

Tandem occlusions after emergent stenting in acute ischemic stroke: A retrospective cohort study from a comprehensive stroke center's experience (TOESIS study)

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Abstract

Objective: In acute tandem occlusion, emergent stenting has recently become an endovascular treatment option combined with mechanical thrombectomy to achieve recanalization. However, data on the beneficial endovascular management of tandem occlusion in two vascular territories remain limited. The purpose of this study was to compare improvements in clinical outcomes between two vascular territories 3 months after emergent stenting.

Methods: This retrospective cohort study included consecutive patients with acute ischemic stroke who underwent emergent extracranial stenting at our hospital. The primary outcomes were the rate of favorable outcome at 3 months and the incidence of postprocedural hemorrhagic transformation.

Results: Posttreatment outcomes were evaluated in 145 eligible patients who underwent emergent extracranial stenting between December 2020 and June 2025. At 3 months postprocedure, 108 patients (74.5%) had favorable outcomes, of whom 97 (66.9%) achieved good outcomes.

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Smoking, dyslipidemia, National Institutes of Health Stroke Scale score ≥ 12 , diffusion-weighted imaging–Alberta Stroke Program Early Computed Tomography Score ≤ 6 , and procedural complications ($p < 0.05$) were significantly associated with poor outcomes.

Conclusions: In summary, emergent stenting for tandem occlusions involving both vascular territories appears to be an essential recanalization method associated with improved clinical outcomes at the 3-month follow-up.

Keywords

Stroke, tandem occlusion, emergent stenting, balloon-expandable stents, vertebrobasilar system

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Introduction

Tandem occlusions represent a distinct and complex subtype of acute ischemic stroke (AIS), involving simultaneous extracranial and intracranial vascular lesions. Typically, this subtype includes high-grade stenosis or occlusion of the cervical internal carotid artery (ICA) accompanied by an intracranial large-vessel occlusion (LVO), often in the middle cerebral artery or terminal ICA. A less common but clinically significant variant involves vertebrobasilar system tandem occlusions, particularly vertebral artery ostium (VAO) stenosis or occlusion in conjunction with basilar artery thrombosis.¹ Together, these entities account for approximately 15%–20% of LVO strokes and are associated with increased morbidity, procedural complexity, and heterogeneous outcomes.^{2,3} Emergent endovascular treatment, particularly mechanical thrombectomy, is the cornerstone of LVO stroke management.^{4–7} However, the optimal strategy for managing extracranial lesions in tandem occlusions remains debated. Emergent carotid or vertebral artery stenting facilitates permanent recanalization, which is an important determinant of outcomes in AIS, by improving thrombectomy access and potentially enhancing collateral flow.⁸ Multiple studies, including the Thrombectomy In TANdem Occlusion (TITAN) registry and

meta-analyses, have demonstrated that emergent stenting in anterior tandem occlusions is associated with higher reperfusion rates and improved functional outcomes without significantly increasing the risk of symptomatic intracranial hemorrhage.^{5,6,9} Data on the vertebrobasilar system remain limited but suggest potential benefit. Successful stenting of VAO lesions may improve access to the basilar artery and enhance perfusion in patients with vertebrobasilar system strokes.^{7,10,11} Although various approaches exist for managing these lesions, the comparative effectiveness between the anterior and posterior vascular territories remains unclear.^{1,4,5} Therefore, this study aimed to compare the baseline characteristics and clinical outcomes of patients with tandem occlusions in the anterior versus vertebrobasilar system following emergent extracranial artery stenting.

Methods

The data that support the findings of this study are available from the corresponding author on reasonable request.

Participants

We conducted a single-center retrospective observational study in patients with AIS and tandem occlusions in two vascular territories, defined as the concomitance of

severe stenosis or occlusion of extracranial arteries (including the carotid artery or VAO) and ipsilateral intracranial LVO, treated with emergent extracranial stenting at our hospital in Can Tho City between December 2020 and June 2025. Consecutive patients who met the following inclusion criteria were enrolled: (a) age >18 years old; (b) premorbid modified Rankin Scale (mRS) score <2; (c) National Institutes of Health Stroke Scale (NIHSS) score >5 at admission; and (d) Alberta Stroke Program Early CT Score (ASPECTS) $\geq$ 5. The exclusion criteria were as follows: (a) onset-to-treatment time >24 h and (b) loss to follow-up after discharge. Informed consent was obtained from all patient representatives after a detailed explanation of the procedure. In our cohort, tandem occlusions were primarily atherothrombotic in origin, arising from high-grade extracranial ICA or VAO stenosis leading to in situ thrombosis or artery-to-artery embolism. No patients presented with cardioembolic- or dissection-related tandem lesions. The flowchart of the study is presented in Figure 1. The reporting of this

study conforms to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.¹² All clinical and imaging data were retrospectively collected from institutional electronic medical records and procedural archives. The study involving human participants was reviewed and approved by the Ethics Council in Biomedical Research at Can Tho S.I.S General Hospital (approval number: 11823/QD-S.I.S) and the Ethical Board of the University of Medicine and Pharmacy at Ho Chi Minh City (approval number 1087/HDDD-DHYD on 2 November 2023). For this retrospective study, the need for signed informed consent was waived by the Institutional Review Board (IRB); however, informed consent for the procedure itself was obtained from all patient representatives before intervention. The study was conducted in accordance with the Declaration of Helsinki of 1975, as revised in 2024. All patient data were fully de-identified before analysis. No individual patient information that could lead to identification is presented in the manuscript or figures.

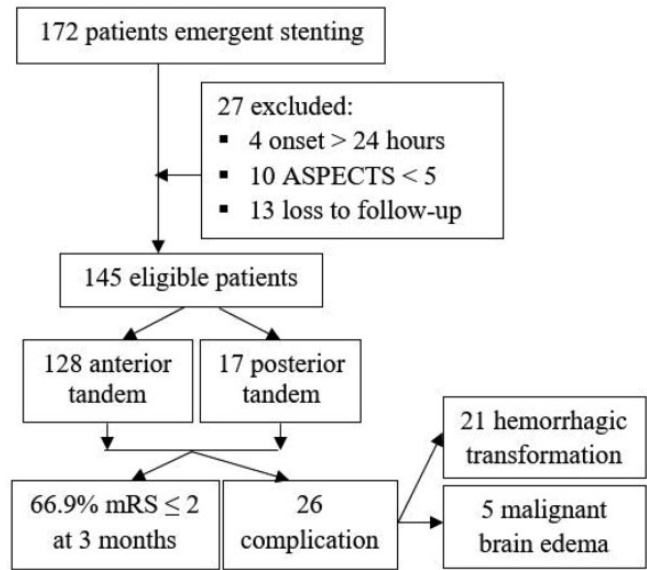


Figure 1. Flowchart illustrating the patient inclusion and exclusion process.

Study size

As this was a retrospective observational study, no formal a priori sample size calculation was performed. Instead, we included all consecutive patients meeting the eligibility criteria during the 4.5-year study period (December 2020 to June 2025) at our comprehensive stroke center. This approach provided a sample of 145 patients, which is one of the largest cohorts reported for emergent stenting in tandem occlusions involving both anterior and posterior circulations in Asia.

Procedures

All procedures were mostly performed under general anesthesia. An 8-F sheath was introduced into the femoral artery. We used a 5-F diagnostic catheter, a 0.035-inch guidewire, and an 8-F guiding catheter to select either the common carotid artery on the affected side or the subclavian artery with the dominant vertebral artery. The distal-to-proximal approach (such as the Diagnostic-Dotter and Dilator-Dotter techniques) was the first choice for tandem occlusions in our center. The Diagnostic-Dotter technique was defined as the use of a coaxial system consisting of an 8-F guiding catheter and a 5-F diagnostic catheter to pass through the extracranial occlusion. The Dilator-Dotter technique differed only in replacing the 5-F diagnostic catheter with the available dilator of the 8-F guiding catheter. After stable positioning of the 8-F guiding catheter, mechanical thrombectomy was performed in the intracranial segments, followed by stent placement in the dissected or re-occluded extracranial arteries with the considerate use of embolic protection devices (EPDs). EPDs were used in cases with unstable or ulcerated plaques, cases with significant residual thrombus, or when the operator deemed distal embolic protection necessary to prevent intracranial

embolization. The proximal-to-distal approach (either angioplasty or extracranial stenting first), in which the guiding catheter was advanced as distally as possible through the occlusions, was performed only after the distal-to-proximal approach failed to advance through the extracranial occlusion, followed by intracranial recanalization with mechanical thrombectomy. Before stent deployment, patients received a loading dose of aspirin (162 mg) and clopidogrel (300 mg) administered orally or via nasogastric tube, along with an intravenous bolus of 3000 IU of heparin during the intervention.^{4,13} In patients with anterior circulation tandem occlusions, self-expanding closed-cell carotid stents were predominantly used. In the vertebrobasilar system, balloon-expandable stents of smaller diameter were preferred to match the smaller vessel caliber of the vertebral artery. Stent type and size were selected according to the vascular territory, vessel diameter, and lesion length; the same standardized protocol was applied in both groups.

When hemorrhagic transformation was not visible on the 24-h posttreatment CT scan or magnetic resonance imaging (MRI), dual antiplatelet therapy with 100 mg aspirin and 75 mg clopidogrel was administered daily for up to 3 months. Procedural time was defined as the time from groin puncture until completion of the procedure.

Outcomes

At 3 months, poor clinical outcome was assessed using the mRS (mRS 4–6). A good outcome was defined as an mRS ≤ 2 , corresponding to functional independence, whereas a favorable outcome was defined as an mRS ≤ 3 , consistent with previously published stroke outcome criteria.⁶ These scores were evaluated through follow-up examinations. Outcome variables comprised age, sex, patient medical history, time of stroke onset, MRI findings, and

hospitalization parameters (intensive care unit and ward stay durations). Information was collected from medical records, pathology reports, paraclinical results, and patient-reported family history (Table 1).

We described two typical cases from our study. The detailed procedures of a representative posterior circulation case are shown in Figure 2. Additionally, a representative anterior circulation case is provided in Figure 3 to better reflect the predominance of anterior circulation involvement in our cohort.

Bias

Potential sources of bias in this retrospective study included selection bias (only patients with emergent stenting were included), information bias (retrospective data collection from medical records), and confounding by indication (stenting decisions based on operator judgment). To minimize selection bias, we included all consecutive eligible patients who met the inclusion criteria during the study period. To reduce information bias, standardized data extraction forms were used by trained researchers, and all imaging and procedural data were cross-checked with the original angiographic

and MRI archives. Confounding was addressed through multivariate logistic regression adjusted for clinically relevant covariates (age, sex, baseline NIHSS, ASPECTS, hypertension, smoking, dyslipidemia, and procedural time). No propensity score matching was performed because of the limited sample size in the vertebrobasilar subgroup.

Variables

Tandem occlusion was defined as severe extracranial stenosis/occlusion ($\geq 70\%$ for the carotid artery or VAO) with ipsilateral intracranial LVO confirmed on CTA/magnetic resonance angiography (MRA)/digital subtraction angiography (DSA). Hemorrhagic transformation was assessed on 24-h follow-up CT or MRI using the Heidelberg classification. Good outcome was defined as mRS ≤ 2 and favorable outcome as mRS ≤ 3 at 3 months. Smoking was defined as current or former smoking (≥ 100 cigarettes lifetime). Dyslipidemia was defined according to Adult Treatment Panel III criteria or the use of lipid-lowering medication. All imaging parameters (NIHSS and ASPECTS) were assessed by board-certified neurologists or neuroradiologists.

Table 1. Definitions of outcome variables and analysis variables.

Variables	Variable definition	Variable classification	Method of data collection
Age	Age of patient (year)	Quantitative variable	Medical report
History	Family history Personal history	Categorical variable	Medical report and patient's relatives
ASPECTS	0–10 scores	Quantitative variable	Medical report
Hemorrhagic transformation stage	HII, HI2, PH1, and PH2	Qualitative variable	Medical report
Procedure	Approaches, devices	Categorical variable	Medical report
Modified Rankin Scale (mRS)	0–6 score	Quantitative variable	Medical report

ASPECTS: Alberta Stroke Program Early CT Score.

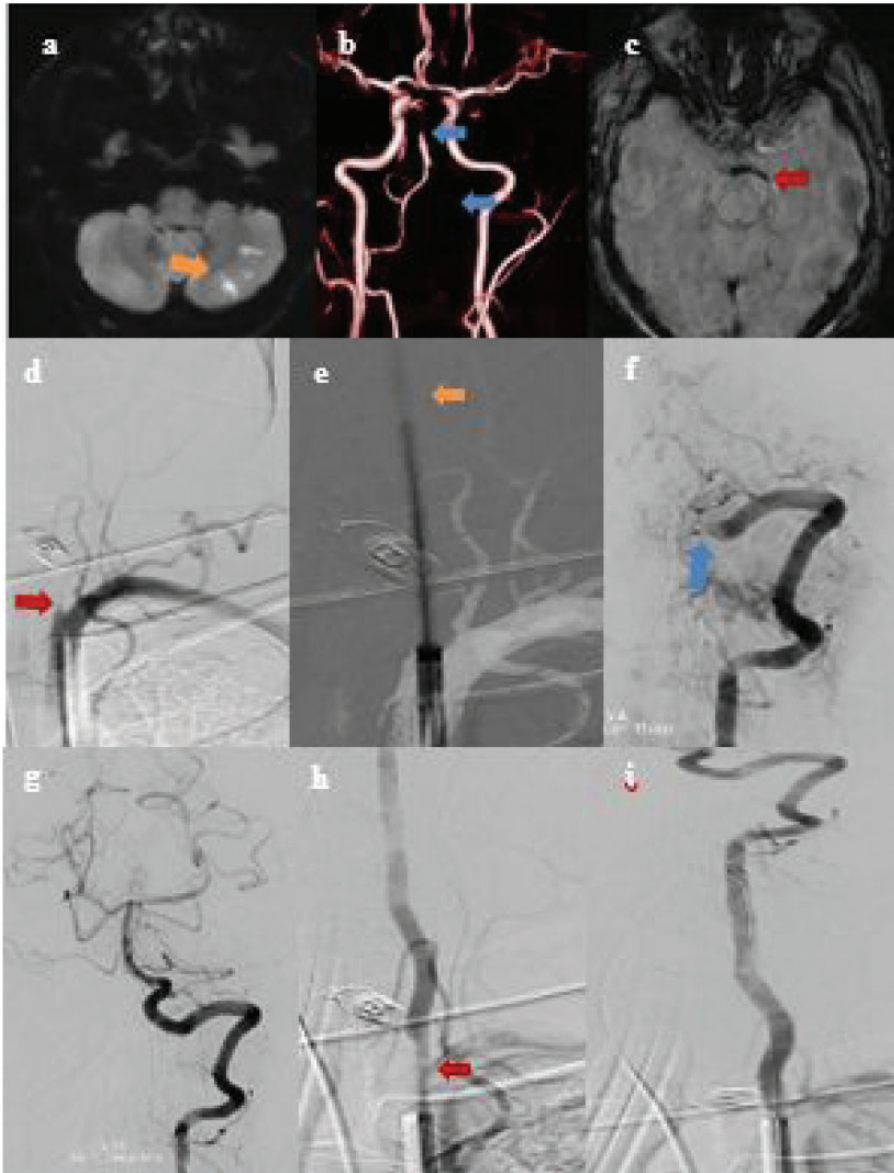


Figure 2. Representative magnetic resonance imaging (MRI) and angiographic findings of posterior circulation tandem occlusion. (a) Scattered cerebellar hyperintensity on DWI (orange arrow); (b) right vertebral artery hypoplasia with left vertebral artery and basilar artery occlusion (blue arrows); (c) hypointense susceptibility vessel sign on susceptibility-weighted imaging (SWI) (red arrow); (d) use of the Diagnostic-Dotter technique for left vertebral artery occlusion initially, but unsuccessful (red arrow); (e) use of the dilator, with the 8F guiding catheter navigated across the occluded segment, with no severe dissection or perforation observed using either the Diagnostic-Dotter or Dilator-Dotter technique (orange arrow); (f) left vertebral artery occlusion (blue arrow); (g) successful reperfusion achieved following aspiration; (h) severe stenosis noted after withdrawal of the 8F guiding catheter from the subclavian artery (red arrow); (i) stent placement resulting in vessel recanalization.

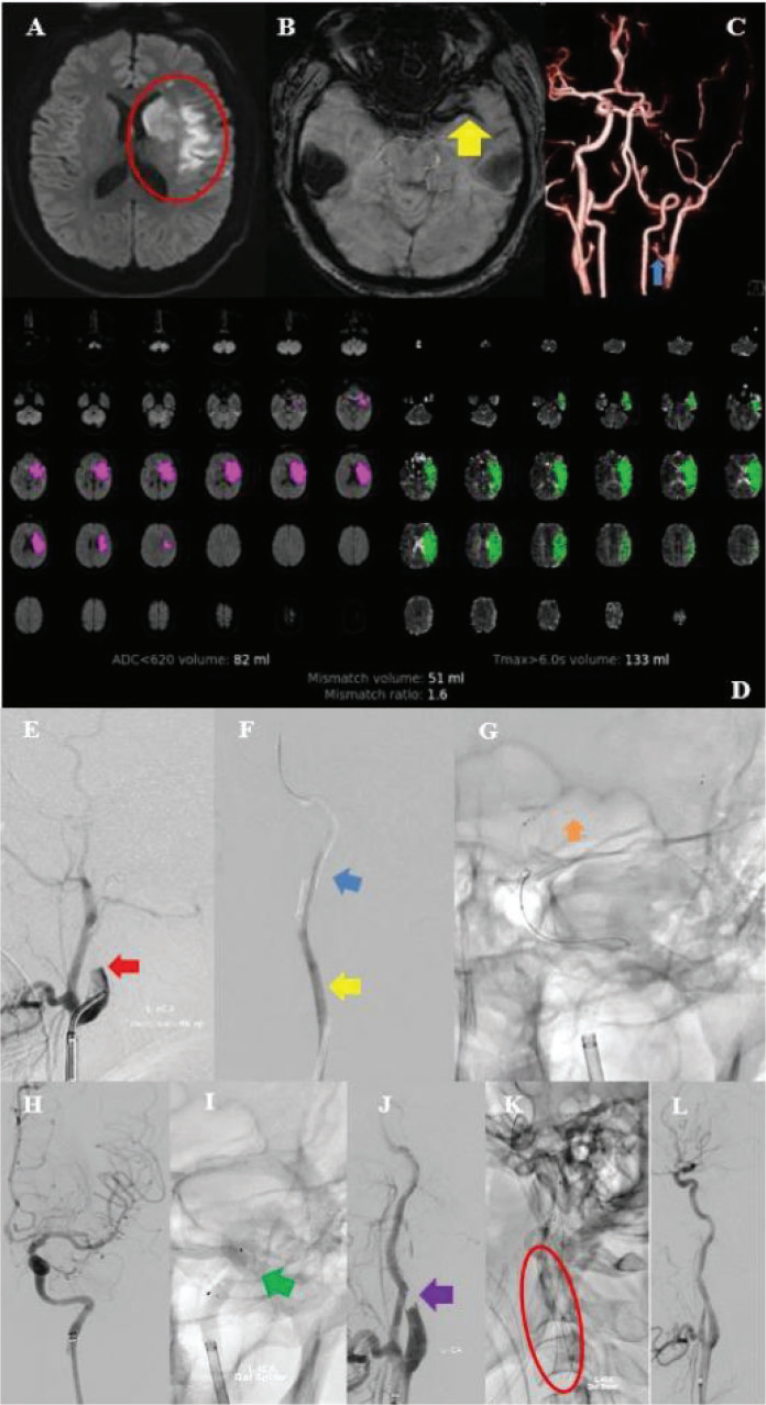


Figure 3. (a) Acute ischemic stroke involving the left lentiform nucleus and external capsule, adjacent to the left lateral ventricle, and the left temporo-occipital region on DWI (red circle); (b) hypointense signal in
Continued.

Statistical analyses

Statistical analyses were performed using Stata 17 (StataCorp LLC, Texas, USA). Continuous variables are presented as mean $\pm$ standard deviation or median (inter-quartile range), as appropriate. Categorical variables are presented as numbers and percentages. For the primary analysis, univariate comparisons were performed using Student's t-test or the Mann-Whitney U test for continuous variables and the chi-square or Fisher's exact test for categorical variables. Multivariate binary logistic regression was used to identify independent predictors of poor outcome (mRS 4–6 at 3 months). Variables with $p < 0.10$ in univariate analysis or those considered clinically important (age, sex, baseline NIHSS, DWI-ASPECTS, smoking, dyslipidemia, procedural time, and hemorrhagic transformation) were entered into the multivariate model. Adjusted odds ratios (ORs) with 95% confidence intervals (CIs) are reported.

Missing data were addressed using complete-case analysis, as the proportion of missing data was low ($<5\%$ for key variables). No imputation was performed. Loss to follow-up was minimized by excluding such patients from the final cohort per protocol; the number of patients and reasons for loss to follow-up are reported in the flow diagram (Figure 1). No sensitivity

analyses were performed because of the retrospective nature of the study and sample size constraints. A two-sided p value < 0.05 was considered statistically significant.

Results

A total of 145 patients with AIS underwent emergent extracranial stenting following mechanical thrombectomy failure at our comprehensive stroke center between December 2020 and June 2025. The mean age was 64.5 ± 11.9 years, and 91.1% of patients were male. Common cardiovascular comorbidities included hypertension (83.5%), smoking (66.2%), and dyslipidemia (24.1%) (Table 2).

Regarding procedural characteristics, the median procedural time was 66.7 ± 2.9 min. The distal-to-proximal approach was employed in 87.6% of cases, and aspiration alone was performed in 57.2%. The majority of patients (75.9%) underwent the Diagnostic-Dotter technique, and EPDs were used in 36.1% of cases. Closed-cell stents with a mean diameter of 7.1 ± 0.1 mm and length of 44.5 ± 1.2 mm were predominantly used.

Postprocedure, 14.5% of patients developed hemorrhagic transformation, and 3.4% underwent decompressive craniectomy. The mean length of ICU stay was 4.1 ± 0.4 days, and the overall hospital

Figure 3. Continued

the left middle cerebral artery (MCA) (M1 segment), corresponding to thrombus in this artery on SWI (yellow arrow); (c) occlusion of the extracranial segment of the left internal carotid artery (ICA) on MRA (blue arrow); (d) RAPID software analysis demonstrating an ADC volume of 82 mL corresponding to the infarct core and a mismatch volume of 51 mL corresponding to the penumbra; (e) occlusion of the extracranial segment of the left ICA on DSA (red arrow); (f) selective distal-to-proximal access using a 5 F diagnostic catheter (blue arrow), facilitating advancement of the 8 F guiding catheter (yellow arrow) across the occluded ICA; (g) deployment of a stent retriever in the left MCA (orange arrow) for mechanical thrombectomy; (h) recanalization of the intracranial ICA and left MCA; (i) deployment of an EPD to prevent distal embolization prior to carotid stenting; (j) withdrawal of the 8 F guiding catheter to the left common carotid artery revealed re-occlusion of the extracranial segment of the left ICA (purple arrow); (k) deployment of a carotid stent (red circle); (l) complete recanalization of the left ICA. ADC: apparent diffusion coefficient; MRA: magnetic resonance angiography; RAPID: Rapid Automated Processing of Perfusion Diffusion; DSA: digital subtraction angiography; EPD: embolic protection device.

Table 2. Baseline characteristics of patients with emergent stenting.

Baseline characteristics	Emergent stenting (N = 145) n (%)
Preprocedure	
Age in years	64.5 ± 11.9
Male sex	132 (91.1)
Hypertension	121 (83.5)
Smoking	96 (66.2)
Dyslipidemia	35 (24.1)
Chronic kidney disease	9 (6.2)
Diabetes	26 (17.9)
NIHSS	14.5 (±0.4)
ASPECTS	6.9 (±0.1)
Left side	74 (51.1)
Procedure	
Aspiration only	83 (57.2)
Distal-to-proximal approach	127 (87.6)
Diagnostic-Dotter technique	110 (75.9)
EPD	55 (37.9)
Postprocedure	
Sedation after procedure	72 (49.7)
Hemorrhagic transformation	21 (14.5)
Length of stay in ICU ≤ 6 days	121 (83.4)
Length of hospital stay ≤ 14 days	118 (81.4)
Stroke rehabilitation	103 (71.1)
Decompressive craniectomy	5 (3.4)

ASPECTS: Alberta Stroke Program Early CT Score; EPD: embolic protection device; NIHSS = National Institutes of Health Stroke Scale.

stay ranged from 1 to 34 days, with a median of 10.2 days. Rehabilitation was initiated in 71.1% of cases. Successful reperfusion (mTICI ≥ 2b) was achieved in 134 patients (92.4%), with comparable rates between the anterior (93.0%) and vertebrobasilar (88.2%) groups ($p = 0.62$) (Table 3). The detailed distribution of intracranial occluded segments is presented in Table 4. At the 3-month follow-up, 97 patients (66.9%) achieved good outcomes (mRS ≤ 2), and the mortality rate was 13.8% (Figure 4). The distribution of the average time intervals from symptom onset to

completion of procedure by year is shown in Figure 5. Factors significantly associated with poor outcomes included smoking ($p = 0.031$), dyslipidemia ($p = 0.014$), admission NIHSS ≥ 12 ($p = 0.032$), DWI-ASPECTS ≤ 6 ($p = 0.005$), and postprocedural sedation ($p = 0.034$). Procedural time > 100 min ($p = 0.009$), procedural complications ($p < 0.0001$, NNH = 2.28), ICU stay ≤ 6 days ($p < 0.0001$, NNH = 2.03), and prolonged hospital stay > 14 days ($p < 0.0001$, NNH = 2.41) were also correlated with poor outcomes (Table 5).

Comparative analysis between anterior and vertebrobasilar system strokes revealed that patients with vertebrobasilar strokes were more likely to undergo aspiration alone than those with anterior circulation strokes (82.4% vs. 53.9%, $p = 0.04$). No significant differences were observed in age, NIHSS score, or complication rates between the two groups (Table 6).

Discussion

This study provides valuable insights into the clinical characteristics, procedural techniques, and outcomes of patients with AIS undergoing emergent extracranial stenting after failed mechanical thrombectomy due to tandem occlusions. Our findings indicate that despite technical complexity and associated risks, emergent stenting is a feasible rescue strategy, with good 3-month outcomes (mRS ≤ 2) observed in 66.9% of cases. These results reinforce the growing body of evidence supporting the role of extracranial stenting in acute stroke management, particularly in patients with failed recanalization or residual critical stenosis of the cervical arteries.

The predominance of older male patients (91.1% male, mean age 64.5 years) aligns with prior reports such as the TITAN and ESCAPE-NA1 trials, where cardiovascular comorbidities like hypertension and smoking were prevalent.^{5,6} The baseline NIHSS

Table 3. Final modified thrombolysis in cerebral infarction (mTICI) reperfusion grades according to vascular territory.

mTICI score	Anterior circulation (n = 128) n (%)	Vertebrobasilar system (n = 17) n (%)	Total (n = 145) n (%)	p value ^a
0–2a (failed)	9 (7.0)	2 (11.8)	11 (7.6)	0.62
2b	52 (40.6)	7 (41.2)	59 (40.7)	–
3	67 (52.3)	8 (47.1)	75 (51.7)	–
Successful reperfusion (mTICI ≥2b)	119 (93.0)	15 (88.2)	134 (92.4)	0.62

^aFisher's exact test.

Table 4. Distribution of intracranial occluded segments in patients with tandem occlusions.

Intracranial occluded segment	Anterior circulation (n = 128) n (%)	Vertebrobasilar system (n = 17) n (%)	Total (n = 145) n (%)
ICA terminus	48 (37.5)	0 (0)	48 (33.1)
M1 segment	58 (45.3)	0 (0)	58 (40.0)
M2 segment	22 (17.2)	0 (0)	22 (15.2)
Basilar artery	0 (0)	17 (100)	17 (11.7)

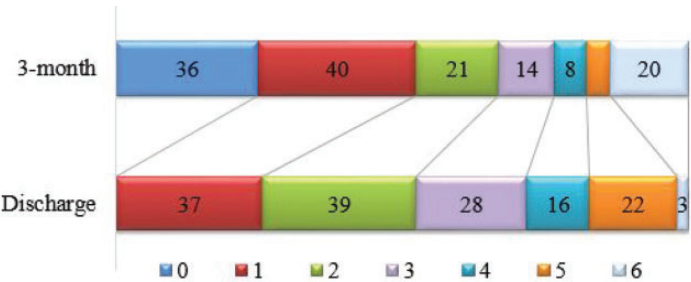


Figure 4. Distribution of 3-month modified Rankin Scale (mRS) outcomes in patients undergoing emergent stenting for tandem occlusions. Bars represent the proportion of patients for each mRS category (0 = no symptoms; 6 = death). Favorable outcome was defined as mRS ≤3.

score (mean 14.5) in our study indicates a more severe neurological presentation than that in some prior studies, including the study by Allard et al.,⁹ whereas the mean ASPECTS of 6.9 is comparable to other stenting studies in carotid–middle cerebral artery (MCA) system tandem occlusions, such as those by Anadani et al.⁵ and Ezcurra–Díaz et al.¹⁴ These clinical features are typical of patients with large-vessel occlusions and tandem lesions, which are

known to present with more severe stroke phenotypes.

One of the critical findings in our study is the significant association between early clinical parameters and long-term outcomes. Higher NIHSS scores on admission, lower ASPECTS scores, and delays in onset-to-door time were all significantly associated with poor outcomes at 3 months. These findings are consistent with prior literature emphasizing the importance of early

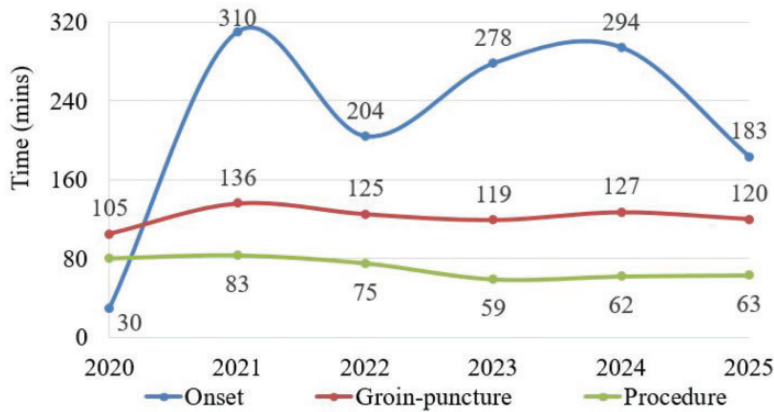


Figure 5. Distribution of average time intervals from symptom onset to completion of procedure by year.

Table 5. Association between patient characteristics and clinical outcome (mRS at 3 months).

Baseline characteristics	Poor outcome (n = 37)	p	OR (95%CI)	NNH
Age ≥ 70	17 (11.7%)	0.057	2.11 (0.98–4.56)	
Male	32 (22.1%)	0.269	0.51 (0.16–1.68)	
Smoking	30 (20.7%)	0.031	2.72 (1.09–6.77)	5.89
Hypertension	29 (20.0%)	0.339	0.63 (0.24–1.62)	
Dyslipidemia	3 (2.07%)	0.014	0.21 (0.06–0.73)	4.47
Diabetes	4 (2.8%)	0.199	0.47 (0.15–1.48)	
Onset > 6 h	11 (7.6%)	0.119	1.98 (0.84–4.69)	
NIHSS ≥ 12	34 (23.5%)	0.032	3.97 (1.13–13.94)	4.96
DWI-ASPECTS ≤ 6	17 (13.3%)	0.005	3.27 (1.43–7.46)	4.08
pc-ASPECTS < 8	2 (11.7%)	0.762	1.50 (0.11–20.67)	
Anterior circulation	34 (23.5%)	0.433	1.69 (0.46–6.24)	
Postprocedural sedation	24 (16.6%)	0.034	2.31 (1.06–5.01)	6.44
Procedural time > 100 min	10 (6.9%)	0.009	5.74 (1.98–16.63)	3.52
Complication	16 (11.1%)	<0.0001	7.47 (2.98–18.73)	2.28
ICU stay > 6 days	16 (11.1%)	<0.0001	9.52 (3.61–25.13)	2.03
Hospital stay > 14 days	16 (11.1%)	<0.0001	6.72 (2.73–16.54)	2.41

reperfusion and the extent of initial infarction in determining long-term prognosis. In our cohort, NIHSS ≥ 12 was strongly predictive of poor outcome ($p = 0.032$), suggesting that initial stroke severity remains a key determinant even in the context of successful extracranial stenting.

In our cohort, emergent stenting was required in patients who exhibited either persistent re-occlusion or flow-limiting residual

stenosis after mechanical thrombectomy, consistent with failure of intracranial recanalization due to underlying atherosclerotic stenosis rather than procedural inefficacy. The need for rescue stenting reflected the high prevalence of atherosclerotic lesions in this Asian cohort rather than device failure. Stenting was performed to secure durable recanalization and prevent re-occlusion secondary to arterial recoil or plaque collapse.

Table 6. Association between patient characteristics and the two vascular territories.

Baseline characteristics	Vascular territories		p value
	Carotid–middle cerebral artery system (n = 128) n (%)	Vertebrobasilar system (n = 17) n (%)	
Age ≥ 70	41 (32.1)	7 (64.7)	0.451 ^a
Male	117 (91.4)	15 (88.2)	0.662 ^b
Parameters on admission			
Admission NIHSS ≥ 12	101 (78.9)	13 (76.5)	0.817 ^a
Procedural time > 100 min	15 (11.7)	5 (29.4)	0.04^a
Proximal-to-distal approach	17 (13.3)	1 (5.9)	0.413 ^b
Only aspiration	69 (53.9)	14 (82.4)	0.04^a
Parameters of postprocedure			
Complication	24 (18.8)	2 (11.8)	0.493 ^a
Length of stay in ICU > 6 days	19 (14.8)	5 (29.4)	0.124 ^a
Length of hospital stay > 14 days	25 (19.5)	2 (11.8)	0.454 ^a

^aChi-square test.^bFisher's exact test.

The mRS was selected as the primary functional outcome for consistency with prior tandem occlusion studies and to ensure comparability with international stroke registries. Although additional scales such as NIHSS improvement could provide complementary insights, uniform data availability restricted our outcome analysis to the mRS. The 3-month good outcome rate (mRS ≤ 3) of 66.9% in the Tandem occlusions after emergent stenting in acute ischemic stroke (TOESIS) study is notably higher than in many prior studies, where functional independence ranged between 55% and 65% for similar populations. This could be attributed to early access to 3 T MRI imaging, expedited intervention decision-making, and high rates of dual antiplatelet administration (94.8%). Postprocedural hemorrhagic transformation occurred in 14.5% of cases across two vascular territories—slightly higher than in Western cohorts but comparable to the study by Han et al.¹⁰ on vertebrobasilar system tandem lesions, where anatomical complexity increases procedural risk.

Pathophysiologically, anterior circulation tandem occlusions typically involve the ICA–MCA axis with richer leptomeningeal collaterals and more straightforward endovascular access. In contrast, posterior circulation occlusions (vertebrobasilar) are often characterized by limited collateral reserve, smaller vessel caliber, and more complex anatomy, making thrombectomy and stenting technically challenging and time-sensitive.

Procedural variables also played an important role in clinical outcomes. The distal-to-proximal approach was adopted in the majority of cases, reflecting a practical strategy to restore intracranial perfusion before addressing extracranial lesions. Although aspiration alone was used in 57.2% of cases, it was significantly more common in patients with vertebrobasilar system strokes ($p=0.04$), possibly due to anatomical considerations or operator preference. Notably, prolonged procedural time (>100 min) was significantly associated with worse outcomes ($p=0.04$), which may reflect more complex or technically

challenging cases. The use of a 3000-IU heparin bolus during the procedure remains controversial in the acute stroke setting. We administered heparin only after confirming the absence of early hemorrhagic transformation on immediate postprocedural imaging and only in patients receiving stents. We acknowledge that some centers prefer antiplatelet therapy alone to minimize bleeding risk; however, our low rate of hemorrhagic transformation (14.5%) supports the safety of this regimen in our selected population.

A particularly noteworthy observation is the low incidence of postprocedural hemorrhagic transformation (14.5%), although it was significantly associated with poor outcomes ($p < 0.0001$). This suggests that although emergent stenting is generally safe, careful patient selection and postprocedural management are essential to minimize complications. Notably, seven patients in the poor outcome group did not receive antiplatelet therapy after the procedure, and this subgroup experienced significantly higher rates of hemorrhagic transformation and poor prognosis. This highlights a clinical dilemma: although antiplatelet therapy is necessary to prevent in-stent thrombosis, it must be carefully balanced against the risk of hemorrhagic conversion during the acute phase.

Another important observation is the role of intensive care parameters in influencing outcomes. ICU stay and overall hospital stay were both significantly longer in patients with poor outcomes. An ICU stay >6 days was associated with a substantially higher risk of poor prognosis ($p < 0.0001$), potentially reflecting the severity of neurological injury, the presence of complications, or the need for prolonged supportive care. Similarly, decompressive craniectomy, although lifesaving in some cases, was performed more frequently in patients with poor outcomes, indicating severe cerebral edema or hemorrhagic transformation.

Vertebrobasilar system tandem occlusions remain less well studied but are increasingly recognized for their distinct challenges. Several studies have emphasized the importance of revascularizing the dominant vertebral artery to ensure access and perfusion, similar to our approach using the distal-to-proximal technique.^{7,8,11} In our study, aspiration-only thrombectomy was significantly more common in patients with posterior circulation strokes (82.4% vs. 53.9%), reflecting anatomical considerations. However, the absence of significant differences in complications or outcomes between anterior and posterior groups reinforces the feasibility of emergent stenting in both vascular territories when performed by experienced teams.

Although vertebrobasilar system cases demonstrated comparable outcomes to anterior strokes, this finding should be interpreted with caution due to the limited sample size ($n = 17$) and potential underpowering for detecting small outcome differences. Further multicenter studies are warranted to validate these observations.

This was the largest study on emergent stenting in tandem occlusions involving two vascular territories and one of the largest Asian cohorts. Our study was conducted in Vietnam, allowing minimization of ethnic heterogeneity-related bias. Moreover, in our hospital, 3T MRI was a first-line diagnostic tool, and multiple interventional devices were available, which facilitated rapid decision-making and early recanalization. Our results should be interpreted in the context of several limitations. First, this is a single-center, retrospective observational study, which may limit generalizability of the findings. Second, selection criteria for stenting and decisions regarding postprocedural antiplatelet therapy were based on operator judgment, introducing potential bias. Third, although vertebrobasilar cases demonstrated comparable outcomes to anterior strokes, this finding should be

interpreted with caution due to the limited sample size ($n=17$) and potential underpowering. Further multicenter studies are warranted. To minimize bias, we performed univariate analyses with exact tests and highlighted that posterior circulation results should be considered exploratory. Fourth, although the 3-month follow-up is standard in stroke outcome studies, longer-term outcomes, including restenosis or recurrent stroke, were not evaluated. Finally, imaging parameters such as collateral status or perfusion mismatch, which are increasingly recognized as important predictors of outcome, were not uniformly available and were therefore not analyzed.

Conclusions

Emergent stenting for tandem occlusions involving two vascular territories was a crucial treatment strategy to improve clinical outcomes, particularly at the 3-month follow-up. Further randomized controlled trials are warranted to better define optimal patient selection criteria, procedural techniques, and poststenting management strategies to improve outcomes in this challenging patient population.

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Author contributions

TML and CCT contributed equally to this article as co-first authors. TML, GLN, CCT, and LBMT handled study conceptualization. TML, GLN, and CCT performed data curation. TML, GLN, and CCT conducted formal analysis. TML, CCT, and TTN performed investigation. TML, CCT, and LBMT handled methodology. TML handled project administration. TML and GLN contributed to resources. TML and TTN contributed to software. TML, CCT, and TTN

supervised the study. TML, CCT, and TTN validated the study. TML, CCT, and TTN contributed to visualization. TML, GLN, CCT, NHN, TTN, and LBMT contributed to writing—original draft. TML, GLN, CCT, NHN, TTN, and LBMT contributed to writing—review and editing.

Data availability statement

The data that support the findings of this study are available from the corresponding author on reasonable request.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethics approval

The study involving human participants was reviewed and approved by the Ethics Council in Biomedical Research at Can Tho S.I.S General Hospital (11823/QD-S.I.S) and the Ethical Board of the University of Medicine and Pharmacy at Ho Chi Minh City (number 1087/HDDD-DHYD on 2 November 2023).

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Informed consent

Informed consent was obtained from all patient representatives after detailed explanation of the procedures.

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