

# 3D Turbo Spin-echo MRI-based Mechanical Thrombectomy at Middle Cerebral Artery Bifurcations

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## Abstract

We describe three cases with acute middle cerebral artery (MCA) occlusion. From the pre-operative MRI, including three-dimensional turbo spin-echo sequences using T1WI and T2WI, we assessed both thrombus configuration and arterial anatomy at the MCA bifurcations. For efficient endovascular thrombectomy, we identified the applied MCA segment 2 (M2) branch, in which the main thrombus was buried. Sufficient recanalization after a single pass was achieved and the patients made a marked recovery. Although mechanical thrombectomy for M2 occlusion has not been of proven benefit, the endovascular procedure based on three-dimensional turbo spin-echo imaging is useful for more complete thrombus removal at MCA bifurcations.

Keywords: 3D turbo spin-echo MRI, mechanical thrombectomy, middle cerebral artery bifurcations, thrombus imaging

## Introduction

Mechanical thrombectomy for acute cerebral ischemia due to large vessel occlusion is an established therapy.<sup>1,2)</sup> The therapeutic applications for the distal cerebral artery, such as the middle cerebral artery (MCA) segment 2 (M2), have been expanded with development of neurovascular devices.<sup>3,4)</sup> However, the stent retrieval procedure for small or inflectional branches may injure the vascular endothelium, leading to dissection or vessel perforation.<sup>5)</sup> In particular, as for arterial occlusion at MCA bifurcations, blind catheterization through the thrombus to the M2 is required and there is a high risk of straightening or perforator avulsion during stent retrieval. Herein, we describe the efficacy of three-dimensional turbo spin-echo (3D-TSE) sequences using T1WI and T2WI to detect both thrombus configuration and vascular structure and report three stroke cases of MCA occlusion successfully treated with a stent retriever based on the pre-operative MRI findings.

## Method

A total of 23 patients with acute MCA occlusion between October 2020 and August 2021 were performed mechanical thrombectomy according to the following MRI protocol. 3D-TSE T2WI demonstrated arterial configuration at MCA bifurcations in all cases. Thrombus locations on 3D-TSE T1WI were identified in 21 cases.

A 3.0T MRI (Skyra system; Siemens, Erlangen, Germany) was used. Our MRI protocol for acute ischemic stroke (AIS) patients included diffusion-weighted imaging (DWI), 3D time-of-flight MRA, T2\*, fluid-attenuated inversion recovery, and 3D-TSE T1WI and T2WI. Total scan time of our stroke protocol was 9 min 47 sec. Parameters for 3D-TSE (slice thickness, 0.6 mm; no gap) were as follows. For T1WI, TR/TE = 600/29.0 ms, respectively, voxel size = 0.4 × 0.4 × 0.6 mm, ETL = 35, FOV = 140 mm, and acquisition time = 138 s. For T2WI, TR/TE = 1300/98 ms, respectively, voxel size = 0.5 × 0.5 × 0.6 mm, ETL = 165, FOV = 140 mm, and acquisition time = 33 s.

Thrombus length was evaluated from measurements between the proximal and distal extent obtained by curved planar reconstruction of 3D-TSE T1WI.<sup>6)</sup>

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## Case Presentation

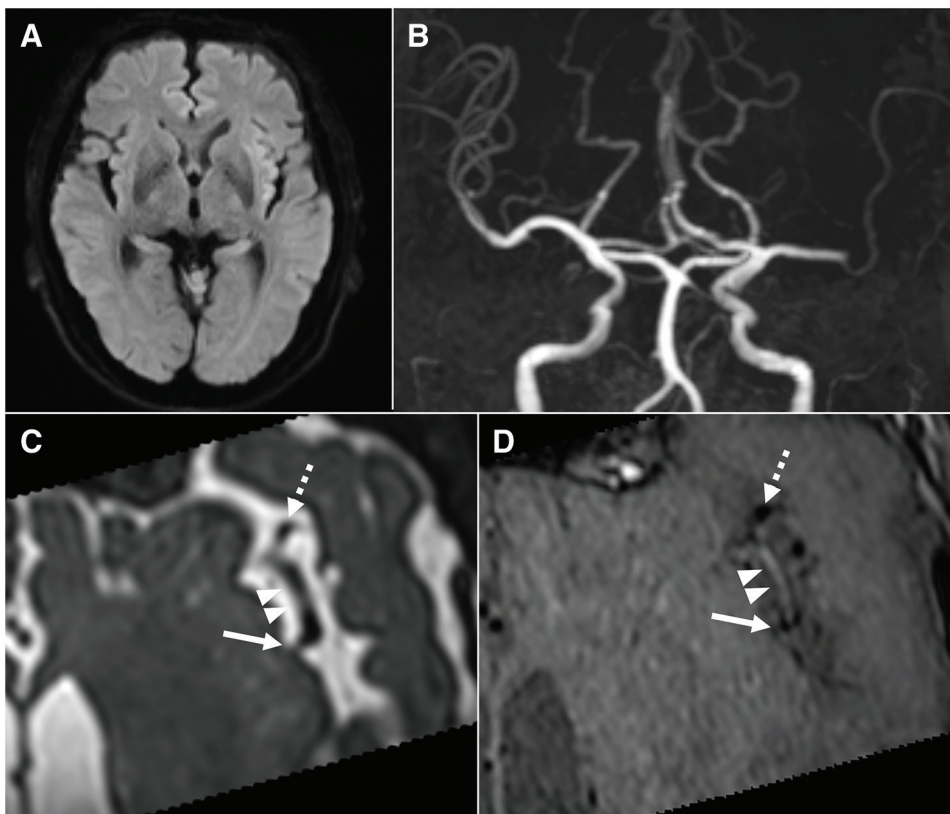
### Case 1

The patient was an 82-year-old, right-handed man with a past medical history of dyslipidemia, who developed motor aphasia and right upper limb paralysis. He was transported to our hospital by ambulance at 1 hr 16 min after onset. Dysarthria, right upper limb paralysis (manual muscle test score, 1), and right paresthesia were observed. His National Institute of Health Stroke Scale (NIHSS) score was 17. Electrocardiogram on arrival showed arterial fibrillation. DWI demonstrated a slightly high intensity area in the left insular cortex and deep white matter, without remarkable changes on fluid-attenuated inversion recovery (door-to-image time, 12 min) (Fig. 1A). His diffusion-weighted Alberta Stroke Program Early CT score was 9. Although MRA showed left distal M1 or M2 occlusion with a small inferior trunk, 3D-TSE T2WI

showed an MCA branching pattern of superior trunk dominant bifurcations and a large pre-frontal artery arising from the proximal superior trunk (Fig. 1B and 1C). 3D-TSE T1WI also identified the thrombus localization from the proximal M2 to just distal of the pre-frontal artery branch in the main superior trunk (Fig. 1D). The thrombus length was 12 mm. From 3D-TSE imaging, a decision to catheterize the main M2 superior trunk, preventing misplacement to the pre-frontal artery, and the choice of stent retriever was made before the endovascular procedure. Based on the diagnosis of acute cerebral infarction, intravenous tissue plasminogen activator was performed (door-to-needle time, 24 min). The patient was then taken to the neurointerventional suite.

### Treatment

Under local anesthesia, a 9 French long sheath was inserted into the right femoral artery (door-to-puncture time, 38 min). A 9 French Optimo (Tokai



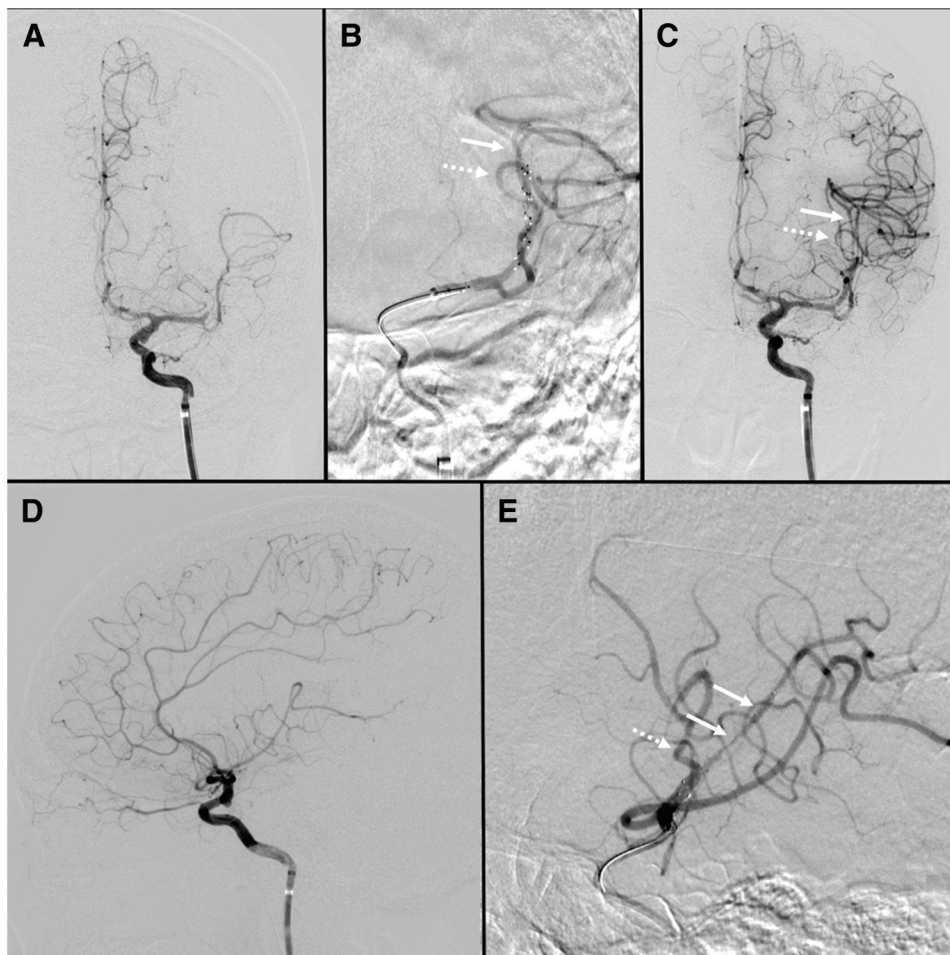
**Fig. 1** Arterial anatomy and thrombus configuration demonstrated by pre-operative MRI. Diffusion-weighted imaging revealed a high-signal-intensity area in the left insular cortex and deep white matter (A). MRA revealed the left distal middle cerebral artery (MCA) occlusion (B). Three-dimensional turbo spin-echo (3D-TSE) T2WI revealed the whole arterial configuration at the MCA bifurcations (prefrontal a, solid arrow; superior trunk, arrowheads; inferior trunk, dotted arrow) (C). 3D-TSE T1WI demonstrated the thrombus (arrowheads) with high intensity, which was located in the main superior trunk. The prefrontal artery and the inferior trunk were patent (D).

Medical, Aichi, Japan) was positioned at the petrous segment of the left internal carotid artery (ICA). A Catalyst 6 (Stryker Neurovascular, Freemont, CA, USA) was gently advanced over a combination of a Chikai 14 microwire (Asahi Intec, Aichi, Japan) and a Rebar 18 microcatheter (Medtronic, Irvine, CA, USA). The microcatheter was guided to the distal of the pre-frontal artery branch in the main superior trunk. A Solitaire device (4 × 20 mm; Medtronic) was deployed via the microcatheter and mechanical thrombectomy was performed using continuous aspiration prior to the intracranial vascular embolectomy technique (Fig. 2A–2E). A single pass led to successful recanalization (modified thrombolysis in cerebral infarction, 2B; puncture to recanalization time, 10 min). Almost complete recanalization was achieved after the second pass (modified thrombolysis in cerebral infarction, 2C) (Fig. 2C).

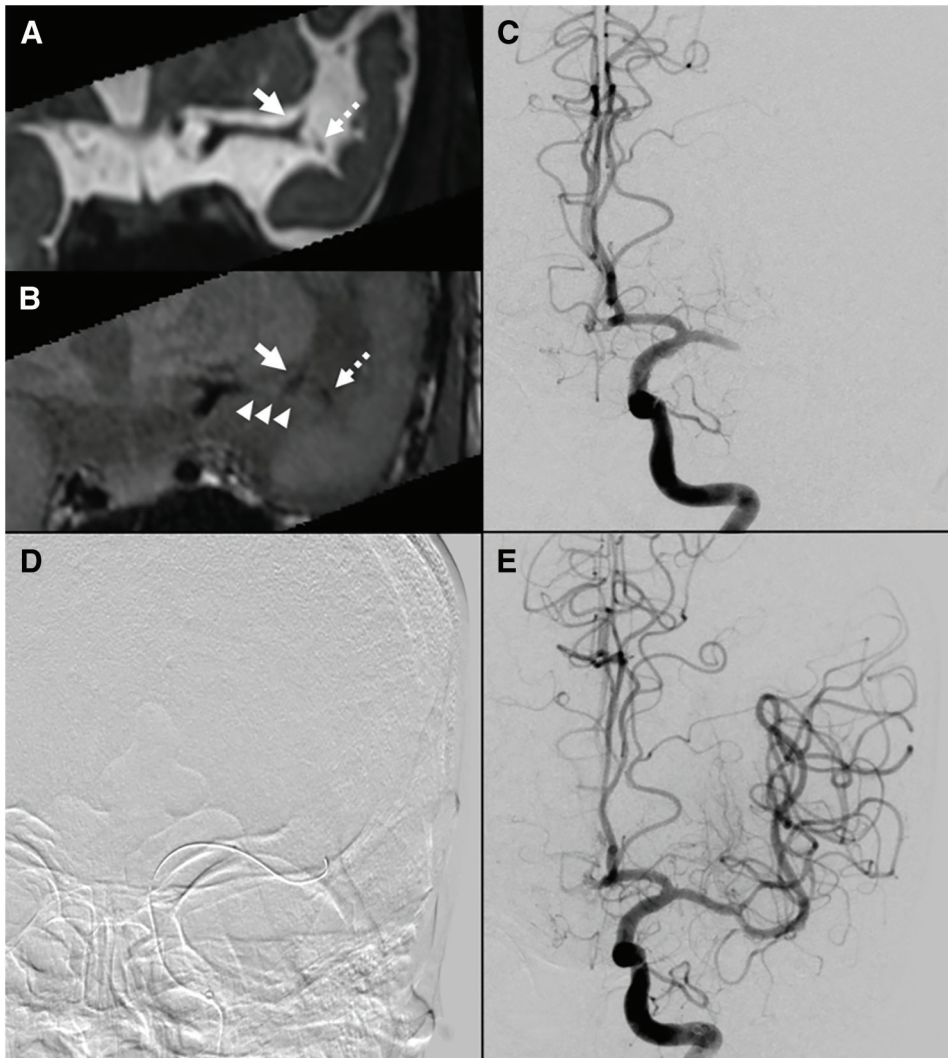
MRI the following day demonstrated a restricted fresh infarction in the left putamen, deep white matter, and insular cortex with small hemorrhagic transformation. The patient was maintained on direct oral anticoagulant without recurrent stroke. His NIHSS scores was 2 and 0 at 24 hr and 1 week, respectively. He made a remarkable recovery and returned home at 9 days after onset (modified Ranking Scale score, 0).

### Case 2

The patient was an 85-year-old man with acute left M1 occlusion. 3D-TSE T2WI demonstrated an MCA vascular structure, including length and branching of the M1 segment (Fig. 3A). 3D-TSE T1WI showed the thrombus location from M1 to the proximal M2 of inferior trunk (Fig. 3B). At the middle portion of M2 inferior trunk, over the insula within Sylvian fissure, the thrombus was not identified. The microcatheter was guided to the inferior trunk, and



**Fig. 2** Pre-operative angiography demonstrated the left distal middle cerebral artery (MCA) occlusion (A, D). The Solitaire device (4 × 20 mm) was deployed at the main M2 of the superior trunk over the entire length of the thrombus (B, E). Almost complete recanalization was achieved after two passes of mechanical thrombectomy (C). Prefrontal artery, dotted arrow; superior trunk, solid arrow.



**Fig. 3** 3D-TSE T2WI demonstrated the arterial structure at the MCA bifurcations (A). 3D-TSE T1WI identified the thrombus (arrowheads), which was located from M1 to the proximal M2 of inferior trunk. No thrombus was detected at either the superior trunk (solid arrow) or the middle portion of M2 inferior trunk (dotted arrow) (B). Pre-operative angiography demonstrated the left MCA occlusion (C). A Rebar 18 microcatheter was advanced to the M2 inferior trunk over the thrombus (D). Successful recanalization was achieved after a single pass of mechanical thrombectomy (E).

mechanical thrombectomy was performed from the middle M2 portion (Fig. 3C and 3D). Successful recanalization with a single pass was achieved (puncture to recanalization time, 33 min) (Fig. 3E).

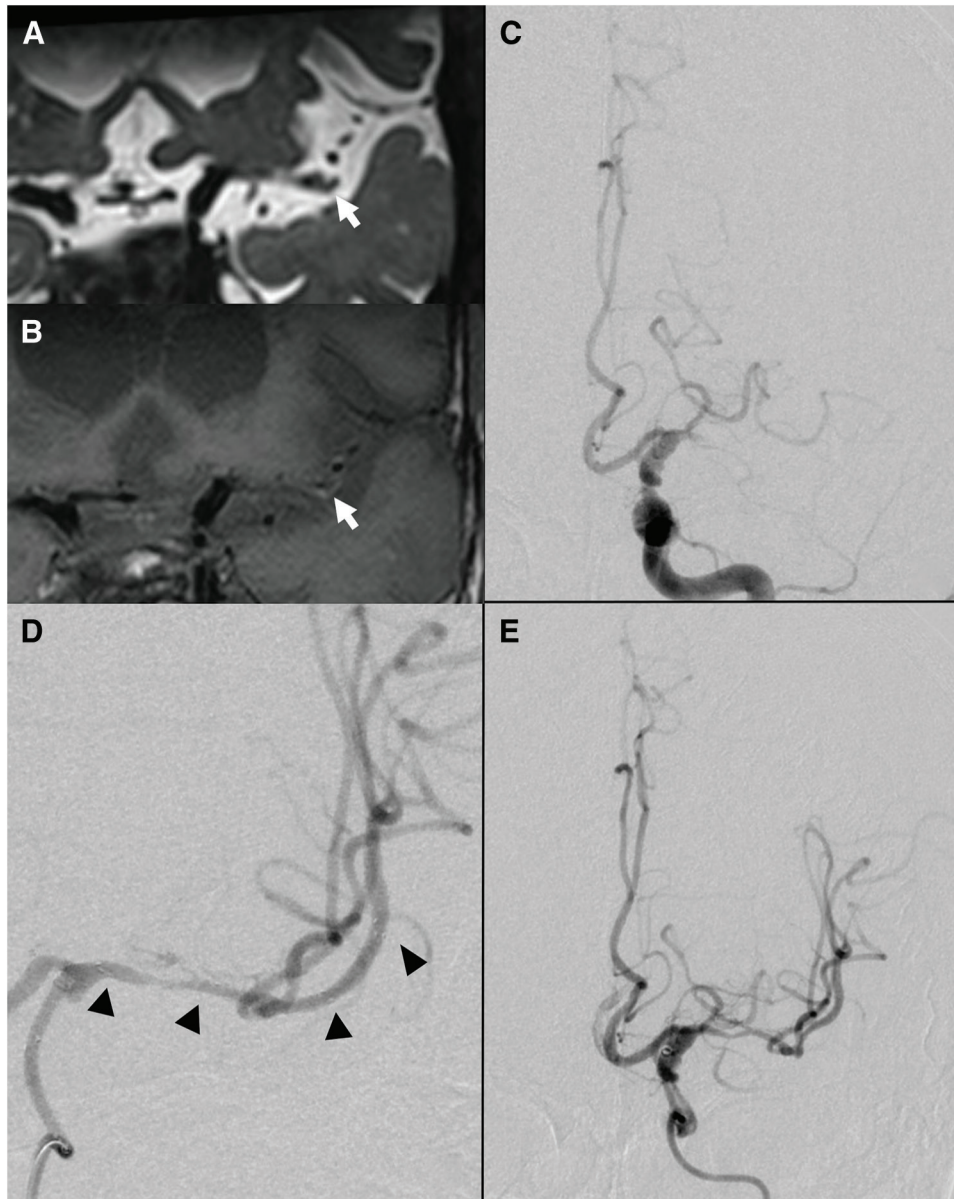
### Case 3

The patient was a 77-year-old man with left M1 proximal occlusion. 3D-TSE T2WI showed the trifurcation of M1/2 junction (Fig. 4A). 3D-TSE T1WI identified the thrombus location from M1 to the M2 inferior trunk (Fig. 4B). The inferior trunk traveled laterally within Sylvian fissure, compared to other M2 segments. The microcatheter was advanced to the inferior trunk, and a retrieval stent was deployed from the M2 inferior segment to the

proximal M1 (Fig. 4C and 4D). Immediate flow restoration was achieved (Fig. 4E). Successful recanalization was performed after the first pass (puncture to recanalization time, 29 min) (Fig. 4E).

### Discussion

M2 occlusions are reported in 3% of AIS patients with significant neurological deficits (median NIHSS score, 12) and represent the second most common occluded location after M1.<sup>3)</sup> Although mechanical thrombectomy for M2 occlusions can improve stroke outcomes, randomized clinical trials have not established the efficacy compared with medical treatment.<sup>1,4,7,8)</sup> Sarraj et al. showed a recanalization rate



**Fig. 4** 3D-TSE T2WI demonstrated the arterial configuration of both internal carotid artery (ICA) and middle cerebral artery (MCA) (A). 3D-TSE T1WI identified the thrombus, which was located from M1 to the proximal M2 of inferior trunk (solid arrow) (B). Pre-operative angiography demonstrated the left MCA proximal occlusion (C). A Solitaire device ( $4 \times 40$  mm) was deployed from the M2 inferior trunk precisely over the thrombus and immediate flow restoration was achieved (D). Successful recanalization after a single pass was performed (E).

of 78%, an incidence of symptomatic intracerebral hemorrhage of 5.6%, and functional independence of 62.8% in a cohort of patients with acute M2 occlusion.<sup>7)</sup> However, the reported rate of good outcome with medical treatment is as high as 54.2%.<sup>9)</sup> Thus, mechanical thrombectomy may not be superior to medical treatment. To establish the endovascular thrombectomy for M2 occlusions, both efficient and immediate revascularization are required, in addition to appropriate patient selection. For the

endovascular procedure, complete revascularization after single pass of a stent retriever is an important factor for good clinical outcome.<sup>10)</sup> For mechanical thrombectomy at arterial bifurcations, where and which branch should be catheterized through the thrombus remains unclear because the arterial structure distal to the thrombus and the thrombus configuration are unknown. Specifically, thrombi at MCA bifurcations can be localized in the distal M1 involving a single M2 branch.<sup>6)</sup> Guenego et al.

demonstrated that thrombi in the M2 extension had a low rate of successful reperfusion compared with a straight distal M1 thrombus.<sup>6)</sup> In cases of an M1 with a single M2 thrombus, partial thrombus complement by stent retrieval from the non-buried M2 branch has a risk of fragmentation, leading to incomplete revascularization and distal embolization during the procedure.<sup>11)</sup> Multiple thrombectomy procedures can also increase the risk of procedural complications due to endothelial injury and naturally prolong the ischemic interval. For effective mechanical thrombectomy, direct catheterization of the occluded M2 branch with the main thrombus and appropriate stent deployment over the entire thrombus length are desirable. Preoperative radiological findings of arterial structure behind the thrombus and the thrombus configuration can help to prevent a rough and blind wire maneuver and reveal the distal end of the thrombus.

Our workflow in AIS patients uses MRI screening. Although MRI takes slightly longer than non-contrast CT, MRI can detect acute cerebral ischemia more precisely, and Provost et al. revealed that MRI-based mechanical thrombectomy had a similar timeframe and functional outcome to CT.<sup>12)</sup> At our institution, the time required for MRI including 3D-TSE images is <10 min. Thus, MRI-based mechanical thrombectomy is acceptable.

Various techniques for thrombus imaging, including histological composition, etiology, and recanalization, have been performed after mechanical thrombectomy.<sup>6,13)</sup> Non-cardioembolic strokes, which have higher proportions of erythrocytes, were associated with the hyperdense artery sign on CT, decreased distance from the ICA-terminus, and longer thrombi compared with cardioembolic strokes.<sup>13)</sup> A thrombus on T2\* gradient-echo sequence MRI (the susceptibility vessel sign) was used to detect thrombus location and evaluate thrombus length.<sup>6)</sup> The development of 3D-TSE imaging with variable refocusing flip angles, which captures a wide range of high-resolution images with reduced partial volume artifacts via decreased image blurring, has contributed to diagnosis of vessel wall lesions or brain tumor invasion.<sup>14,15)</sup> In particular, 3D-TSE T1WI and T2WI have a high sensitivity for intramural hematomas and a dilated outer arterial diameter in cerebral artery dissection, respectively, using multiplanar or curved planar reconstruction.<sup>15)</sup> In our cases, 3D-TSE T1WI showed the thrombus configuration at the M2 segment and determined the affected branch and the distal end of the thrombus. The high spatial resolution on 3D-TSE T1WI is useful for identifying the thrombus location. 3D-TSE T2WI also clearly demonstrated the whole arterial

configuration at MCA bifurcations, which could not be assessed by MRA or DSA.

In conclusion, blind catheterization through a thrombus and partial thrombus integration by stent retrieval can cause vessel injury and incomplete revascularization. The combination of 3D-TSE T1WI and T2WI can help to create a strategy design for effective mechanical thrombectomy.

## Conflicts of Interest Disclosure

Motoaki Fujimoto received consulting fee from Biomedical Solutions. The other authors declare no conflicts of interest associated with this manuscript.

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