

ENDOVASCULAR INTERVENTION FOR ACUTE ISCHEMIC STROKE DUE TO M1 MIDDLE CEREBRAL ARTERY OCCLUSION WITH UNDERLYING CHRONIC STENOSIS: A PROSPECTIVE COHORT STUDY

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ABSTRACT

Background: Acute ischemic stroke due to M1 middle cerebral artery (MCA) occlusion with underlying intracranial atherosclerotic stenosis (ICAS) presents unique therapeutic challenges. We investigated the safety and efficacy of endovascular intervention in this complex clinical scenario.

Methods: This prospective cohort study enrolled 27 patients with acute M1 occlusion and underlying chronic stenosis treated at Hue Central Hospital Stroke Center from November 2023 to January 2025. Primary endpoints included successful recanalization (mTICI $\geq$ 2b) and functional independence (mRS 0 - 2) at 3 months.

Results: Mean age was 62 ± 9 years with 55.6% male predominance. All patients underwent stent-retriever thrombectomy with 81.5% requiring rescue balloon angioplasty and 37.0% requiring stent placement. Complete recanalization (mTICI 3) was achieved in 74.1% of patients. At 3 - month follow-up, 63.0% achieved functional independence with no mortality observed.

Conclusions: Endovascular intervention for M1 occlusion with underlying stenosis demonstrates acceptable safety and efficacy profiles. The combined approach of thrombectomy followed by rescue angioplasty and selective stenting provides favorable clinical outcomes in carefully selected patients.

Keywords: Acute ischemic stroke, intracranial atherosclerotic stenosis, mechanical thrombectomy, balloon angioplasty, M1 occlusion.

I. BACKGROUND

Acute ischemic stroke from large vessel occlusion (LVO), particularly middle cerebral artery (MCA) M1 segment occlusion, is a neurological emergency requiring immediate intervention to minimize damage. LVOs are associated with substantial morbidity and mortality, with M1 occlusions being a predominant subtype in anterior circulation LVOs. M1 occlusion involves embolic or in-situ thrombosis

from intracranial atherosclerotic stenosis (ICAS). ICAS-related LVO poses unique challenges due to high reocclusion rates after standard mechanical thrombectomy, stemming from residual stenosis. ICAS is significantly more prevalent in Asian populations (up to ~50% of ischemic strokes, 33-67% of stroke/TIA cases) compared to Caucasians [1-4].

Mechanical thrombectomy has revolutionized acute stroke care for LVO, demonstrating

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superior outcomes. However, landmark trials primarily focused on embolic occlusions, leaving optimal ICAS-related LVO management under investigation. Standard thrombectomy for ICAS-LVO often results in high reocclusion rates (57.1-77.3%), necessitating rescue interventions. Advances in endovascular techniques offer rescue therapies like balloon angioplasty, stent placement, and intra-arterial glycoprotein IIb/IIIa inhibitors for ICAS-related LVO, showing promise for sustained recanalization. Yet, these interventions carry inherent risks, including vessel perforation, distal embolization, and hemorrhagic complications, critical in acute stroke [1, 5, 6].

The modified Thrombolysis in Cerebral Infarction (mTICI) scale serves as the standard metric for assessing recanalization success, with mTICI 2b-3 considered successful reperfusion. However, achieving sustained recanalization in ICAS-related M1 occlusions remains challenging due to the underlying stenotic vessel architecture. Current stroke guidelines recommend mechanical thrombectomy for large vessel occlusion (LVO) within 24 hours based on imaging criteria. However, these recommendations are largely derived from trials assessing LVOs in general, without clear evaluation of the underlying etiologies of the occlusion [7, 8]. Specific evidence-based protocols for managing acute M1 occlusion with underlying chronic stenosis are limited, with treatment decisions often relying on individual physician expertise and institutional experience rather than standardized approaches. The lack of endovascular strategies specifically tailored for this population represents a significant knowledge gap in acute stroke management [9-13]. This study aims to evaluate the safety and efficacy of a systematic endovascular approach for acute M1 occlusion with underlying chronic stenosis.

II. MATERIALS AND METHODS

2.1. Study design and setting

This prospective observational cohort study was conducted at the Stroke Center of Hue Central Hospital, a medical center in Central Vietnam. The

study protocol was designed as a cross-sectional analysis with 3-month longitudinal follow-up, enrolling consecutive patients from November 2023 to January 2025. The informed consents were obtained from all patients or their legal representatives.

2.2. Patient selection criteria

Inclusion criteria: Age ≥ 18 years with acute ischemic stroke confirmed by clinical presentation and neuroimaging; National Institutes of Health Stroke Scale (NIHSS) ≥ 6 [7]; Symptom onset to intervention time < 24 hours, or patients with transient ischemic attack/minor stroke (NIHSS ≤ 5) at admission who subsequently deteriorated (NIHSS increase ≥ 2 points) with intervention within 24 hours of deterioration [14]; Confirmed M1 MCA occlusion on computed tomographic angiography (CTA) or magnetic resonance angiography (MRA); Alberta Stroke Program Early CT Score (ASPECTS) ≥ 5 on non-contrast CT or diffusion-weighted imaging [7]; Evidence of underlying chronic stenosis defined as residual stenosis $\geq 50\%$ after initial thrombectomy, with angiographic features suggestive of atherosclerotic disease [15]

Exclusion criteria: Non-atherosclerotic etiology of stroke including cardioembolic sources, dissection, or vasculitis; Tandem occlusions involving multiple large vessel territories; Previous stroke with moderate to severe disability (modified Rankin Scale mRS ≥ 3); Contraindications to endovascular intervention including coagulopathy or recent major surgery; Life expectancy < 5 years due to comorbid conditions; Refusal to participate in the study

2.3. Imaging protocols

All patients underwent multimodal neuroimaging upon presentation including non-contrast CT, CTA of the head and neck, and when clinically appropriate, CT perfusion or MRI with diffusion-weighted imaging. ASPECTS was assessed on presentation imaging by certified neuroradiologists. Follow-up imaging was performed at 24 hours post-intervention and included non-contrast CT or MRI to assess for hemorrhagic transformation and infarct evolution.

2.4. Endovascular intervention protocol

Pre-procedural management: Patients presenting within the 4.5-hour window who met criteria for intravenous thrombolysis received alteplase (0.9 mg/kg) according to standard protocols. For patients without tPA indication, dual antiplatelet loading with clopidogrel 300mg and aspirin 324mg was administered immediately upon confirmation of intervention indication. Antiplatelet therapy was continued post-procedure unless contraindicated by hemorrhagic complications [7, 16].

Thrombectomy technique: All procedures were performed under general anesthesia or conscious sedation at operator discretion. An 8F guiding catheter was positioned in the ipsilateral internal carotid artery. Initial thrombectomy was performed using stent retrievers with or without adjunctive aspiration techniques. Angiographic assessment was performed after each retrieval attempt to evaluate recanalization success and identify underlying stenosis [17].

Rescue intervention criteria: Rescue therapy was indicated for patients with [18]: (1) Residual stenosis $\geq 70\%$ following mechanical thrombectomy; (2) Residual stenosis $\geq 50\%$ following thrombectomy with progressive stenosis advancing from 50-69% to $\geq 70\%$ during observation period; (3) Procedural reocclusion.

Stenosis Assessment: Stenosis severity was measured using WASID study methodology [19]: $\text{Stenosis (\%)} = (\text{D}_{\text{normal}} - \text{D}_{\text{stenosis}}) / \text{D}_{\text{normal}} \times 100$, where D_{normal} is the normal diameter at the nearest disease-free segment and $\text{D}_{\text{stenosis}}$ is the minimum luminal diameter at the stenotic site. Classification: mild ($<50\%$), moderate (50-69%), severe (70-99%), complete occlusion (100%).

Balloon Angioplasty Protocol: Balloon diameter was selected to match the vessel diameter proximal to the stenotic segment. Inflation was performed at nominal pressure for 30 seconds, followed by

angiographic reassessment. Repeat angioplasty was performed if residual stenosis remained $\geq 50\%$ [20].

Stent Placement Indications [21]: Reocclusion or restenosis $\geq 70\%$ after balloon angioplasty; Vessel dissection compromising flow; Failure to achieve mTICI $\geq 2b$ after balloon angioplasty; Preference in patients not receiving prior intravenous thrombolysis

2.5. Outcome measures

Primary Endpoints: Successful recanalization defined as mTICI 2b-3; Functional independence (mRS 0-2) at 3 months.

Secondary endpoints: Complete recanalization (mTICI 3); Symptomatic intracranial hemorrhage (sICH) within 48 hours; Early neurological improvement (NIHSS reduction ≥ 4 points at 24 hours); Mortality at 3 months; Stroke recurrence during follow-up period.

Safety Endpoints: Procedural complications including vessel perforation, dissection, or distal embolization; Hemorrhagic transformation (HI-1, HI-2, PH-1, PH-2); Device-related adverse events.

2.6. Statistical analysis

Descriptive statistics were used to characterize baseline demographics, procedural variables, and outcomes. Continuous variables are presented as mean $\pm$ standard deviation or median with interquartile range as appropriate. Categorical variables are presented as frequencies and percentages. Given the sample size ($n=27$), formal statistical comparisons were limited, and results are presented descriptively with confidence intervals where appropriate. All analyses were performed using standard statistical software with significance set at $p < 0.05$.

III. RESULTS

3.1. Baseline patient characteristics

The cohort consisted of predominantly hypertensive patients with moderate-to-severe stroke severity at admission. A quarter experienced neurological deterioration after an initially minor presentation (Table 1).

Table 1: Baseline characteristics of the study cohort (n = 27)

Variable	Value
Age, mean $\pm$ SD (years)	62 $\pm$ 9
Male sex, n (%)	15 (55.6%)
Hypertension, n (%)	27 (100%)
Diabetes mellitus, n (%)	12 (44.4%)
Smoking history (current/former), n (%)	12 (44.4%) (73% of males)
Prior stroke or TIA, n (%)	2 (7.4%)
NIHSS at presentation, mean $\pm$ SD	14 $\pm$ 3
Baseline ASPECTS, mean $\pm$ SD	7.2 $\pm$ 1.5
Symptom onset to admission, mean $\pm$ SD (min)	320 $\pm$ 50
Received IV thrombolysis, n (%)	5 (18.5%)
Initial minor stroke (NIHSS $\leq$ 5) with decline	7 (25.9%)
Door-to-groin puncture time, median (IQR)	120 $\pm$ 65 min

3.2. Procedural characteristics and immediate angiographic outcomes

All patients underwent stent-retriever thrombectomy. Recanalization rates were high, with no instances of intraprocedural hemorrhage or stent occlusion. Adjunctive balloon angioplasty and rescue stenting were frequently necessary to manage residual stenosis (Table 2).

Table 2: Procedural and angiographic results

Parameter	Value
Stent-retriever thrombectomy performed, n (%)	27 (100%)
General anesthesia used, n (%)	20 (74.1%)
First-pass success (mTICI $\geq$ 2b), n (%)	22 (81.5%)
Balloon angioplasty required, n (%)	19 (70.4%)
Rescue stenting performed, n (%)	10 (37.0%)
Final angiographic result mTICI 3, n (%)	20 (74.1%)
Final angiographic result mTICI 2b, n (%)	7 (25.9%)
Residual stenosis $\geq$ 50% post-procedure	0 (0%)
Distal embolization, n (%)	3 (11.1%)
Vessel dissection during angioplasty, n (%)	3 (11.1%)
Intraprocedural hemorrhage, n (%)	0 (0%)

3.3. Early post-procedural outcomes (24 hours)

There was a significant neurological improvement at 24 hours, with NIHSS decreasing from 14 $\pm$ 3 to 8 $\pm$ 2 ($p < 0.01$), while ASPECTS remained relatively stable ($p = 0.47$), indicating clinical recovery without early infarct progression. Despite a relatively high rate of hemorrhagic transformation on imaging, the incidence of symptomatic intracerebral hemorrhage was low (7.4%). Only two patients (7.4%) experienced early neurological worsening (Table 3).

Table 3: Hemorrhagic events and neurological status at 24 hours

Outcome	Value
NIHSS at 24 hours, mean $\pm$ SD	8 $\pm$ 2
NIHSS change (24h vs admission), p-value	-6.1 $\pm$ 1.4, p < 0.01
ASPECTS at 24 hours, mean $\pm$ SD	7.5 $\pm$ 1.8
ASPECTS change (24 h vs admission), p-value	+0.3 $\pm$ 1.8, p = 0.47
Subarachnoid hemorrhage, n (%)	11 (40.7%)
Hemorrhagic infarction type 1 (HI-1), n (%)	5 (18.5%)
Hemorrhagic infarction type 2 (HI-2), n (%)	4 (14.8%)
Parenchymal hematoma type 1 (PH-1), n (%)	1 (3.7%)
Parenchymal hematoma type 2 (PH-2), n (%)	1 (3.7%)
Symptomatic intracerebral hemorrhage, n (%)	2 (7.4%)
Early neurological worsening (NIHSS $\uparrow \geq 4$), n (%)	2 (7.4%)

3.4. Three-month functional outcomes

At 90 days, functional independence (mRS 0 - 2) was achieved in 63.0% of patients, while favorable outcomes (mRS 0 - 3) were achieved in 88.9%. No patients died during the follow-up period. Stroke recurrence occurred in 7.4% of patients, with no substantial functional decline observed (Table 4).

Table 4: Distribution of 90 - day Modified Rankin Scale (mRS) scores

mRS Score	Proportion (%)
0	11.1
1	29.6
2	22.2
3	25.9
4	7.4
5	3.7
6	0.0

IV. DISCUSSION

4.1. Patient population and risk factor profile

The universal prevalence of hypertension (100%), high rates of diabetes mellitus (44.4%), and significant smoking history (44.4% with 73% male predominance) strongly validate the study's focus on ICAS as the underlying etiology. This cardiovascular risk factor profile is consistent

with known epidemiological patterns of ICAS and reinforces that the selected patient population is representative of the challenging ICAS-related LVO cases that require specialized management approaches [22].

The presentation pattern, with 25.9% of patients initially presenting with mild symptoms (NIHSS $\leq$ 5) before experiencing neurological deterioration, highlights the dynamic nature of ICAS-related occlusions [23]. This finding underscores the importance of vigilant monitoring and readiness for emergent intervention in patients with suspected underlying stenosis, as the clinical course can be unpredictable and rapidly progressive.

4.2. Temporal considerations and treatment paradigm

Despite the median onset-to-admission time of 320 $\pm$ 50 minutes and door-to-groin puncture time of 120 $\pm$ 65 minutes, the study achieved favorable clinical outcomes. This observation suggests that for ICAS-related LVO, the effectiveness of comprehensive in-hospital management protocols, particularly systematic rescue interventions, may be more crucial for achieving good outcomes than extremely short pre-hospital or door-to-puncture times. This finding contrasts with the well-established time-dependent outcomes in embolic stroke and could inform resource allocation and

clinical expectations in settings where rapid transport or immediate intervention is challenging [24].

The differential door-to-groin puncture times between patients proceeding directly to intervention (70 ± 25 minutes) versus those who initially stabilized before deteriorating (220 ± 70 minutes) reflects the clinical complexity of managing patients with fluctuating neurological status, yet both groups ultimately achieved favorable outcomes through the systematic approach employed.

4.3. Procedural success and technical considerations

The superior recanalization rates observed in this study can be attributed to several critical technical factors. The prioritization of initial stent-retriever thrombectomy followed by aggressive rescue interventions, achieved remarkable success rates with 100% successful recanalization (mTICI $\geq 2b$) and 74.1% complete recanalization (mTICI 3). This outcome significantly surpasses many reported outcomes for ICAS-related LVO, including a Chinese study involving 22 patients with ICAS-related M1 occlusion that reported successful reperfusion in 68.2% of patients treated with rescue balloon angioplasty and stenting, although their definition of success included mTICI 2a while the current study required mTICI $\geq 2b$ [25, 26].

The high first-pass success rate of 81.5% (mTICI $\geq 2b$) indicates that initial thrombectomy was frequently effective at achieving basic recanalization. However, the universal presence of residual stenosis, classified as moderate (50 - 69%) in 37.0% and severe (70-99%) in 63.0% of patients, necessitated the appropriate rescue intervention protocol. Previous studies have consistently reported high reocclusion rates, ranging from 57.1% to 77.3%, after initial stent-retriever thrombectomy in ICAS-related LVO, requiring additional interventions to achieve sustained recanalization [22]. The rescue therapy employed in this study appears to have effectively mitigated this challenge, as evidenced by the low reocclusion rate and excellent final mTICI 3 rate.

The frequent requirement for balloon angioplasty (70.4%) and selective rescue stenting (37.0%) accurately reflects the underlying pathophysiology of ICAS-related occlusion, where mechanical removal of thrombus alone is insufficient to maintain vessel patency. The protocol's emphasis on balloon

angioplasty over immediate stenting aligns with recent evidence suggesting that balloon angioplasty can effectively increase luminal diameter and reduce re-occlusion risk in ICAS-related LVO [27].

The approach is particularly relevant given that balloon angioplasty combined with tirofiban has demonstrated successful recanalization rates of 87.2% with acceptable safety profiles. However, since tirofiban was not readily available in our center, early DAPT loading was implemented as soon as possible before the procedure, which helped minimize re-occlusion rates due to new thrombus formation when rescue interventions were required [28].

4.4. Safety profile and complication management

The safety profile observed in this study merits comprehensive evaluation. The absence of intraprocedural hemorrhagic complications and the low incidence of vessel dissection (11.1%) without flow compromise are noteworthy achievements. This outcome likely reflects the conservative balloon sizing protocol and the emphasis on nominal pressure inflation during angioplasty. The successful management of all cases of distal embolization (11.1%) demonstrates the effectiveness of the technical approach and operator experience.

Although various forms of hemorrhagic transformation were documented across multiple patients at 24 hours, including subarachnoid hemorrhage in 40.7% and different types of hemorrhagic infarction, the relatively low incidence of symptomatic intracranial hemorrhage (7.4%) compares favorably with rates reported in the literature for complex endovascular procedures, which may reach up to 30% [29].

The observation of high rates of radiographic hemorrhagic transformation alongside low rates of symptomatic intracranial hemorrhage is particularly significant. It suggests that while aggressive reperfusion strategies may lead to some degree of bleeding into ischemic tissue, the majority of these events are clinically silent, indicating effective post-procedural management and a successful balance between achieving aggressive reperfusion and mitigating severe complications.

4.5. Clinical outcomes and functional independence

Early neurological improvement, characterized by a mean NIHSS reduction from 14 ± 3 to

8±2 at 24 hours, demonstrates rapid functional recovery following successful recanalization and is consistent with effective penumbra salvage in appropriately selected patients [30, 31]. The 63% functional independence rate (mRS 0-2) at 3 months represents an excellent outcome for this complex patient population. Although this figure is lower than some reported studies [26, 32, 33], it remains consistent with meta-analyses demonstrating that endovascular thrombectomy improves outcomes compared to medical therapy alone [25, 31, 34]. The zero mortality rate also exceeds that of typical contemporary cohorts (6-20%) [25, 35], likely reflecting stringent patient selection criteria and meticulous management protocols.

4.6. Long-term management and stroke prevention

With no patients having residual stenosis $\geq 50\%$ and only 18.5% having final stenosis $< 50\%$, the aggressive intervention strategy effectively addressed both acute occlusion and underlying stenotic pathology.

The low stroke recurrence rate of 7.4% during the 3 - month follow-up period, with both cases being minor strokes that did not significantly impact functional status, suggests that the combination of successful acute intervention and appropriate secondary prevention with dual antiplatelet therapy (DAPT) may provide effective long-term protection.

The implementation of DAPT as part of the protocol appears to have been well-tolerated and effective in preventing recurrent thrombotic events while maintaining an acceptable bleeding risk profile. This is particularly important in patients with ICAS, who remain at elevated risk for recurrent events due to their underlying vascular pathology [28]. The approach is also consistent with current recommendations from the AHA/ASA and ESO for antiplatelet therapy in patients with stroke due to moderate to severe intracranial large artery stenosis [36, 37].

V. CONCLUSIONS

This prospective cohort study demonstrates that endovascular intervention for acute M1 middle cerebral artery occlusion with underlying chronic stenosis can achieve good clinical outcomes. The combination of initial stent-retriever thrombectomy followed by rescue balloon angioplasty and selective

stent placement resulted in 100% successful recanalization (mTICI $\geq 2b$), 74.1% complete recanalization (mTICI 3), and 63% functional independence at 3 months, with a remarkable zero mortality.

Ethical statements

This study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of Hue Central Hospital. Informed consent was obtained from all patients or their legal representatives prior to enrollment. Patient confidentiality was preserved throughout the study.

Conflict of interest

The authors declare that they have no competing interests related to this study.

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