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Predictors of distal embolization during thrombectomy for anterior circulation large vessel bifurcation occlusion stroke

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ABSTRACT

Background Distal embolization is a frequent complication of mechanical thrombectomy (MT) for acute ischemic stroke, often leading to poor clinical outcomes. The vascular bifurcations represent a specialized anatomical location, thereby augmenting the complexity of MT. The specific factors contributing to distal embolization in this context have not been thoroughly explored. This study seeks to identify the factors associated with distal embolization during MT in patients with anterior circulation large vessel bifurcation occlusion stroke.

Methods A retrospective analysis was conducted on patients who underwent MT for acute anterior circulation bifurcation occlusion stroke between January 2015 and December 2023. Baseline characteristics, procedural details, and clinical outcomes were assessed. Univariate and multivariable analyses were performed to identify predictors of distal embolization during MT.

Results The study included 119 patients. Univariate analysis revealed significant associations between distal embolization and occlusion location, internal carotid artery (ICA) tortuosity, first-line thrombectomy strategy, and the number of device passes. Multivariate analysis identified ICA bifurcation occlusions (odds ratio (OR) 3.21, 95% confidence interval (CI) 1.188 to 8.672, P=0.021), stent retriever thrombectomy (SRT) (OR 6.177, 95% CI 1.77 to 21.555, P=0.004), and a higher number of device passes (OR 1.778, 95% CI 1.132 to 2.792, P=0.013) as independent predictors of distal embolization.

Conclusions ICA bifurcation occlusion, the use of SRT, and an increased number of device passes are significant predictors of distal embolization during MT in patients with anterior circulation large vessel bifurcation occlusion strokes.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Distal embolization is a frequent complication of mechanical thrombectomy for acute ischemic stroke, often leading to poor clinical outcomes. The vascular bifurcations represent a specialized anatomical location, thereby augmenting the complexity of MT. The specific factors contributing to distal embolization in this context have not been thoroughly explored.

WHAT THIS STUDY ADDS

⇒ This retrospective review suggests that internal carotid artery bifurcation occlusion, stent retriever thrombectomy, and a greater number of device passes are linked to an elevated risk of distal emboli during MT for anterior circulation large vessel bifurcation occlusion strokes.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Our study suggests that the factors contributing to distal embolization associated with mechanical thrombectomy in bifurcation occlusion of the anterior circulation differ from those observed in other anatomical locations. The specific strategy employed in mechanical thrombectomy plays a critical role in determining the occurrence of distal embolization. Further clinical studies are required to identify the most effective thrombectomy techniques for treating ischemic stroke caused by bifurcation occlusions.

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INTRODUCTION

Mechanical thrombectomy (MT) is the standard treatment for acute ischemic stroke caused by large vessel occlusion (LVO).[1] However, thrombus fragmentation and distal embolization during endovascular therapy (EVT) are frequent complications that can negatively impact patient outcomes.[2 3] Distal embolization during MT involves both emboli traveling to downstream areas of the targeted occlusion and to previously unaffected regions.[4] Contributing factors include intravenous thrombolysis, balloon guide catheter (BGC) usage, atrial fibrillation, occlusion location, embolus length, and thrombus histology.[5–8] Vascular bifurcation is a common site for large vessel intracranial occlusions, where thrombi can either block the main vessel alone or extend into one or both branches. This variation in occlusion patterns can influence MT effectiveness.[9] Furthermore, the factors contributing to distal embolization during MT may differ from those observed in other sites of occlusion.[10] However, there are few studies focusing on this aspect. This study seeks to identify these factors to provide clinical evidence

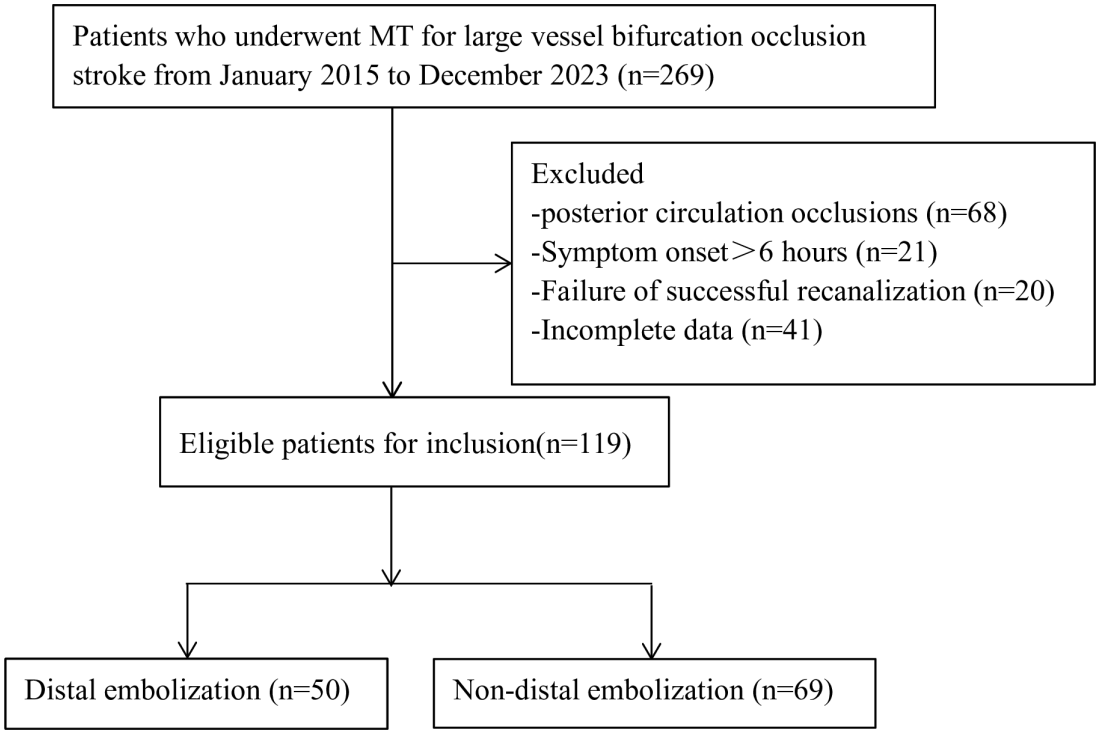

Figure 1 Flowchart of the patient inclusion process. MT, mechanical thrombectomy.

that may guide region-specific MT protocols for strokes involving bifurcation occlusions in the anterior circulation.

METHODS

Study design

The present study conducted a retrospective cohort analysis on consecutive patients with acute ischemic stroke who underwent MT at our institution between January 2015 and December 2023. The primary endpoint was to identify factors influencing distal embolization following MT for anterior circulation bifurcation stroke. The efficacy of various thrombectomy techniques for vascular bifurcation occlusion stroke, as well as clinical outcomes and safety indicators, was also evaluated. Approval for the study was granted by the institution's review board, and in compliance with relevant national legislation, the acquisition of informed consent was not necessary.

Patient selection

The study included patients with occlusions at the bifurcation of major vessels in the anterior circulation, specifically involving the carotid terminus and distal M1 segment of the middle cerebral arteries (MCA), as confirmed by digital subtraction angiography (DSA) prior to the procedure. No patients with bifurcation occlusions of the anterior cerebral artery/anterior communicating artery were observed in this study. We analyzed DSA images obtained before and after microcatheter positioning distal to the occlusion site in order to confirm the occlusion sites at regions of large vessel bifurcation. Two experienced neuroradiologists respectively examined all angiograms to achieve a consensus on the identification of occlusions occurring at vessel bifurcations. Any disagreement was resolved by a third researcher. Cases with MCA trifurcation were excluded. Additionally, they also fulfilled the following inclusion criteria: (1) Age ≥18 years; (2) Symptom onset within 6 hours; (3) Alberta Stroke Program Early CT Score (ASPECTS) >6; (4) Pre-onset modified Rankin Scale (mRS) score <3; and (5)Successful reperfusion, defined as an extended Thrombolysis in Cerebral Infarction (eTICI) score of 2c or 3.

Procedural details

If patients met the criteria for intravenous thrombolysis, a dose of 0.9 mg/kg recombinant tissue-type plasminogen activator (rt-PA) was administered before MT following current guidelines for acute ischemic stroke management.[11] MT procedures were carried out by two expert interventional neuroradiologists with over a decade of specialized experience. A transfemoral approach was utilized, with local anesthesia and conscious sedation administered as necessary. Due to limitations in available device conditions, the balloon guide catheter (BGC) was not utilized in any of the procedures. The MT techniques employed included stent retriever thrombectomy (SRT), contact aspiration thrombectomy (CAT), or a combination of both, as detailed in previous literature.[12–14] Stent retrieval was performed using either the Solitaire FR 6*30 mm/4*20 mm (Medtronic, Minnesota, USA) or Trevo ProVue 4*20 mm (Stryker, Michigan, USA). Aspiration was achieved with the AXS Catalyst-6 (Stryker, Michigan, USA) or 6F RuiFly F (RICOTON, Hunan, China). Selection of devices and techniques was guided by the operator's professional judgment. If successful recanalization was not achieved after three attempts with the initial strategy, alternative endovascular treatment techniques were employed to ensure a satisfactory therapeutic outcome.

Data collection

Demographic data, stroke risk factors, anatomical details of vascular access, stroke severity assessments, procedural duration, and functional outcomes were retrospectively gathered from the patients. The degree of vessel occlusion pre- and post-thrombectomy was evaluated using the eTICI classification, where successful recanalization was defined by a postoperative eTICI score of 2c/3.[15] Neurological severity was assessed with

Table 1 Comparison of baseline characteristics and clinical outcomes stratified by the presence of distal embolization

	Total (n=119)	Distal embolization (n=50)	Non-distal embolization (n=69)	P
Age, median (IQR)	75.0 (65.0–84.0)	72.5 (63.5–83.3)	78.0 (65.50–85.0)	0.314
Gender (female), n (%)	55 (46.2)	27 (54.0)	28 (40.6)	0.147
Medical history, n (%)				
Hypertension	80 (67.2)	31 (62.0)	49 (71.0)	0.301
Diabetes mellitus	25 (21.0)	11 (22.0)	14 (20.3)	0.821
Hyperlipidemia	33 (27.7)	13 (26.0)	20 (29.0)	0.720
Coronary artery disease	40 (33.6)	21 (42.0)	19 (27.5)	0.099
Previous stroke	26 (21.8)	12 (24.0)	14 (20.3)	0.629
Smoking	27 (22.7)	12 (24.0)	15 (21.7)	0.771
Atrial fibrillation	63 (52.9)	22 (44.0)	41 (59.4)	0.096
Prior use of antiplatelets, n (%)	36 (30.3)	16 (32.0)	20 (29.0)	0.724
Prior use of anticoagulants, n (%)	25 (21.0)	9 (18.0)	16 (23.2)	0.493
Wake up stroke	36 (30.3)	14 (28.0)	22 (31.9)	0.649
Occlusion location, n(%)				
MCA bifurcation	72 (60.5)	23 (46.0)	49 (71.0)	0.006
ICA bifurcation	47 (39.5)	27 (54.0)	20 (29.0)	
ICA tortuosity, n(%)	61 (51.3)	32 (64.0)	29 (42.0)	0.018
NIHSS at baseline, median (IQR)	13.0 (10.0–19.0)	13.0 (10.0–19.0)	13.0 (9.0–19.0)	0.566
ASPECTS at baseline, median (IQR)	10.0 (8.0–10.0)	10.0 (8.0–10.0)	10.0 (8.0–10.0)	0.640
Prior IVT, n (%)	55 (46.2)	26 (52.0)	29 (42.0)	0.282
First-line thrombectomy strategy, n(%)				0.009
SRT	50 (42.0)	28 (56.0)	22 (31.9)	
CAT	29 (24.4)	6 (12.0)	23 (33.3)	
SRT and CAT	40 (33.6)	16 (32.0)	24 (34.8)	
Number of passes (IQR)	2 (2–3)	2 (2–3)	2 (1–2)	< 0.001
Timing (min), median (IQR)				
Onset to puncture	206.0 (135.0–360.0)	225.5 (139.5–332.5)	200.0 (129.5–392.5)	0.936
Door to puncture	83.0 (63.0–108.0)	86.5 (68.5–108.7)	81.0 (61.0–102.5)	0.343
Puncture to recanalization	112.0 (90.0–165.0)	72.5 (63.5–83.3)	78.0 (65.5–85.0)	0.557
Improvement of NIHSS scores ≥4 at 24 hours, n(%)	55 (46.2)	20 (40.0)	35 (50.7)	0.247
Improvement of NIHSS scores ≥4 at discharge, n(%)	81 (68.1)	33 (66.0)	48 (69.6)	0.681
90-d mRS 0–2, n(%)	48 (40.3)	14 (28.0)	34 (49.3)	0.020
sICH, n(%)	15 (12.6)	6 (12.0)	9 (13.0)	0.866
90-d Mortality, n(%)	17 (14.3)	8 (16.0)	9 (13.0)	0.649

ASPECTS, Alberta Stroke Program Early CT Score; CAT, contact aspiration thrombectomy; 90d, 90 day; ICA, internal carotid artery; IQR, interquartile range; IVT, intravenous thrombolysis; MCA, middle cerebral artery; min, minute; mRS, modified Rankin Scale; NIHSS, National Institutes of Health Stroke Scale; sICH, symptomatic intracranial hemorrhage; SRT, stent retriever thrombectomy.

the National Institutes of Health Stroke Scale (NIHSS), with scores ranging from 0 to 42, where higher scores indicated greater severity. Functional outcomes at 90 days were measured using the modified Rankin Scale (mRS), with scores of 0 to 2 denoting favorable outcomes. "Distal embolization" were characterized as new filling defects on final DSA images that were absent on initial DSA, appearing either distally to the occlusion or in previously unaffected areas. Carotid artery tortuosity was evaluated following previously established standards.[16] Postoperative head computed tomography (CT) or magnetic resonance imaging (MRI) was conducted within 24 hours to identify intracranial hemorrhage, with symptomatic intracerebral hemorrhage (sICH) defined as hemorrhage occurring post-procedure and accompanied by a NIHSS score deterioration of ≥4 points.

Statistical analysis

Statistical analysis was conducted using SPSS 26.0 software (IBM Corp., NY, USA). Quantitative variables are reported as mean±SD for parametric data and median (interquartile range (IQR)) for non-parametric data, based on normality assessed via the Shapiro–Wilk test. Qualitative data are presented as frequencies and percentages. Continuous variables were compared using Student's t-test or Mann–Whitney U test, according to their distribution, while categorical variables were analyzed using a Chi-squared test. Variables that achieved statistical significance in univariate analyses were included in a multivariate regression analysis to identify independent predictors of distal embolization. All tests were two-sided, with a significance level set at <0.05.

Table 2 Multivariate analysis of potential predictors of distal embolization

Predictors	OR (95% CI)	P
First-line thrombectomy strategy		
CAT	1（ref）	
SRT	6.177（1.77–21.555）	0.004
SRT and CAT	1.723（0.465–6.389）	0.416
Occlusion location		
MCA bifurcation	1（ref）	
ICA bifurcation	3.21（1.188–8.672）	0.021
ICA tortuosity	0.816（0.296–2.253）	0.695
Number of passes	1.778（1.132–2.792）	0.013

CAT, contact aspiration thrombectomy; CI, confidence interval; ICA, internal carotid artery; MCA, middle cerebral artery; OR, odds ratio; SRT, stent retriever thrombectomy.

RESULTS

This study evaluated 269 patients with acute ischemic stroke and bifurcation occlusions treated between January 2015 and December 2023. After excluding cases with posterior circulation occlusions, unsuccessful recanalization, incomplete data, and symptom onset beyond 6 hours, 119 patients remained in the final analysis. These patients were divided into two groups: those with distal embolization and those without (figure 1 illustrates the patient inclusion process). The median age of patients was 75 years (IQR 65–84), with 46.2% being female. Distal embolization were confirmed by DSA in 50 patients (42.0%) following MT.

Distal embolization was significantly more frequent in internal carotid artery (ICA) bifurcation occlusions compared with MCA occlusions (54.0% vs 46.0%, P=0.006). Additionally, ICA tortuosity was linked to a higher incidence of distal embolization (64.0% vs 42.0%, P=0.018). The initial thrombectomy strategy had a significant impact on the occurrence of distal embolization (P=0.009). Among patients with distal embolization, SRT was identified as the most frequently employed approach (56.0% vs 31.9%), while CAT exhibited the lowest utilization rate (12.0% vs 33.3%). Furthermore, the number of device passes was positively correlated with the occurrence of distal embolization (median 2 (IQR 2–3) vs 2 (IQR 1–2), P<0.001). The proportion of patients with favorable outcomes (mRS 0–2) at 90 days was significantly lower in the distal embolization group compared with the non-distal embolization group (28.0% vs 49.3%, P=0.020). However, no significant differences were observed between the groups in other effectiveness and safety measures (table 1).

Multivariate analysis identified SRT (OR 6.177, 95% CI 1.77 to 21.555, P=0.004), ICA bifurcation occlusion (OR 3.21, 95% CI 1.188 to 8.672, P=0.021), and the number of passes (OR 1.778, 95% CI 1.132 to 2.792, P=0.013) as independent risk factors for distal embolization. In contrast, no significant correlation was found between ICA tortuosity and distal embolization (OR 0.816, 95% CI 0.296 to 2.253, P=0.695) (table 2).

DISCUSSION

Our study identified a 42.02% incidence of distal embolization during MT for anterior circulation large vessel bifurcation occlusion stroke, a rate slightly exceeding previous reports.[3 7 17–19] The inherent challenges of occlusions at vascular bifurcations likely contribute to this elevated risk of distal embolization.[20–22] Additionally, the lack of BGC use in all patients may have further increased the incidence of distal embolism. Procedural embolic complications can disrupt collateral blood flow, potentially leading to preventable tissue ischemia and even ischemia in previously unaffected regions.[23–25] These fragmented clots are linked to poor clinical outcomes,[2 3] consistent with our findings that patients experiencing distal embolization had worse outcomes at 90 days.

In this study, univariate analysis revealed a higher incidence of distal embolization at the bifurcation occlusion of ICA compared with MCA occlusions during MT. Multivariate analysis further identified ICA bifurcation occlusions as an independent risk factor for distal embolization. The thrombus location plays a critical role in distal embolism,[7 18] with a strong correlation between thrombus burden and embolism incidence.[26] The complex anatomy and significant thrombus presence in the carotid bifurcation area increase the likelihood of distal embolization during MT.

Carotid artery tortuosity significantly impairs MT efficiency and negatively impacts clinical outcomes.[16] In tortuous vessels, stent retrievers may stretch and collapse during retrieval, reducing their interaction with the clot.[26 27] Moreover, vessel tortuosity can hinder the aspiration catheter tip from effectively engaging the clot, further complicating clot removal.[28] These factors collectively elevate the risk of distal embolism. While univariate analysis in our study showed a significant increase in distal embolism incidence among patients with carotid artery tortuosity (P=0.018), multivariate analysis did not confirm this association as statistically significant.

The study revealed that SRT had the highest incidence of distal embolism at 56.00%, while CAT had the lowest at 12.00%. Multivariate regression analysis confirmed that SRT significantly increased the risk of distal embolism at bifurcations compared with CAT (OR 6.177, 95% CI 1.77 to 21.555, P=0.004). The results of this study are inconsistent with the findings of previous research.[19] During thrombectomy at bifurcations, a thrombus may occlude the main vessel or extend into one or both branches. SRT involves positioning the stent distally within a branch, which can fragment the thrombus and cause distal embolization. In contrast, CAT positions the aspiration catheter in direct contact with the thrombus and applies negative pressure before reaching the bifurcation, allowing for intact thrombus extraction and reducing the risk of distal embolization.

This study has several limitations. The scope of our study was limited to patients presenting within 6 hours of symptom onset and excluded cases of posterior circulation stroke, thereby restricting the generalizability of the findings to all patients undergoing MT. The utilization of DSA as the sole method for evaluating vessel bifurcation occlusion may potentially lead to inaccuracies. Additionally, histological analysis of thrombi was not included. The study's retrospective nature, single-center setting, and small sample size could introduce bias. Future research should address these issues through rigorous, multicenter, prospective randomized controlled trials.

In conclusion, internal carotid artery bifurcation occlusion, stent retriever thrombectomy, and a greater number of device passes are linked to an elevated risk of distal embolization during mechanical thrombectomy for anterior circulation large vessel bifurcation occlusion strokes. Further clinical studies are required to identify the most effective thrombectomy techniques for treating stroke caused by bifurcation occlusions.

Contributors HF was responsible for the study design, data analysis, and drafting of the manuscript. HF, ZM, and ZL were responsible for performing mechanical thrombectomy procedures and patient care. HF, ZM and YT took part in patient care, patients' follow-up, data collection, and drafting of the manuscript. All authors contributed to the article and approved the submitted version. HF is responsible for the overall content and is the guarantor of the entire work. He accepts full responsibility for the work and conduct of the study, had access to the data, and controlled the decision to publish.

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Competing interests None declared.

Patient consent for publication Not applicable.

Ethics approval Our study received approval from the ethics committee of Guangzhou Red Cross Hospital (approval number 2024-367-01). Based on the nature of the study, informed consent was waived.

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