta stroke program early CT score; DPT, door-to-puncture time; IQR, interquartile range; LKWT, last-known well time; NIHSS, National Institute of Health stroke scale. sICH, symptomatic intracerebral hemorrhage.

Discussion

Despite major advances in providing care for AIS patients worldwide, predicting the prognosis of patients has remained a challenging issue for clinicians. Therefore, identifying factors which predict favorable outcomes in patients undergoing EVT can help clinical decision making by channeling resources as well as implementing measures to reduce risk factors associated with poor functional outcomes. In the current study, we identified factors related to the outcomes of working age patients with AIS who underwent EVT. Our analysis from 309 patients across five comprehensive stroke centers revealed that hypertension, diabetes mellitus, pre-EVT NIHSS, baseline ASPECTS, successful recanalization, and sICH can predict the 3-months outcome of working age patients.

China accounts for roughly one third of stroke mortality worldwide.[26] Over the past two decades, China has made significant efforts to tackle challenges in providing effective stroke treatment, and data shows improvements in that stroke outcomes.[3,27] Despite such advances, the prevalence of AIS has been rising in China due to multiple factors, including sedentary lifestyle, obesity, diabetes mellitus, and hypertension, which is a similar trend to global data.[6–8] Given the current trend, it is expected that the future cost of stroke care to rise in China and globally.[28]

A group of patients who can significantly benefit from effective AIS treatment is patients who are of working age. There is no universal consensus on the accepted age range for working population; however, the retirement age is 60 years old in China;[20] therefore, our analysis considered adults between 18 and 60 years of age as working age. Global

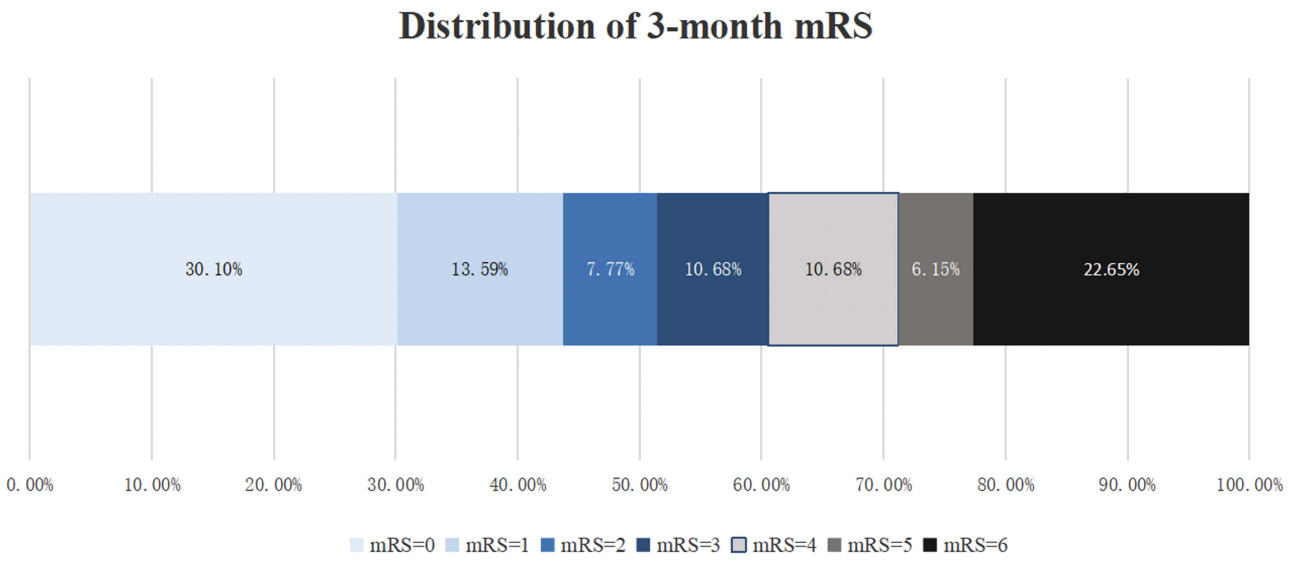

Figure 2 3-months mRS distribution of patients.

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Table 2 Factors Associated with Long-Term Outcome by Multivariable Regression

Factor	Coefficient	*p*	OR	95% CI
Hypertension	−0.740	0.011	0.477	0.270–0.845
Diabetes mellitus	−0.884	0.011	0.413	0.208–0.820
Successful recanalization	1.667	0.003	5.298	1.735–16.174
Pre-EVT NIHSS	−0.114	0.000	0.892	0.852–0.934
Baseline ASPECTS	0.476	0.000	1.609	1.274–2.032
sICH	−3.094	0.003	0.045	0.006–0.359

Notes: Regression model used: Age, hypertension, diabetes mellitus, hyperlipidemia, successful recanalization, pre-EVT NIHSS, baseline ASPECTS, sICH.
Abbreviations: ASPECTS, Alberta stroke program early CT score; EVT, endovascular thrombectomy; NIHSS, National Institute of Health stroke scale; sICH, symptomatic intracerebral hemorrhage.

data show a rising trend of stroke incidence among this younger demographic.[29] Stroke survivors of working age can face significant challenges dealing with the physical, psychological, and social burden of AIS.[30] They can also face rehabilitation challenges to regain their independence and return to work.[31–35] In addition to the personal impact of AIS for survivors, the financial burden associated with stroke on the individual of working age, their family, and the larger economy is considerable.[30]

Significant challenges exist in predicting the outcome of AIS patients undergoing EVT. One of the factors from our multivariate regression analysis that predicted favorable outcomes was a lack of diabetes mellitus. Similar to our findings from the Chinese population, a large multi-center European study investigating 695 patients reported that the diagnosis of diabetes mellitus was an independent risk factor in predicting unfavorable functional outcome as well as mortality at 3 months.[36] Multiple investigations from animal models of stroke have also shown that elevated serum glucose level can cause a larger infarct volume.[37,38] It has been hypothesized that more severe tissue damage, including intracellular acidosis, aggregation of extracellular glutamate, blood–brain barrier disruption, cerebral edema, and plasma fibrinolysis impairment, are associated with diabetes mellitus in AIS patients.[39,40] Furthermore, diabetes mellitus is a risk factor for the occurrence of AIS, as well.[41,42] As the prevalence of diabetes mellitus is increasing in China,[43] measures to control this condition can help protect against AIS occurrence as well as improve the outcome of those working age patients undergoing EVT.

Lack of hypertension was another factor associated with favorable outcomes in our patient cohort. Similar to the findings reported in the current cohort, a prospective, multi-center American study of 443 patients reported that hypertension was associated with poor functional outcome at 3-months, measured by mRS of 3–6.[44] Other studies further validated these findings.[45–47] Such observations can be important in implementing measures to regulate blood pressure to achieve favorable outcome among AIS patients undergoing EVT.

Consistent with findings reported in the current study, a prospective multi-center study also reported that baseline NIHSS was correlated with unfavorable functional outcomes in AIS patients who underwent EVT.[48] As a critical and well-established tool to determine the risk associated with clinical deterioration, NIHSS assesses the severity of stroke to help guiding clinical decision-making to select suitable treatment options, especially before initiating EVT.[48,49]

Another predictor of favorable functional outcome identified in our study was successful recanalization. EVT has become the gold-standard approach for the treatment of AIS patients.[50] EVT recanalization has been associated with significant neurological improvements and reduced mortality in AIS patients.[51,52] Multiple studies across other global regions have reported that the degree of recanalization can play a crucial role in predicting functional outcome.[53,54]

Recent meta-analyses have underscored the critical role of successful recanalization (pooled odds ratio [OR] 4.2 for favorable outcomes) and higher baseline ASPECTS (OR 1.4 per point increase) in predicting clinical outcomes following

EVT,[55] findings that align with our results. Nevertheless, the specific influence of these factors on younger, working-age patients remains insufficiently explored—a gap that our study seeks to fill.

Successful recanalization restores cerebral perfusion, resulting in better patient prognosis.[56–58] In contrast, several factors influencing unsuccessful recanalization, including prolonged procedures and multiple thrombectomy passes have been associated with poor functional outcome.[59,60] In addition, sICH was another factor that was associated with functional outcome, which is consistent with previously published data.[21,61] Furthermore, sICH is an independent factor to predict several morbidities, including secondary cerebral edema, neurological impairment, intracranial hypertension, and mortality.[62,63]

The strong association between symptomatic intracranial hemorrhage (sICH) and poor clinical outcomes (odds ratio 0.045, p=0.003) likely reflects the influence of multiple pathophysiological mechanisms. Hemorrhagic transformation, often driven by reperfusion injury, compromises the integrity of the blood–brain barrier—an effect that is particularly pronounced in hyperglycemic states.[64] In addition, the mass effect from hematoma expansion can compress the surrounding penumbral tissue, further impairing recovery.[65] Secondary cerebral edema, triggered by hemoglobin breakdown products, activates cytotoxic inflammatory cascades that exacerbate neuronal injury.[66] Finally, coagulopathy induced by mechanical thrombectomy devices—such as platelet dysfunction—may heighten the risk of bleeding complications.[67] These interconnected mechanisms contribute to the significantly worse outcomes observed in patients who develop sICH following EVT.

Favorable functional outcome was also associated with higher baseline ASPECTS. Previous studies reported that higher ASPECTS was associated with favorable outcome post-EVT, as well as reduced inpatient mortality and 3-months mortality.[68–71] In addition, ASPECTS can be used as an independent tool to aid in patient prognostication post-EVT.[72]

The findings from the current study can have important implications for global health. Predicting the AIS patient outcome remains challenging for many clinicians. This is especially true for younger patients of working age. Data from the current study can be used with other factors to build models to predict the outcome of working-age AIS patients undergoing EVT.[73,74]

This study has several strengths. This study was a multi-center investigation of 309 patients across five comprehensive stroke centers in China. As China is facing a growing stroke burden in the next 25 years,[75] disseminating data can prompt other developing countries facing similar challenges to conduct similar studies and contribute to our current understanding of stroke care for policymaking and clinical decision making. Furthermore, the consistency of our findings with studies conducted in developed countries across Europe and North America supports the validity of our results and motivates further large-scale global studies to identify inter-continental similarities and differences in the outcome of AIS patients. To the best of our knowledge, this is the first direct investigation of AIS outcomes among working age patients undergoing EVT in China.

Future studies should perform supplemental analyses examining: pre-procedure antithrombotic use (antiplatelets/anticoagulants), operator experience (years performing EVT, annual case volume), center volume (annual EVT cases per center), and post-procedure antithrombotic management to address some of the existing questions in the field.

This study is also subject to several limitations which should be acknowledged. This is a retrospective analysis of data; therefore, data collection and recording can be at the risk of recall and classification bias, despite all the efforts made to standardize data collection and classification across all five centers involved in the study. In addition, the relatively small size of the study can compromise the external validity of the reported findings. Furthermore, as the study was geographically limited to China; data from other geographical areas are required to validate and extend these findings. Also, by excluding NIHSS <6 patients, our findings apply specifically to moderate-severe strokes. While this reflects current treatment guidelines, future studies should examine whether our identified predictors generalize to milder strokes in working-age populations. Although detailed EVT protocol information was not available, some technical variability existed across centers, particularly in device selection, which was at the operator's discretion based on individual case characteristics. However, all sites adhered to standardized inclusion criteria and outcome assessments, ensuring consistency where feasible while reflecting real-world clinical practice. One important limitation of our study is the absence of detailed information regarding patients' pre-stroke occupations and daily functional activities. While we focused on working-age individuals, we were unable to account for the specific cognitive, communicative, or physical

demands associated with their professional roles. This limits our ability to fully interpret the clinical significance of low NIHSS scores in the context of post-stroke functional recovery. For example, even minor language deficits may be profoundly disabling for individuals in occupations requiring fluent communication, such as teachers or lawyers. Future studies should aim to incorporate occupational and functional baseline data to more accurately assess the impact of stroke on return to work and quality of life.[76–79]

Conclusion

In conclusion, our real-world investigation revealed that 51.5% of working age patients with AIS achieved favorable outcome after undergoing EVT. Successful recanalization, higher baseline ASPECTS, lower pre-EVT NIHSS, lack of hypertension, diabetes, and sICH were associated with favorable outcome of working age patients after EVT. As stroke remains a leading cause of death in China and globally, identifying such factors associated with favorable functional outcome in various populations is crucial to demonstrate the effectiveness and safety of EVT.

Future research should focus on several key directions to enhance outcomes for working-age stroke patients. First, multinational validation of the working-age-specific prognostic thresholds identified in this study is needed, ideally through large-scale collaborations such as the WHO Global Stroke Registry. Second, randomized controlled trials investigating the impact of intensive comorbidity management prior to EVT could help determine whether optimizing pre-procedural risk factors improves clinical outcomes in this demographic. Third, there is a need to develop age-adapted EVT selection criteria that not only consider clinical parameters but also integrate occupational and functional outcome measures, ensuring that treatment decisions align with the unique recovery goals of working-age individuals.

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Disclosure

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