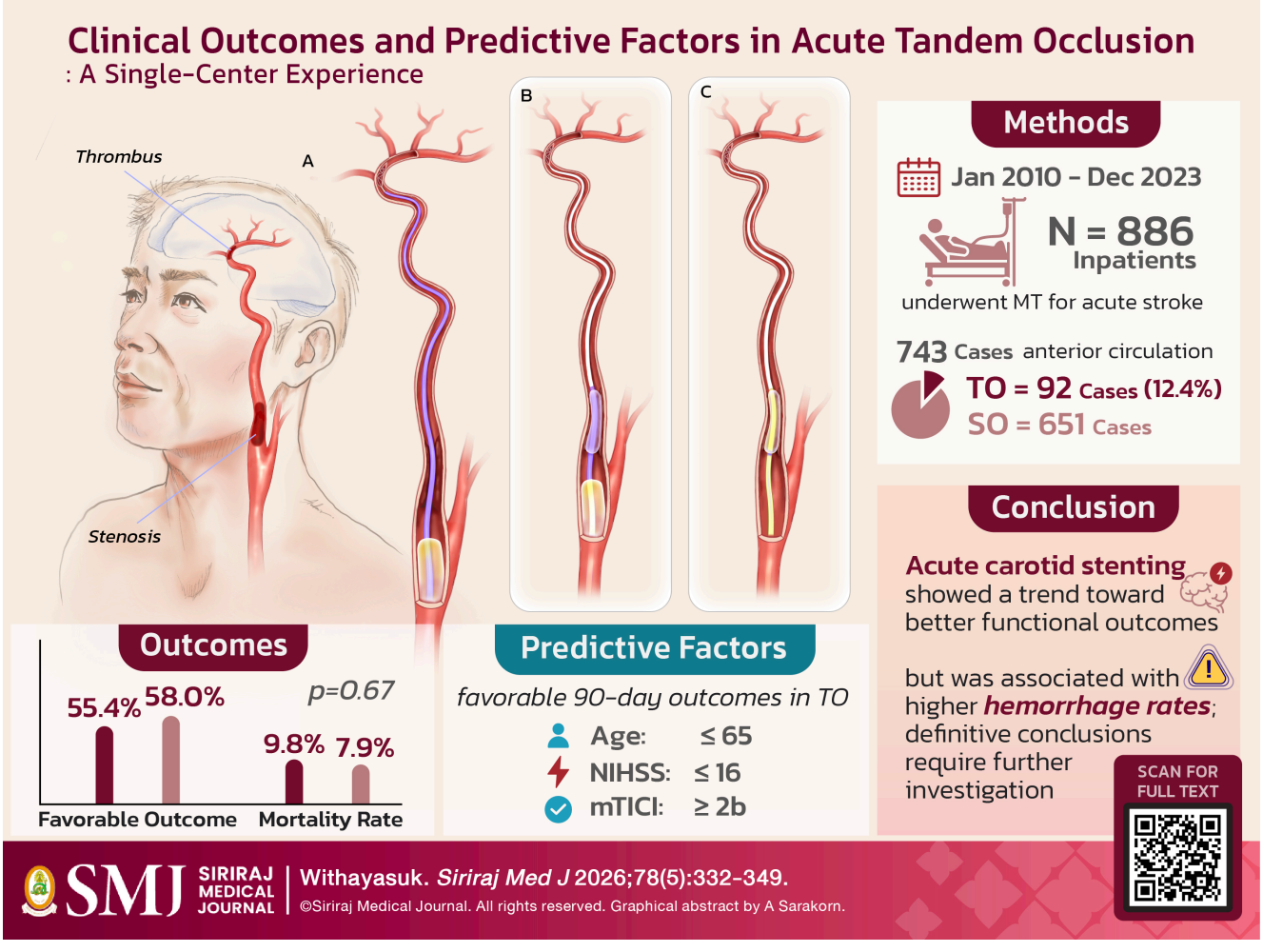
Clinical Outcomes and Predictive Factors in Acute Tandem Occlusion: A Single-Center Experience

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Received 28 October 2025 Revised 25 February 2026 Accepted 7 March 2026
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https://doi.org/10.33192/smj.v78i5.278546

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ABSTRACT

Objective: To evaluate treatment outcomes and analyze predictive factors associated with favorable outcomes in patients with acute tandem occlusion (TO) stroke who underwent mechanical thrombectomy (MT) at a single, high-volume center.

Materials and Methods: This retrospective study analyzed patients with anterior circulation stroke who underwent MT between January 2010 and December 2023. Ninety-two patients with TO, defined as severe stenosis (>70%) or occlusion of the cervical internal carotid artery (c-ICA) with concurrent intracranial occlusion, were identified. The primary endpoint was a favorable functional outcome (modified Rankin Scale [mRS] 0–2) at 90 days. Multivariate logistic regression was performed to identify independent predictors.

Results: Of 743 anterior circulation patients (651 single occlusion [SO], 92 TO [12.4%]), favorable outcomes were achieved in 55.4% of TO patients with a mortality rate of 9.8%, not significantly different from SO (58.0% favorable, 7.9% mortality; p=0.67) in unadjusted comparison. Multivariate analysis identified three independent predictors of favorable outcomes: age ≤65 years (OR 5.2, 95% CI 1.6–16.5, p=0.005), initial NIHSS ≤16 (OR 3.9, 95% CI 1.2–12.5, p=0.022), and successful recanalization (mTICI ≥2b) (OR 6.5, 95% CI 1.1–39.9, p=0.043).

Conclusion: MT for acute TO yields outcomes comparable to SO in unadjusted analysis. Age ≤65 years, lower initial NIHSS, and successful recanalization are key predictors of favorable outcomes. Acute carotid stenting showed a trend toward better functional outcomes but was associated with higher hemorrhage rates; definitive conclusions require further investigation.

Keywords: Tandem occlusion; mechanical thrombectomy; acute ischemic stroke; carotid stenting; clinical outcome; predictive factors (Siriraj Med J 2026;78(5):332-349)

INTRODUCTION

Approximately 10–20%[1–3] of individuals with large vessel occlusion (LVO) undergoing endovascular mechanical thrombectomy (MT) for anterior circulation acute ischemic stroke (AIS) present with tandem occlusion (TO). TO is defined as the simultaneous presence of severe stenosis (>70% based on NASCET criteria) or complete occlusion of the extracranial carotid artery, together with an ipsilateral intracranial vascular territory occlusion.[2]

TO is more prevalent in males than females (approximately 60% versus 40%)[4] and is associated with less favorable functional outcomes compared to single occlusion (SO). Management remains challenging due to limited inclusion of TO cases in randomized controlled MT trials[5] and the absence of definitive, guideline-based recommendations, particularly regarding acute stenting for severe stenosis or occlusion of c-ICA.[6–8] Recanalization strategies vary considerably, influenced by clinical considerations, anatomical factors, and physician preference.[9] Despite undergoing endovascular MT, individuals with tandem occlusion still experience high rates of disability and death.[8]

This study aims to examine the demographics, treatment strategies, and outcomes of TO patients undergoing mechanical thrombectomy at Siriraj Hospital. It further aims to analyze factors associated with favorable results and evaluate the safety, efficacy, and technical strategies employed during the intervention. While the primary clinical findings are consistent with those of major registries such as TITAN, ETIS, and ESCAPE-NA1, this study offers several distinct contributions: (1) a detailed procedural complication profile—including iatrogenic carotid-cavernous fistula and retinal artery occlusion—that has been underreported in prior registries; (2) clot pathology data showing a high prevalence of RBC-rich thrombi; and (3) geographic and practice-pattern diversity as one of the few reports from a high-volume center in Southeast Asia.[6–8,19,20] The ultimate goal is to provide evidence-based insights into the management of tandem occlusion cases to guide optimal management and improve overall patient outcomes.

MATERIALS AND METHODS

This retrospective study utilized data from the Siriraj Center of Interventional Radiology stroke registry, which includes patients who underwent MT at Siriraj Hospital. Data collected included demographic details, premorbid factors, and clinical parameters such as the NIHSS score at admission and discharge. Additionally, the study includes information on pre-interventional radiological studies, procedural variables, complications arising during the intervention, and functional outcomes assessed at 90-day follow-up.

Patients diagnosed with TO who underwent mechanical thrombectomy between January 2010 and December 2023 were included. Out of a total of 866 stroke patients, 92 were identified as having tandem occlusion and subsequently underwent MT. Tandem occlusion was defined as the simultaneous anterior circulation occlusion and ipsilateral severe stenosis (>70% stenosis) or occlusion of the c-ICA. Thorough data regarding baseline characteristics, comorbidities, safety outcomes, and clinical outcomes were collected. The investigation also assessed factors influencing safety and functional outcomes. Ethical approval was duly obtained from the regional ethics committee, and informed consent was secured from patients or their legal representatives.

It is important to acknowledge that the 14-year inclusion period (2010–2023) spans substantial changes in thrombectomy devices, imaging selection criteria, anesthesia practice, and post-procedural management protocols. During the earlier part of the study period, first-generation mechanical thrombectomy devices were predominantly used, whereas later years saw the adoption of newer-generation stent retrievers and large-bore aspiration catheters. Similarly, patient selection evolved with the increasing use of advanced imaging (e.g., CT perfusion) in later years.[19] These temporal changes may introduce confounding that should be considered when interpreting the results.

The Siriraj Protocol for Tandem Occlusion

The choice between antegrade and retrograde approaches was determined by the interventionalist based on the following criteria (Fig 1). The antegrade approach—in which the cervical ICA lesion was treated first before navigating to the intracranial occlusion—was preferred when the cervical ICA stenosis was deemed passable with standard devices (e.g., balloon angioplasty and/or carotid stenting) and when pre-procedural imaging suggested that the cervical lesion could be crossed safely without significant risk of dissection or perforation. The retrograde approach—in which the intracranial occlusion was addressed first by navigating through or bypassing the cervical ICA lesion—was chosen when the cervical ICA was completely occluded or when the operator judged that attempting cervical treatment first would unacceptably delay intracranial reperfusion. In cases where the cervical ICA could not be crossed, alternative access routes (e.g., contralateral ICA via anterior communicating artery) were considered. The primary objective in all cases was to achieve prompt reperfusion of the intracranial occlusion.

The recanalization procedure was carried out under either general anesthesia (GA) or local anesthesia (LA). Overall, GA was used in 91.3% of cases. During the earlier study period (2010–2015), both GA and LA were employed at the clinician's discretion, with LA selected in cases where rapid neurological assessment was prioritized or when anesthesia-related delays were a concern. From 2015 onward, the institutional protocol was standardized to GA for all mechanical thrombectomy procedures to optimize patient immobility and airway control during complex neurointerventional procedures. This transition accounts for the high overall proportion of GA in the cohort. Cerebral angiography and MT were conducted via femoral access. MT for intracranial lesions involved manual aspiration alone, the use of a stent retriever, or a combination of both techniques. Cervical ICA lesions were treated with percutaneous transluminal angioplasty and/or stenting.

For patients undergoing placement of a permanent stent (carotid stenting), Flat-paneled CT was performed beforehand to ensure the absence of intracranial hemorrhage. Regarding the timing of dual antiplatelet therapy (DAPT) relative to stenting: patients were administered either Eptifibatide (a glycoprotein IIb/IIIa inhibitor) intravenously during the procedure immediately prior to stent deployment, or an oral dual antiplatelet regimen (aspirin with clopidogrel or ticagrelor) via nasogastric tube intraoperatively. Stents used included Acculink® (Abbott, USA) and Wallstent® (Boston Scientific, USA). Post-stenting, systolic blood pressure was maintained between 100–140 mmHg for 72 hours, depending on final recanalization status and core infarction size. A follow-up brain CT was performed at 24 hours post-procedure. Once this follow-up imaging confirmed the absence of hemorrhagic complications, patients who had received only the glycoprotein IIb/IIIa inhibitor intraoperatively were transitioned to oral DAPT, which included aspirin (81 mg/day) along with either Clopidogrel (150 mg/day) or Ticagrelor (180 mg/day).

Stroke severity was assessed using the National Institutes of Health Stroke Scale (NIHSS) at both the preprocedural and post-procedural stages. The level of dependence or disability was assessed using the modified Rankin Scale (mRS) 90 days following mechanical thrombectomy.

Early signs of infarction were assessed using the Alberta Stroke Program Early CT Score (ASPECTS). The occlusion site was determined by computed tomography angiography (CTA) or magnetic resonance angiography (MRA). Collateral circulation was evaluated using multiphase CTA, and recanalization success post-MT was evaluated based on the modified Thrombolysis in Cerebral Infarction (mTICI) scale on the final digital subtraction angiography (DSA), with successful reperfusion defined as a mTICI score of 2b, 2c, or 3.

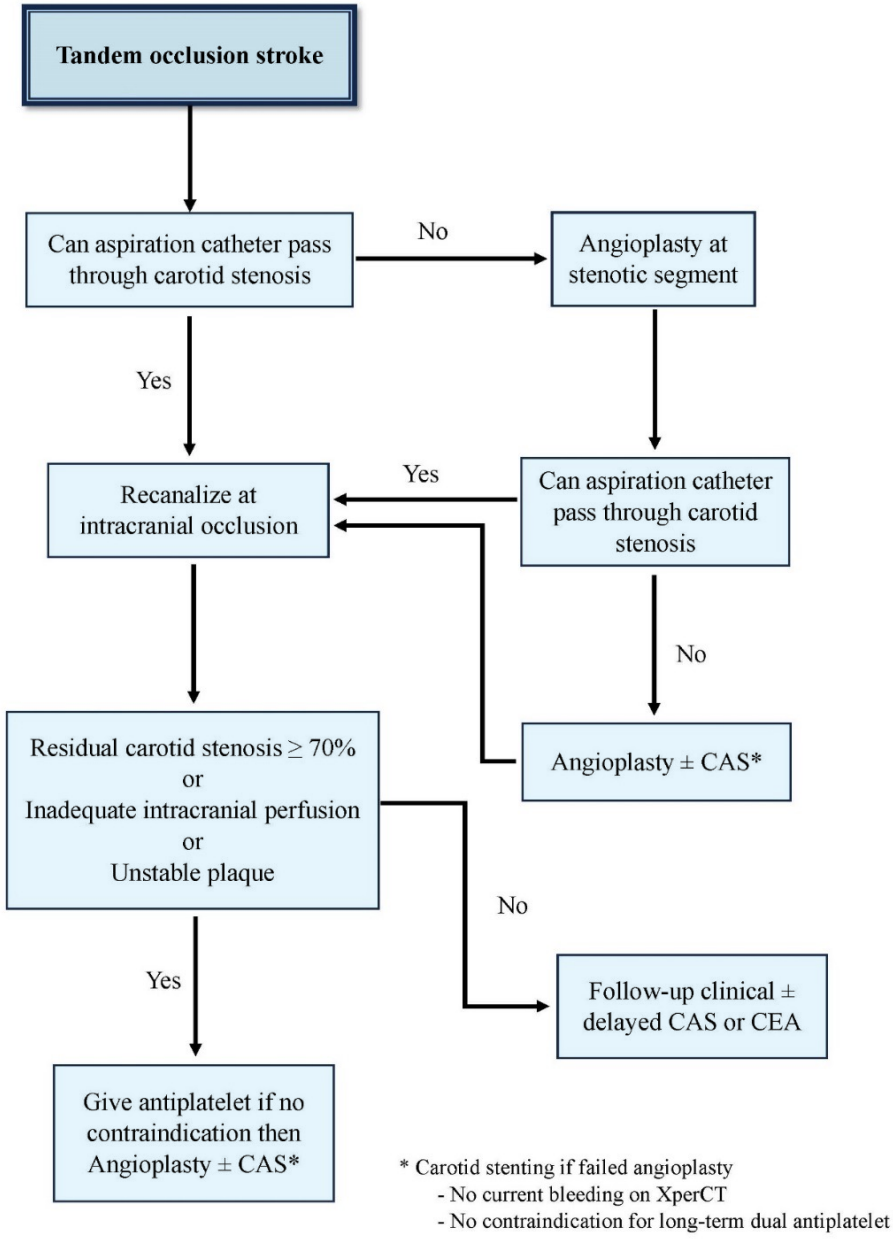


Fig 1. Siriraj treatment protocol for acute tandem occlusion stroke.
Abbreviations: CAS = Carotid artery stenting, CEA = Carotid endarterectomy

Intracranial hemorrhage was classified according to the Heidelberg Bleeding Classification (HBC). Symptomatic intracranial hemorrhage (sICH) was defined as a ≥4-point worsening in NIHSS attributable to hemorrhage.[10]

Statistical analyses

Statistical analyses were performed using SPSS version 26.0. Continuous variables were summarized as mean and standard deviation (SD), and categorical variables as frequency (percentage). Bivariate analyses were conducted using the χ^2 or Fisher's exact test, as appropriate. Binary logistic regression was utilized with favorable functional outcomes as the dependent variable. Variables with a p-value <0.05 in bivariate analyses were entered into a multivariate logistic regression model.

Limitations of statistical comparisons: Given the retrospective, observational design and the relatively small sample size (n=92 for TO), the comparisons between tandem and single occlusion, acute stenting versus no stenting/delayed treatment, and antegrade versus retrograde approaches are descriptive and unadjusted. No propensity-score matching or multivariable adjustment was performed for these subgroup comparisons. Consequently, statements regarding comparability of outcomes between

groups should be interpreted with caution, as residual confounding and limited statistical power may affect the findings.

The study was approved by the Regional Ethics Committee of Siriraj Hospital, Mahidol University. Written informed consent was obtained from each patient or their legally authorized representative.

RESULTS

During the study period, 866 patients underwent MT for acute stroke, of whom 743 had anterior circulation medium or large vessel occlusion (651 with single occlusion and 92 with tandem occlusion). Ninety-two patients met the criteria for TO (Fig 2). The most common lesion locations were left-sided occlusion (52 patients, 56.5%), cervical ICA (52, 56.5%), and M1 segment (71, 77.2%). The mean age of TO patients (Table 1) was 68.88±12.89 years, and 62 patients (67.4%) were male. Comorbidities included diabetes mellitus in 25 patients (27.2%), hypertension in 52 (56.5%), dyslipidemia in 31 (33.7%), atrial fibrillation in 24 (26.1%), coronary disease in 13 (14.1%), previous or current smoking in 30 (32.6%), and prior stroke or TIA in 13 (14.1%). Median NIHSS score on presentation was 17 (IQR 2–28), and 59.8% received rt-PA. Upon imaging examination, median ASPECTS was 8 (IQR 5–10), and the most frequent collateral score was 4 (59.8%).

Mechanical thrombectomy was performed under general anesthesia in 91.3% of cases, using either anterograde or retrograde approaches. Successful recanalization (mTICI ≥ 2b) was achieved in 85.9% of patients. The most common intracranial technique for reperfusion was manual aspiration alone, accounting for 41.3% of cases, followed by a combination of manual aspiration plus stent retriever at 29.3%, stent retriever alone at 18.5%, and the Solumbra technique at 10.9%.

In the management of cervical internal carotid artery, angioplasty was required in 26.1% of cases, angioplasty with primary stenting in 19.6%, and primary stenting alone in 2.2%. Notably, 52.1% of cervical ICA lesions were managed conservatively during the index procedure. In this context, "conservative" management refers to cases where no acute intervention was performed on the cervical ICA during the thrombectomy procedure itself; however, this did not necessarily mean permanent non-intervention. Among these conservatively managed patients, some had spontaneous recanalization of the cervical ICA following intracranial thrombectomy, some had residual stenosis that was deemed hemodynamically non-significant during the acute phase, and others were planned for delayed carotid treatment (CEA or CAS) within 90 days after clinical stabilization. The average time from puncture-to-recanalization was 54.70±51.39 minutes, while the mean onset-to-recanalization time was 337.31±184.61 minutes.

A favorable outcome, defined as a modified Rankin Scale (mRS) score of 0–2 at 90 days post mechanical

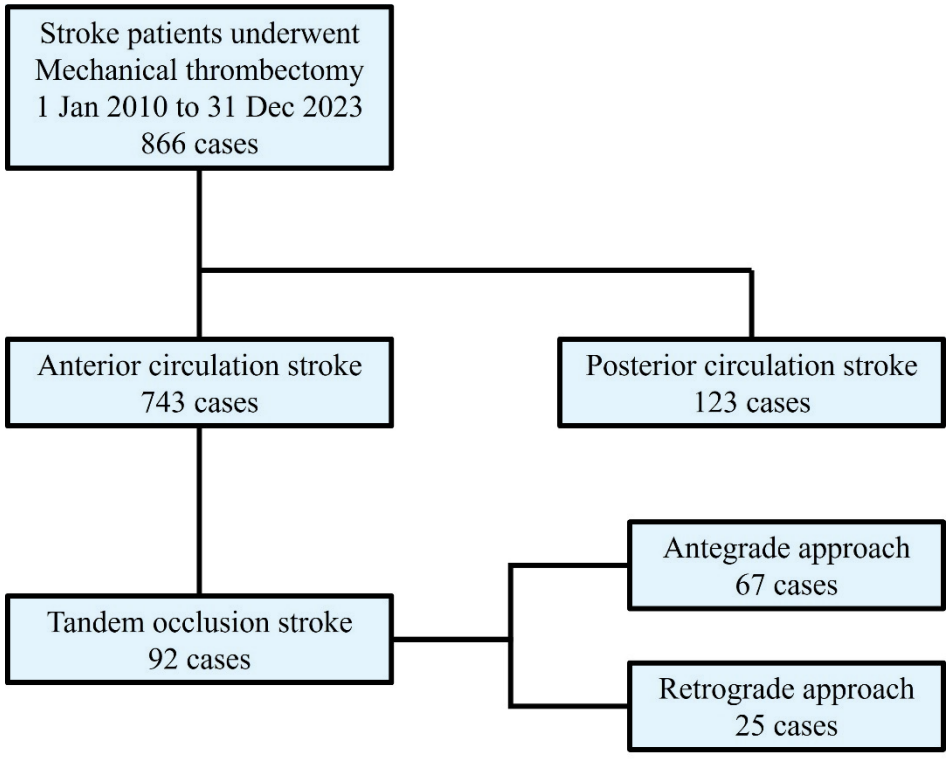


Fig 2. Study flowchart.

TABLE 1. Baseline characteristics of patients with acute tandem occlusion stroke.

Characteristic	Tandem occlusion (N=92)
Age, years	68.88±12.89
Gender	
Male	62 (67.4%)
Female	30 (32.6%)
Comorbidities	
Diabetes mellitus	25 (27.2%)
Hypertension	52 (56.5%)
Dyslipidemia	31 (33.7%)
Atrial fibrillation	24 (26.1%)
Coronary disease	13 (14.1%)
Previous or current smoking	30 (32.6%)
Previous stroke or TIA	13 (14.1%)
Received intravenous rt-PA	55 (59.8%)
NIHSS	
Initial	17 (2-28)
Post mechanical thrombectomy	7 (0-32)
ASPECT	8 (5-10)
Collateral score	
3	11 (12.0%)
4	55 (59.8%)
5	21 (22.8%)
No evaluation	5 (5.4%)
Left side occlusion	52 (56.5%)
Location of occlusions	
C-ICA and M1	71 (77.2%)
C-ICA and M2	6 (6.5%)
C-ICA and intracranial ICA	8 (8.7%)
CCA and M1	5 (5.4%)
CCA and intracranial ICA	2 (2.2%)
Puncture to recanalization, mins	54.70±51.39
Onset to recanalization, mins	337.31±184.61
Successful recanalization (mTICI 2b-3)	79 (85.9%)
Anesthesia	
General anesthesia	84 (91.3%)
Local anesthesia	8 (8.7%)
Cervical ICA pathology	
Atherosclerosis	79 (85.9%)
Dissection	13 (14.1%)

TABLE 1. Baseline characteristics of patients with acute tandem occlusion stroke. (Continue)

Characteristic	Tandem occlusion (N=92)
Approach technique	
Antegrade	67 (72.8%)
Retrograde	25 (27.2%)
Acute cervical ICA treatment	
PTBA	24 (26.1%)
PTBA with CAS	18 (19.6%)
CAS only	2 (2.2%)
Conservative	48 (52.1%)
Intracranial occlusion treatment	
Manual aspiration	38 (41.3%)
Stent retriever	17 (18.5%)
Solumbra technique	10 (10.9%)
Manual aspiration and stent retriever	27 (29.3%)
Favorable outcome at 90 days (mRS 0-2)	51 (55.4%)
Symptomatic ICH	4 (4.3%)
Mortality rate	9 (9.8%)
Delayed cervical ICA treatment within 90 days	
Carotid endarterectomy	4 (4.3%)
Carotid stenting	9 (9.8%)
Antiplatelet/Anticoagulant	
Aspirin	65 (70.7%)
Ticagrelor	15 (16.3%)
Clopidogrel	28 (30.4%)
Warfarin	11 (11.9%)
Dual antiplatelet/anticoagulant	44 (47.8%)

Abbreviations: TIA = Transient ischemic attack, rt-PA = Recombinant Tissue Plasminogen Activator, NIHSS = National Institutes of Health Stroke Scale, ASPECT = Alberta Stroke Program Early CT Score, C-ICA = cervical segment of internal carotid artery, ICA = internal carotid artery, CCA = common carotid artery, mTICI = Modified Treatment in Cerebral Ischemia score, PTBA = percutaneous transluminal balloon angioplasty, CAS = Carotid artery stenting, mRS = modified Rankin Scale, ICH = intracranial hemorrhage

thrombectomy, was achieved in 55.4% of patients. The mortality rate was 9.8%, and symptomatic intracranial hemorrhage (ICH) occurred in 4.3% of cases. Importantly, outcomes following mechanical thrombectomy for tandem occlusion did not differ significantly from those for single occlusion cases (p=0.67), Fig 3; however, this comparison is unadjusted and should be interpreted with caution given potential confounders and limited power. A formal comparison of baseline characteristics between the TO and SO groups was not performed in the current study; this limitation is acknowledged in the Limitations section, and we recognize that baseline imbalances may have influenced the observed similarity in outcomes.

Most collected clot pathologies were characterized as RBC-rich (red clots), constituting 89% of cases. This high proportion of RBC-rich clots is noteworthy, as RBC-rich thrombi are classically associated with cardioembolic or stasis-related mechanisms—such as thrombi formed in the cardiac chambers in the setting of atrial fibrillation—rather than platelet-rich (white) thrombi typically seen in local arterial atherothrombosis. In our cohort, 26.1%

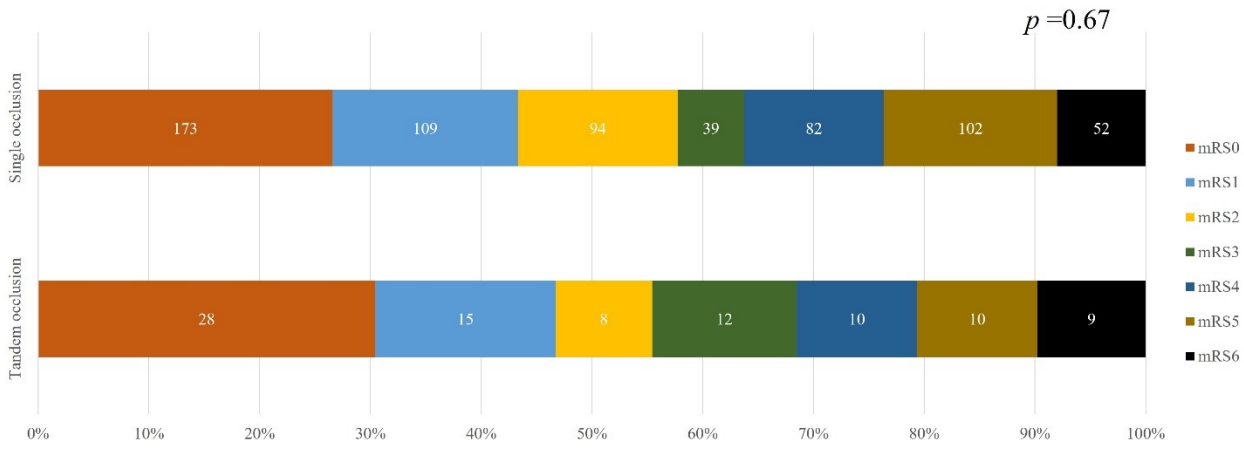


Fig 3. Functional outcomes at 90 days after mechanical thrombectomy: comparison between tandem occlusion and single occlusion.
Abbreviation: mRS = modified Rankin Scale

of patients had atrial fibrillation, which aligns with this finding and suggests that a substantial proportion of intracranial occlusions in TO may represent cardioembolism superimposed on pre-existing carotid atherosclerosis, rather than local propagation of carotid thrombus. This dual pathological mechanism has implications for both acute management (anticoagulation strategy) and long-term secondary prevention.[20]

Thirteen patients (14.1%) scheduled appointments for delayed cervical ICA treatment within 90 days post mechanical thrombectomy, with carotid endarterectomy (CEA) performed in 4.3% of cases and carotid artery stenting (CAS) in 9.8% of cases. The average length of hospital stay was approximately 10.9±10.4 days.

Among the nine deaths recorded, the causes varied and encompassed a range of complications and medical conditions, including two cases of periprocedural complications occurring after the completion of thrombectomy (within 24 hours) that led to intracerebral hemorrhage. Additionally, sequelae from poor recanalization in two cases resulted in the subsequent development of malignant brain infarction. Cardiac complications were also identified as the cause of death in two cases (one patient experienced immediate postoperative cardiac arrest of unknown cause, while another suffered acute myocardial infarction 72 hours post MT). In-hospital infections also played a role in mortality in two cases (acute pyelonephritis and COVID-19 pneumonia). One case presented with hemorrhagic shock, and the precise point of bleeding could not be defined, ultimately exacerbating progressive brain swelling.

Procedural complications were classified as intraprocedural or post-procedural. During MT, six patients sustained puncture site injuries, and three developed iatrogenic CCF, which fortunately resolved spontaneously. Ischemic events were observed, including six cases of distal emboli, one central retinal artery occlusion, and one branch retinal artery occlusion. Additionally, three patients suffered from malignant MCA infarction post-MT.

When comparing outcomes between TO and SO following mechanical thrombectomy (Fig 3), no statistically significant differences were observed (p=0.67). In the SO group, favorable outcomes occurred in 58% of cases with a mortality rate of 7.9%, while in the TO group, favorable outcomes were noted in 55% of cases with a mortality rate of 9.8%. These unadjusted comparisons should be interpreted cautiously, as baseline differences between groups may have influenced the observed outcomes. Detailed baseline characteristics of the SO group were not available for direct comparison in the current study design; this is acknowledged as a limitation.

Regarding procedural approach (Table 2), 67 patients underwent the antegrade method and 25 the retrograde method. No significant difference in age was observed between the antegrade and retrograde groups (69.06±12.95 vs. 67.68±13.05 years, p=0.65). No significant differences were observed in successful recanalization rates (86.6% vs. 84.0%, p=0.75), puncture-to-recanalization time (55.02±49.42 vs. 50.94±48.59 min, p=0.76), or symptomatic intracranial hemorrhage (4.5% vs. 4.0%, p=0.92). Occlusion sites were mainly the cervical ICA and M1 segment in both groups. No significant differences were found between groups regarding comorbidities, pre-stroke mRS (p=0.49), initial NIHSS (p=0.65), left occlusion side (p=0.59), ASPECTS (p=0.73), and good collateral

TABLE 2. Comparison of treatment strategies for acute tandem occlusion stroke.

Characteristic (N=92)	Strategies		*p* value
	Antegrade (N=67)	Retrograde (N=25)	
Gender			
Male	44 (65.7%)	18 (72.0%)	0.57
Female	23 (34.3%)	7 (28.0%)	
Age, years	69.06±12.95	67.68±13.05	0.65
Comorbidities			
Diabetes mellitus	20 (29.9%)	5 (20.0%)	0.35
Hypertension	40 (59.7%)	12 (48.0%)	0.31
Dyslipidemia	21 (31.3%)	10 (40.0%)	0.44
Atrial fibrillation	18 (26.9%)	6 (24.0%)	0.78
Coronary disease	11 (16.4%)	2 (8.0%)	0.30
Previous or current smoking	20 (29.9%)	10 (40.0%)	0.36
Previous stroke or TIA	11 (16.4%)	2 (8.0%)	0.30
Pre-stroke mRS at 90 days			
0	57 (85.1%)	24 (96.0%)	
1	5 (7.5%)	1 (4.0%)	0.49
2	1 (1.5%)	0	
3	4 (5.9%)	0	
Initial NIHSS	17 (2-28)	18 (6-26)	0.65
ASPECTS	8 (5-10)	8 (5-10)	0.73
IV rt-PA	40 (59.7%)	15 (60.0%)	0.98
Good collateral score	56 (83.6%)	20 (80.0%)	0.95
Location			
C-ICA, M1	51 (76.1%)	20 (80.0%)	
C-ICA, M2	5 (7.5%)	1 (4.0%)	
C-ICA, intracranial ICA	4 (5.9%)	4 (16.0%)	0.46
CCA, M1	5 (7.5%)	0	
CCA, intracranial ICA	2 (3.0%)	0	
Left side occlusion	39 (58.2%)	13 (52.0%)	0.59
Cervical ICA pathology			
Dissection	8 (11.9%)	5 (20.0%)	0.32
Atherosclerosis	59 (88.1%)	20 (80.0%)	
Cervical ICA stenosis/occlusion			
100%	30 (44.8%)	10 (40.0%)	0.68
70-99%	37 (55.2%)	15 (60.0%)	

TABLE 2. Comparison of treatment strategies for acute tandem occlusion stroke. (Continue)

Characteristic (N=92)	Strategies		*p* value
	Antegrade (N=67)	Retrograde (N=25)	
Successful recanalization (mTICI ≥ 2b)	58 (86.6%)	21 (84.0%)	0.75
Puncture to recanalization, minutes	55.02±49.42	50.94±48.59	0.76
Onset to recanalization, minutes	349.40±184.47	316.77±172.90	0.55
Anesthesia			
GA	63 (94.0%)	21 (84.0%)	0.13
LA	4 (6.0%)	4 (16.0%)	
Antiplatelet/Anticoagulant			
Aspirin	46 (68.7%)	19 (76.0%)	0.49
Ticagrelor	10 (14.9%)	5 (20.0%)	0.56
Clopidogrel	20 (29.9%)	8 (32.0%)	0.84
Warfarin	9 (13.4%)	2 (8.0%)	0.48
Cervical ICA treatment within 90 days			
Stenting or CEA	24 (35.8%)	9 (36.0%)	0.99
Non-Stenting	43 (64.2%)	16 (64.0%)	
Symptomatic ICH	3 (4.5%)	1 (4.0%)	0.92
Length of hospital stay, days	7 (3-47)	7 (5-55)	0.14
Clot pathology			
RBC-rich	60 (89.6%)	22 (88.0%)	0.83
Fibrin-rich	7 (10.4%)	3 (12.0%)	

Abbreviations: TIA = Transient ischemic attack, mRS = modified Rankin Scale, NIHSS = National Institutes of Health Stroke Scale, ASPECT = Alberta Stroke Program Early CT Score, IV rt-PA = Intravenous Recombinant Tissue Plasminogen Activator, C-ICA = cervical segment of internal carotid artery, ICA = internal carotid artery, CCA = common carotid artery, mTICI = Modified Treatment in Cerebral Ischemia score, GA = General anesthesia, LA = Local anesthesia, CEA = Carotid endarterectomy, ICH = intracranial hemorrhage

score (p=0.95). Furthermore, post-MT treatment with antiplatelet or anticoagulant therapy did not significantly differ between the groups.

For patients with tandem occlusion stroke, 13 underwent extracranial carotid treatment within 90 days. Among the 79 patients analyzed, acute carotid stenting was performed in 20 cases, while 59 were managed without stenting. Favorable functional outcomes at 90 days (Fig 4) were numerically more frequent in the stenting group (65% vs 46%), although the difference was not statistically significant (p=0.15). The mortality rate associated with acute carotid stenting was 15%, with causes including malignant brain edema resulting from infarction (n=1), intracerebral hemorrhage (n=1), and cardiac arrest due to unknown arrhythmia (n=1). Intracranial hemorrhage occurred significantly more often in the stenting group (p=0.01), although the incidence of symptomatic ICH did not differ significantly (p=0.99). These findings should be interpreted with caution given the small subgroup sizes and absence of adjusted analyses.

Comparing acute carotid stenting with delayed carotid treatment within 90 days after mechanical thrombectomy, no significant differences were observed in successful recanalization (p=0.75), favorable outcomes (p=0.22), or symptomatic ICH (p=0.41).

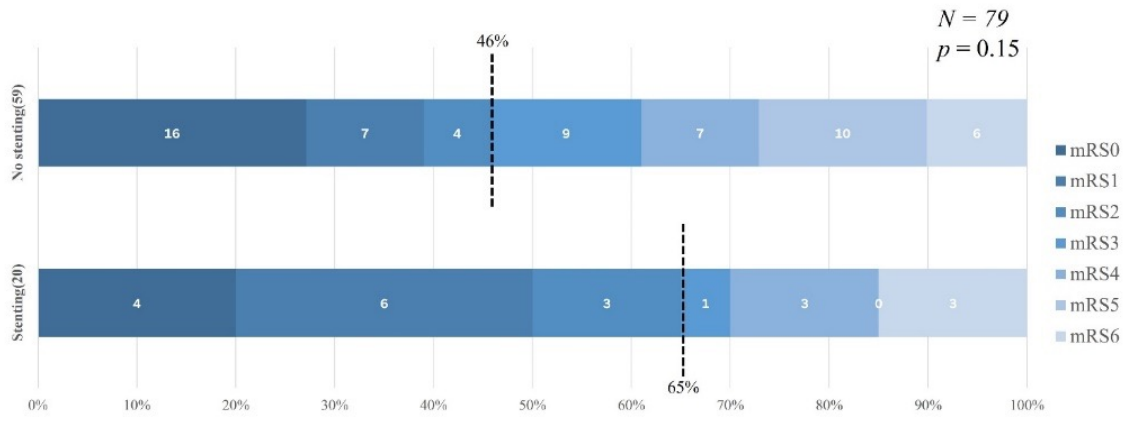


Fig 4. Functional outcomes at 90 days after mechanical thrombectomy: comparison between acute carotid stenting and non-carotid stenting.
Abbreviation: mRS = modified Rankin Scale

TABLE 3. Procedure-related complications.

Intraprocedural complications	Post procedural complications
Access site	Neurological complication
4 Groin hematoma	3 Malignant MCA territory infarction
2 Groin pseudoaneurysm	3 Symptomatic ICH
Vascular injury	17 Asymptomatic ICH/SAH
3 Carotid-cavernous fistula	
Hemorrhagic	
1 Asymptomatic SAH	
1 Symptomatic ICH	
Ischemic	
6 Distal territory emboli	
3 Femoral artery emboli	
1 CRAO	
1 BRAO	

Abbreviations: SAH = Subarachnoid hemorrhage, ICH = Intracranial hemorrhage, CRAO = Central retinal artery occlusion, BRAO = Branch retinal artery occlusion, MCA = Middle cerebral artery

The primary outcome of the study was the 90-day mRS score, with favorable outcomes achieved in 51 cases (Table 4). There were notable differences between this group and the remaining 41 cases regarding gender (p=0.004), age (p<0.001), atrial fibrillation (p=0.04), left side occlusion (p=0.04), and initial NIHSS scores (p<0.001). Furthermore, treatment-related parameters such as cervical ICA treatment within 90 days (p=0.01), successful recanalization (p=0.004), and the administration of dual antiplatelet therapy post MT (p=0.02) varied significantly between the groups. The incidence of symptomatic ICH was higher in the poor outcome group (p=0.04), along with a significantly longer length of hospital stay (p<0.001).

Subgroup analysis with univariate logistic regression identified potential predictors of favorable outcomes at 90 days: male gender, age ≤ 65 years, absence of atrial fibrillation, initial NIHSS score ≤ 16, right-side occlusion, successful recanalization, cervical carotid treatment within 90 days, and dual antiplatelet therapy post MT. Multivariate logistic regression confirmed three independent predictors of favorable outcomes: age ≤ 65 years (p=0.005, OR 5.2, 95% CI 1.6–16.5), initial NIHSS score ≤ 16 (p=0.022, OR 3.9, 95% CI 1.2–12.5),

TABLE 4. Ninety-day functional outcomes after mechanical thrombectomy in acute tandem occlusion stroke.

Characteristic (N=92)	Outcome		*p* value
	Favorable outcome (N=51)	Poor outcome (N=41)	
Gender			
Male	41 (80.4%)	21 (51.2%)	0.004*
Female	10 (19.6%)	20 (48.8%)	
Age, years	63.75±13.03	75.27±12.95	<0.001*
Comorbidities			
Diabetes mellitus	10 (19.6%)	15 (36.6%)	0.77
Hypertension	27 (52.9%)	25 (60.9%)	0.45
Dyslipidemia	20 (39.2%)	11 (26.8%)	0.21
Atrial fibrillation	9 (17.6%)	15 (36.6%)	0.04*
Coronary disease	7 (13.7%)	6 (14.6%)	0.90
Previous or current smoking	20 (39.2%)	10 (24.4%)	0.13
Previous stroke or TIA	7 (13.7%)	6 (14.6%)	0.90
Pre-stroke mRS			
0	48 (94.0%)	33 (80.5%)	
1	1 (2.0%)	5 (12.2%)	0.14
2	1 (2.0%)	0	
3	1 (2.0%)	3 (7.3%)	
Initial NIHSS	16 (2-26)	17 (9-28)	<0.001*
ASPECT	8 (5-10)	8 (5-10)	0.58
IV rt-PA	32 (62.7%)	23 (56.1%)	0.52
Good collateral score	46 (90.2%)	30 (73.2%)	0.13
Location			
C-ICA, M1	41 (80.4%)	30 (73.2%)	
C-ICA, M2	5 (9.8%)	1 (2.4%)	
C-ICA, intracranial ICA	3 (5.9%)	5 (12.2%)	0.12
CCA, M1	2 (3.9%)	3 (7.3%)	
CCA, intracranial ICA	0	2 (4.9%)	
Left side occlusion	24 (47.1%)	28 (68.3%)	0.04*
Cervical ICA pathology			
Dissection	7 (13.7%)	6 (14.6%)	0.90
Atherosclerosis	44 (86.3%)	35 (85.4%)	
Cervical ICA stenosis/occlusion			0.30
100%	17 (33.3%)	23 (56.1%)	
70-99%	34 (66.7%)	18 (43.9%)	
Successful recanalization (mTICI ≥ 2b)	49 (96.1%)	30 (73.2%)	0.004*
Puncture to recanalization, minutes	46.26±51.09	65.65±51.03	0.10
Onset to recanalization, minutes	348.49±186.31	332.24±185.62	0.51

TABLE 4. Ninety-day functional outcomes after mechanical thrombectomy in acute tandem occlusion stroke. (Continue)

Characteristic (N=92)	Outcome		*p* value
	Favorable outcome (N=51)	Poor outcome (N=41)	
Anesthesia			
GA	46 (90.2%)	38 (92.7%)	0.68
LA	5 (9.8%)	3 (7.3%)	
Technique			
Antegrade	37 (72.5%)	30 (73.2%)	0.95
Retrograde	14 (27.5%)	11 (26.8%)	
Cervical ICA treatment within 90 days			
Stenting or CEA	24 (47.1%)	9 (21.9%)	0.01*
Non-Stenting	27 (52.9%)	32 (78.1%)	
Dual antiplatelet post MT	30 (58.8%)	14 (34.1%)	0.02*
Symptomatic ICH	0	4 (9.7%)	0.04*
Length of hospital stay, day	7 (3-18)	7 (1-55)	<0.001*
Clot pathology			
RBC-rich	46 (90.2%)	36 (87.8%)	0.72
Fibrin-rich	5 (9.8%)	5 (12.2%)	

Abbreviations: TIA = Transient ischemic attack, mRS = modified Rankin Scale, NIHSS = National Institutes of Health Stroke Scale, ASPECT = Alberta Stroke Program Early CT Score, IV rt-PA = Intravenous Recombinant Tissue Plasminogen Activator, C-ICA = cervical segment of internal carotid artery, ICA = internal carotid artery, CCA = common carotid artery, mTICI = Modified Treatment in Cerebral Ischemia score, GA = General anesthesia, LA = Local anesthesia, CEA = Carotid endarterectomy, MT = mechanical thrombectomy, ICH = intracranial hemorrhage

TABLE 5. Univariate and multivariate analyses of predictors of favorable outcomes.

Characteristic	Univariate		Multivariate	
	p value	Odds ratio (95%CI)	*p* value	Odds ratio (95%CI)
Gender, male	0.004*	3.9 (1.55-9.83)	0.284	2.0 (0.57-6.91)
Age ≤ 65 years	<0.001*	5.5 (2.21-13.46)	0.005*	5.2 (1.67-16.53)
Atrial fibrillation	0.043*	0.4 (0.14-0.97)	0.728	0.8 (0.2-3.03)
Initial NIHSS ≤ 16	0.004*	3.6 (1.52-8.65)	0.022*	3.9 (1.22-12.81)
Left side occlusion	0.043*	0.4 (0.18-0.97)	0.357	0.6 (0.18-1.85)
Successful recanalization (mTICI ≥ 2b)	0.006*	9.0 (1.86-43.34)	0.043*	6.5 (1.06-39.41)
Cervical carotid treatment within 90 days	0.014*	3.2 (1.26-7.94)	0.373	1.7 (0.53-5.49)
Dual antiplatelet post MT	0.020*	2.8 (1.17-6.47)	0.824	1.1 (0.36-3.66)

Abbreviations: CI = confidence interval, NIHSS = National Institutes of Health Stroke Scale, mTICI = Modified Treatment in Cerebral Ischemia score, MT = mechanical thrombectomy bral Ischemia score, MT = mechanical thrombectomy

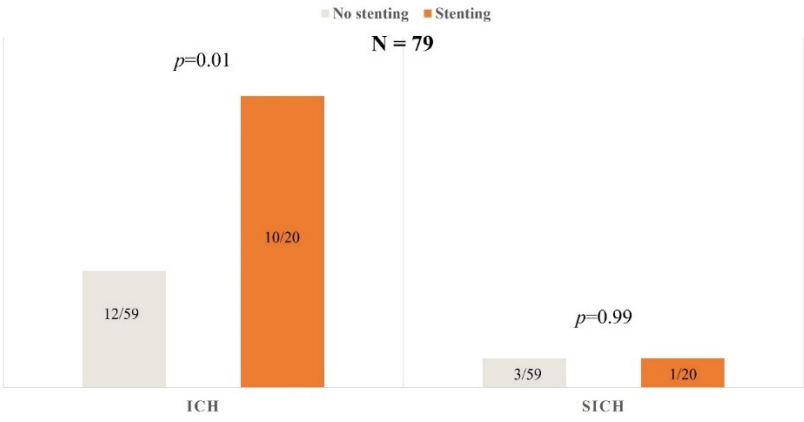


Fig 5. Procedural-related hemorrhage between acute carotid stenting and non-stenting.
Abbreviations: ICH = intracranial hemorrhage, SICH = symptomatic hemorrhage

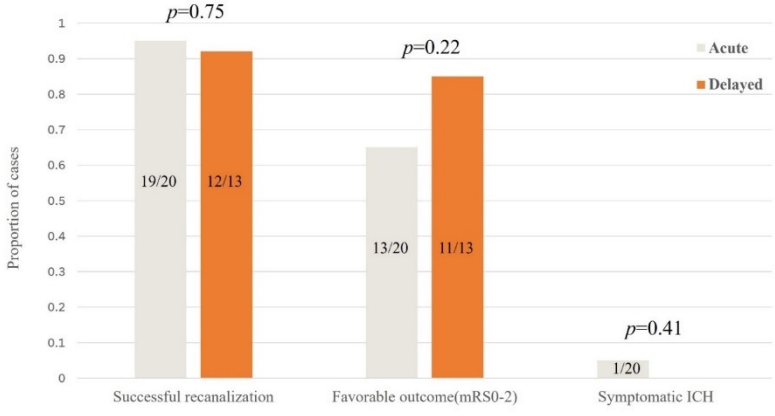


Fig 6. Comparison of acute carotid stenting and delayed cervical ICA treatment in successful recanalization, favorable outcomes and symptomatic ICH.
Abbreviations: ICA = Internal carotid artery, mRS = modified Rankin Scale, ICH = Intracranial hemorrhage

and successful recanalization (p=0.043, OR 6.5, 95% CI 1.1–39.9) (Table 5). The complete multivariate results for all variables, including those that did not reach statistical significance, are presented in Table 5.

DISCUSSION

Tandem occlusion in acute stroke did not significantly decrease the likelihood of a favorable outcome compared with single occlusion cases in unadjusted analysis. Predictive factors for favorable outcomes 90 days after treatment included age ≤ 65 years old, initial NIHSS ≤ 16, and successful recanalization (mTICI ≥ 2b). These predictors are consistent with those reported in multiple prior tandem occlusion cohorts and registries[1,4,7,8], providing confirmatory evidence from a high-volume Southeast Asian center. The Siriraj protocol for mechanical thrombectomy in tandem occlusion emphasizes rapid intracranial reperfusion to minimize infarction progression, although extracranial carotid artery access was often technically challenging. Notably, the study found no significant difference in time from puncture to recanalization between antegrade and retrograde approaches, with both methods yielding comparable outcomes and rates of symptomatic ICH.

Novelty and added value of this study: While the primary outcome findings align with those of major registries (TITAN, ETIS, ESCAPE-NA1), this study offers several distinct contributions. First, it provides a detailed procedural complication profile, including three cases of iatrogenic carotid-cavernous fistula (CCF) associated with cavernous ICA tortuosity type III, a complication that has been underreported in the tandem occlusion literature. Second, the high prevalence of RBC-rich clot pathology (89%) is noteworthy and adds to the limited data available on clot composition in tandem occlusion, supporting a cardioembolic mechanism in a substantial proportion of cases. Third, this is one of the few single-center reports from Southeast Asia with a substantial sample size, contributing geographic and practice-pattern diversity to a field dominated by Western and European registries.[6–8,19–22]

The ESCAPE-NA1 trial[7] reported a notable contrast in 90-day favorable outcomes between tandem occlusion and non-tandem occlusion cases, with rates of 71.3% and 59.5%, respectively. However, our study observed similar favorable outcomes across both groups. In the context of carotid stenosis during mechanical thrombectomy, many cases involved acute carotid stenting. Previous research[6,7,11] has highlighted the favorable impact of this approach, reporting superior 90-day outcomes ranging from 56.6% to 75.8%, alongside reduced mortality rates

Subgroup	OR	95% CI		*P* value
Gender				
Male	3.9	1.55	9.83	0.004
Female	0.3	0.10	0.65	
Age				
≤ 65 yr	5.5	2.21	13.46	<0.001
> 65 yr	0.2	0.07	0.45	
Atrial fibrillation				
Yes	0.4	0.14	0.97	0.04
No	2.7	1.03	7.03	
Initial NIHSS				
≤ 16	3.6	1.52	8.65	0.004
> 16	0.3	0.12	0.66	
Occlusion side				
Right	2.4	1.03	5.71	0.04
Left	0.4	0.18	0.97	
Collateral score				
Good	1.8	0.52	6.57	0.35
Intermediate	0.6	0.18	2.25	0.48
ASPECT				
8-10	1.0	0.45	2.41	0.92
5-7	1.0	0.42	2.21	
Technique				
Antegrade approach	0.9	0.38	2.44	0.95
Retrograde approach	1.0	0.41	2.60	
Recanalization				
mTICI 2b to 3	9.0	1.86	43.34	0.006
mTICI 0 to 2a	0.1	0.02	0.54	
C-ICA treatment within 90 days				
Stenting or CEA	3.2	1.26	7.94	0.01
No treatment	0.3	0.13	0.79	
Dual antiplatelet post MT				
Yes	2.8	1.17	6.47	0.02
No	0.4	0.16	0.85	

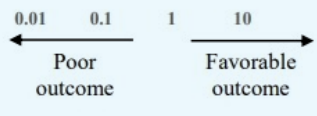


Fig 7. Univariate logistic regression for subgroup analysis of factors associated with 90-day favorable outcomes.
Abbreviations: OR = Odds ratio, 95%CI = 95% confidence interval, NIHSS = National Institutes of Health Stroke Scale, ASPECT = Alberta Stroke Program Early CT Score, mTICI = Modified Treatment in Cerebral Ischemia score, C-ICA = cervical segment of internal carotid artery, CEA = Carotid endarterectomy, MT = Mechanical thrombectomy

ranging from 6.5% to 11.6%. In our study, a numerically higher rate of favorable outcomes was observed in the acute stenting group compared to those without stenting (65% vs. 46%); however, this difference did not reach statistical significance (p=0.15). Importantly, the acute stenting group also exhibited a higher mortality rate (15%) and a significantly higher rate of any intracranial hemorrhage (p=0.01), although symptomatic ICH rates were similar (p=0.99). These findings do not allow us to conclude that acute stenting is definitively safe or beneficial, and the observed trends should be validated in larger, adequately powered studies with appropriate adjustment for confounders.

Stenting and mortality: The higher mortality rate in the acute stenting group (15% vs. 10.2% in the non-stenting group) warrants further discussion. Among the three deaths in the stenting group, one was attributed to intracerebral hemorrhage. The significantly higher rate of any intracranial hemorrhage in the stenting group (p=0.01) likely reflects the need for periprocedural antiplatelet therapy (glycoprotein IIb/IIIa inhibitors or oral DAPT) administered during the acute phase of infarction, which may increase hemorrhagic risk. This relationship between acute stenting, early antiplatelet administration, and hemorrhagic complications has been noted in previous studies.[11,12] However, the other two deaths in the stenting group (malignant brain edema and cardiac arrest from unknown arrhythmia) were

not directly related to hemorrhage, suggesting that the higher mortality may be multifactorial rather than solely attributable to stenting-related hemorrhage. These observations underscore the importance of careful patient selection for acute stenting and close monitoring in the post-procedural period.

Clot pathology considerations: The striking finding that 89% of retrieved clots were RBC-rich (red clots) merits further discussion. RBC-rich thrombi are classically associated with cardioembolic or stasis-related mechanisms, where thrombi formed under low-flow conditions—such as in the left atrial appendage during atrial fibrillation—tend to trap a high proportion of red blood cells within a fibrin meshwork. This is in contrast to platelet-rich (white) thrombi typically seen in local arterial atherothrombosis at sites of high shear stress. In our cohort, 85.9% of cervical ICA pathology was attributed to atherosclerosis, yet the predominance of RBC-rich intracranial clots (89%) suggests that many of these intracranial occlusions may not have arisen from local propagation of the carotid plaque. Instead, they may represent concurrent cardioembolic events—consistent with the 26.1% rate of diagnosed atrial fibrillation in our cohort—or embolism of stasis-formed thrombus from the post-stenotic segment of a severely stenosed ICA where flow is markedly reduced. Some patients may also have had undiagnosed paroxysmal atrial fibrillation as a concurrent cardioembolic source. This dual pathological mechanism has important implications: for acute management, it supports consideration of anticoagulation alongside antiplatelet therapy; for long-term secondary prevention, screening for occult atrial fibrillation may be warranted in tandem occlusion patients.[20]

Temporal considerations: The 14-year study period (2010–2023) encompasses substantial evolution in thrombectomy technology, imaging-based patient selection, and periprocedural care. While we were unable to perform formal stratified or sensitivity analyses by era (e.g., pre- vs. post-2015) due to the limited sample size, we acknowledge that secular trends in device technology (first-generation devices vs. modern stent retrievers and large-bore aspiration catheters), imaging selection (expansion of treatment windows with perfusion imaging), and anesthetic management may confound the observed outcomes. A pre- vs. post-2015 subgroup analysis would be valuable to determine whether the Siriraj protocol remained equally effective as technology advanced; however, this was not feasible with the current sample size and will be addressed in future studies with larger cohorts.

The treatment strategy for acute tandem stroke requires balancing the speed of intracranial recanalization and weighing the merits of antegrade and retrograde approaches in expediting penumbral salvage. While the retrograde approach[13,14] often achieves faster reperfusion, outcomes remain comparable to the antegrade method in terms of successful reperfusion and clinical efficacy. The antegrade approach[15,16] provides enhanced accessibility to intracranial lesions for MT, reducing the risk of vessel dissection or perforation attributed to non-blind navigation of the ICA. However, this approach may prolong reperfusion time and increase infarct development. Moreover, stenting during antegrade MT carries the risk of device entrapment within the stent. Our findings are consistent with prior reports, demonstrating similar outcomes and complication rates across both approaches.

Procedural-related complications were observed, with three patients developing vascular injury in the form of carotid-cavernous fistula (CCF) during MT. Importantly, all three cases exhibited cavernous ICA tortuosity type III[17,18], a known predisposing factor for such complications. In these cases, the CCF likely resulted from microwire or microcatheter perforation of the thin-walled cavernous ICA during navigation through severely tortuous segments. The use of stiffer guidewires to maintain access through the tortuous cavernous segment, combined with repeated device passes (stent retriever deployment and aspiration catheter advancement), may have contributed to cumulative vessel wall trauma. Although CCFs can resolve spontaneously, two of these cases resulted in poor outcomes. These findings highlight the importance of pre-procedural assessment of cavernous ICA tortuosity and consideration of alternative strategies (e.g., softer microwires, reduced number of passes) when severe tortuosity is identified. Additionally, ischemic events occurred in the form of central retinal artery occlusion and branch retinal artery occlusion, with no subsequent improvement noted in either case.

We observed hemorrhagic complications in 22 cases, with four cases manifesting as symptomatic ICH (4.3%), which is a lower incidence compared to previous studies.[1,4,7,8] Notably, patients undergoing acute stenting displayed a higher risk of any hemorrhage compared to the non-stenting group, although this did not significantly differ in terms of symptomatic ICH.[11] This finding suggests a potential association between the need for early antiplatelet therapy during acute infarction and the occurrence of hemorrhage. One patient in the acute stenting group died from massive intracerebral hemorrhage.

Limitations

This study has several important limitations. First, this retrospective analysis was based on medical records and radiographic data retrieved from the hospital's PACS system. Data inconsistencies were present, and there was no established protocol for determining the optimal timing of delayed carotid stenosis treatment following mechanical thrombectomy. Second, the study's relatively small sample size (n=92) limits the generalizability of the findings and the statistical power for subgroup comparisons. Third, the comparisons between tandem and single occlusion, acute stenting versus non-stenting/delayed treatment, and antegrade versus retrograde approaches are largely descriptive and unadjusted; no propensity-score matching or multivariable adjustment was performed for these subgroup analyses. Therefore, statements regarding the comparability or equivalence of outcomes between these groups should be interpreted as hypothesis-generating rather than definitive. Fourth, detailed baseline characteristics of the single occlusion group (age, NIHSS, ASPECTS) were not available for formal comparison with the tandem occlusion group; therefore, the observed similarity in outcomes between TO and SO may be influenced by unmeasured baseline imbalances. Fifth, the 14-year inclusion period spans substantial changes in thrombectomy devices, imaging selection, anesthesia practice, and post-procedural management, which may introduce confounding by secular trends. Formal era-stratified or sensitivity analyses (e.g., pre- vs. post-2015 or by device generation) were not feasible due to the limited sample size. Sixth, only dichotomized mRS outcomes (0–2 vs. 3–6) are reported; full mRS distributions and ordinal shift analysis were not performed. Finally, as a single-center study from a high-volume, experienced center[19,20], the results may reflect the institutional expertise and may not be easily replicable in lower-volume settings. Nonetheless, prior analyses from the TITAN, ETIS, and ESCAPE-NA1 trials[6–8] reported similar functional outcomes, consistent with those observed under the treatment protocol employed in this study.

CONCLUSIONS

The Siriraj protocol for mechanical thrombectomy in acute tandem occlusion stroke demonstrates outcomes and mortality rates comparable to those seen in single occlusion cases in unadjusted analysis. Independent predictors of favorable 90-day outcomes included age ≤ 65 years old, initial NIHSS score ≤ 16, and successful recanalization (mTICI ≥2b). Acute carotid stenting showed a trend toward higher rates of favorable functional outcomes (65% vs. 46%, p=0.15) but was also associated with a higher rate of overall intracranial hemorrhage (p=0.01) and a numerically higher mortality rate (15%). These observational findings do not allow definitive conclusions about the safety and efficacy of acute stenting and should be interpreted with caution. Larger, preferably prospective, multicenter studies with adjusted analyses are needed to clarify the role of acute carotid stenting in tandem occlusion management.

Data Availability Statement

The data that support the findings of this study are available from the Siriraj Center of Interventional Radiology stroke registry, Siriraj Hospital, Mahidol University. However, restrictions apply to the availability of these data due to patient privacy and ethical considerations, and the data are not publicly available. Data may be available from the corresponding author upon reasonable request and with the approval of the Siriraj Institutional Review Board.

ACKNOWLEDGEMENTS

The authors would like to express their sincere gratitude to the dedicated staff of the Siriraj Center of Interventional Radiology, the Division of Neurosurgery, and the nursing team at Siriraj Hospital for their invaluable assistance in data collection and patient care throughout this study. We also thank the patients and their families for their trust and participation.

DECLARATIONS

Grants and Funding Information

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors. The study was conducted using the institutional resources of the Faculty of Medicine, Siriraj Hospital, Mahidol University.

Conflict of Interest

The authors declare that they have no conflict of interest.

Registration Number of Clinical Trial

Not applicable. This study is a retrospective analysis of existing clinical data and was not registered as a prospective clinical trial.

Author Contributions

Conceptualization and Methodology: R.W., P.W. ; Investigation and Data Curation: R.W., B.S., T.A., E.C., A.C. ; Formal Analysis: R.W., P.W. ; Writing – Original

Draft: R.W. ; Writing – Review & Editing: R.W., B.S., T.A., E.C., A.C., P.W. ; Supervision: P.W., A.C. ; All authors have read and agreed to the published version of the manuscript.

Use of Artificial Intelligence

During the preparation of this manuscript, artificial intelligence (AI) was not used for the analysis of clinical data or the generation of scientific conclusions. AI language models were utilized solely for proofreading, grammar correction, and formatting of the final text to improve clarity and conform to publication standards.

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