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Original Article

Safety and efficacy of rescue endovascular treatment in ischemic stroke patients with early neurological deterioration caused by large vessel occlusion

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Abstract: Objectives: The optimal treatment after deterioration following ischemic stroke has not been established in the current guidelines. Therefore, this study evaluated the efficacy of rescue endovascular treatment in patients with early neurological deterioration after acute ischemic stroke. Methods: This study analyzed data retrospectively retrieved from the electronic medical records at the First Affiliated Hospital of Anhui Medical University. Results: A total of 20 patients were included in the rescue endovascular treatment group and 23 in the medical group. The 90-day favorable outcome rate in the rescue endovascular treatment group was significantly better than that of the medical group (75.0% *vs.* 34.8%, *P*=0.031). However, no significant difference in all-cause mortality within 90 days was observed between the rescue endovascular treatment group and the medical group (5.0% *vs.* 8.7%, *P*=1.000). The 90-day prognosis of patients with mild stroke of anterior circulation and large vessel occlusion who underwent rescue endovascular treatment after deterioration was significantly better than that of those in the medical group (76.5% *vs.* 31.6%, *P*=0.010). Conclusion: Rescue endovascular treatment is effective and safe for patients with ischemic stroke and deterioration due to large vessel occlusion, leading to no significant increase in the risk of hemorrhage or death even when the time window exceeds 24 h.

Keywords: Acute ischemic stroke, early neurological deterioration, large vessel occlusion, rescue endovascular treatment, prognosis

Introduction

Stroke is the third leading cause of death and disability worldwide (expressed in disability-adjusted life years) [1]. Moreover, early neurological deterioration (END) can occur within a short time after stroke onset. The definition of END varies among studies, with this condition being usually defined as an increase of ≥4 points in the National Institutes of Health Stroke Scale (NIHSS) score [2]. Previous research has indicated that up to one-third of patients with stroke will experience neurological deterioration [3]. Another investigation found that END incidence was significantly higher in patients with atherosclerotic cerebral infarction than in those with cardiogenic embolism and small artery occlusion [4]. A recent study also showed that END incidence in patients with minor stroke and large vessel occlusion (LVO) was as high as 39.4% [5], while lesion growth and hypoperfusion were determined as the primary causes of END in patients with intracranial atherosclerotic stenosis in different research [6]. END was demonstrated to be a strong predictor of poor clinical prognosis [7] and was selected in many studies as an early alternative endpoint in numerous studies [8, 9]. Thus, appropriate interventions addressing the underlying mechanisms of END are crucial in improving outcomes in this patient population [10].

Currently, guidelines recommend employing endovascular treatment (EVT) for eligible patients with LVO within 24 h from symptom onset to improve patient outcomes. However, there is limited evidence to support the use of endovascular treatment in patients with LVO-related END. Individual studies have reported adverse

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outcome rates of AIS patients with END [11]. Previous studies indicated a clinically significant association between mild neurological deficits (NIHSS scores ≤5) accompanied by large vessel occlusion and heightened risk of early neurological deterioration [5]. However, current research remains insufficient for comprehensively evaluating both the safety profile and therapeutic efficacy of rescue EVT in patients experiencing END. Few studies have focused on rescue endovascular treatment after deterioration in patients with low NIHSS scores [12-14]. Notably, a critical evidence gap persists regarding the application of endovascular therapies beyond conventional 24-hour treatment windows, particularly concerning long-term functional outcomes and complication rates in real-world clinical scenarios.

According to the relevant literature, 16%-25.4% of patients with acute ischemic stroke (AIS) progress within 24 h [15, 16] and >20% exhibit progression after 24 h [7, 17]. However, clinical research evidence investigating whether patients with AIS can benefit from EVT within 24 h or beyond the 24 h time window is still lacking, with the treatment guidelines providing no clear recommendations for these patients group. The effect of rescue endovascular treatment in LVO-related END patients without immediate access to thrombectomy is currently unclear and is relevant for most patients. In this study, we aimed to investigate the efficacy and safety of rescue EVT in ischemic stroke patients who experienced END resulting from LVO.

Methods

Study design and patients

This retrospective study was approved by the Institutional Review Board of the First Affiliated Hospital of Anhui Medical University. The electronic medical records from the neurology ward were queried and patients with AIS who presented END between January 2019 and December 2022 were retrospectively identified. The patient inclusion criteria were as follows: 1) age ≥18 years, unrestricted by sex; 2) a modified Rankin Scale (mRS) score at onset ranging from 1-2; 3) a diagnosis of ischemic END defined as a ≥4-point increase in the NIHSS score from baseline to within 7 days post-symptom onset; 4) NIHSS score post-neurological deterioration ranging: 6 to 20 points; 5) LVO of the internal carotid artery (ICA), middle cerebral artery (M1 and M2 segments), vertebral artery (VA), basilar artery (BA), or posterior cerebral artery (PCA) was confirmed by computed tomographic (CT) angiography, magnetic resonance angiography, or digital subtraction angiography and clinically confirmed as the vessel responsible for the stroke; 6) rescue EVT initiation within 24 h of neurological deterioration. The patient exclusion criteria were as follows: 1) imaging-confirmed hemorrhagic transformation or malignant edema causing symptom progression; 2) contralateral intracranial/extracranial vascular occlusion or ≥70% stenosis; 3) incomplete clinical data or loss to follow-up.

Data collection

We systematically collected comprehensive clinical data, encompassing demographic characteristics (age and sex), medical history (including prior stroke, hypertension, diabetes mellitus, and coronary artery disease), lifestyle factors (tobacco use and alcohol consumption), stroke classification, collateral circulation status, and therapeutic interventions. In the medical group, patients received guideline-directed medical therapy consisting of dual antiplatelet therapy (standard-dose aspirin and clopidogrel) combined with atorvastatin. Additionally, intravenous thrombolysis was administered in patients presenting within the therapeutic time window without contraindications. In contrast, patients in the rescue EVT group underwent supplementary interventional procedures along with standard medical therapy, comprising mechanical thrombectomy, intra-arterial thrombolytic administration, emergent angioplasty, and stent placement. Collateral circulation status in patients with anterior circulation stroke was quantitatively assessed using a validated 4-point ordinal scale, with 0 representing absent collateral flow of the occluded territory; 1 representing poor collateral flow (50% flow of the occluded territory); 2 representing intermediate collateral flow (between 50% and 100% flow of the occluded territory); and 3 representing good collateral flow (100% flow of the occluded territory).

Furthermore, neurological status was serially evaluated using the NIHSS and mRS at baseline, pre-deterioration, post-deterioration, and

discharge. In particular, neurological deterioration was defined as a ≥4-point increase in the NIHSS score, while mild stroke was defined as an NIHSS score of <6. ΔNIHSS and ΔmRS were also calculated (discharge assessment minus post-deterioration phase score). The time from onset to aggravation and that from aggravation to rescue EVT were also determined. Written informed consent was obtained from the patients undergoing rescue EVT or their legally authorized representatives.

Outcome measures

The primary endpoint was functional independence, which was defined as an mRS score of 0-2 at the 90-day follow-up. Secondary outcomes included neurological deficit severity (NIHSS score) and functional status (mRS score) at discharge. Blinded outcome assessment was conducted by structured telephone interviews by independent neurologists who were masked to the treatment allocation. The safety outcome was any intracranial hemorrhage within 90 days, including symptomatic and asymptomatic intracranial hemorrhage (symptomatic intracranial hemorrhage was defined according to European Cooperative Acute Stroke Study III criteria as the presence of extravascular blood in the cranium that was associated with an increase of ≥4 points in the NIHSS score or death). All-cause mortality within 90 days post-intervention was also recorded.

Statistical analysis

All data analyses were performed using IBM SPSS Statistics 25.0 (IBM Corp., Armonk, NY). Continuous variables were assessed for normality through the Shapiro-Wilk test. Parametric data were expressed as mean ± standard deviation and analyzed using the independent Student's *t*-test. Non-parametric data were reported as median (interquartile range) and compared with the Mann-Whitney *U* test. Categorical variables were presented as frequency (percentage). Moreover, the basic chi-square test formula was applied when the sample size was ≥40 and the theoretical frequency (*T*) was ≥5, while Yates's correction for continuity was performed when the sample size was ≥40 and *T* was between 1 and 5. In the case of sample size <40 or *T* <1, Fisher's exact probability method was employed. Multivariable binary logistic regression models were utilized to quantify the therapeutic effect of rescue EVT on achieving functional independence, which was reported as adjusted odds ratios (ORs) along with corresponding 95% confidence intervals (CIs) and two-tailed *p*-values.

Results

Among 225 patients with AIS and END, a total of 54 patients with AIS and ischemic END due to LVO were included, of which five cases exhibited progression due to aggravation of cerebral edema, one showed progression caused by intracranial hemorrhage, and five experienced complication of severe stenosis or occlusion of non-ipsilateral vessels. Finally, 43 patients with AIS and ischemic END due to LVO who met the study exclusion criteria were selected, including 23 in the medical group and 20 in the rescue EVT group (**Figure 1**). In the rescue EVT group, thrombectomy was performed in five patients, balloon dilation in three, thrombectomy combined with balloon dilation in five, balloon dilation combined with stent implantation in one, and thrombectomy combined with balloon dilation and stent implantation in six. Additionally, low-dose tirofiban was used in 11 patients, and alteplase was administered in one patient during the operation. All patients in the rescue EVT group underwent the procedure under general anesthesia and achieved complete recanalization, which was defined by a modified Thrombolysis in Cerebral Infarction (mTICI) score of 2b or 3. Furthermore, the median aggravation-operation time in the rescue EVT group was 285.0 min (142.3-523.8 min).

The treatment measures after deterioration for the patients in the medical group were as follows: combined dual antiplatelet therapy (100 mg/day of aspirin plus 75 mg/day of clopidogrel) in 12 patients, dual antiplatelet therapy + tirofiban in one, and aspirin alone in three. Dual antiplatelet therapy + low-molecular-weight heparin was administered in seven patients, among which three were also treated with tirofiban. Statin therapy and the management of risk factors (e.g., elevated systolic blood pressure and diabetes) were also performed according to the relevant guidelines.

Comparison of baseline data between the medical and the rescue EVT groups

Among the 23 patients in the medical group, 19 were male and four were female, with an

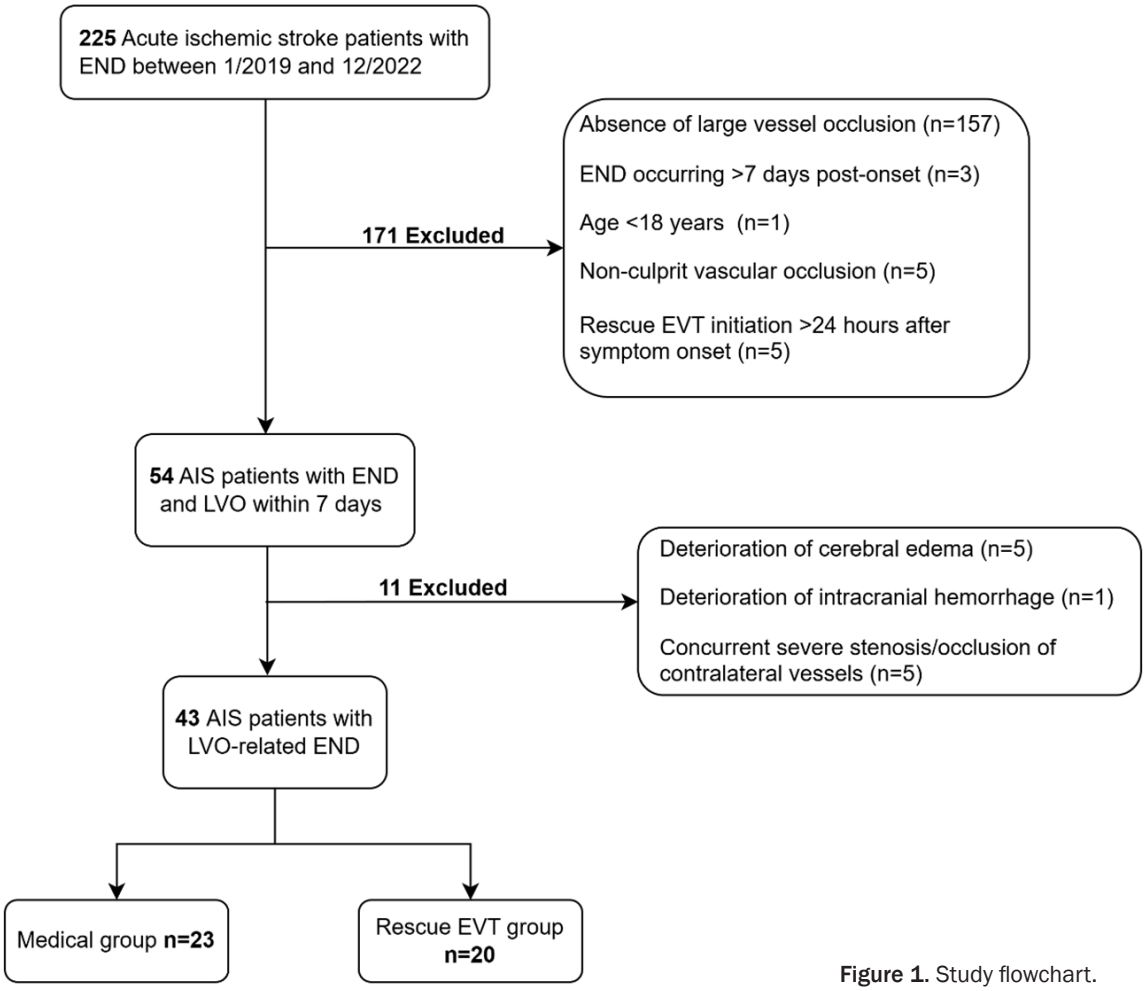

Figure 1. Study flowchart.

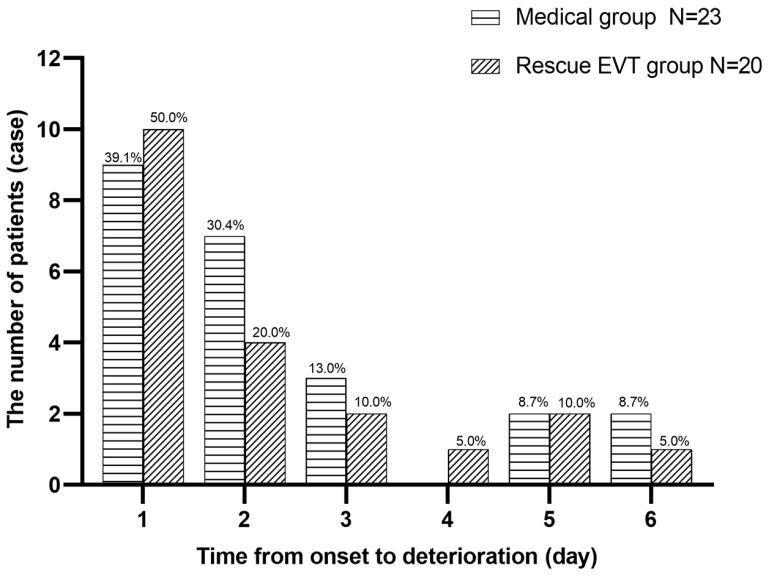

Figure 2. Time distribution from onset to deterioration in the medical group and rescue endovascular treatment group. EVT, endovascular treatment.

average age of 62.4±11.4 years. In the rescue EVT group, 18 were male and two were female, with an average age of 64.8±9.1 years. The distribution of stroke progression time between the two groups is presented in **Figure 2**, with 60.9% of the patients in the medical group and 50.0% of those in the rescue EVT group progressing after 24 h. No significant differences in age, sex, cerebrovascular disease risk factors, vascular occlusion site, NIHSS score before and after deterioration, or mRS score before and after deterioration were observed between the two groups (**Table 1**).

Table 1. Comparison of data between the medical group and rescue EVT group

Item	Total *N*=43	Medical group *N*=23	Rescue EVT group *N*=20	*P* value
Age (years)	63.5±10.4	62.4±11.4	64.8±9.1	0.464
Sex, no. (%)				
Male	37 (86.0)	19 (82.6)	18 (90.0)	0.798
Female	6 (14.0)	4 (17.4)	2 (10.0)	
Medical history, no. (%)				
Hypertension	30 (69.8)	16 (69.6)	14 (70.0)	0.975
Diabetes mellitus	12 (27.9)	6 (26.1)	6 (30.0)	0.775
Atrial fibrillation	4 (9.3)	1 (4.3)	3 (15.0)	0.501
Hyperlipidemia	2 (4.7)	1 (4.3)	1 (5.0)	1.000
Coronary heart disease	4 (9.3)	2 (8.7)	2 (10.0)	1.000
Stroke	5 (11.6)	3 (13.0)	2 (10.0)	1.000
Smoking	13 (30.2)	5 (21.7)	8 (40.0)	0.193
Drinking	7 (16.3)	2 (8.7)	5 (25.0)	0.303
Occlusion site, no. (%)				0.655
ICA	11 (25.6)	6 (26.1)	5 (25.0)	
MCA-M1	22 (51.2)	12 (52.2)	10 (50.0)	
MCA-M2	3 (7.0)	2 (8.7)	1 (5.0)	
PCA	2 (4.7)	2 (8.7)	0 (0.0)	
VA	2 (4.7)	1 (4.3)	1 (5.0)	
BA	1 (2.3)	0 (0.0)	1 (5.0)	
ICA + MCA	2 (4.7)	0 (0.0)	2 (10.0)	
IV r-tPA, no. (%)	8 (18.6)	5 (21.7)	3 (15.0)	0.862
Time from onset to deterioration (h)	33.0 (18.0-72.0)	34.0 (21.0-72.0)	26.0 (12.4-72.0)	0.766
Pre-END NIHSS	2.0 (2.0-4.0)	2.0 (2.0-4.0)	2.0 (2.0-4.0)	0.809
After-END NIHSS	9.7±2.5	9.7±2.6	9.8±2.4	0.945
NIHSS at discharge	7.0 (4.0-10.0)	8.0 (5.0-12.0)	7.0 (3.3-8.8)	0.126
ΔNIHSS		0 (-3 to 0)	-3.5 (-5.8 to -1.3)	0.011
Pre-END mRS	1.0 (1.0-2.0)	1.0 (1.0-2.0)	1.5 (1.0-2.0)	0.892
After-END mRS	4.0 (4.0-4.0)	4.0 (4.0-4.0)	4.0 (4.0-4.0)	1.000
mRS at discharge	4.0 (3.0-4.0)	4.0 (3.0-4.0)	3.5 (2.0-4.0)	0.188
90-day mRS	2.0 (1.0-3.0)	3.0 (2.0-4.0)	2.0 (1.0-2.8)	0.006
ΔmRS		0 (-1 to 0)	-1 (-2 to 0)	0.066
Safety index				
Death from any cause at 90 days (%)	3 (7.0)	2 (8.7)	1 (5.0)	1.000
Any intracranial hemorrhage at 90 days (%)	5 (11.6)	2 (8.7)	3 (15.0)	0.868

Note: EVT, endovascular treatment; ICA, internal carotid artery; MCA, middle cerebral artery; PCA, posterior cerebral artery; VA, vertebral artery; BA, basilar artery; IV, intravenous; NIHSS, National Institutes of Health Stroke Scale; END, early neurological deterioration; ΔNIHSS, discharge NIHSS minus after-END NIHSS; mRS, modified Rankin Scale; ΔmRS, discharge mRS minus after-END mRS.

Comparison of 90-day prognosis and safety between the medical and rescue EVT groups

The distribution of the 90-day mRS scores in the two groups is illustrated in **Figure 3**. The favorable outcome rate (mRS 0-2) in the rescue EVT group was significantly better than that of the medical group (75.0% *vs.* 34.8%, *P*=0.031). Furthermore, the proportion of mRS scores of 0-1 reached 45.0% in the rescue EVT group, whereas it was 13.0% in the medical group (**Figure 3**). The mRS and NIHSS scores at discharge also did not significantly differ between the two groups. After adjusting for

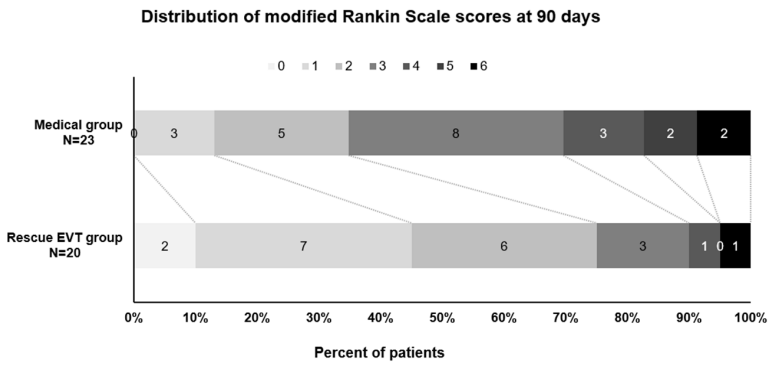

Figure 3. Distribution of 90-day modified Rankin Scale scores in the medical group and the rescue endovascular treatment group. EVT, endovascular treatment.

age, sex, and pre-END NIHSS and mRS scores, a significant association was found between rescue EVT and favorable outcome (odds ratio 5.915; 95% confidence interval 1.463-23.904, *P*=0.013).

In the rescue EVT group, three patients (15.0%) developed hemorrhagic transformation, including one who died from severe symptomatic intracranial hemorrhage. Two patients (8.7%) in the medical group had a hemorrhagic transformation. The 90-day all-cause mortality rate was 5.0% (1/20) in the rescue EVT group compared to 8.7% (2/23) in the medical group. However, no statistical differences were detected in the 90-day all-cause mortality rate or intracranial hemorrhage incidence between the two groups (**Table 1**).

Moreover, the ΔNIHSS analysis demonstrated significant improvement in the rescue EVT cohort compared to the medical group (-3.5 [-5.8 to -1.3] *vs.* 0 [-3 to 0], *P*=0.011). However, there was no significant difference in ΔmRS between the two groups.

Comparison between EVT within and beyond 24 h from onset in the rescue EVT group

In the rescue EVT group, five patients underwent operation within 24 h from onset and 15 received treatment beyond 24 h. No significant differences in age, sex, and NIHSS and mRS scores were noted between the patients who received EVT within and beyond 24 h before and after deterioration and at discharge. The 90-day favorable outcome rate of EVT beyond 24 h from symptom onset was higher than that of EVT within 24 h from onset; however, this difference was not statistically significant (86.7% *vs.* 40.0%, *P*=0.073). The 90-day all-cause mortality and hemorrhage rates also did not significantly differ between the two groups.

Comparison between rescue EVT and medical therapy after deterioration in patients with mild stroke and LVO of anterior circulation

Presently, EVT for patients with LVO of anterior circulation is based on sufficient evidence and recommended by guidelines. However, scarce evidence is available for the appropriate treatment strategy for patients with LVO presenting with a low NIHSS score. In this study, rescue EVT was compared with medical therapy in patients with AIS and ischemic END due to LVO who were defined as having a minor stroke (NIHSS score <6) of anterior circulation at onset.

A total of 36 patients presented with mild stroke at onset, including 19 in the medical group and 17 in the rescue EVT group. No significant differences in the NIHSS score and mRS scores were observed between the two groups before and after deterioration or at discharge (**Table 2**). The 90-day mRS score in the rescue EVT group was significantly lower than that in the medical group (*P*=0.003), while the favorable outcome rate in the rescue EVT group was significantly higher than that of the medical group (76.5% *vs.* 31.6%, *P*=0.010). Additionally, the collateral score was higher in the EVT group than in the medical group (2 [1-2] *vs.* 3 [2-3], *P*=0.004). Finally, no statistical differences in 90-day all-cause mortality rate and incidence of intracranial hemorrhage were found between the two groups (**Table 2**).

Discussion

The primary finding of this study was that rescue EVT was effective and safe for patients with AIS and END due to LVO even when the treatment time window exceeded 24 h from onset.

Previous studies have reported that the incidence of END in patients with ischemic stroke

Table 2. Comparison between the medical group and the rescue EVT group after the deterioration of mild stroke with large vessel occlusion of anterior circulation

Item	Medical group *N*=19	Rescue EVT group *N*=17	*P* value
Age (years)	60.6±11.7	65.4±9.3	0.188
Sex, no. (%)			
Male	15 (78.9)	15 (88.2)	0.662
Female	4 (21.1)	2 (11.8)	
Collateral score	2 (1-2)	3 (2-3)	0.004
Pre-END NIHSS	2.0 (2.0-4.0)	2.0 (1.5-3.5)	0.707
After-END NIHSS	9.6±2.8	9.7±2.4	0.986
NIHSS at discharge	10.0 (5.0-12.0)	7.0 (2.5-9.5)	0.100
Pre-END mRS	1.0 (1.0-2.0)	1.0 (1.0-2.0)	0.900
After-END mRS	4.0 (4.0-4.0)	4.0 (4.0-4.0)	0.827
mRS at discharge	4.0 (3.0-4.0)	3.0 (2.0-4.0)	0.208
90-day mRS	3.0 (2.0-4.0)	2.0 (1.0-2.5)	0.003
90-day mRS 0-2 (%)	6 (31.6)	13 (76.5)	0.010
90-day mRS 0-1 (%)	1 (5.3)	7 (41.2)	0.016
Safety index			
Any intracranial hemorrhage at 90 days (%)	2 (10.5)	3 (17.6)	0.650
Death from any cause at 90 days (%)	2 (10.5)	1 (5.9)	1.000

Note: EVT, endovascular treatment; NIHSS, National Institutes of Health Stroke Scale; END, early neurological deterioration; mRS, modified Rankin Scale.

ranged from 4.3% to 40% [18-20], with the proportion of those with a poor prognosis and END reaching as high as 77% at 90 days (mRS 3-6) [11]. In our study, the 90-day poor prognosis rate (mRS 3-6 at 90 days) in the medical group was 65.2%, while the proportion of patients with mRS 0-1 was only 13.0%, similar to the rates found in previous literature reports. Currently, no guideline recommendations exist on the treatment approach for this patient group. The current evidence base regarding EVT in patients with AIS and END remains constrained by a lack of randomized controlled trial data, with existing clinical insights predominantly derived from retrospective cohort analyses. A single-center retrospective analysis of patients with anterior circulation AIS and END within 72 h from onset indicated that rescue EVT improved clinical outcomes, with the 90-day prognosis in those who underwent EVT within 6-72 h being slightly better than that in those who received EVT within 6 h (*P*=0.043) [21]. Another single-center retrospective analysis of patients with AIS and END in the anterior and posterior circulation who were treated with EVT within 24 h indicated that the 90-day favorable outcome rate was significantly higher in the EVT group (19 patients) than in the medical group (39 patients) [22]. In a multicenter clinical registry study of patients with acute basilar artery occlusion who were administered EVT within 24 h, subgroup data analysis of those with AIS and END indicated that EVT was safe and effective within 6 h and 6-24 h [23]. Our study also showed that the 90-day favorable outcome rate of patients with AIS and END undergoing rescue EVT was significantly higher than that of those receiving medical therapy (75.0% *vs.* 34.8%, *P*=0.014). Moreover, rescue EVT beyond 24 h from onset was still safe and effective, with the favorable outcome rate found to be even higher than that of patients treated within 24 h (86.7% *vs.* 40.0%). This finding was consistent with the results from previous literature [21], probably due to the better collateral circulation in patients operated after 24 h. In our study, the collateral circulation score of patients operated after 24 h was slightly better than that of those operated within 24 h [3.0 (3.0-3.0) *vs.* 2.0 (2.0-2.8), *P*=0.138], however, this result was not statistically significant.

Although most thrombectomy trials excluded patients with NIHSS score <6, 39.4% of those with minor stroke and LVO were found to have

END [5]. The possible mechanisms for this incidence include thrombosis extension in place, re-embolization, and collateral circulation failure. Despite all patients in the present study having LVO, 95.3% presented with mild stroke (NIHSS score <6) before deterioration. The initial mild symptoms of patients with stroke indicate that blood supply to the brain tissue can continue maintaining the basic function of the brain cells, with good collateral circulation causing the infarction to progress slowly. However, a further decrease in hemodynamics leads to the expansion of the infarct core area even beyond the initial penumbral zone, ultimately resulting in END [24]. Previous studies have suggested that no imaging indicators can accurately predict the occurrence of END [25]. Moreover, the application of immediate EVT after onset or EVT after END in patients with mild stroke is still lacks consensus. Earlier retrospective studies have demonstrated that the 90-day favorable outcome rate of patients with mild stroke who underwent immediate EVT after onset was not statistically different from that of those in the medical group, with the proportion of favorable outcome being extremely high in the two groups [13]. Prior studies have also suggested that the prognosis of immediate EVT in patients with mild stroke might be better than that of rescue EVT after neurological deterioration [26, 27]. However, a recent study with a larger sample size revealed that the favorable outcome rate of the immediate EVT group was similar to that of the medical group, even though immediate EVT was associated with an increased risk of bleeding and death [28, 29]. All these studies suggest that although the proportion of patients with AIS and END is high and those with mild stroke and LVO have a poor prognosis, effective predictors of END are scarce and the implementation of immediate EVT is not fully supported.

Only a few retrospective studies have confirmed the efficacy and safety of rescue EVT after END in patients with AIS [12, 14]. In line with these findings, our results highlight that rescue EVT is an effective and safe method for treating patients with AIS and END due to LVO. Early improvement in neurological function after EVT is an effective indicator to predict a favorable 90-day outcome [30]. However, in our study, no significant differences in the NIHSS and mRS scores were observed between the two groups at discharge, whereas significant differences in the 90-day mRS score were detected between the two groups. Our results showed that compared to medical therapy, rescue EVT in patients with AIS and END due to LVO was more beneficial in improving the 90-day prognosis than in mRS score at discharge. Neurological function recovery after a stroke encompasses blood circulation recovery, neural circuit recombination, neural tissue reconstruction, myelin regeneration, axon growth, and synaptic regulation [31, 32], and this recovery process can extend for a long duration (several months). After aggravation in patients with AIS, rescue EVT can restore normal hemodynamics and prevent further brain cell death in the penumbra tissue, thereby preserving part of the brain function as achieved through other vascular recanalization therapies, such as intravenous thrombolysis and EVT within 24 h [33, 34].

Previous studies have indicated that rescue EVT can improve the prognosis of patients with AIS and END; however, relatively fewer patients were treated beyond 24 h from onset in these investigations [21-23]. Furthermore, randomized controlled trials published in 2015-2018 on patients treated with mechanical thrombectomy within 24-h time window only had a small number of patients with a low NIHSS score [35-38]. Additionally, early exploratory studies showed that in the case of patients with good collateral circulation, EVT may not depend on the time window but on the tissue window and could be extended to a maximum of 68 h [39]. The DEFUSE 2 study also found that the relationship between the delay in infarct growth and reperfusion in patients with salvageable ischemic tissue was independent of time [40]. In recent years, researchers have demonstrated that 38.1%-41.1% of patients without END can still attain a favorable outcome after 90 days even when EVT is performed beyond 24 h from onset [41, 42], underscoring that the treatment time window for some patients can be extended to 24 h. These studies indicate that patients with persistent perfusion mismatches may still benefit from EVT, even beyond 24 h after onset. In the present study, 55.8% of the patients developed neurological deterioration after 24 h and 75% underwent rescue EVT beyond 24 h from onset. Moreover, the favorable outcome rate of patients who

underwent rescue EVT beyond 24 h from symptom onset reached as high as 86.7% consistent with the outcomes previously reported (81.3%) for those with AIS and END who received rescue EVT within 6-72 h [21]. Before deterioration in patients with AIS, the ischemic penumbral zone may be maintained for a long period owing to better collateral circulation; thus, the symptoms remain mild at disease onset and worsen later because the collateral circulation cannot continue to maintain the necessary blood supply. Nevertheless, the results from our study emphasize that rescue EVT may also improve the prognosis of patients with AIS and END due to LVO who experience neurological deterioration after 24 h from onset.

The current study has several limitations that should be considered. First, given the retrospective nature of this study, our findings should be interpreted cautiously because of the possible influence of selection and assessment biases. Second, additional imaging assessment indicators and outcome indicators should be incorporated into future research. Finally, this study was a single-center retrospective investigation; therefore, further investigation involving biologic registries and larger prospective studies is required to establish the generalizability of our findings.

Conclusion

Our study revealed that the prompt recanalization of the occluded vessels remains a safe and effective approach in patients with AIS and END due to LVO, even when the time window exceeds 24 h from onset. However, this single-center retrospective study had limitations such as selection bias during operation, lack of blinding, and a small number of patients. Therefore, prospective multicenter randomized controlled clinical studies should be conducted to confirm our results.

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Disclosure of conflict of interest

None.

Abbreviations

AIS, acute ischemic stroke; BA, basilar artery; CT, computed tomographic; DAWN, DWI or CTP Assessment with Clinical Mismatch in the Triage of Wake-Up and Late Presenting Strokes Undergoing Neurointervention with Trevo; DEFUSE3, Endovascular Therapy Following Imaging Evaluation for Ischemic Stroke 3; END, early neurological deterioration; EVT, endovascular treatment; ICA, internal carotid artery; LVO, large vessel occlusion; mRS, modified Rankin Scale; MCA, middle cerebral artery; mTICI, modified Thrombolysis in Cerebral Infarction; NIHSS, National Institutes of Health Stroke Scale; PCA, posterior cerebral artery; TOAST, Trial of Org 10172 in Acute Stroke Treatment; VA, vertebral artery.

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