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Technical notes & surgical techniques

Risk of mechanical thrombectomy recanalization failure: Intraoperative nuances and the role of intracranial atherosclerotic disease

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ABSTRACT

Objective: To present intraoperative observations that when recognized may facilitate the identification of patients at high risk of MT recanalization failure. We illustrate 4 cases of successful recanalization via rescue treatment with balloon angioplasty and/or stenting when such observations were noted. We also discuss the role of intracranial atherosclerotic disease in recanalization failure.
Patients and methods: We conducted a retrospective review of a prospectively maintained database for 450 stroke patients and identified 122 patients who underwent MT that failed to achieve recanalization. Operative notes were reviewed, and intraoperative nuances were discussed amongst neurointerventionalists.
Results: Intraoperative observations that may suggest a high risk of MT recanalization failure include resistance to microwire advancement, significant resistance to microcatheter advancement, temporary antegrade flow upon stent retriever (SR) deployment, temporary retrograde flow upon SR deployment with simultaneous aspiration, restricted SR expansion ("pinched device"), moderate resistance to total impedance of SR removal causing vessel/SR stretch on angiographic roadmap, and minimal recanalization after $\geq$3 device passes.
Conclusion: Intraoperative observations may facilitate early recognition of patients at high risk of MT recanalization failure. We suggest considering rescue treatment when such observations are noted to avoid prolonged procedure times, futile reperfusion, and reocclusion post-MT. Intracranial balloon angioplasty and/or stenting may be a safe and effective treatment in this patient subgroup. Stent placement may be considered depending on the patient's antiplatelet status, angioplasty success, and concern for intracranial hemorrhage. Further studies amongst larger patient cohorts are needed.

1. Introduction

The HERMES Collaboration, a meta-analysis of five independent randomized control trials, demonstrated that successful recanalization with mechanical thrombectomy (MT) is strongly associated with improved functional outcomes and reduced mortality in acute ischemic stroke [1]. Current guidelines recommend endovascular therapy (EVT) with stent retrievers as first-line treatment of acute large vessel

Abbreviations: AIS, acute ischemic stroke; CT, computed tomography; CTA, computed tomography angiography; CTP, computed tomography perfusion; EVT, endovascular therapy; ICAD, intracranial atherosclerotic disease; ICH, intracranial hemorrhage; mRS, modified Rankin scale; NIHSS, National Institute Health Stroke Scale; LVO, large vessel occlusion; MCA, middle cerebral artery; MT, mechanical thrombectomy; SR, stent retriever; TICI, thrombolysis in cerebral infarction; tPA, tissue plasminogen activator.

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Table 1
Intraoperative nuances that may suggest a high risk of MT recanalization failure.
Abbreviations: MT, Mechanical Thrombectomy.

	Low Risk of MT Failure	High Risk of MT Failure
Microwire Passing the Clot	No Resistance	Resistance
Microcatheter Passing the Clot	No Resistance	Significant Resistance
Temporary Antegrade Flow Upon Stent Retriever Deployment	Not Always	Almost Always
Temporary Retrograde Flow Upon Stent Retriever Deployment Under Simultaneous Aspiration	Not Always	Almost Always
Resistance to Stent Retriever Removal Causing Vessel/Stent Retriever Stretch on Angiographic Roadmap	No Resistance	Moderate Resistance to Total Impedance
Restricted Stent Retriever Expansion ("Pinched" Device)	No Restriction	Restriction
Recanalization	Partial or Full After 1–2 Passes	Minimal After ≥3 Passes

occlusion (LVO) [2]. However, MT recanalization failure with Thrombolysis in Cerebral Infarction (TICI) scores of 0–1 has been observed in up to 20% of patients [1,3], which results in greater infarct volumes and poorer clinical outcomes [4]. Intracranial atherosclerotic disease (ICAD) is a major factor associated with recanalization failure or re-occlusion post-MT [5,6], which results in high rates of rescue treatment during EVT and longer procedure times for successful recanalization of (ICAD)-related LVOs [7].

In this study, we present intraoperative nuances that may facilitate early identification of patients at high risk of MT recanalization failure. We also discuss the role of ICAD in MT recanalization failure and suggest an alternative treatment approach with the potential to improve outcomes of EVT in this patient subgroup.

2. Patients and methods

2.1. Study design

The study protocol was approved by our Institutional Review Board, and the need for informed consent was waived. The authors declare that all supporting data is present within the article. We conducted a retrospective review of a prospectively maintained database for 450 stroke patients and identified 122 patients who underwent MT that failed to achieve recanalization. Operative notes were reviewed, and intraoperative nuances were discussed amongst neurointerventionalists. We accessed patients' electronic medical record and collected relevant data related to their procedure and clinical course.

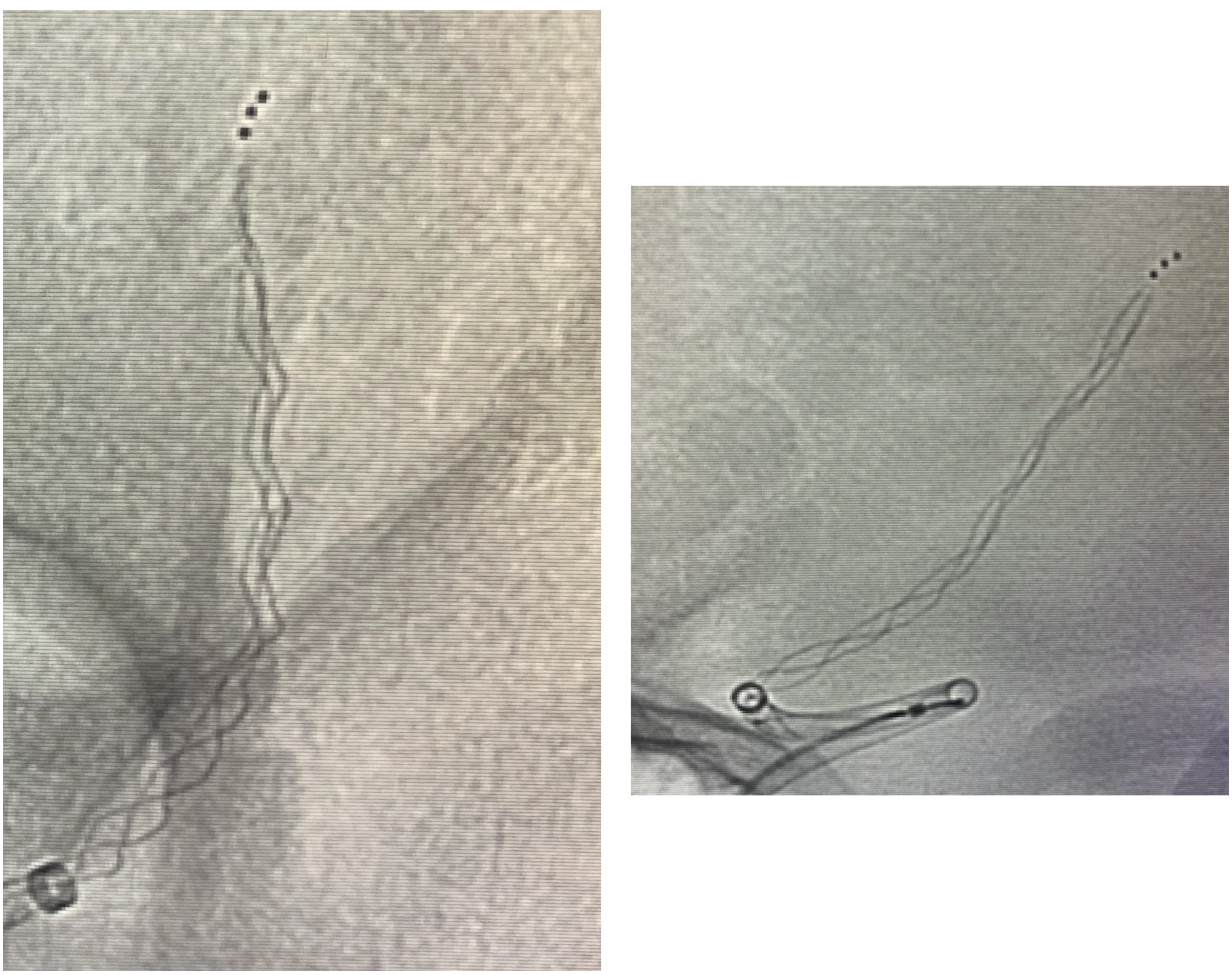

Fig. 1. (a) Restricted stent retriever expansion; (b) Resistance to device removal caused the vessel/stent retriever to stretch.

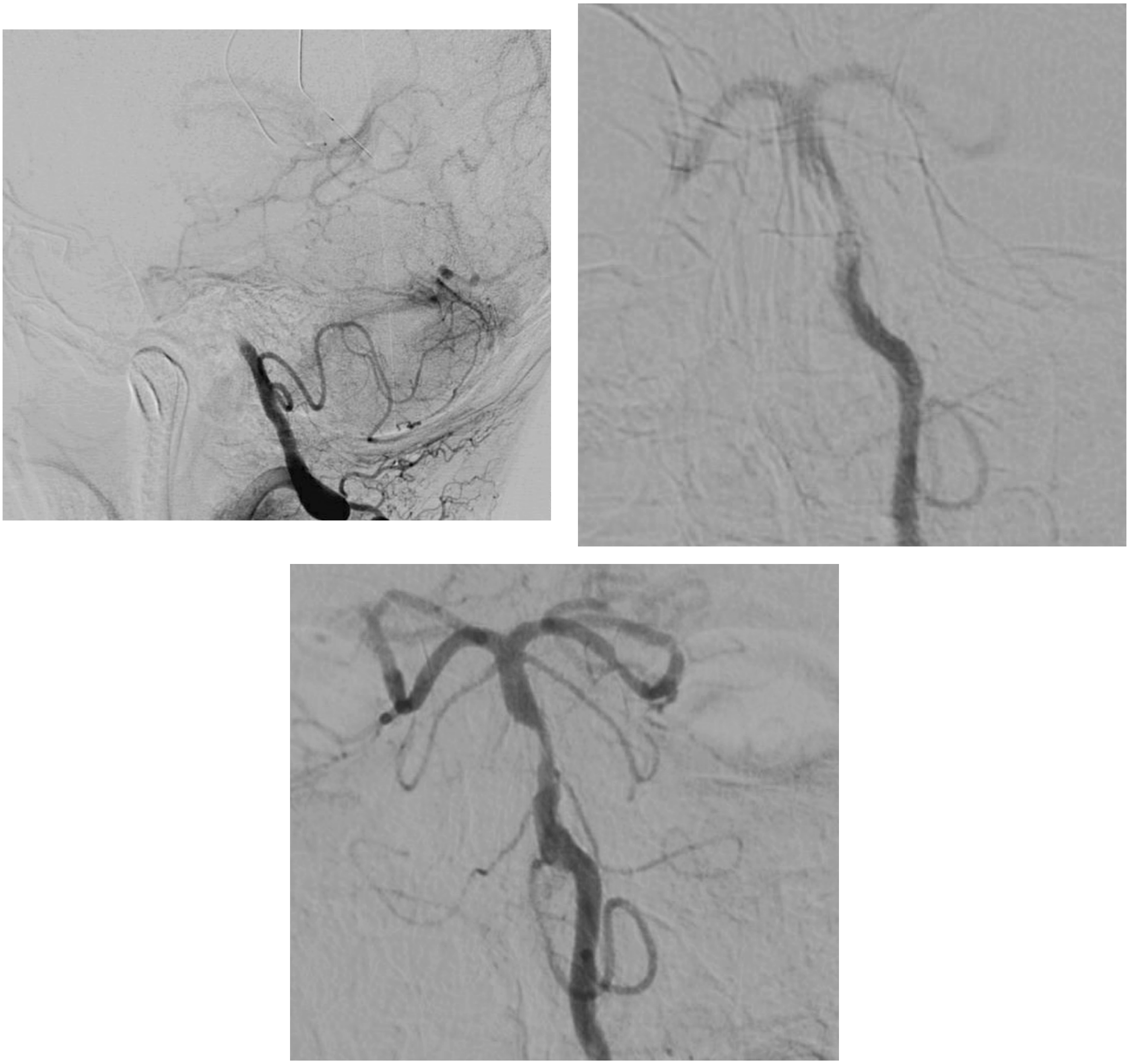

Fig. 2. (a–c) Digital subtraction angiography (DSA) of emergent revascularization. (a) Basilar artery occlusion; (b) Minimal antegrade flow after 3 device passes due to severe stenosis; (c) Improved antegrade flow post-angioplasty. *Abbreviations:* DSA, Digital Subtraction Angiography.

3. Results

3.1. Intraoperative observations

Intraoperative observations (Table 1) that may suggest a high risk of MT recanalization failure include resistance to microwire advancement, significant resistance to microcatheter advancement, temporary antegrade flow upon stent retriever deployment, temporary retrograde flow upon stent retriever deployment under simultaneous aspiration via penumbra pump device, restricted stent retriever expansion or a "pinched" device (Fig. 1a), moderate resistance to total impedance of stent retriever removal causing vessel/stent retriever stretch on angiographic roadmap (Fig. 1b), and minimal recanalization after ≥3 device passes (TICI 0-2a).

3.2. Case illustration 1

62-year-old male presented to the emergency department after developing left hand and face numbness as well as burning discomfort of the head and eyes while driving. The patient also endorsed nausea, vomiting (2×), and dizziness. On neurological exam, the patient had left hemiparesis and NIHSS 6. Computed tomography angiography (CTA) of the head revealed a mid-basilar artery occlusion. The patient was taken for emergent revascularization, which confirmed total occlusion in the mid basilar artery (Fig. 2a). MT via stent retrieval was performed but failed to achieve successful recanalization after 3 device passes due to severe stenosis (Fig. 2b). Alternative treatment with balloon angioplasty of the basilar artery was then performed and improved antegrade flow (Fig. 2c). The patient was neurologically intact at discharge.

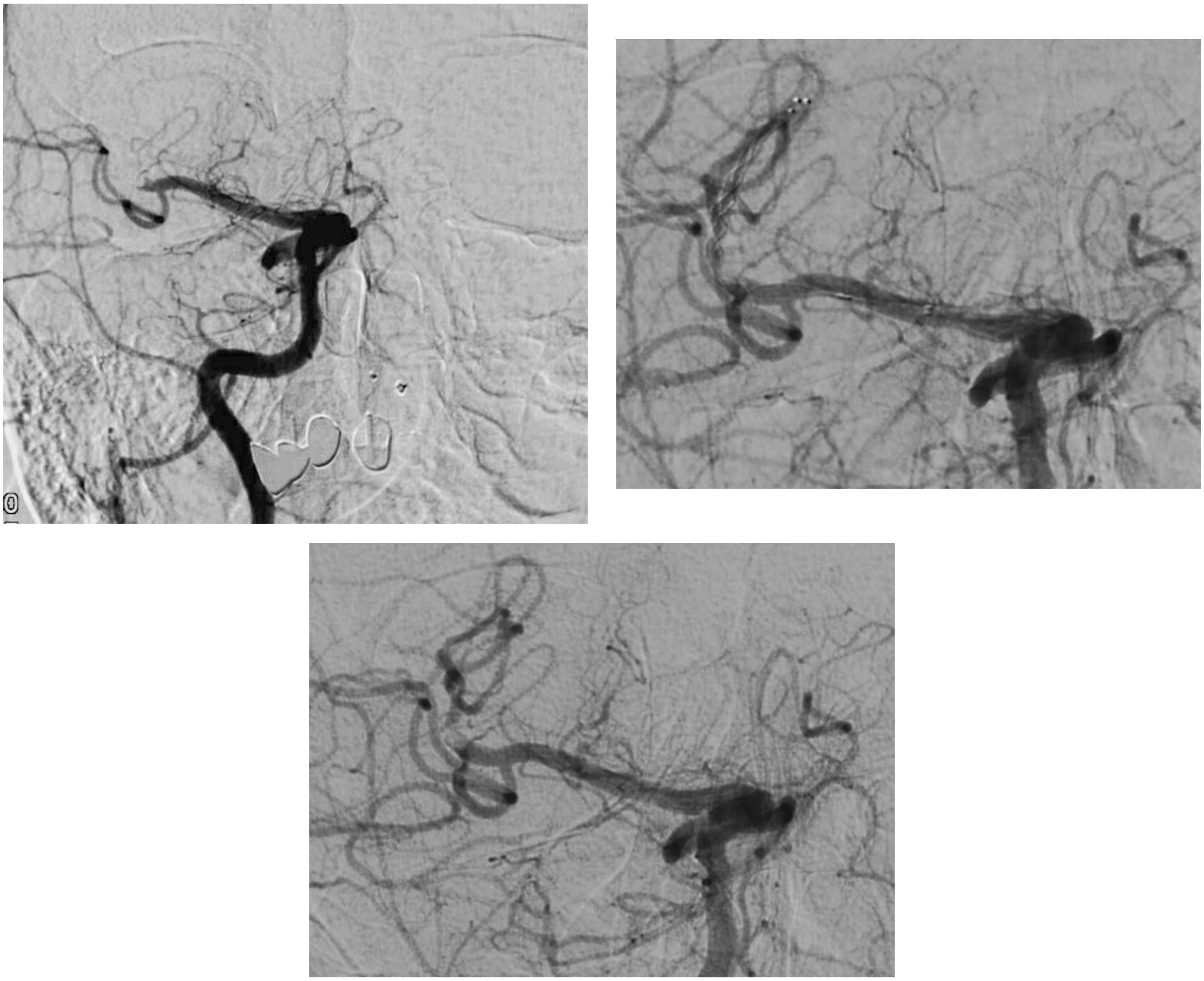

Fig. 3. (a–c) DSA of emergent revascularization. (a) Right MCA M2 branch occlusion; (b) Temporary antegrade flow upon stent retriever deployment; (c) Improved antegrade flow post-angioplasty. *Abbreviations:* DSA, Digital Subtraction Angiography; MCA, Middle Cerebral Artery.

3.3. Case illustration 2

75-year-old female was brought to the emergency department by her son due to altered mental status. On arrival, NIHSS was 19. CTA revealed occlusion of the dominant M2 branch of the right middle cerebral artery (MCA). The patient was taken for emergent revascularization, which confirmed the M2 occlusion (Fig. 3a). MT via stent retrieval was performed resulting in temporary antegrade flow upon stent retriever deployment (Fig. 3b). After 3 device passes, alternative treatment with balloon angioplasty was performed resulting in improved antegrade flow (Fig. 3c). The patient was discharged with NIHSS 1.

3.4. Case illustration 3

61-year-old female presented to the emergency department with a NIHSS of 16. CTA revealed a left vertebral and basilar artery occlusion, and the patient was taken for emergent revascularization (Fig. 4a). MT was performed with a combination of stent retrieval and aspiration, but MT ultimately resulted in minimal recanalization after 2 passes due to significant residual stenosis (Fig. 4b). Of note, narrowing of the stent retriever was observed when crossing the area of stenosis ("pinched device"). Alternative treatment via stent placement was performed and resulted in TICI 3 recanalization (Fig. 4c). At 1 month follow-up, modified rankin scale (mRS) was 1.

3.5. Case illustration 4

91-year-old female presented to the emergency department with a NIHSS of 18. CTA revealed a right M2 occlusion, and the patient was taken for emergent revascularization (Fig. 5a). MT was performed with a combination of stent retrieval and aspiration but resulted in minimal recanalization after 4 device passes (Fig. 5b). Alternative treatment was implored via stent placement, which resulted in improved antegrade flow and TICI 3 recanalization (Fig. 5c).

4. Discussion

In the present study, we aimed to illustrate intraoperative nuances that may facilitate early identification of patients at high risk of MT recanalization failure: resistance to microwire advancement, significant resistance to microcatheter advancement, temporary antegrade flow upon stent retriever deployment, temporary retrograde flow upon stent retriever deployment under simultaneous aspiration via penumbra pump device, moderate resistance to total impedance of stent retriever removal causing vessel/stent retriever stretch on angiographic roadmap, minimal recanalization after ≥3 device passes (TICI 0-2a), and restricted

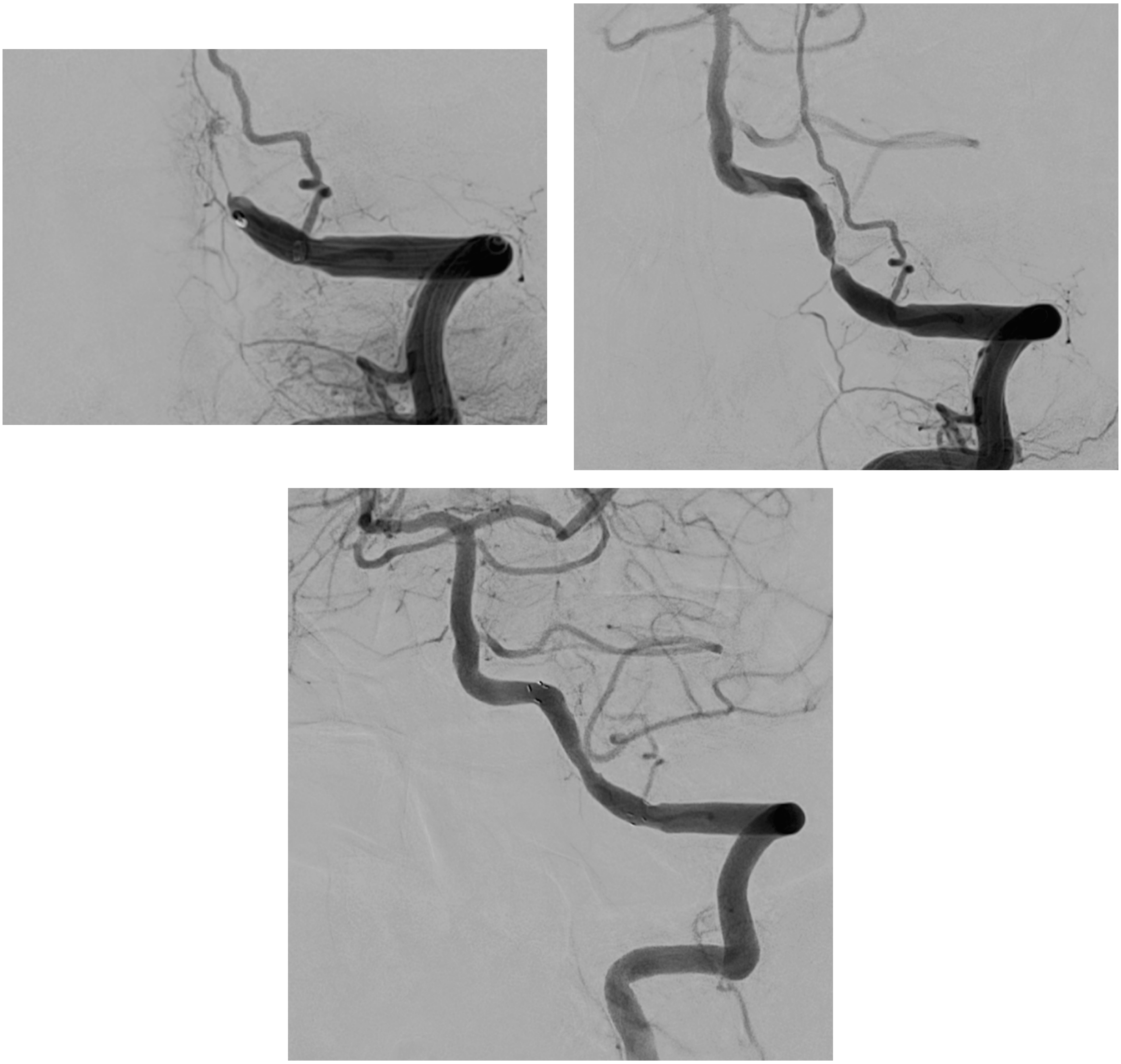

Fig. 4. (a–c) DSA of emergent revascularization. (a) Left vertebrobasilar occlusion; (b) Minimal recanalization after 2 device passes due to residual stenosis; (c) Successful recanalization (TICI 3) post-stent placement. *Abbreviations:* DSA, Digital Subtraction Angiography; TICI, Thrombolysis in Cerebral Infarction.

stent retriever expansion ("pinched" device). Of note, the stent retriever fails to expand beyond the diameter at initial deployment and remains "pinched" throughout the dwell time. If these intraoperative nuances are observed, we suggest considering an alternative treatment approach with intracranial balloon angioplasty and/or stenting to avoid prolonged procedure times, futile reperfusion, and reocclusion post-MT. It is important to note that not all of the aforementioned intraoperative nuances must be present to suggest an increased risk of MT recanalization failure. In the 4 case illustrations presented in this study, we demonstrated that rescue treatment with intracranial balloon angioplasty and/or stenting resulted in successful recanalization when MT failed to achieve recanalization after $\geq$2 device passes.

Stent retrievers have limited efficacy in the treatment of acute ICAD-related LVO due to hidden stenosis [8]. Patients with ICAD-related LVO have a poorer prognosis following MT compared to embolic occlusion, which can be attributed mainly to longer procedure time, higher rates of recanalization failure, and higher reocclusion rates [6,9]. Longer MT procedural times and multiple device passes are independently associated with worse outcomes [10,11], and may also lead to futile reperfusion with rescue therapy [11]. Lee et al. [8] reported that 78% of patients with ICAD-related LVO who underwent MT required rescue treatment. Angioplasty was the most common rescue therapy (71%) and was found to be effective in the distal MCA and intracranial vertebral arteries. If successful recanalization of ICAD-related LVO were to occur via tPA or MT, neither treatment addresses the underlying stenosis leaving a high risk for reocclusion of atherosclerotic lesions. Vessel rupture and intracerebral hemorrhage (ICH) is also concern when encountering stenotic impedance to MT device retrieval [12].

Given the tendency for ICAD-related LVO to reocclude and high rates of residual stenosis, rescue treatment or additional definitive treatment may be necessary. Yang et al. [12] found that primary angioplasty may be superior to MT in acute atherosclerotic LVOs. In patients receiving primary angioplasty, 70% (vs. 48%) had favorable independent outcomes at 90 days (mRS 0–2) and only 9% (vs 31%) had asymptomatic

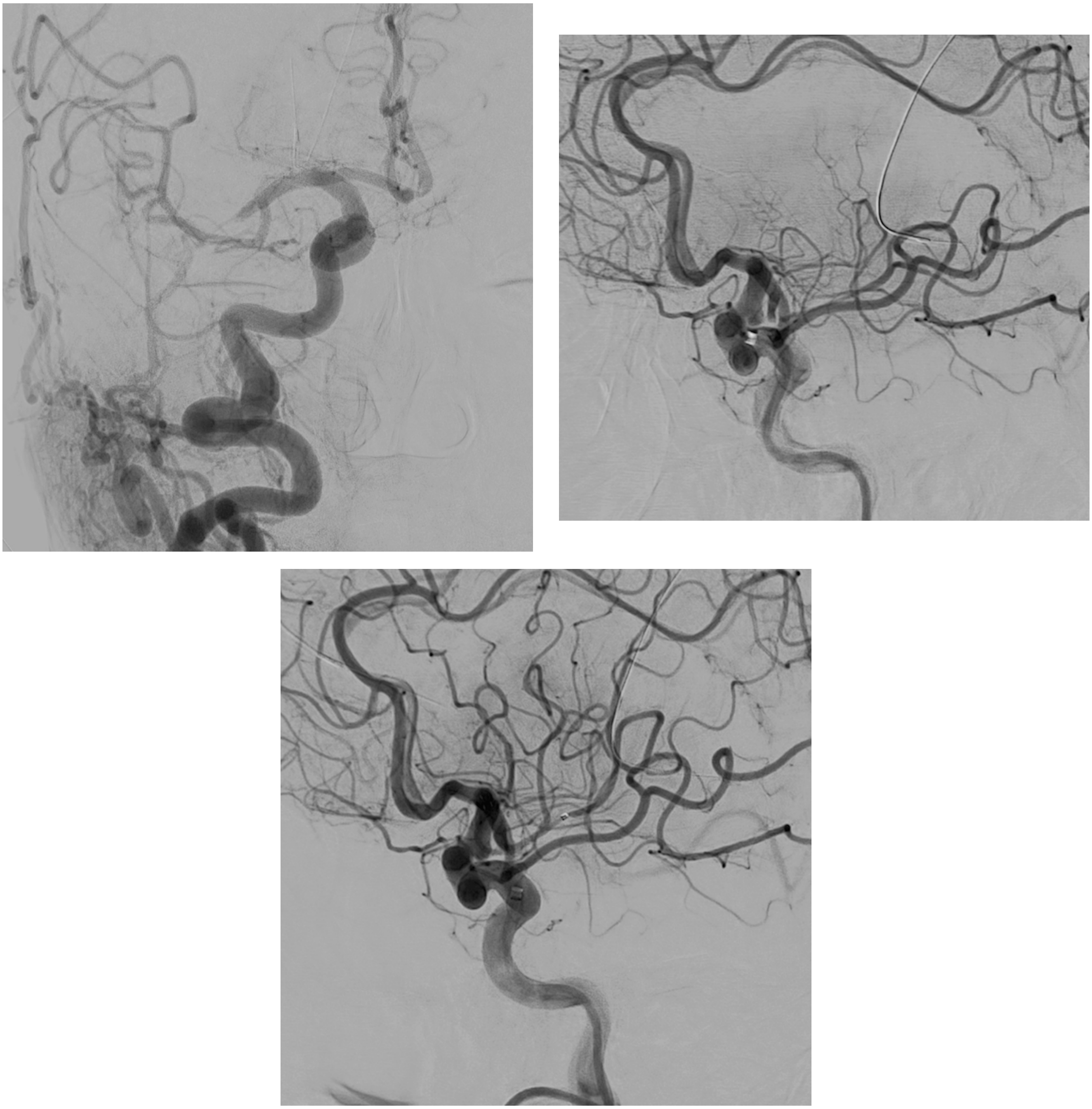

Fig. 5. (a–c) DSA of emergent revascularization. (a) Right MCA M2 branch occlusion; (b) Minimal antegrade flow after 4 device passes due to severe stenosis; (c) Improved antegrade flow post-stent placement. *Abbreviations:* DSA, Digital Subtraction Angiography; MCA, Middle Cerebral Artery.

intracranial hemorrhage. Primary angioplasty therapy was also a protective factor against poor functional outcome (OR, 0.27; 95% confidence interval (CI): 0.08–0.90; $p = 0.03$) [12]. In a recent meta-analysis, Wareham et al. [5] found that rescue therapy utilizing self-expandable stents achieved successful recanalization in 71% and a favorable clinical outcome in 43%. However, stent deployment in LVOs is associated with a higher bleeding risk when using antiplatelet therapy [5,13,14], and no long-term data exists on thrombus remodeling after rescue stenting in the setting of resistant thrombus or ICAD [5].

Early differentiation between acute atherosclerotic and embolic stroke etiology can save time and guide alternative treatment strategies. A recent prospective trial found that the recanalization failure rate with TICI 0-2a after 3 passes was still 20% [15], which highlights the importance of early recognition of MT recanalization failure and efficacious bailout technique. The lack of established biomarkers or another adequate modality to identify ICAD-related LVOs prior to intervention makes procedural planning challenging [16]. A 2018 study found that patients with ICAD-related LVOs were younger, predominately male, had a higher frequency of middle cerebral artery M1 occlusion, and a lower initial NIHSS score compared to embolic LVOs [9]. Additionally, there was a higher incidence of ICAD-related occlusions in Asian populations [17]. Diabetes and hyperlipidemia were also directly associated with ICAD, while atrial fibrillation was inversely associated with ICAD [18,19]. Haussen et al. [16] found that ICAD LVO patients have greater than twice the frequency of diabetes, higher A1c levels, and higher LDL cholesterol levels compared to non-ICAD. However, these baseline characteristics are not accurate predictors of underlying ICAD etiology due to their ubiquitous nature within the LVO patient population but computed tomographic perfusion (CTP) imaging has recently shown potential.

Haussen et al. [16] observed that patients with acute ICAD-related LVO have more benign CTP images due to enhanced chronic recruitment of collateral vessels compared to embolic occlusions. On multivariate analysis, CTP defect severity ratios were independent predictors of underlying ICAD in LVO. This offers one potential modality to facilitate early detection of an ICAD-related LVO, which may enable neurointerventionalists to avoid multiple stent retriever passes and implore earlier definitive revascularization techniques such as angioplasty [16]. However, the etiology of resistant occlusions may only become apparent intraoperatively, therefore early recognition of MT recanalization failure or ICAD-related LVO may be imperative to achieve favorable patient outcomes. In addition to our observations, Yi et al. [20] found that the microcatheter first-pass effect had a sensitivity, specificity, PPV, and accuracy for ICAD identification of 90.9%, 87.2%, 80.0%, 88.5%, respectively. This phenomenon is defined as "temporary blood flow through the occluded intracranial artery when the angiographic microcatheter is initially advanced through the site of total occlusion and immediately retrieved proximally." Intra-operative guidelines are needed to indicate when it is appropriate to transition to an alternative intervention taking into consideration core infarct size and time from ictus [5].

The current study is limited by the small sample size, retrospective nature, and lack of formal data analysis due to inconsistent documentation in operative notes written by different authors. This study was intended to demonstrate the intraoperative surgical nuances to facilitate early identification of patients at high risk of MT recanalization failure, discuss role of ICAD-related LVO in recanalization failure, and discuss an alternative treatment with intracranial balloon angioplasty and/or stenting in such cases.

5. Conclusion

Intraoperative observations may facilitate early recognition of patients at high risk of MT recanalization failure. We suggest considering rescue treatment when such observations are noted to avoid prolonged procedure times, futile reperfusion, and reocclusion post-MT. Intracranial balloon angioplasty and/or stenting may be a safe and effective treatment in this patient subgroup. Stent placement may be considered depending on the patient's antiplatelet status, angioplasty success, and concern for intracranial hemorrhage. Further studies amongst larger patient cohorts are needed.

6. Contributorship statement

JHW, AS, HZ drafted the manuscript and revised the manuscript for important intellectual content. JHW, AS, AA, KP, DJ assisted with the data acquisition and analysis. AA, RA, ST, PJ reviewed the important intellectual content presented in the manuscript. ST, RG, RHR, PJ, HZ performed treatment procedures and critically revised the important intellectual content. All authors read and approved the final manuscript.

7. Data sharing statement

The relevant anonymized patient level data are available on reasonable request from the authors.

Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. For this type of study formal consent is not required.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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