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Revascularization Results in Acute Cerebral Infarction: Updated Report from Vietnam

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Objective: To evaluate the effectiveness of intravenous thrombolysis (IVT), mechanical thrombectomy (MT), and bridging therapy (IVT followed by MT) in Vietnamese patients with acute ischemic stroke.

Materials and Methods: The present study was a longitudinal case series study conducted at E Hospital, Vietnam, between November 2020 and April 2023. Eighty-one patients were included and divided into three groups: IVT alone, MT alone, and bridging therapy. Clinical characteristics, imaging findings, and outcomes were analyzed using chi-square tests, Fisher's exact test, and logistic regression.

Results: Among 81 patients, 46 (56.8%) were male, and 53 (65.4%) were older than 60 years. Fifty-three patients (65.4%) received IVT only, seven (8.6%) underwent MT only, and 21 (25.9%) received bridging therapy. Hypertension was present in 64.2% of the patients, and 22.2% had a prior history of stroke. At the 3-month follow-up, no significant differences in functional outcomes were observed among the three treatment groups. However, the National Institutes of Health Stroke Scale (NIHSS) score at admission, 24 hours post-intervention, and at discharge differed significantly across groups. In addition, aged over 60 years, NIHSS at 24 hours, and the Alberta Stroke Program Early CT Score (ASPECTS) at 24 hours were significantly associated with 3-month outcomes ($p<0.05$).

Conclusion: Reperfusion therapies yielded comparable three-month outcomes, while early neurological scores and imaging (NIHSS and ASPECTS at 24 hours) were strong predictors of short-term prognosis.

Keywords: Revascularization; Acute cerebral infarction; Mechanical thrombectomy; Fibrinolytic therapy; NIHSS; ASPECTS

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Stroke is the second leading cause of mortality worldwide, following myocardial infarction, according to the World Health Organization's 2020 report. Beyond its devastating mortality, stroke imposes a significant burden of disability on individuals and represents a critical challenge for public health systems globally[1]. The initial clinical trials investigating the use of thrombolytic agents to recanalize occluded cerebral arteries were conducted in the 1990s, marking a groundbreaking advancement in the treatment of acute ischemic stroke[2]. Subsequently, the advent of mechanical thrombectomy (MT) techniques a decade later further revolutionized stroke care, particularly for patients with large vessel occlusions or those presenting beyond the 4.5-hour window when intravenous thrombolysis (IVT) is no longer indicated[3]. Advances in imaging and treatment strategies have now extended the therapeutic time window to up to 24 hours in select cases, as incorporated into contemporary international treatment guidelines[4]. Administering reperfusion therapy within this extended window has demonstrated profound improvements in clinical outcomes for stroke patients. However, the optimal reperfusion strategy for patients with large vessel occlusion who are eligible for both IVT and MT remains controversial. Recent randomized clinical trials and meta-analyses comparing direct MT with bridging therapy have reported heterogeneous results, highlighting ongoing uncertainty regarding the incremental benefit of intravenous alteplase prior to thrombectomy[5-8].

In Vietnam, thrombolysis and MT have been progressively implemented in tertiary hospitals over the past two decades, reflecting progress in stroke

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care. Nevertheless, although recent randomized trials have compared MT alone with bridging therapy in highly selected populations, evidence from low- and middle-income countries remains limited, and the applicability of these findings to real-world clinical practice in Vietnam has not been fully established[5,6]. Moreover, certain aspects of the Ministry of Health's national stroke guidelines remain insufficiently supported by local clinical evidence, such as optimal alteplase dosing and the strength of evidence derived from Vietnamese patient cohorts[9]. These limitations highlight the urgent need for locally generated data to inform practice and refine national guidelines.

To address these gaps and enhance the understanding of reperfusion therapy outcomes in Vietnamese stroke patients, the authors conducted the present study to evaluate the efficacy of reperfusion strategies in patients with acute ischemic stroke treated at E Hospital, a major stroke center in Hanoi, Vietnam. Unlike prior studies that examined single interventions, the present study directly compared three reperfusion strategies: IVT alone, MT alone, and bridging therapy. By evaluating their relative efficacy and prognostic factors, the present study provided novel insights into short-term and medium-term outcomes in a Vietnamese cohort. To the authors' knowledge, this was the first comprehensive investigation in Vietnam to simultaneously assess and compare the three reperfusion approaches, thereby filling an important gap in regional stroke research and contributing data of relevance to international audiences, particularly in Asia, where stroke incidence is high, and healthcare resources are variable.

The specific objective of the present study was to compare the clinical effectiveness and safety of IVT, MT, and bridging therapy in Vietnamese patients with acute ischemic stroke. The authors prespecified the hypothesis that early neurological improvement and imaging findings within 24 hours [the National Institutes of Health Stroke Scale (NIHSS) and Alberta Stroke Program Early CT Score (ASPECTS)] would be strong predictors of short-term functional outcomes, irrespective of the reperfusion strategy applied.

Materials and Methods

Study design and setting

The present study was a longitudinal case-series study conducted at E Hospital, Hanoi, Vietnam, between November 2020 and April 2023. Clinical data were prospectively collected for eligible patients and supplemented by a retrospective review of electronic medical records to ensure data completeness and accuracy.

Participants

The present study included patients aged 18 years or older, diagnosed with acute ischemic stroke based on criteria outlined in the "Guidelines for Diagnosis and Management of Stroke" issued by the Ministry of Health of Vietnam (Decision No. 5331/QD-BYT), the American Heart Association/American Stroke Association (AHA/ASA) guidelines, and the Japanese Stroke Society recommendations[9,10].

Exclusion criteria encompassed a range of factors including, a recent history of head trauma within the previous three months, lumbar puncture within the past seven days, major surgery, or severe trauma within the prior 14 days, clinical conditions such as subarachnoid hemorrhage, presentations inconsistent with stroke, or extensive brain edema leading to mass effect or herniation, hemorrhagic or vascular complications, including recent brain hemorrhage, vascular malformations, or gastrointestinal or genitourinary bleeding within the last 21 days, hematologic or metabolic abnormalities, such as coagulation disorders (INR >1.7), platelet count of less than 100,000/mm^3, or blood glucose levels outside the range of 2.7 to 22.2 mmol/L. Additionally, patients and families who refused reperfusion interventions (thrombolysis or MT) or whose retrospective clinical data were incomplete were also excluded.

Data collection and outcome measurements

Clinical and imaging data were extracted from the electronic hospital information system and the institutional stroke registry. The primary outcome was functional recovery at three months, defined as a modified Rankin Scale (mRS) score of 0 to 2. Secondary outcomes included in-hospital mortality and major complications (hemorrhagic transformation, pneumonia, urinary tract infection, and decompressive craniectomy).

Neurological severity was assessed using the NIHSS at baseline, 24 hours, and discharge. The mRS was assessed at baseline, discharge, and three months by a neurologist under the supervision of another neurologist. Three months later, the mRS assessor was blinded to the treatment received. ASPECTS was rated on computed tomography (CT) or magnetic resonance imaging (MRI) by a radiologist with independent review by a second radiologist;

discrepancies were resolved through consensus.

Selection bias was minimized by including all consecutive eligible patients during the study period. Information bias was reduced through standardized protocols for NIHSS, mRS, and ASPECTS assessments, with supervision and consensus meetings to ensure reliability. Blinded outcome assessment at three months further mitigated detection bias. Potential confounders (age, gender, baseline NIHSS, baseline ASPECTS, and comorbidities) were adjusted for in multivariable logistic regression. Patients lost to follow-up or with missing primary outcome data were excluded from the final analysis (complete-case analysis).

Sample size

All eligible patients during the study period were included, which was 81 patients. Although no formal a priori sample size calculation was performed, the sample size achieved was sufficient to perform multivariable analyses with adjustment for major prognostic factors.

Statistical and data analysis

Data was processed using IBM SPSS Statistics, version 22.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation (SD) or median with interquartile range (IQR), depending on distribution. Categorical variables were presented as frequencies and percentages. Descriptive statistics were used to summarize the study variables, and comparisons of mean values were performed. A p-value of less than 0.05 was considered statistically significant. Chi-square tests were applied for categorical variables, and univariate analysis was conducted to assess the relationship between clinical and paraclinical factors with three-month treatment outcomes. Fisher's exact test was used where appropriate.

Univariable logistic regression was first performed to estimate crude odds ratios (ORs) and 95% confidence intervals (CIs) for potential predictors of a favorable functional outcome (mRS 0 to 2 at three months). Because quasi-complete separation was observed in standard maximum-likelihood logistic regression, multivariable analysis was conducted using Firth's penalized likelihood logistic regression to obtain bias-reduced adjusted odds ratios (aORs) with 95% CIs. Prespecified dichotomizations were applied as follows: age 60 or younger versus older than 60 years, NIHSS at 24 hours ≤10 versus >10, and ASPECTS at 24 hours ≥8 versus <8. Two-sided p-values of less than 0.05 were considered statistically significant.

Ethical approval

The present study was approved by the Institutional Review Board (IRB) of VNU-University of Medicine and Pharmacy Ethics Committee (IRB00013221). The study included both prospectively collected and retrospectively reviewed data. Written informed consent was obtained from patients enrolled prospectively. For the retrospective component, the requirement for informed consent was waived by the ethics committee due to the use of anonymized data.

Results

Baseline characteristics

During the study period, the stroke unit admitted an average of 40 to 60 acute ischemic stroke patients per month, of whom approximately 15% received reperfusion therapy. All patients who underwent IVT or MT were assessed for eligibility. After excluding those who did not meet the inclusion criteria or had incomplete data (e.g., misdiagnosed stroke mimics or concurrent traumatic brain injury), 81 patients were included in the analysis (Figure 1). Among these, 53 patients (65.4%) received IVT alone, seven patients (8.6%) underwent MT alone, and 21 patients (25.9%) received combined IVT followed by MT (bridging therapy).

Baseline demographic and clinical characteristics of the study population are summarized in Table 1. The mean age of patients was 65±13.3 years, with 65.4% of patients aged over 60 years. The median baseline NIHSS score was moderate, at 10 points overall, with higher stroke severity in the MT and bridging groups compared to the IVT-only group. Baseline ASPECTS on initial brain imaging were high in most patients (median score of 8), indicating small core infarcts at presentation. Vascular risk factors such as hypertension, diabetes, and atrial fibrillation were comparable among the groups. Hypertension was the most prevalent comorbidity (64.2%), followed by type 2 diabetes (14.8%), smoking (9.9%), and atrial fibrillation (8.6%). A previous ischemic stroke was documented in 22.2% of patients. The mean onset-to-needle time for recombinant tissue plasminogen activator (rtPA) was 161.8 minutes, and the mean onset-to-groin puncture time for endovascular therapy was 330 minutes. The onset-to-needle time was longer in the IVT-only group compared with the MT plus rtPA

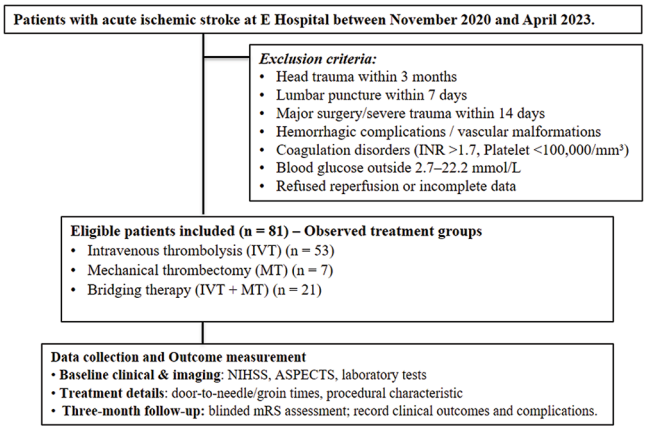

Figure 1. Study flow diagram.

Table 1. Baseline characteristics of the study population

	rtPA (n=53)	MT (n=7)	rtPA+MT (n=21)
Demographics			
BMI (kg/m²); mean±SD	22.5±2.6	21.7±2.0	22.1±2.0
Age (years); mean±SD	65.2±13.6	72.0±10.1	63.8±13.5
Female sex; n (%)	25 (47.2)	3 (42.9)	7 (33.3)
Age >60 years; n (%)	32 (60.4)	7 (100)	14 (66.7)
Length of hospital stay; mean±SD	15.7±14.8	13.1±6.4	14.8±9.3
Comorbidities; n (%)			
Hypertension	37 (69.8)	4 (57.1)	11 (52.4)
Diabetes mellitus	9 (17.0)	0 (0.0)	3 (14.3)
Hyperlipidemia	2 (2.5)	0 (0.0)	0 (0.0)
Smoking	7 (13.2)	0 (0.0)	1 (4.8)
Previous stroke	13 (24.5)	1 (14.3)	4 (19)
Atrial fibrillation	2 (3.8)	3 (42.9)	2 (9.5)
Coronary artery disease	2 (3.8)	2 (28.6)	3 (14.3)
Heart failure	0 (0.0)	2 (28.6)	0 (0.0)
Stroke etiology; n (%)			
Large artery atherosclerosis	7 (13.2)	2 (28.6)	9 (42.9)
Cardioembolism	6 (11.3)	3 (42.9)	4 (19.0)
Lacunar infarction	29 (54.7)	0 (0.0)	0 (0.0)
Undetermined etiology	11 (20.8)	2 (28.6)	8 (38.1)
Clinical scores at admission; median (IQR)			
NIHSS	9 (1 to 22)	12 (6 to 32)	12 (6 to 22)
mRS	4 (0 to 5)	4 (3 to 5)	5 (1 to 5)
Time from symptom onset or last known well to start of treatment; mean±SD			
Onset to needle time (minutes)	161.8±73.1	114.8±46.2	
Onset to groin time (minutes)		177.1±65.8	330.0±155.7

MT=mechanical thrombectomy; rtPA=recombinant tissue plasminogen activator; BMI=body mass index; SD=standard deviation; IQR=interquartile range; NIHSS=National Institutes of Health Stroke Scale score; mRS=modified Rankin Scale score

group, whereas the onset-to-groin time was shorter in the MT plus rtPA group than in the MT-only group (both $p<0.05$). No patients were lost to follow-up or had missing data for key variables after exclusion of incomplete records. The mean follow-up duration for the entire cohort was 90 days.

Table 2. Clinical outcomes according to reperfusion methods and ASPECTS

	Intervention method; n (%)			ASPECTS at admission; n (%)			ASPECTS at 24 hours; n (%)		
	rtPA	MT+rtPA	p-value	8-10 points	<8 points	p-value	8-10 points	<8 points	p-value
NIHSS									
NIHSS at 24 hours			0.048**			0.062*			0.001*
• Increased	5 (9.4)	4 (19.0)		9 (11.8)	2 (40.0)		3 (4.9)	7 (46.7)	
• Decreased 0-4 points	20 (37.7)	2 (9.5)		20 (26.3)	2 (40.0)		17 (27.9)	3 (20.0)	
• Decreased >4 points	28 (52.8)	15 (71.4)		47 (61.8)	1 (20.0)		41 (67.2)	5 (33.3)	
NIHSS at discharge			0.001*			0.021*			0.001*
• Increased	1 (1.9)	2 (10.5)		2 (2.8)	2 (40.0)		0 (0.0)	4 (30.8)	
• Decreased 0-4 points	20 (38.5)	0 (0.0)		19 (26.4)	1 (20.0)		17 (28.3)	1 (7.7)	
• Decreased >4 points	31 (59.6)	17 (89.5)		51 (70.8)	2 (40.0)		43 (71.7)	8 (61.5)	
NIHSS at 3 months			0.174*			1.000*			0.266*
• Increased	2 (3.8)	1 (5.3)		3 (4.2)	0 (0.0)		2 (3.3)	1 (7.7)	
• Decreased 0-4 points	16 (30.8)	2 (10.5)		17 (23.6)	1 (20.0)		15 (25.0)	1 (7.7)	
• Decreased >4 points	34 (65.4)	16 (84.2)		52 (72.2)	4 (80.0)		43 (71.7)	11 (84.6)	
mRS									
mRS at 24 hours			0.166**			0.020*			0.001*
• 0-1 points	19 (35.8)	3 (14.3)		23 (30.3)	0 (0.0)		21 (34.4)	0 (0.0)	
• 2-3 points	23 (43.4)	11 (52.4)		37 (48.7)	1 (20.0)		32 (52.5)	5 (25.0)	
• ≥4 points	11 (20.8)	7 (33.3)		16 (21.1)	4 (80.0)		8 (13.1)	10 (50.0)	
mRS at discharge			0.657**			0.004*			0.001*
• 0-1 points	24 (45.3)	8 (38.1)		35 (46.1)	1 (20.0)		32 (52.5)	4 (20.0)	
• 2-3 points	21 (39.6)	8 (38.1)		30 (39.5)	0 (0.0)		25 (41.0)	5 (25.0)	
• ≥4 points	8 (15.1)	5 (23.8)		11 (14.5)	4 (80.0)		4 (6.6)	11 (55.0)	
mRS at 3 months			0.515**			1.000*			0.219*
• 0-1 points	34 (64.2)	11 (52.4)		46 (60.5)	3 (60.0)		39 (63.9)	7 (46.7)	
• 2-3 points	11 (20.8)	7 (33.3)		19 (25.0)	1 (20.0)		16 (26.2)	4 (26.7)	
• ≥4 points	8 (15.1)	3 (14.3)		11 (14.5)	1 (20.0)		6 (9.8)	4 (26.7)	

ASPECTS=Alberta Stroke Program Early CT Score; NIHSS=National Institutes of Health Stroke Scale score; mRS=modified Rankin Scale scores; MT=mechanical thrombectomy; rtPA=recombinant tissue plasminogen activator

* Proportions were compared using Fisher's exact test, ** Proportions were compared using chi-square test

Neurological severity, functional scores, and ASPECTS outcomes

The median baseline NIHSS score was 11.3±5.3, significantly lower in the IVT-only group compared with the MT and MT+IVT groups ($p<0.05$). Group differences in NIHSS remained statistically significant at 24 hours ($p=0.048$) and at discharge ($p=0.001$) but were no longer significant at three months ($p>0.05$). Similarly, mRS scores did not differ significantly among groups at 24 hours ($p=0.166$) or at discharge ($p=0.657$). Patients with ASPECTS of 8 or greater at admission and at 24 hours had better neurological and functional outcomes at 24 hours and at discharge ($p<0.05$). These associations, however, diminished over time and were no longer significant at three months. All results are summarized in Table 2.

Treatment outcomes

Among patients undergoing MT, complete reperfusion (TICI 3) was achieved in 71.4% of the MT-only group and 61.9% of the bridging group. NIHSS improvement of 10 points or more at discharge was observed in 16.7%, 60.0%, and 29.4% of the IVT, MT, and MT+IVT groups, respectively ($p=0.057$). After three months, differences in NIHSS improvement were no longer statistically significant ($p=0.472$). The proportion of patients achieving good-to-moderate functional outcome (mRS 0 to 2) at three months was 75.5%, 71.4%, and 66.7% across the IVT, MT, and MT+IVT groups, respectively ($p=0.734$) (Table 3).

Figure 2 illustrates the distribution of mRS scores at three months according to reperfusion strategy. Favorable functional outcomes (mRS 0 to 1) accounted for the largest proportion of patients in all three groups, whereas poor outcomes (mRS of 4 or more) were observed in a smaller subset. Overall, the distribution of mRS categories appeared broadly

Table 3. Treatment outcomes following intervention with three reperfusion methods

Treatment outcome	rtPA (n=53) n (% of total)	MT (n=7) n (% of total)	MT+rtPA (n=21) n (% of total)	p-value
Reperfusion status				1.000
TICI 3 (complete reperfusion)	-	5 (71.4)	13 (61.9)	
TICI <3 (partial/inadequate reperfusion)	-	2 (28.6)	8 (38.1)	
NIHSS at discharge				0.057
NIHSS reduction >10 points	8 (16.7)	3 (60.0)	5 (29.4)	
NIHSS reduction ≤10 points	40 (83.3)	2 (40.0)	12 (70.6)	
NIHSS at 3 months				0.472
NIHSS reduction >10 points	13 (27.7)	2 (33.3)	8 (44.4)	
NIHSS reduction ≤10 points	34 (72.3)	4 (66.7)	10 (55.6)	
mRS at 3 months				
mRS 0-1 (good functional outcome)	34 (64.2)	4 (57.1)	11 (52.4)	0.636
mRS 0-2 (favorable functional outcome)	40 (75.5)	5 (71.4)	14 (66.7)	0.734

MT=mechanical thrombectomy; rtPA=recombinant tissue plasminogen activator; TICI=thrombolysis in cerebral infarction; NIHSS=National Institutes of Health Stroke Scale score; mRS=modified Rankin Scale scores

Proportions were compared using Fisher's exact test

Table 4. Complications following intervention with three reperfusion methods

Complications	rtPA (n=53)	MT (n=7)	MT+rtPA (n=21)	All patients (n=81)
Intracranial hemorrhagic transformation	7	0	6	13
Decompressive craniectomy	0	2	3	5
Pneumonia	12	3	8	23
Urinary tract infection	2	0	3	5
Pressure ulcer	1	0	0	1
Recurrent or worsening stroke	0	1	0	1
Mortality	1	1	2	4

MT=mechanical thrombectomy; rtPA=recombinant tissue plasminogen activator

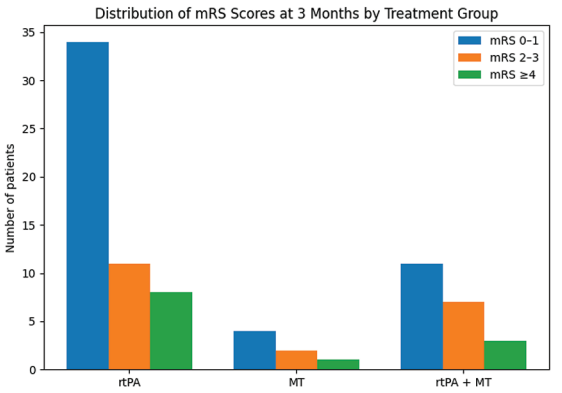

Figure 2. Distribution of mRS scores at 3 months according to reperfusion strategy.

rtPA indicates intravenous thrombolysis; MT, mechanical thrombectomy

similar across the rtPA, MT, and rtPA+MT groups.

Complications

The most common complications were pneumonia (28.4%), hemorrhagic transformation (16.0%), and decompressive craniectomy (6.2%). In-hospital mortality occurred in four patients (4.9%), distributed across all three treatment groups (Table 4).

Prognostic factors

In the logistic regression analyses, continuous variables were categorized according to prespecified clinical thresholds: age (60 or younger versus older than 60 years), NIHSS score at 24 hours (≤10 versus >10 points), and ASPECTS at 24 hours (≥8 versus <8 points). These cutoffs were selected based on prior literature and their applicability in routine stroke care at the authors' center. In univariable analysis, age 60 years or less and NIHSS ≤10 at 24 hours were significantly associated with a favorable 3-month functional outcome, whereas ASPECTS ≥8 at 24 hours was not statistically significant (Table 5).

Adjusted odds ratios (aORs) were estimated using Firth's penalized likelihood logistic regression to address (quasi-)separation in small samples. The outcome was defined as mRS 0 to 2 at three months. Age 60 years or less (aOR 11.61, 95% CI

Table 5. Analysis of factors associated with 3-month recovery prognosis

Factors		mRS at 3 months; n (%)		95% CI	OR
		0-2	>2		
Age	≤60 years	27 (96.4)	1 (3.6)	2.24 to 140.48	17.72
	>60 years	32 (60.4)	21 (39.6)		
Time from onset to intravenous thrombolysis (n=53)	<3 hours	22 (75.9)	7 (24.1)	0.30 to 3.69	1.05
	≥3 hours	18 (75.0)	6 (25.0)		
Time from onset to successful reperfusion (n=28)	<3 hours	2 (50.0)	2 (50.0)	0.05 to 3.53	0.41
	≥3 hours	17 (70.8)	7 (29.2)		
Systolic blood pressure (mmHg)	<180	48 (70.6)	20 (29.4)	0.09 to 2.15	0.44
	≥180	11 (84.6)	2 (15.4)		
Mean arterial pressure (mmHg)	≤110	33 (75.0)	11 (25.0)	0.30 to 2.10	0.79
	>110	26 (70.3)	11 (29.7)		
	≤100	18 (66.7)	9 (33.3)	0.57 to 4.35	1.56
	>100	41 (75.9)	13 (24.1)		
Diastolic blood pressure (mmHg)	<110	52 (72.7)	20 (27.8)	0.14 to 3.88	0.74
	≥110	7 (77.8)	2 (22.2)		
Blood glucose on admission (mmol/L)	<11.8	56 (73.7)	20 (26.3)	0.29 to 12.00	1.87
	≥11.8	3 (60.0)	2 (40.0)		
NIHSS score at 24 hours post-intervention	≤ 10	57 (81.4)	13 (18.6)	3.80 to 102.36	19.73
	>10	2 (18.2)	9 (81.8)		
ASPECT score at 24 hours post-intervention	<8	11 (55.0)	9 (45.0)	0.11 to 0.97	0.33
	≥8	48 (78.7)	13 (21.3)		
Hemorrhagic transformation post-intervention	No	52 (76.5)	16 (23.5)	0.82 to 9.49	2.79
	Yes	7 (53.8)	6 (46.2)		

NIHSS=National Institutes of Health Stroke Scale score; ASPECTS=Alberta Stroke Program Early CT Score; mRS=modified Rankin Scale scores; CI=confidence interval; OR=odds ratio

1.40 to 96.04, p=0.023) and NIHSS at 24 hours ≤10 (aOR 28.60, 95% CI 2.72 to 360.11, p=0.009) remained independently associated with a favorable functional outcome. ASPECTS ≥8 at 24 hours was not independently associated with outcome after adjustment (aOR 0.31, 95% CI 0.04 to 2.80, p=0.299).

Discussion

Recent randomized clinical trials and contemporary meta-analyses have refined the evidence base regarding optimal reperfusion strategies for acute ischemic stroke due to large vessel occlusion. The SWIFT DIRECT trial did not demonstrate non-inferiority of MT alone compared with bridging therapy, whereas the DEVT randomized clinical trial reported non-inferiority of direct thrombectomy within predefined margins[5,6]. These discrepant findings have been further contextualized by meta-analyses, which overall suggest no clear superiority of one strategy over the other with respect to 90-day functional outcomes[7,8]. Earlier meta-analyses, evidenced prior to 2022, similarly failed to demonstrate a consistent advantage of bridging therapy over direct thrombectomy, as shown in a meta-analysis by Du et al., which synthesized available comparative data on IVT before endovascular treatment[10]. More recently, an updated systematic review and meta-analysis by Elfil et al. further reinforced this perspective, reporting comparable functional and safety outcomes between MT with and without preceding IVT across contemporary clinical trials[11]. In this context, the present study's findings of no statistically significant differences in 3-month functional outcomes among IVT alone, MT alone, and bridging therapy are broadly consistent with the current international literature. Compared to previous reports from Vietnam, the present study population exhibited a moderately lower male predominance (56.8%) than that reported by Mai et al[12].

Hypertension was the leading comorbidity in the present study (64.2%), consistent with regional data from Thailand and Vietnam, but lower than the 76.8% reported by Mai et al[12,13]. These variations emphasize heterogeneity in patient populations across centers and underline the importance of local epidemiological data in guiding stroke care strategies.

With regard to workflow-related time metrics, the authors observed that onset-to-needle time was significantly longer in the IVT-only group compared with the bridging therapy group, while onset-to-groin time was shorter in patients receiving bridging therapy than in those undergoing MT alone.

In contrast, Minnerup et al. reported a significant difference only in onset-to-groin time between the bridging therapy and direct thrombectomy groups, with longer delays observed in the MT-only group[14]. These discrepancies may reflect differences in prehospital logistics, interhospital transfer patterns, and institutional workflows across healthcare systems.

The present study's findings regarding ASPECTS corroborate its role as a short-term prognostic indicator[15-17] but highlight its limited utility for long-term prediction. Significant associations with neurological status were observed at 24 hours and at discharge, but not at three months. This temporal limitation aligns with clinical practice, in which ASPECTS primarily informs acute management decisions rather than long-term prognosis.

Mortality in the present study cohort was 4.9%, lower than that reported in European studies, but direct comparison is complicated by sample size differences and treatment selection. Importantly, no significant differences in mortality or 3-month functional outcomes were observed among the three reperfusion strategies, echoing findings by Mai et al. in Vietnamese populations[12,18].

From a prognostic standpoint, the present multivariable penalized logistic regression analysis identified age 60 years or younger and NIHSS ≤10 at 24 hours as independent predictors of favorable 3-month outcomes, whereas ASPECTS ≥8 at 24 hours was not independently associated with outcome after adjustment. The lack of independent association for ASPECTS after adjustment may reflect its close correlation with early neurological status, as NIHSS at 24 hours captures both infarct burden and early reperfusion success. Therefore, early clinical improvement may provide incremental prognostic value beyond imaging alone in the present study cohort.

These findings align with established risk models such as DRAGON and GADIS[19,20], which integrate clinical and imaging variables for outcome prediction. Although the present study was not designed to formally assess the impact of treatment timing, these findings are consistent with accumulating evidence emphasizing the critical role of workflow efficiency. Previous studies have suggested that IVT may independently influence clinical outcomes among patients undergoing MT. As reported by Kaesmacher et al., earlier administration of rtPA could contribute to improved functional outcomes, potentially through early partial recanalization or enhancement of microvascular reperfusion. In particular, Kaesmacher et al. demonstrated that shorter time to IVT prior to thrombectomy was associated with improved functional outcomes, underscoring the importance of timely reperfusion rather than treatment sequence alone[21]. In real-world clinical settings where interhospital transfer is required prior to endovascular treatment, a systematic review and meta-analysis by Katsanos et al. further suggested that initiating IVT before transfer was associated with better functional outcomes without an increased risk of symptomatic intracranial hemorrhage or mortality, highlighting the potential importance of workflow optimization in resource-variable healthcare systems[22]. The wide confidence intervals observed in the multivariable model reflect the small sample size and the strong prognostic impact of early neurological improvement, which resulted in quasi-complete separation requiring penalized regression methods. However, the present study contributes novel data specific to the Vietnamese population, suggesting that incorporating locally validated predictors may enhance prognostic accuracy.

The present study has limitations. The small sample size, particularly in the MT-only subgroup (seven patients), reduced statistical power and limited the ability to draw definitive conclusions regarding therapeutic equivalence. Therefore, the absence of statistically significant differences should be interpreted as insufficient evidence of superiority rather than proof of equivalence. Baseline differences in treatment-related time metrics may reflect selection bias and should be considered when interpreting outcome comparisons. In addition, the single-center design may limit generalizability beyond E Hospital, given variations in patient characteristics, treatment protocols, and healthcare resources across Vietnam. E Hospital is a tertiary referral hospital in Hanoi and one of the major stroke centers in Northern Vietnam, providing round-the-clock thrombolysis and MT services, which ensures standardized acute stroke care but may not fully reflect other healthcare contexts. Beyond these limitations, potential sources of bias should also be considered. Selection bias may have arisen because only patients with complete datasets and who underwent reperfusion at a tertiary referral center were included. Information bias was minimized through standardized protocols and independent review of clinical and imaging outcomes, yet interobserver variability may still have influenced assessments. Residual confounding from unmeasured factors, such as blood pressure management or

adherence to secondary prevention after discharge, cannot be excluded. Finally, the generalizability of these findings should be interpreted cautiously. The results primarily reflect the context of a well-equipped tertiary stroke center with trained staff and 24/7 access to reperfusion therapies. Extrapolation to provincial or resource-limited hospitals should therefore be made with caution.

Conclusion

The present study evaluating the effectiveness of reperfusion therapies in acute ischemic stroke at E Hospital found that all three treatment methods, thrombolysis, MT, and thrombectomy with thrombolysis, yielded comparable outcomes. Neurological impairment after 24 hours of intervention, both clinically and on imaging, strongly correlated with three-month clinical outcomes. CT and MRI play a crucial role in short-term prognostication of treatment outcomes in acute ischemic stroke.

What is already known about this topic?

IVT and MT are established reperfusion therapies for acute ischemic stroke, supported by international guidelines and multiple clinical trials. However, most available data come from Western populations, while local evidence in Vietnam and similar healthcare settings remains limited.

What does this study add?

This study is the first comprehensive Vietnamese report to compare IVT, MT, and bridging therapy. It demonstrates that although long-term outcomes among the three strategies were comparable, early NIHSS and ASPECTS scores were strong predictors of prognosis. These findings underscore the critical role of early neurological and imaging assessments in guiding stroke management and refining national practice guidelines.

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Authors' contributions

PTN and PTHN contributed equally to this work. PTN contributed to conceptualization, methodology, data curation, formal analysis, and writing-original draft; PTHN contributed to conceptualization, methodology, data curation, formal analysis, and writing-original draft; TTN contributed to conceptualization, methodology, supervision, and writing-review & editing; PXH contributed to investigation, data curation, and writing-review editing; NTN contributed to investigation, data curation, and writing-review editing; NNVY contributed to investigation, data curation, and writing-review editing; and NTH contributed to investigation, data curation, and writing-review editing.

Data availability statement

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

This study was approved by the Institutional Review Board (IRB) of VNU-University of Medicine and Pharmacy Ethics Committee (IRB00013221). The study included both prospectively collected and retrospectively reviewed data. Written informed consent was obtained from patients enrolled prospectively. For the retrospective component, the requirement for informed consent was waived by the ethics committee due to the use of anonymized data.

Clinical trial registration

Not applicable. This was an observational longitudinal case-series study and was not registered as a clinical trial.

Use of artificial intelligence

Artificial intelligence tools (ChatGPT) were used to assist with language editing and formatting. All content was reviewed and verified by the authors.

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Conflicts of interest

The authors declare no conflicts of interest.

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