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Original Article

Clinical Usefulness of Preoperative MCA Anatomical Scanning MRI in Thrombectomy Therapy for Acute Anterior Circulation Vessel Occlusion

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Objective: The aim of the present study was to evaluate the usefulness of the T2-weighted three-dimensional sequence method, known as "basi-parallel anatomical scanning (BPAS)-magnetic resonance imaging (MRI)," in demonstrating the running course of the obstructed middle cerebral artery (MCA) before acute mechanical thrombectomy.

Methods: Patients whose M1 part and internal carotid artery (ICA) were occluded on preprocedural MRA, but well demonstrated on MCA anatomical scanning (MAS)-MRI were enrolled in this study. The MAS-MR images for patients in whom thrombectomy was performed were compared with the post-thrombectomy angiography. We compared the running course of the C1-M2 bifurcation on MAS-MRI and angiography after thrombectomy, and the results were classified into 3 groups (Excellent, Good, and Poor).

Results: A total of 13 patients (range: 54–89) were enrolled, among whom 12 underwent thrombectomy. We compared MAS-MRI and post-thrombectomy angiography in 10. On comparison between MAS-MRI and post-procedural angiography, visualization was excellent in six (60%) patients. The mean age was 75.7 years, ranging from 54 to 89, and 6 were males. 3 patients had ICA occlusion and seven had MCA occlusion.

Conclusion: MAS-MRI was considered useful to clarify the running course of the MCA before acute mechanical thrombectomy.

Keywords ▶ MCA anatomical scanning MRI, acute thrombectomy, anterior circulation vessels occlusion

Introduction

Recently, evidence regarding the efficacy of mechanical thrombectomy for acute occlusion of a major artery was presented,[1)] and the number of patients in whom this procedure is performed is rapidly increasing. The results of this therapy depend on the interval until recanalization; therefore, recanalization must be achieved as early as possible.[2)]

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However, no area distal to the site of occlusion is visualized on angiography at the start of treatment. For treatment, it is necessary to blindly guide a microguidewire into an occluded blood vessel; the risks of vascular injury and perforation are unavoidable.

Nagahata et al.[3,4)] devised basi-parallel anatomical scanning (BPAS)-magnetic resonance imaging (MRI) to visualize the appearance of the vertebrobasilar artery. This method facilitates the visualization of the course of an occluded blood vessel.[5)] If the vascular course at the site of occlusion can be confirmed using this imaging method before mechanical thrombectomy, the incidence of complications may be reduced. The purpose of this study was to evaluate whether the course of the occluded middle cerebral artery (MCA) can be assessed using preoperative imaging similar to BPAS-MRI.

Materials and Methods

The subjects were 13 patients with internal carotid artery (ICA) or M1 (horizontal segment)[6)] occlusion in whom

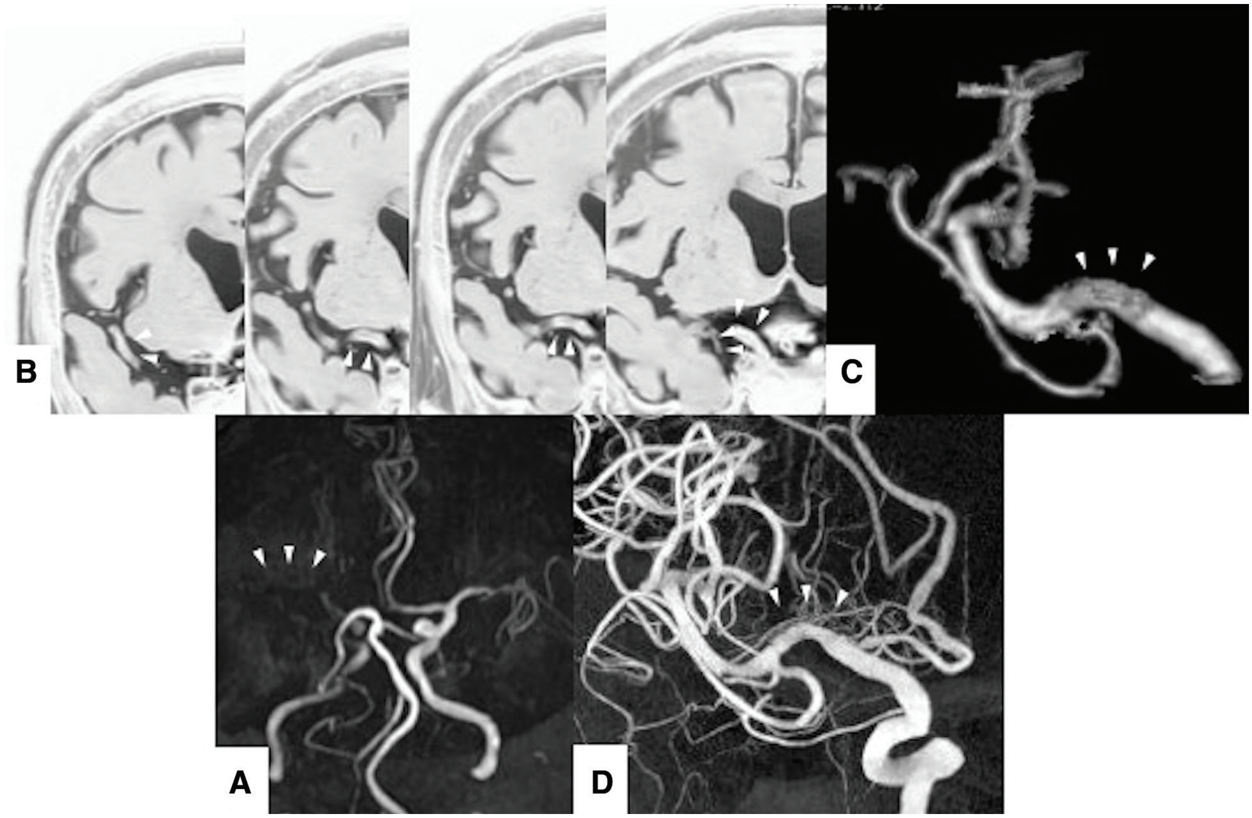

Fig. 1 An 82-year-old woman with sudden consciousness disturbance and left hemiparesis. (**A**) MRA presents right MCA occlusion. (**B**) The occluded MCA from the proximal to the distal side of the occlusion point can be seen by MAS-MRI. The arrowheads indicate the MCA. (**C**) 3D image of MAS-MRI shows the occluded MCA from the proximal to the distal area three-dimensionally. The arrowheads indicate the occlusion point. (**D**) Right internal carotid angiography after thrombectomy. Arrowheads indicate the recanalization point. MAS: MCA anatomical scanning; MCA: middle cerebral artery; MRA: magnetic resonance angiography; MRI: magnetic resonance imaging

BPAS-MRI-applied imaging of the MCA, MCA anatomical scanning (MAS)-MRI, was performed due to the necessity of mechanical thrombectomy on arrival to our hospital between May 2018 and October 2019. Of these patients, we compared the course of the C1 (supraclinoid segment)[6] to M1 (insular segment)[6] segments of the ICA on MAS-MRI after arrival with that at the same site on angiography after mechanical thrombectomy in 10 in whom mechanical thrombectomy led to recanalization, and evaluated the accuracy of MAS-MRI. For MRI, T2-weighted three-dimensional (3D) BPAS-MRI was applied, and imaging conditions were established in order to visualize the M1 to M2 segments of the MCA. A cross-section was vertical to the orbitomeatal base line (OM line). An MRI device by Philips (3 Tesla, Ingenia 3.0T) was used. The repetition time (TR)/echo time (TE) was established as 1514/253, the field of view (FOV) as 200 mm × 200 mm, the matrix as 256 × 325, and the scan time as 1 minute and 32 seconds. The slice thickness/interval was 1.2 mm/0.6 mm. The number of slices was approximately 40 on 24-mm imaging. Images were prepared using Ziostation 2 (AMIN Co., Ltd., Tokyo, Japan).

To evaluate the accuracy of MAS-MRI, the vascular course involving the M1 segment to M2 bifurcation of the MCA was compared with that on angiography after treatment, and retrospectively classified into grades (excellent, good, and poor). When the vascular course involving the M1 segment to M2 bifurcation on preoperative MAS-MRI was consistent with that on postoperative angiography, the accuracy of MAS-MRI was regarded as "excellent" (**Fig. 1**). When the vascular course was able to be evaluated despite the partially unclear distal margin of an occluded blood vessel, it was regarded as "good" (**Fig. 2**). When the distal course of an occluded blood vessel was unable to be evaluated, it was regarded as "poor." For image assessment, two specialists in neuroendovascular therapy examined the accuracy using the kappa coefficient through image-based diagnosis. Based on the results of image assessment, the subjects were divided into Excellent

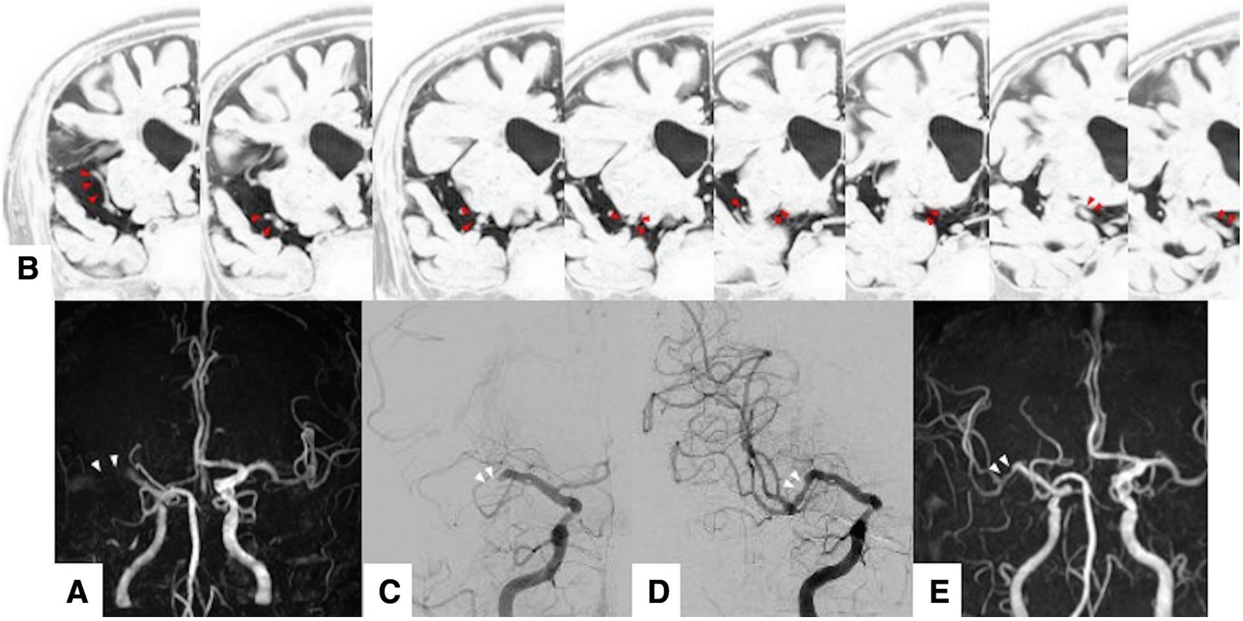

Fig. 2 A 77-year-old-man with repeated left hemiparesis and dysarthria. (**A**) MRA presents right MCA occlusion. The occlusion point is indicated by the arrowheads on MRA. (**B**) It is possible to visualize the total occluded M1 (horizontal segment) by MAS-MRI. The occluded MCA can be observed by MAS-MRI. The arrowheads indicate M1 from the proximal side to the distal side of the occlusion point. M1 was steeply descending. Part of the blood vessel wall was in contact with the brain; therefore, the M1 was invisible. (**C**) Right internal carotid angiography shows M1 occlusion. (**D**) Right internal carotid angiography shows recanalization of the occluded vessel. (**E**) MRA after thrombectomy. The arrowheads indicate the recanalization point. MAS: MCA anatomical scanning; MCA: middle cerebral artery; MRA: magnetic resonance angiography; MRI: magnetic resonance imaging

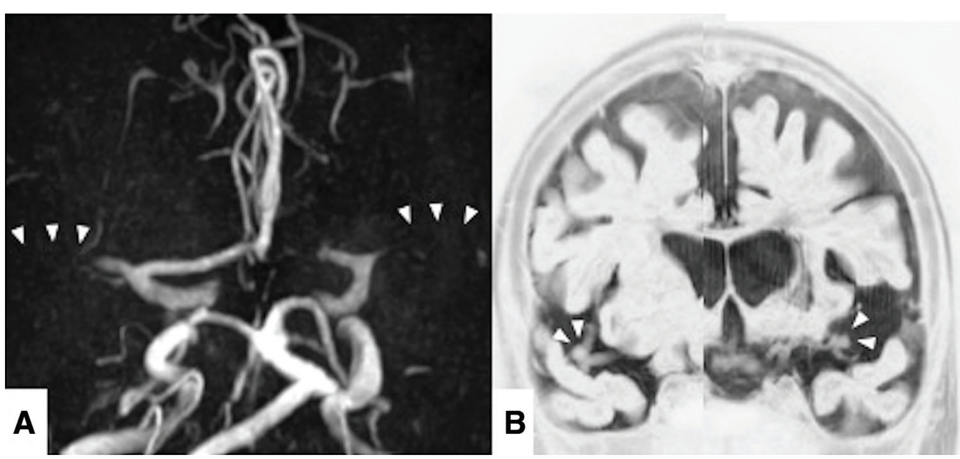

Fig. 3 An 84-year-old woman with consciousness disturbance. (**A**) MRA shows occlusions on both sides of the MCA, as indicated by arrowheads. (**B**) Bifurcation aneurysms on both sides of the MCA can be seen on MAS-MRI. The arrowheads indicate aneurysms. MAS: MCA anatomical scanning; MCA: middle cerebral artery; MRA: magnetic resonance angiography; MRI: magnetic resonance imaging

and Good/Poor groups to compare the age, reperfusion time, and Thrombolysis in Cerebral Infarction (TICI) grade. Significance was tested using the Mann–Whitney U-test and chi square test.

Prior to this study, its protocol was approved by the ethics review board of our hospital (Ethical Examination/Approval No.: 2020-03, approved on June 1, 2020).

Results

Of the 13 subjects, mechanical thrombectomy was performed based on MAS-MRI findings in 12. The subjects' ages ranged from 54 to 89 years, with a mean of 76 years (±10.3). There were 7 males and 6 females. The sites of vascular occlusion consisted of the ICA in 3 patients and

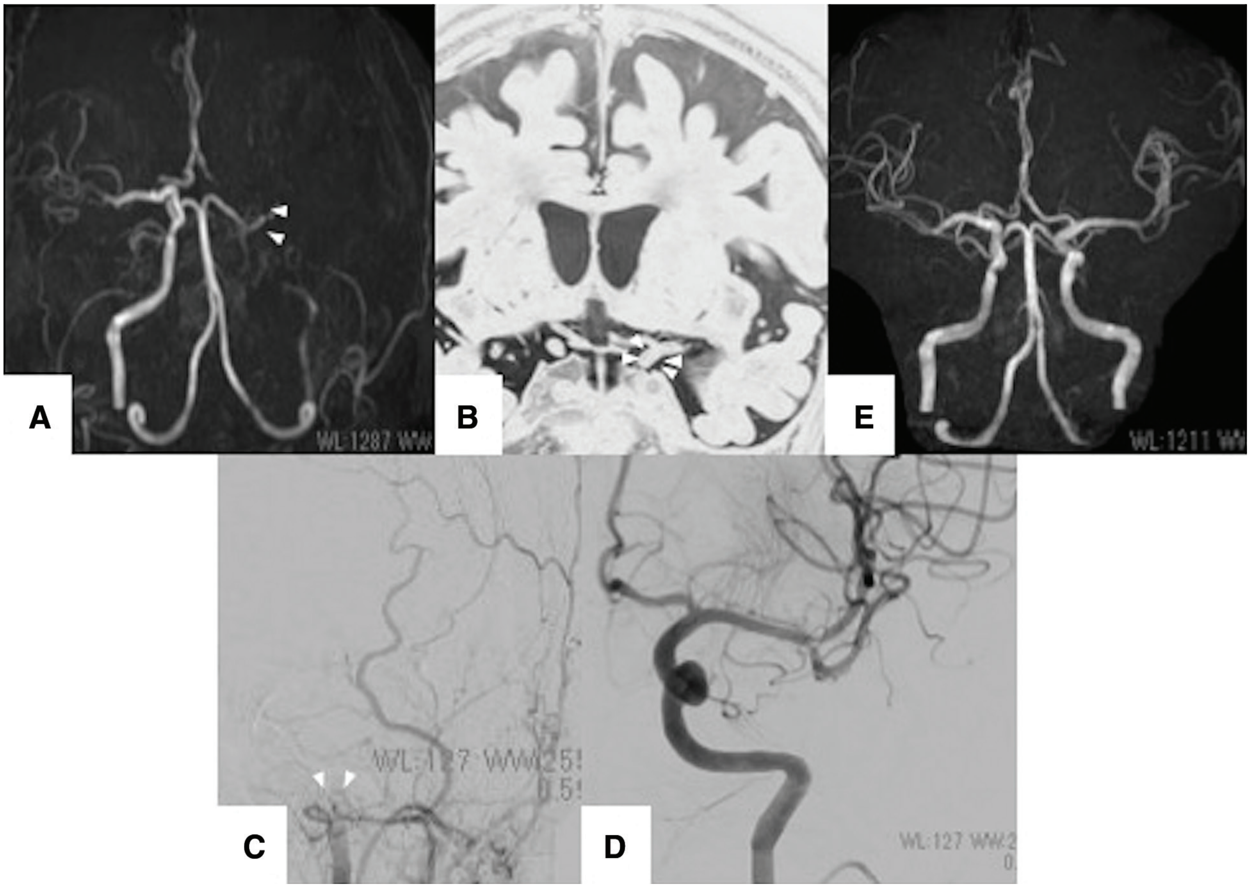

Fig. 4 An 89-year-old-man with consciousness disturbance and right hemiparesis. (**A**) MRA on arrival shows left ICA occlusion. The ICA can be followed until C1. (**B**) The ICA bifurcation was visualized by MAS-MRI. (**C**) Left ICA angiography shows ICA occlusion. (**D**) Left ICA angiography shows recanalization of the occluded vessel. (**E**) MRA after thrombectomy. ICA: internal carotid artery; MAS: MCA anatomical scanning; MRA: magnetic resonance angiography; MRI: magnetic resonance imaging

M1 in 10. In 1 patient, mechanical thrombectomy was not performed because MAS-MRI findings suggested the presence of aneurysms involving the site of occlusion to its distal ends (**Fig. 3**). In 2 of the 12 patients who underwent mechanical thrombectomy, recanalization was not achieved and comparison with MAS-MRI findings was impossible. Of the two patients, hemorrhage occurred on stent removal in one patient.

In the other 10 patients, recanalization was achieved. The TICI grade was 2b or higher, and the mean reperfusion time was 26.7 minutes (±13 minutes).

The vascular course on angiography after recanalization was able to be compared with that on MAS-MRI in 10 patients. Their ages ranged from 54 to 89 years, with a mean of 75.7 years (±11.5). They consisted of 6 males and 4 females. The sites of vascular occlusion consisted of the ICA in 3 patients and MCA in 7. A patient with occlusion at the ICA terminal is presented (**Fig. 4**).

The results of MAS-MRI accuracy assessment by evaluators 1 and 2 in 10 patients in whom MAS-MRI findings were able to be compared with angiography findings after recanalization are shown in **Table 1**. The 2 evaluators regarded the accuracy of MAS-MRI as "excellent" in 6 patients (60%). When calculating the secondary weighted kappa coefficient based on their assessment, it was 0.81, suggesting a high degree of consistency.

The results of assessment by the 2 evaluators were not consistent in one patient: "good" and "poor" (**Fig. 5**).

The age, reperfusion time, and TICI grade were evaluated in the Excellent and Good/Poor groups. There was a significant difference in the mean age (Excellent group: 82 years, Good/Poor group: 66.3 years, $p = 0.033$), but there were no significant differences in the reperfusion time (Excellent group: 29.8 minutes, Good/Poor group: 22 minutes, $p = 0.915$) or number of TICI 2b-3 patients (Excellent group: 6 patients, Good/Poor group: 4 patients, $p = 0.778$).

Table 1 Summary of the patients whose MAS-MRI was able to be compared with cerebral angiography

No.	Sex	Age	NIHSS on arrival	Occlusion site	Classification	Device	Reperfusion time (min)	TICI grade	Comparison with MAS-MRI evaluator1	Comparison with MAS-MRI evaluator2	3D MAS-MRI	mRS
1	M	73	23	Rt.M1 proximal	Cardioembolic	Trevo	15	2b	Excellent	Excellent	–	4
2	F	78	21	Rt.ICA C1	Cardioembolic	Solitaire, Trevo	52	2b	Excellent	Excellent	–	5
3	F	76	16	Lt.M1 proximal	Atherothrombotic	Trevo Solitaire	18	3	Good	Good	–	6
4	M	77	5	Rt.M1 distal	Atherothrombotic	Solitaire	25	3	Good	Good	–	0
5	F	86	10	Rt.ICA C3	Cardioembolic	ADAPT technique	13	3	Excellent	Excellent	–	3
6	M	54	20	Lt.M1 proximal	Cardioembolic	Solitaire	19	3	Good	Poor	–	3
7	M	58	8	Rt.M1	Cardioembolic	Solitaire	26	2b	Good	Good	–	0
8	M	89	22	Lt.ICA C1	Cardioembolic	Solitaire	24	3	Excellent	Excellent	–	1
9	M	84	22	Lt.M1 distal	Cardioembolic	Trevo	50	3	Excellent	Excellent	+	3
10	F	82	22	Rt.M1 proximal	Cardioembolic	Trevo	25	3	Excellent	Excellent	+	4

ADAPT: a direct aspiration first pass technique; C1: supraclinoid segment; C3: cavernous segment6); ICA: internal carotid artery; M1: middle cerebral artery horizontal segment; MAS-MRI: MCA anatomical scanning-magnetic resonance imaging; mRS: modified Rankin Scale; NIHSS: National Institutes of Health Stroke Scale; TICI: Thrombolysis in Cerebral Infarction; Trevo: Trevo XP ProVue (Stryker. Kalamazoo, MI, USA); Solitaire: Solitaire Platinum (Medtronic)

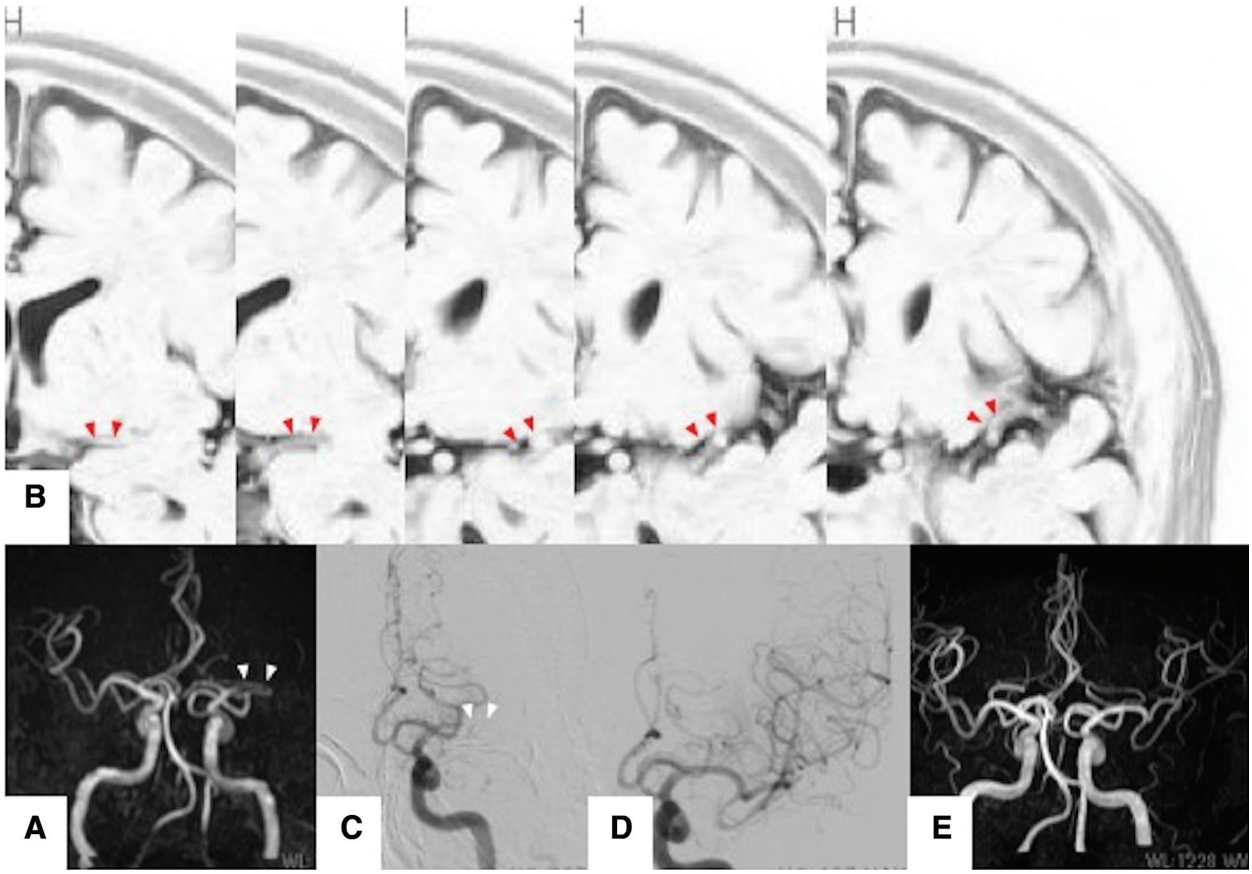

Fig. 5 A 54-year-old-man with consciousness disturbance, left conjugate deviation, and right hemiparesis. (**A**) MRA on arrival shows right M1 occlusion. (**B**) MAS-MRI shows part of M1, although it was difficult to visualize in full because part of M1 contacted the brain. (**C**) Left internal carotid angiography shows M1 occlusion. (**D**) Left internal carotid angiography shows recanalization of the occluded vessel. (**E**) MRA after thrombectomy. MAS: MCA anatomical scanning; MRA: magnetic resonance angiography; MRI: magnetic resonance imaging

Discussion

For acute-phase mechanical thrombectomy, it is necessary to blindly guide a guidewire in the absence of information on an area distal to the site of occlusion. Therefore, the risk of hemorrhagic complications related to factors, such as penetration, is reportedly high, especially in patients with tortuous blood vessels or aneurysms.[7,8] The concomitant development of aneurysms is not rare, with an incidence of approximately 5%.[9] The incidence of vascular perforation related to acute-phase revascularization is reportedly 1.1%, and patients who died of serious cerebral hemorrhage related to vascular perforation have also been reported.[10.11] In this study, some information regarding the course of the occluded MCA was able to be obtained on preoperative MAS-MRI in all patients; this may have been effective for avoiding vascular perforation. Furthermore, the duration of imaging was short (≤2 minutes), suggesting the usefulness of MAS-MRI as a pretreatment examination. Preoperative MAS-MRI may improve the safety of mechanical thrombectomy.

In this study, MRI was adopted, but a previous study revealed that angiography through a collateral pathway using high-resolution cone-beam computed tomography (CT) immediately before surgery in a catheter treatment room provided information on distal blood vessels.[12] If CT alone is performed in the absence of MRI before mechanical thrombectomy, this method may be useful. However, for this examination method, the analysis is slightly complex and there is a limitation that contrast medium must be additionally used. On the other hand, MAS-MRI does not require contrast medium and the additional examination time is ≤2 minutes, being short, which are advantageous. Therefore, when performing MRI before surgery, the addition of this examination method may be useful.

In this study, 3-Tesla MRI was adopted. A study reported the application of 1.5-Tesla BPAS-MRI for the diagnosis of basilar artery dissection.[13] As the space between the basilar artery and brain parenchyma is large, there is no problem regarding visualization even when selecting 1.5-Tesla MRI, which has poorer resolution than 3-Tesla MRI.

However, the space between the MCA, which was investigated in this study, and brain parenchyma is narrow; therefore, when performing 1.5-Tesla MRI, the vascular margin is unclear and the image quality may be reduced in comparison with 3-Tesla MRI. However, 1.5-Tesla MRI may be sufficient for evaluating the course or shape of a major artery, which does not require high resolution. If the duration of imaging is increased on 1.5-Tesla MRI, images similar to 3-Tesla MR images can be obtained.[14] In addition, in this study, a scan time of 1 minute and 32 seconds was required for MAS-MRI. However, if a steady-state coherent-type sequence system (Balanced-FFE by Philips) is used, the scan time can be further shortened to 33 seconds. As the steady-state coherent-type sequence TR/TE ranges from 3 to 4/1.5 to 2, respectively, the duration of imaging is shorter than on MAS-MRI with a TR/TE of 1,514/253, respectively.[15] In our hospital, as steady-state coherent-type sequence imaging conditions, the TR/TE, imaging FOV, and matrix are 5.3/2.2, 200 mm × 200 mm, and 252 × 252, respectively. The slice thickness/interval and number of slices on 32-mm imaging are 1.0 mm/0.5 mm and approximately 60, respectively.

In this study, MAS-MRI revealed MCA occlusion complicated by an aneurysm in 1 patient, although mechanical thrombectomy was not performed. The MCA (M1-2) is a frequent site of cerebral aneurysms, but it is difficult to evaluate whether vascular occlusion is complicated by an aneurysm using MRI/magnetic resonance angiography (MRA) or 3D-CT angiography (CTA) in many cases. If an aneurysm is concomitantly present, it may rupture during mechanical thrombectomy.[16] Indeed, a previous study reported aneurysmal rupture during mechanical thrombectomy.[17] Another study suggested that the presence of an aneurysm can be predicted based on guidewire motion.[9] However, the guidewire must be blindly operated. This examination procedure may facilitate evaluating the course of the occluded MCA and presence of an aneurysm before mechanical thrombectomy; therefore, it may be useful.

Occlusion at the ICA terminal was favorably visualized on MAS-MRI. Even in patients with MCA occlusion, the ICA was favorably visualized. The ICA terminal is not adjacent to the brain in many cases and good images may be obtained by MAS-MRI.

Several studies reported that the appearance of the occluded or markedly stenotic MCA was visualized on MRI. Kuribara et al.[18] presented a method to confirm the vascular course distal to the site of occlusion by fusing MR images with MRA images. Furthermore, Kato et al.[19] reported a method to confirm the course of the intra-Sylvian-fissure MCA in parallel to the Sylvian fissure. This method does not require complex image arrangement from multiple slices and may facilitate evaluating the MCA course from the ICA bifurcation to M2.

On the other hand, as the limitation of MAS-MRI, it is difficult to evaluate the vascular course when a blood vessel is adjacent to the brain. When evaluating the course, an image is compared with slices before and after the image; therefore, it is difficult to evaluate the courses of M1, which is tortuous in the Z-axis direction, and a Z-axis-direction segment distal to M2. When taking a sagittal section on angiography using this method, the vascular course involving the periphery can be evaluated in patients with marked cerebral atrophy. However, in those without cerebral atrophy, the brain is adjacent to blood vessels and the vascular margin may be unclear on MAS-MRI. In this analysis, the results of assessment by evaluators 1 and 2 differed ("good" and "poor") in one patient. This was because the brain-adjacent area of the blood vessel was greater than in the other patients due to slight age-related cerebral atrophy at the youngest age (54 years) of this patient. When the number of brain-adjacent points is large, the entire course is evaluated based on the vascular margin on the non-brain-adjacent side and images before and after the image on MAS-MRI; therefore, this may have played a role in the above difference between the two evaluators. In the Excellent group, the mean age was 82 (±5.8) years, being significantly more advanced than that in the Good/Poor group (66.3±11.9 years). As cerebral atrophy is more marked in the elderly, MAS-MRI may have facilitated clearer visualization of a blood vessel in the Excellent group. To visualize more peripheral blood vessels, 3D MAS-MRI was recently introduced, but images remain rough and clearer images must be obtained for the clinical application of this procedure.

Conclusion

This study suggests that information useful for evaluating the course of the MCA or presence of an aneurysm can be obtained by performing MAS-MRI prior to acute-phase mechanical thrombectomy.

Disclosure Statement

The authors declare no conflict of interest.

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