

Outcomes of emergent carotid artery stenting for tandem occlusion in acute ischemic stroke: a single center retrospective study

Nguyen Thuy Anh Thu¹✉, Nguyen Thi Bao Lien², Tran Anh Tuan^{1,3}, Do Khanh Ha⁴

¹ University of Medicine and Pharmacy, Vietnam National University, Hanoi

² Saint Paul General Hospital

³ Bach Mai Hospital

⁴ Vinmec Ocean Park 2 International Hospital

Correspondence to

Nguyen Thuy Anh Thu, MD
University of Medicine and Pharmacy,
Vietnam National University, Hanoi
Email: nguyennhthudhyhp@gmail.com

Manuscripts submission: 3/8/2026

Peer Review: 25/9/2026

Manuscripts accepted: 23/10/2026

ABSTRACT

Objectives: To describe outcomes and explore factors associated with functional recovery after emergent carotid stenting for acute ischemic stroke with tandem occlusion.

Methods: This retrospective study included 90 patients treated at Bach Mai Hospital from February 1, 2024, to January 31, 2026. Favorable outcome was a modified Rankin Scale score of 0-2 at 30 days.

Results: Successful reperfusion was achieved in 94.4%; 47.8% had favorable outcomes and 12.2% died by 30 days. Imaging-defined hemorrhagic transformation occurred in 58.9%; internal carotid and middle cerebral artery re-occlusion occurred in 8.9% and 4.4%, respectively. Among 53 patients with hemorrhagic transformation, hemorrhagic infarction was associated with higher odds of favorable outcome than parenchymal hematoma (odds ratio [OR], 6.74; 95% confidence interval [CI], 1.34-33.82; $p=0.015$). Procedure time ≤ 60 minutes was also associated with favorable outcome (OR, 2.56; 95% CI, 1.05-6.25; $p=0.037$).

Conclusions: Successful reperfusion was frequent, but imaging-defined hemorrhagic transformation was common. These unadjusted associations require cautious interpretation because of the small retrospective cohort and absence of a non-stenting comparator.

Keywords: acute ischemic stroke; Tandem occlusion; carotid artery stenting; mechanical thrombectomy; endovascular therapy.

I. INTRODUCTION

Tandem occlusion combines an extracranial internal carotid artery lesion with an ipsilateral intracranial arterial occlusion. Treating both lesions introduces decisions about procedural sequence and

antiplatelet exposure during acute cerebral ischemia.¹ Observational evidence supports emergent carotid stenting in selected patients, including the pooled Thrombectomy in Tandem Lesions (TITAN) and Endovascular Treatment in Ischemic Stroke (ETIS) registries.² The 2026 CERES-TANDEM multicenter cohort also found an association between stenting and better 90-day functional outcomes, although residual confounding remains possible.³

Local outcome data are needed to characterize the patients selected for this approach at Bach Mai Hospital and the complications encountered in routine practice. This study had two objectives: (1) to describe baseline clinical and imaging characteristics, procedural results, and 30-day outcomes after emergent carotid stenting for tandem occlusion; and (2) to explore unadjusted associations between treatment or postprocedural characteristics and 30-day functional outcome.

II. PATIENTS AND METHODS

2.1. Study design and eligibility

We conducted a retrospective observational study at the Stroke Center, Bach Mai Hospital. Eligible patients underwent endovascular treatment with carotid artery stenting for acute ischemic stroke due to tandem occlusion between February 1, 2024, and January 31, 2026. Data analysis was conducted from April to September 2026.

Patients were eligible if tandem occlusion was diagnosed, endovascular treatment included carotid artery stenting, and the clinical, imaging, procedural, and outcome data required for analysis were available. Records lacking key variables or the required functional outcome were excluded. All eligible records during the study period were included, yielding 90 patients.

2.2. Variables and outcome definitions

Baseline variables included age, sex, vascular risk factors, neurological presentation, the National Institutes of Health Stroke Scale (NIHSS) score, prestroke modified Rankin Scale (mRS) score, Glasgow Coma Scale score, and onset-to-admission time. Baseline imaging variables included the Alberta Stroke Program Early CT Score (ASPECTS) and intracranial occlusion site. Successful reperfusion was defined as modified Thrombolysis in Cerebral Infarction (mTICI) grade 2b-3.

Treatment variables included intravenous recombinant tissue plasminogen activator (IV rtPA), revascularization sequence, thrombectomy passes, recorded onset-to-reperfusion interval, and procedure time. Antegrade treatment refers to treatment of the cervical lesion before intracranial thrombectomy; retrograde treatment refers to the reverse sequence. Time variables were analyzed using the recorded categories of ≤ 360 versus > 360 minutes and ≤ 60 versus > 60 minutes, respectively.

Hemorrhagic transformation (HT) on imaging within 24 hours was grouped as hemorrhagic infarction (HI1-HI2) or parenchymal hematoma (PH1-PH2). HI denotes petechial hemorrhage within the infarct, whereas PH denotes a parenchymal blood clot. These imaging categories were not treated as equivalent to symptomatic intracranial hemorrhage (sICH). Other complications included recorded arterial re-occlusion within 24 hours, vessel injury, vasospasm, hematoma or pseudoaneurysm, and contrast-media allergy.

Early neurological change was assessed using NIHSS scores on admission and at 24 hours. Reductions of > 4 and > 8 points were retained as the recorded thresholds. Favorable functional outcome was defined as mRS 0-2 at 30 days; mRS

3-6, including death, was unfavorable. Discharge and 30-day outcomes are additionally presented as mRS 0-2, mRS 3-5, and death (mRS 6).

2.3. Data collection and statistical analysis

Data were extracted using a standardized form from inpatient records, interventional records, diagnostic imaging reports, the picture archiving and communication system (PACS), discharge records, and recorded follow-up assessments. Records were cross-checked for consistency. The analyzed cohort contained 90 recorded 30-day outcomes. Analyses used the available counts for each comparison; the HI-PH comparison was restricted to the 53 patients with HT.

Data entry and the original analyses used EpiData 3.1 and SPSS 22.0. Continuous variables are summarized as mean ± standard deviation (SD), and categorical variables as n (%). Row percentages and unadjusted odds ratios (ORs) were checked using the reported 2×2 counts, with 95% confidence intervals (CIs) obtained by the log-Wald method. Pearson chi-square tests without continuity correction were used for nonsparse tables; two-sided Fisher exact tests were used when any observed cell contained fewer than five patients. Finite conventional ORs were not estimated for tables containing a zero cell. All available treatment categories in Table 7 were examined; HT subtype was analyzed separately as a postprocedural characteristic. No multivariable adjustment or imputation was performed in this aggregate-data recalculation. A two-sided p<0.05 was the nominal threshold; the analyses were exploratory and were not adjusted for multiple comparisons.

2.4. Ethics

The study was reviewed by the Protocol Review Committee of the University of Medicine and Pharmacy, Vietnam National University,

Hanoi, and approved by the Institutional Biomedical Research Ethics Committee of Bach Mai Hospital under Decision No. 830/BM-HĐĐĐ, dated October 8, 2026. The study was retrospective and did not alter clinical care. Patient information was coded, kept confidential, and used only for research.

III. RESULTS

3.1. Baseline clinical and imaging characteristics

The cohort included 90 patients, with a mean age of 65.7 ± 11.7 years; 72 (80.0%) were men. Hypertension was the most frequent vascular risk factor, and hemiparesis was the most frequent neurological deficit (Table 1). The mean admission NIHSS score was 12.84 ± 4.76.

Table 1. Baseline clinical characteristics of 90 patients

Characteristic	n (%) or mean ± SD
Age, years	65.7 ± 11.7
Male sex	72 (80.0)
Female sex	18 (20.0)
Hypertension	66 (73.3)
Diabetes mellitus	22 (24.4)
Dyslipidemia	45 (50.0)
Atrial fibrillation	6 (6.7)
Previous stroke	11 (12.2)
Current smoking	9 (10.0)
Hemiparesis	84 (93.3)
Central facial palsy	39 (43.3)
Language disturbance	38 (42.2)
Impaired consciousness	32 (35.6)
Glasgow Coma Scale score	13.57 ± 1.65
Admission NIHSS score	12.84 ± 4.76
Prestroke mRS score	0.23 ± 0.56
Onset-to-admission time, min	261.1 ± 177

NIHSS, National Institutes of Health Stroke Scale; mRS, modified Rankin Scale; SD, standard deviation. Risk factors and neurological deficits may coexist.

The mean ASPECTS was 6.98 ± 1.28 . The M1 segment of the middle cerebral artery was the most frequent intracranial occlusion site (78.9%; Table 2).

Table 2. Baseline imaging characteristics of 90 patients

Characteristic	n (%) or mean $\pm$ SD
ASPECTS	6.98 ± 1.28
M1 middle cerebral artery occlusion	71 (78.9)
M2 middle cerebral artery occlusion	4 (4.4)
Terminal internal carotid artery occlusion	11 (12.2)
Anterior cerebral artery occlusion	4 (4.4)

ASPECTS, Alberta Stroke Program Early CT Score; SD, standard deviation. Percentages may not sum to 100 because of rounding.

3.2. Treatment characteristics and complications

Twenty patients (22.2%) received IV rtPA. Retrograde treatment was used in 58 (64.4%), and successful reperfusion was achieved in 85 (94.4%). Procedure time was ≤ 60 minutes in 57 patients (63.3%; Table 3).

Table 3. Treatment characteristics and angiographic results

Characteristic	n (%)
IV rtPA before endovascular treatment	20 (22.2)
Antegrade strategy	32 (35.6)
Retrograde strategy	58 (64.4)
Thrombectomy passes ≤ 4	87 (96.7)

Characteristic	n (%)
Thrombectomy passes >4	3 (3.3)
Recorded onset-to-reperfusion interval ≤ 360 min ^a	52 (57.8)
Recorded onset-to-reperfusion interval >360 min ^a	38 (42.2)
Procedure time ≤ 60 min	57 (63.3)
Procedure time >60 min	33 (36.7)
Successful reperfusion, mTICI 2b-3	85 (94.4)
mTICI $<2b$	5 (5.6)

IV rtPA, intravenous recombinant tissue plasminogen activator; mTICI, modified Thrombolysis in Cerebral Infarction. Denominator: 90 patients.^a The recorded time categories include five patients with mTICI $<2b$ and should not be interpreted as time to successful reperfusion for every patient.

Vasospasm, arterial dissection or vessel-wall injury, and contrast-media allergy each occurred in 2 patients (2.2%); hematoma or pseudoaneurysm occurred in 3 (3.3%). Within 24 hours, imaging-defined HT occurred in 53 patients (58.9%), comprising 35 HI and 18 PH cases. Internal carotid artery re-occlusion was recorded in 8 patients (8.9%) and middle cerebral artery re-occlusion in 4 (4.4%). No deaths were recorded during the first 24 hours (Table 4).

Table 4. Periprocedural and early postprocedural complications

Timing and complication	n (%)
During or immediately after the procedure	
Vasospasm	2 (2.2)
Arterial dissection or vessel-wall injury	2 (2.2)
Distal embolization due to thrombus fragmentation	0 (0.0)

Timing and complication	n (%)
Hematoma or pseudoaneurysm	3 (3.3)
Contrast-media allergy	2 (2.2)
Within 24 hours after the procedure	
Any hemorrhagic transformation	53 (58.9)
Hemorrhagic infarction, HI1-HI2	35 (38.9)
Parenchymal hematoma, PH1-PH2	18 (20.0)
Internal carotid artery re-occlusion	8 (8.9)
Middle cerebral artery re-occlusion	4 (4.4)
Myocardial infarction	0 (0.0)
Death	0 (0.0)

HI, hemorrhagic infarction; PH, parenchymal hematoma. Percentages use the full cohort (n=90). Imaging-defined hemorrhage is not equivalent to symptomatic intracranial hemorrhage. Patients may have more than one complication.

3.3.Neurological and functional outcomes

The mean NIHSS score decreased by 5.17 points between admission and 24 hours. Reductions of >4 and >8 points occurred in 63.3% and 28.9%, respectively (Table 5).

Table 5. NIHSS scores and early neurological change

Measure	Value
Admission NIHSS, mean ± SD	12.84 ± 4.76
24-hour NIHSS, mean ± SD	7.67 ± 6.54
Mean reduction, admission minus 24 hours	5.17 points
Reduction >4 points, n (%)	57 (63.3)
Reduction >8 points, n (%)	26 (28.9)

NIHSS, National Institutes of Health Stroke Scale; SD, standard deviation. Denominator: 90 patients. The reduction thresholds are nested. The mean reduction is the difference between the reported means; the SD of paired change is not available.

Functional independence increased from 12 patients (13.3%) at discharge to 43 (47.8%) at 30 days. Cumulative mortality increased from 1 (1.1%) at discharge to 11 (12.2%) at 30 days (Table 6).

Table 6. Functional outcomes at discharge and 30 days

mRS category	Discharge, n (%)	30 days, n (%)
Functional independence, mRS 0-2	12 (13.3)	43 (47.8)
Moderate to severe disability, mRS 3-5	77 (85.6)	36 (40.0)
Death, mRS 6	1 (1.1)	11 (12.2)
Total	90 (100.0)	90 (100.0)

mRS, modified Rankin Scale. For association analyses, unfavorable outcome includes mRS 3-6, including death (n=47 at 30 days).

3.4. Exploratory associations with 30-day outcome

Among patients with HT, favorable outcome occurred in 16/35 with HI and 2/18 with PH (OR, 6.74; 95% CI, 1.34-33.82; p=0.015). Procedure time ≤60 minutes was associated with favorable outcome (OR, 2.56; 95% CI, 1.05-6.25; p=0.037). The recorded onset-to-reperfusion category was also associated with outcome, but the handling of this interval in the five patients with mTICI <2b limits interpretation. IV rtPA and revascularization sequence showed no statistically significant associations (Table 7).

Table 7. *Unadjusted associations with 30-day functional outcome*

Factor and comparison	mRS 0-2 n/N (%)	mRS 3-6 n/N (%)	OR (95% CI)	p
IV rtPA Yes / No	11/20 (55.0) 32/70 (45.7)	9/20 (45.0) 38/70 (54.3)	1.45 (0.53-3.94)	0.463
Reperfusion mTICI 2b-3 / <2b	43/85 (50.6) 0/5 (0.0)	42/85 (49.4) 5/5 (100.0)	NE	0.057 ^a
Revascularization Antegrade / Retrograde	16/32 (50.0) 27/58 (46.6)	16/32 (50.0) 31/58 (53.4)	1.15 (0.48-2.72)	0.754
Thrombectomy passes ≤4 / >4	43/87 (49.4) 0/3 (0.0)	44/87 (50.6) 3/3 (100.0)	NE	0.243 ^a
Recorded onset-to-reperfusion interval ^b ≤360 / >360 min	30/52 (57.7) 13/38 (34.2)	22/52 (42.3) 25/38 (65.8)	2.62 (1.10-6.24)	0.028
Procedure time ≤60 / >60 min	32/57 (56.1) 11/33 (33.3)	25/57 (43.9) 22/33 (66.7)	2.56 (1.05-6.25)	0.037
Postprocedural HT subtype ^c HI / PH	16/35 (45.7) 2/18 (11.1)	19/35 (54.3) 16/18 (88.9)	6.74 (1.34-33.82)	0.015 ^a

Each pair of lines follows the category order in the first column; the second category is the reference. Percentages use each category denominator. OR, odds ratio; CI, confidence interval; mRS, modified Rankin Scale; IV rtPA, intravenous recombinant tissue plasminogen activator; mTICI, modified Thrombolysis in Cerebral Infarction; HT, hemorrhagic transformation; HI, hemorrhagic infarction; PH, parenchymal hematoma; NE, not estimable as a finite conventional OR because of a zero cell.^a Two-sided Fisher exact test; other p values use Pearson chi-square tests.^b Exploratory comparison; see Table 3 regarding patients with mTICI <2b.^c Restricted to 53 patients with HT; this is a postprocedural subgroup, not a baseline predictor.

IV DISCUSSION

This cohort documents a high rate of successful reperfusion (94.4%) after endovascular treatment with emergent carotid stenting. Functional

independence at 30 days was achieved by 47.8%, while mortality reached 12.2%. The difference between angiographic success and functional recovery emphasizes that reperfusion alone does not fully characterize treatment outcome. The frequent imaging-defined HT and early re-occlusion also need to be considered alongside technical success.

4.1. Patient characteristics and reperfusion

The mean age of 65.7 years was similar to the 64.4 years reported by Grigoryan et al. in a 100-patient tandem-occlusion cohort. Our patients had a lower mean admission NIHSS score (12.84 versus 17.6), a lower mean ASPECTS (6.98 versus 7.5), and more frequent M1 occlusion (78.9% versus 53%).⁴ Differences in neurological severity and established ischemic change may affect outcome comparisons even when age is similar. The mean onset-to-admission interval of 261.1 minutes describes this cohort but does not, by itself, establish

delayed arrival relative to other centers.

Successful reperfusion was numerically higher than the 88% reported by Grigoryan et al. and the 90.5% reported in the stenting group of Farooqui et al.^{1,4} Patient selection, lesion anatomy, technique, and grading practices may contribute to this difference. Because every patient in our cohort received a stent, these data cannot distinguish the contribution of carotid stenting from that of intracranial thrombectomy or establish superiority over angioplasty alone.

4.2. Hemorrhage and early re-occlusion

HT was recorded in 58.9%, including Hlin in 38.9% and PH in 20.0%. These are radiological outcomes. A separate sICH rate was not established in this analysis, so the findings cannot be compared directly with symptomatic hemorrhage rates or used to conclude that stenting was clinically safe. The HI-PH comparison suggests worse recovery with PH, but it includes only 53 patients and only two favorable outcomes in the PH group. Its wide confidence interval indicates substantial uncertainty in the magnitude of association.

Internal carotid artery re-occlusion occurred in 8.9% within 24 hours. Pop et al. reported day-1 stent thrombosis in 14/96 patients (14.5%) whose stents were patent at the end of treatment.⁵ Their endpoint and denominator differ from our recorded carotid re-occlusion outcome; the two rates therefore do not establish a difference in stent thrombosis risk. Without detailed antiplatelet exposure and confirmation of the site of re-occlusion, we cannot attribute these events to a particular drug regimen or stent strategy.

4.3. Neurological recovery and mortality

The mean NIHSS reduction was 5.17 points, and 28.9% had a reduction of >8 points. Wallocha et al. reported early improvement in 48.4%, using a reduction of ≥8 points at 24 hours or a residual

NIHSS score of 0-1 at 3 days.⁶ Their composite definition is broader than the threshold available here. The two percentages should therefore not be treated as directly comparable.

Our 30-day functional independence rate of 47.8% lies between the 90-day rates reported by Grigoryan et al. (42%) and the stenting group of TITAN-ETIS (57%).^{2,4} The shorter follow-up allows less time for recovery, while differences in baseline severity and selection also prevent direct ranking of outcomes. The increase in functional independence from discharge to day 30 is compatible with continued recovery, but aggregated mRS categories do not describe each patient's trajectory.

Mortality increased from 1.1% at discharge to 12.2% at 30 days, representing ten additional deaths during follow-up. Grigoryan et al. reported 20% mortality at 90 days.⁴ Our shorter observation period and the absence of cause-specific mortality prevent attribution of the difference to treatment. In particular, the present data do not establish whether post-discharge deaths reflected the index stroke, hemorrhage, recurrent vascular events, infection, or other conditions.

4.4. Interpretation of exploratory associations

Procedure time ≤60 minutes was associated with higher odds of functional independence. A shorter procedure may reflect less complex anatomy or easier clot retrieval as well as faster treatment; these explanations cannot be separated without adjustment. Likewise, the recorded onset-to-reperfusion association is difficult to interpret until the timing endpoint in patients with mTICI <2b is clarified. Neither association identifies an independent predictor or demonstrates that changing a time threshold would improve outcome.

The absence of a significant association for IV rtPA or revascularization sequence does not

establish equivalence. Sparse cells also prevented finite conventional OR estimates for reperfusion status and thrombectomy passes. Contemporary comparative evidence, including the 4,053-patient CERES-TANDEM cohort, supports further evaluation of emergent stenting, but its adjusted association with 90-day outcome cannot be inferred from our uncontrolled series.³

4.5. Limitations

The retrospective single-center design and selection of records with available outcomes introduce selection and information bias. Exclusion of incomplete records may limit representativeness, and the risk cannot be quantified without the screening and missing-data counts. Outcome assessment was not documented as blinded. The small cohort and sparse subgroups produced imprecise estimates; unadjusted analyses and multiple exploratory comparisons leave confounding and chance findings unresolved. The HI-PH comparison conditions on a postprocedural complication and is not a baseline prognostic analysis. Incomplete reporting of extracranial lesion characteristics, stent devices, antiplatelet treatment, sICH, and causes of death limits interpretation of safety. Thirty-day follow-up and the absence of a non-stenting comparator further limit interpretation.

V CONCLUSIONS

Among 90 patients treated with endovascular therapy and emergent carotid stenting for tandem occlusion, 94.4% achieved successful reperfusion and 47.8% were functionally independent at 30 days. Imaging-defined HT occurred in 58.9%; internal carotid and middle cerebral artery re-occlusion occurred in 8.9% and 4.4%, respectively; 30-day mortality was 12.2%. Procedure time ≤60 minutes and HI rather than PH were associated with favorable outcome in

unadjusted analyses. The uncontrolled design and limited safety data preclude conclusions about comparative efficacy or clinical safety.

REFERENCES

1. Farooqui M, Zaidat OO, Hassan AE, et al. Functional and safety outcomes of carotid artery stenting and mechanical thrombectomy for large vessel occlusion ischemic stroke with tandem lesions. *JAMA Netw Open*. 2023;6(3):e230736. doi:10.1001/jamanetworkopen.2023.0736
2. Anadani M, Marnat G, Consoli A, et al; TITAN and ETIS Registry Investigators. Endovascular therapy of anterior circulation tandem occlusions: pooled analysis from the TITAN and ETIS registries. *Stroke*. 2021;52(10):3097-3105. doi:10.1161/STROKEAHA.120.033032
3. Romoli M, Molina CA, Zapata-Arriaza E, et al; CERES-TANDEM. Emergent carotid stenting for acute anterior circulation ischemic stroke with tandem lesions: the multicenter CERES-TANDEM study. *Neurology*. 2026;106(2):e214528. doi:10.1212/WNL.0000000000214528
4. Grigoryan M, Haussen DC, Hassan AE, et al. Endovascular treatment of acute ischemic stroke due to tandem occlusions: large multicenter series and systematic review. *Cerebrovasc Dis*. 2016;41(5-6):306-312. doi:10.1159/000444069
5. Pop R, Hasiu A, Mangin PH, et al. Postprocedural antiplatelet treatment after emergent carotid stenting in tandem lesions stroke: impact on stent patency beyond day 1. *AJNR Am J Neuroradiol*. 2021;42(5):921-925. doi:10.3174/ajnr.A6993
6. Wallocha M, Chapot R, Nordmeyer H, Fiehler J, Weber R, Stracke CP. Treatment methods and early neurologic improvement after endovascular treatment of tandem occlusions in acute ischemic stroke. *Front Neurol*. 2019;10:127. doi:10.3389/fneur.2019.00127