

Identifying Cerebral Large Vessel Occlusion in Acute Ischemic Stroke by MRI Positioning Scanning

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Abstract

Various approaches have been tried for acute ischemic stroke (AIS) treatment to shorten the time from onset to recanalization. MRI positioning scanning (PS), which must be taken before any MRI sequences, was examined whether it can detect cerebral large vessel occlusion. A total of 68 consecutive patients with AIS who underwent MRI and were treated with intravenous recombinant tissue plasminogen activator or mechanical thrombectomy at our hospital were retrospectively included in this study. Occluded vessels were identified on the axial or coronal views of PS images, and these images were compared with 3D time-of-flight MRA and digital subtraction angiogram. The sensitivities, positive predictive values (PPVs), and negative predictive values (NPVs) for internal carotid artery (ICA), the proximal M1, distal M1, and M2 segment of the middle cerebral artery occlusion were assessed, and the number of PS slices was assessed. The sensitivities of the axial slices for ICA, proximal M1, distal M1, and M2 occlusion were 62%, 21%, 35%, and 86%, respectively. The PPVs of the axial slices for ICA, proximal M1, distal M1, and M2 occlusion were 81%, 88%, 100%, and 97%, respectively, and the NPVs of the axial slices for ICA, proximal M1, distal M1, and M2 occlusion were 94%, 90%, 86%, and 100%, respectively. The detection rate for the ICA was significantly higher with three axial slices (91%) than with two slices (47%) ($p < 0.01$). MRI PS is warranted to be referred to detect large cerebral vessel occlusion.

Keywords: acute ischemic stroke, endovascular thrombectomy, large vessel occlusion, MRI, tissue plasminogen activator

Introduction

The benefit of endovascular thrombectomy for patients with acute ischemic stroke (AIS) caused by occlusion of the proximal anterior circulation has been recently proven by five randomized controlled trials.^{1–5} Moreover, a meta-analysis of these studies revealed that the shorter time from symptom onset to reperfusion by endovascular thrombectomy was associated with better outcomes for AIS patients at 3 months.^{6,7} Furthermore, several studies have reported that this benefit is sustained for years,^{8,9} and thus various ways to shorten the time to reperfusion have been explored.

Diffusion-weighted imaging (DWI) provides more certain detection of AIS and higher agreement rates among readers in identifying early ischemic areas compared with noncontrast CT.^{10–12} Moreover, 3D time-of-flight MRA (3D TOF-MRA) allows us to determine vascular variation, stenosis, dilation, and occlusion noninvasively. MRI is often used for the diagnosis of AIS because it is easy to access MRI in Japan. However, it generally takes a long time compared with CT.

Positioning scanning (PS) must be performed initially to adjust the sections of the images of whichever MRI sequence is selected. As the T1-weighted imaging gradient echo method, which is used in TOF-MRA, is also used in PS, the images are partially like those of TOF-MRA; thus, cerebral large vessel

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occlusion can sometimes be detected using PS alone. Moreover, PS requires much less time—a few dozen seconds—thereby possibly saving the time to reperfusion. However, the accuracy of PS in detecting large vessel occlusion has not been verified thus far. In this study, we sought to determine the accuracy of PS in detecting cerebral large vessel occlusion.

Materials and Methods

Patients

This study was approved by the institutional ethics committee of the hospital and a waiver of informed consent was granted by the institutional ethics committee because of the retrospective design. A total of 68 consecutive patients with AIS who underwent MRI and were treated with intravenous recombinant tissue plasminogen activator and/or mechanical thrombectomy at one comprehensive stroke center between January 2015 and June 2017 were included in this study. There were no exclusion criteria, and some of the patients included in this study were affected by posterior circulation occlusion or did not have large vessel occlusion. The axial or coronal views of the PS were reviewed and occluded arteries were identified: the internal carotid artery (ICA), the proximal M1 segment of the middle cerebral artery (MCA), the distal M1 segment of the MCA, the M2 segment of the MCA, and others. Next, we compared the images with those taken by 3D TOF-MRA and digital subtraction angiography (DSA). Furthermore, we assessed the sensitivities (the agreement rate in diagnosis between PS and TOF when any large vessel occlusions were identified by the use of 3D TOF-MRA), positive predictive values (PPVs; the agreement rate in diagnosis between PS and 3D TOF-MRA when any large vessel occlusions were identified by the use of PS), and negative predictive values (NPVs; the agreement rate in diagnosis between PS and 3D TOF-MRA when any large vessels were identified by the use of PS as being patent) for the ICA, proximal M1, distal M1, and M2. In some cases, DSA was performed, and the PS diagnoses were also compared with DSA in cases wherein PS could detect the vessels of interest. Furthermore, we compared the number of PS axial slices and assessed which could detect the large vessels (ICA, proximal M1, distal M1, and M2) more certainly.

Emergency room protocol

MRI was performed in patients transported to the emergency room of our hospital for the first

radiological examination after neurological examination, venous sampling, and venous line secured; CT was skipped. The indication for intravenous recombinant tissue plasminogen activator and/or endovascular thrombectomy was determined using only MRI and not using CT or CTA.

MRI protocol

MRI was performed using a 1.5T scanner (Symphony, Siemens, Munich, Germany/Avanto, Siemens). The imaging parameters of PS were as follows: FOV = 280 × 280 mm, TR = 9.0 ms, TE = 2.88 ms, flip angle = 20°, matrix size = 256 × 205, section thickness = 10 mm, and intersection gap = 10 mm. The imaging parameters of TOF-MRI were as follows: FOV = 200 × 200 mm, TR = 35 ms, TE = 7.15 ms, flip angle = 20°, matrix size = 384 × 192 × 256. In all cases, PS, DWI, fluid-attenuated inversion recovery (FLAIR), and MRA were performed. It takes 22 s to undertake PS, 1 min and 25 s to undertake DWI, 2 min and 14 s to undertake FLAIR, and 7 min and 8 s to undertake MRA; hence, all sequences need ~12 min to be completed.

PS diagnosis

PS diagnosis was a blind assessment; the images were read by a neurosurgeon who had never known the clinical symptoms or the MRI, MRA, or DSA findings. Artery occlusion shown on PS was defined as a condition wherein the artery was not described (Figs. 1A–H) or was described more poorly compared with the contralateral side (Figs. 1I–L). If the artery was described as clearly as that of the contralateral side, as per our definition, it was not occluded. If the artery was not described on the contralateral side, we did not diagnose the presence or lack of occlusion but still included these cases in the assessment of sensitivity.

Statistical analysis

Categorical variables were expressed as numbers and percentages. Using 3D TOF-MRA as a criterion standard, the sensitivity, PPV, and NPV of PS on per-segment analyses were calculated. Categorical variables were analyzed using the chi-square test and p-values <0.05 were considered significant.

Results

Table 1 shows the patients' demographic data. Fifty-one large vessel occlusion cases were included. The other 17 cases were cases of posterior circulation occlusion, anterior cerebral artery occlusion, distal segment of MCA occlusion, or lacunar infarction.

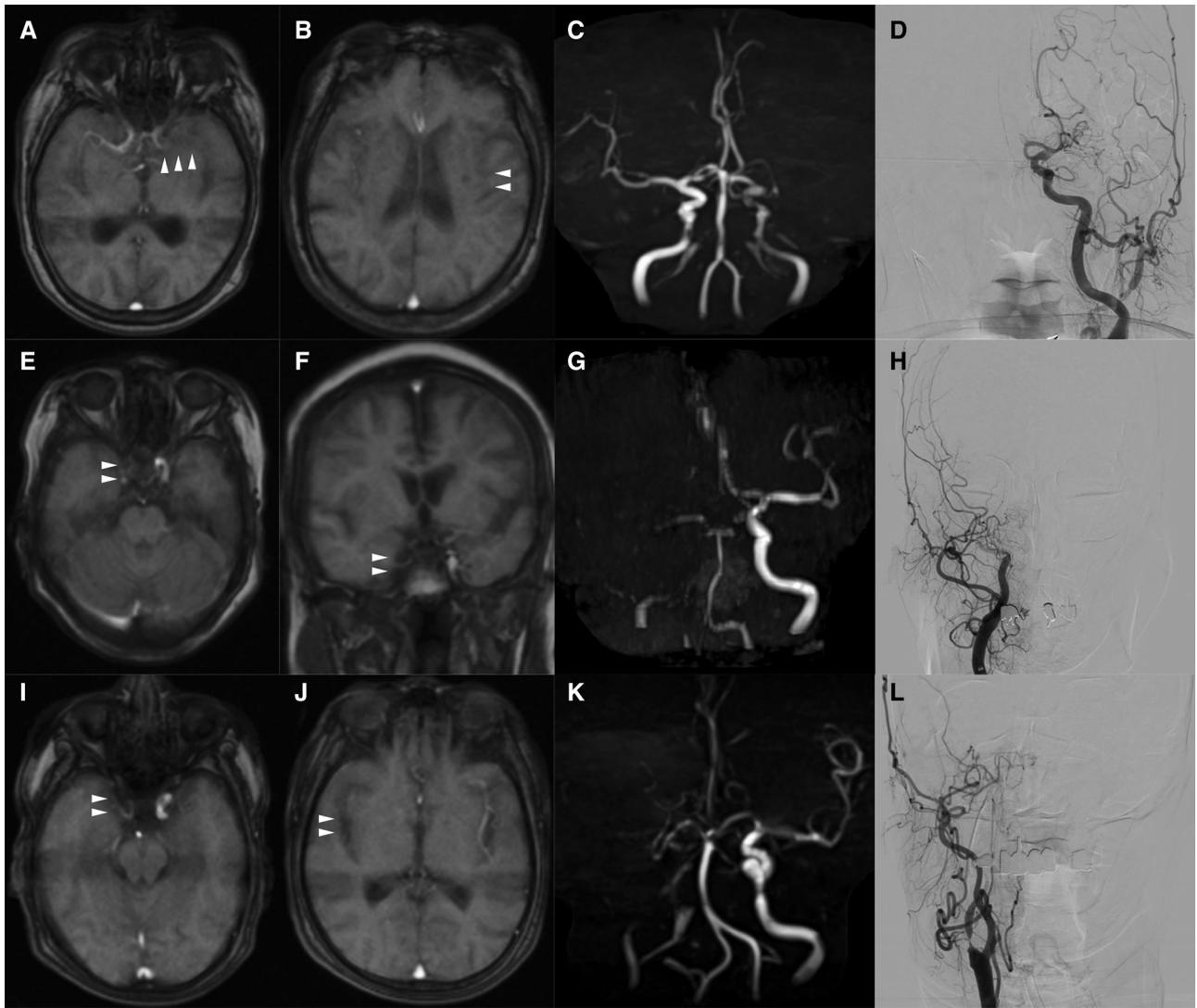


Fig. 1 Illustrative cases. (A–D) This patient presented with right hemiplegia and dysarthria, and the National Institutes of Health Stroke Scale (NIHSS) score was 16 on arrival. In the MRI positioning scanning (PS) axial slices (A and B), the left middle cerebral artery was not described from the proximal part, so we made a diagnosis of “left proximal M1 occlusion.” 3D time-of-flight MRA (TOF-MRA) (C) and digital subtraction angiography (DSA) (D) showed the same result. (E–H) This patient had left hemiplegia and consciousness disorder and the NIHSS score was 18 on arrival. In the PS lower axial slice (E) and coronal slice (F), the right internal carotid artery (ICA) was not described, so we made a diagnosis of “right ICA occlusion.” 3D TOF-MRA (G) and DSA (H) showed the same result. (I–L) This patient had left hemiparesis and dysarthria and the NIHSS score was 6 on arrival. The right ICA was described more poorly than that of the other side in the PS lower axial slice (I), and the right M2 was not described in the upper axial slice (J), so we made a diagnosis of “right ICA nearly occlusion.” 3D TOF-MRA (K) gave the same result as PS, but DSA (L) diagnosed it as right ICA severe stenosis.

The sensitivities of the axial slices of PS for ICA, proximal M1, distal M1, and M2 occlusion were 62%, 21%, 35%, and 86%, respectively. The sensitivities of the coronal slices were lower than those of the axial slices (Table 2).

The PPVs of the PS axial slices for ICA, proximal M1, distal M1, and M2 occlusion were 81%, 86%, 100%, and 97%, respectively, and the PPVs of the

coronal slices for ICA, proximal M1, distal M1, and M2 occlusion were 86%, 50%, 67%, and 91%, respectively. Focusing on false positive cases (i.e., the segment of interest was diagnosed as occlusion with PS but not with MRA) for ICA or M1 occlusion, the distal segment of the vessels was occluded in seven of these eight cases. In the other case, no occlusion was detected by MRA but large ischemic

Table 1 Demographic data and diagnosis with 3D time-of-flight MRA

	Total (n = 68)
Demographic data	
Age (average, year)	72.2 (range: 32–96)
Female	27.9% (19)
Diagnosis with 3D TOF-MRA	
ICA not terminal occlusion	10.3% (7)
ICA terminal occlusion	20.6% (14)
Proximal M1 occlusion	14.7% (10)
Distal M1 occlusion	16.2% (11)
M2 occlusion	13.2% (9)
Others	25.0% (17)

ICA: internal carotid artery, MCA: middle cerebral artery, M1: the M1 segment of the MCA, M2: the M2 segment of the MCA, TOF-MRA: time-of-flight MRA.

Table 2 The sensitivities, PPVs, NPVs, and the agreement rate in diagnosis between PS and DSA

	Axial	Coronal
The sensitivities		
ICA	62% (13/21)	29% (6/21)
Proximal M1	21% (7/23)	9% (2/23)
Distal M1	35% (13/37)	5% (2/37)
M2	86% (34/44)	63% (32/44)
The PPVs		
ICA	81% (13/16)	86% (6/7)
Proximal M1	86% (7/8)	50% (2/4)
Distal M1	100% (13/13)	67% (2/3)
M2	97% (34/35)	91% (30/33)
The NPVs		
ICA	94% (29/31)	93% (24/26)
Proximal M1	90% (19/21)	82% (9/11)
Distal M1	86% (18/21)	100% (3/3)
M2	100% (17/17)	76% (16/21)
The agreement rate in diagnosis between PS and DSA		
ICA	77% (17/22)	80% (12/15)
Proximal M1	79% (11/14)	100% (5/5)
Distal M1	83% (15/18)	0% (0/1)
M2	71% (20/28)	69% (20/29)

DSA: digital subtraction angiography, ICA: internal carotid artery, MCA: middle cerebral artery, M1: the M1 segment of the MCA, M2: the M2 segment of the MCA, NPV: negative predictive values, PPV: positive predictive values, PS: positioning scanning.

lesion was observed in the ipsilateral ICA perfusion area by DWI. The NPVs of the PS axial slices for ICA, proximal M1, distal M1, and M2 occlusion were 94%, 90%, 86%, and 100%, respectively, and the NPVs of the coronal slices for ICA, proximal M1, distal M1, and M2 occlusion were 93%, 82%, 100%, and 76%, respectively. Focusing on false negative cases (i.e., the segment of interest was diagnosed as patent with PS but not with MRA) for ICA or M1 occlusion, PS diagnosed the vessel as the distal segment occluded in 9 of these 11 cases. In the other two cases, PS could not detect any lesion but MRA clarified them as the distal M1 occlusion. DSA was performed in 30 cases. The diagnoses by the use of PS and DSA matched well.

The rate for description of the arteries of the contralateral side in PS was not high. The rate of the arteries described normally in axial slices was 69%, 35%, 44%, and 78% and in coronal slices was 41%, 24%, 12%, and 93% for ICA, proximal M1, distal M1, and M2 occlusion, respectively (Table 3). The number of PS axial slices was one slice in two cases, two slices in 38 cases, and three in 28 cases. The detection rate for the ICA in the ipsilateral side was significantly higher with increasing axial slices from two (18/38 cases, 47%) to three (27/28 cases, 96%; $p < 0.01$). There was no association between the number of slices and the detection

Table 3 How the arteries of the normal side described in PS imaging

	Axial		
	Normally described	Abnormally described	Not described
ICA	69% (47/68)	0% (0/68)	31% (21/68)
Proximal M1	35% (24/68)	0% (0/68)	65% (44/68)
Distal M1	44% (30/68)	0% (0/68)	56% (38/68)
M2	78% (53/68)	0% (0/68)	22% (15/68)
	Coronal		
	Normally described	Abnormally described	Not described
ICA	41% (28/68)	4% (3/68)	55% (37/68)
Proximal M1	24% (16/68)	0% (0/68)	76% (52/68)
Distal M1	12% (8/68)	0% (0/68)	88% (60/68)
M2	93% (63/68)	0% (0/68)	7% (5/68)

ICA: internal carotid artery, MCA: middle cerebral artery, M1: the M1 segment of the MCA, M2: the M2 segment of the MCA, PS: positioning scanning.

rate for the proximal M1 (13/38 cases, 34% vs 11/28 cases, 39%; $p = 0.672$), distal M1 (17/38 cases, 45% vs 13/28 cases, 46%; $p = 0.892$), and M2 (31/38 cases, 82% vs 22/28 cases, 79%; $p = 0.761$).

Discussion

MRI plays a crucial role in a clinicians' judgment regarding which AIS patients fall within the criteria of requiring treatment. MRI diagnosis can be made with less discrepancy between interpreters.^{10–12} Regarding FLAIR in patients with an unknown onset, the PRE-FLAIR study proved that a DWI-FLAIR mismatch indicates that the patient is likely to be within 4.5 h of symptom onset, and the WAKE-UP study revealed that intravenous recombinant tissue plasminogen activator guided by a DWI-FLAIR mismatch significantly improves the functional outcome.^{13,14} The DAWN trial and DEFUSE 3 trial revealed that endovascular thrombectomy guided by perfusion images calculated from CT perfusion and diffusion and perfusion MRI significantly improves functional outcomes in AIS after 16 h from symptom onset.^{15,16}

In contrast, when judging whether endovascular thrombectomy should be adapted for AIS, noncontrast CT and CTA are widely used because of their easy accessibility and shorter time to be performed than MRI. However, CT also has some limitations. CT exposes patients to radiation and contrast agents, although more radiation and contrast agents may be needed for endovascular thrombectomy. Moreover, although volume-rendered images and maximum intensity projection images are useful for detecting large vessel occlusion, especially for M2 or more distal arteries, it takes time to edit these images. Indeed, it takes longer to complete all MRI sequences including MRA, if identification of cerebral large vessel occlusion with the first sequence, preparation of reperfusion therapies such as intravenous recombinant tissue plasminogen activator, and/or mechanical thrombectomy can be accelerated. Gathering medical staff, discussing treatment strategy, explanation to the patient and their families, launching angiography equipment, and preparing devices of radiological intervention in this imaging period may save several minutes to reperfusion of large vessel occlusion. This benefit may be relatively large in small stroke centers that have only a small stroke team.

To the best of our knowledge, the usefulness of MR PS imaging or the CT scout view has been evaluated in only a few reports, although these images may have much information which had not been recognized so far.^{17,18} This is the first study

to assess the diagnostic potential of PS and clarify the sensitivities, PPVs, and NPVs. The PPVs were proven to be high but there were some false positive cases. However, in most of these cases, it was shown that the distal segment of the arteries was occluded. Therefore, from the point of view of not per segment but per patient, PS positives indicate the presence of cerebral large vessel occlusion strongly. The NPVs were also proven to be high but there were some false negative cases. However, in most of these cases, it was shown that PS could diagnose the arteries as occluded at the distal segment instead. Thus, from a per-patient perspective, due to PS false negative, it is very unlikely that a large vessel occlusion is missed. PS may have enough certainty to accelerate reperfusion therapies and may play a role like hyperdense MCA sign or dot sign in noncontrast CT.^{19–22} Although DWI is needed to assess the ischemic core and to decide adaptation of reperfusion therapies, it takes ~2 min to complete PS and DWI. Furthermore, Hayashi et al. reported that PS could also detect acute intracerebral hemorrhage.¹⁸ In some cases, it may be possible to decide treatment strategy using the discrepancy between PS images and DWI, i.e., relatively small DWI lesion compared with what is expected from PS images.

The low sensitivities may be attributed to the fact that, in many cases, the area of interest was not included in the PS slices. It can also explain the low description rates with PS imaging for the normal side. As described in this report, adding PS slices may help improve the detection rate. We tried to adjust the PS protocol by narrowing the intersection gap and increasing the number of slices (Fig. 2). If the new protocol can include the circle of Willis in the images more certainly, it may help us to improve the sensitivity without extra time as PS can take a slice in only a few seconds.

Based on the above, PS does not have enough performance to replace MRA. In other words, we believe that MRA should be performed in all AIS cases to ensure the quality of treatment, and we proposed the possibility of utilizing the imaging time for other sequences, including MRA, if PS and DWI determine the rough indication for reperfusion therapies.

There are some limitations to this study. First, because all the data were obtained retrospectively, some selection and information biases were inevitable. Second, we assessed a small patient cohort, thereby limiting our ability to evaluate the role of PS in the context of other factors. Third, although the diagnostic potential of PS was clarified, it remains to be elucidated that whether PS can help shorten the time from door to revascularization and

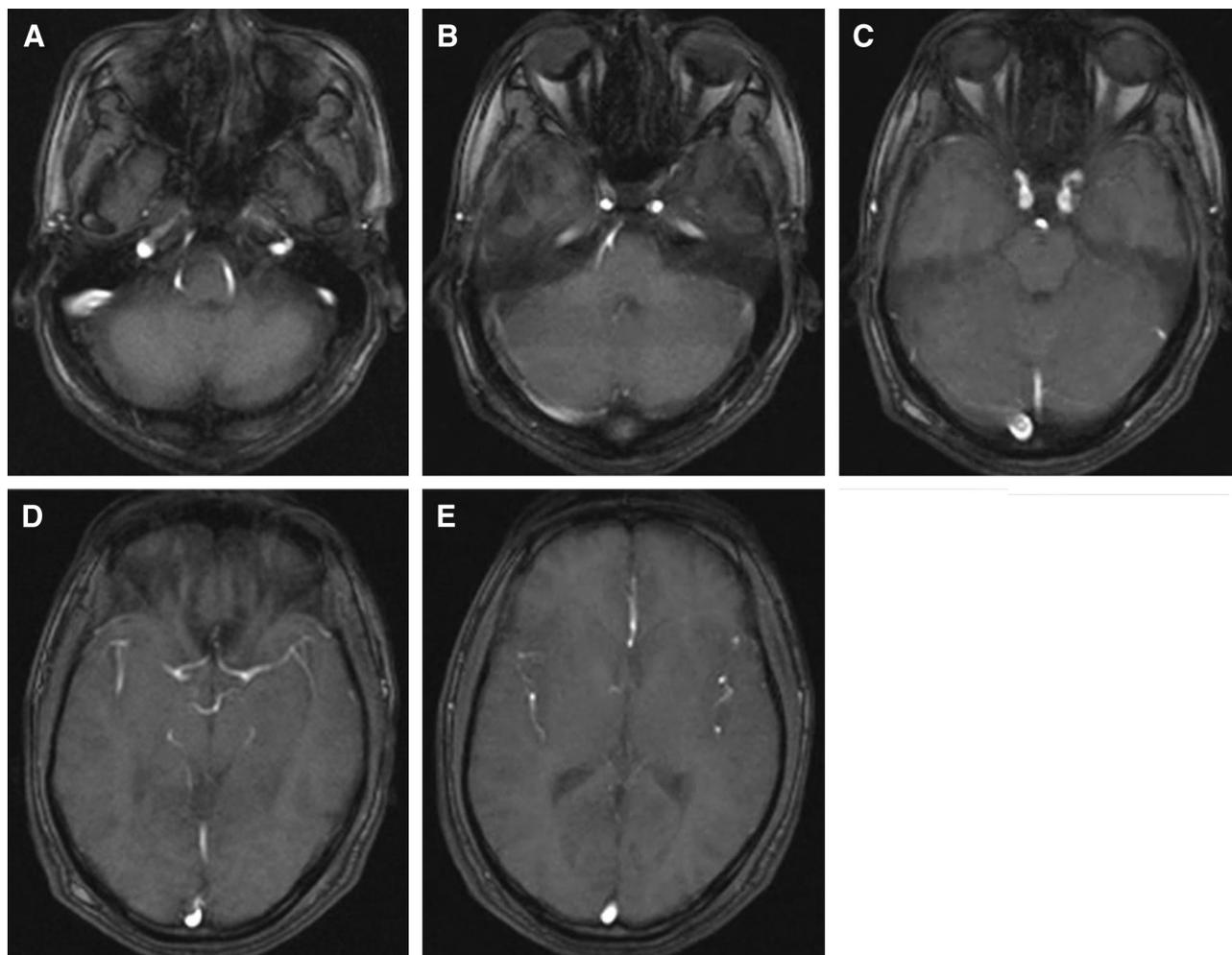


Fig. 2 Magnetic resonance positioning scanning images of a healthy volunteer taken by the new protocol; narrowing the intersection gap and increasing the number of slices (A–E). Bilateral M1 is clearly detected (D).

improve the survival or functional outcome in the real world. Since there is no need to add, change, or omit any MRI sequences, and treatment strategies can be modified based on the results of MRA, we believe that the impact of the clinical application on patients will be very limited. Prospective studies with a large cohort are warranted.

Conclusions

MRI PS has high PPVs to identify large vessel occlusion and high NPVs to confirm patency, but its sensitivities were not high in this study's setting. In cases wherein some diagnoses are obtained from PS, starting preparation of reperfusion therapies using the period of the other sequences imaging may be reasonable. Prospective studies remain to be done to elucidate the diagnostic potential of PS in the real world.

Conflicts of Interest Disclosure

All authors have no conflict of interest and have registered online self-reported COI disclosure statement forms through website for The Japan Neuro-surgical Society members.

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