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Original Article

Comparison of Access Route for Endovascular Treatment by Time-Spatial Labeling Inversion Pulse (Time-SLIP) MRA and Contrast-Enhanced MRA

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Objective: In endovascular treatment, it is important to evaluate the access route for placing a catheter into the common carotid artery (CCA) promptly and safely prior to the procedure. We examined whether non-contrast MRA using time-spatial labeling inversion pulse (Time-SLIP) can be used in patients prior to endovascular thrombectomy for acute ischemic stroke. We compared Time-SLIP MRA to contrast-enhanced (CE) MRA and evaluated the efficacy in the evaluation of access routes.
Methods: We retrospectively reviewed 31 patients admitted between October 2018 and December 2018 for cerebral infarction at our hospital. Blood vessels were imaged from the aortic arch to the CCA. A radiologist blindly evaluated quality score, stenosis, shape of the aorta, and degree of tortuosity.
Results: There were no “non-diagnostic” images. The sensitivity, specificity, positive predictive value, and negative predictive value for stenosis were 83%, 96%, 83%, and 96%, respectively. The sensitivity for the aorta type classification was 100%. The sensitivity for mild tortuosity was 93%, for moderate was 100%, and for severe was 100%.
Conclusion: Time-SLIP MRA can be an alternative to CE MRA in access route assessment for patients with cerebral infarction who are not eligible for acute thrombectomy therapy.

Keywords MRA, stroke, diagnosis, aorta, thrombectomy

Introduction

Prompt and safe evaluation of the vessels used for obtaining access to place the guiding catheter in the target artery before endovascular procedures is important. Assessment of the access route is also useful when performing thrombectomy for acute ischemic stroke (AIS). With the increasing use of thrombectomy in recent years, it is necessary to reduce the time to recanalization, and quicker preoperative evaluation of the access route will reduce the time lost due to access route changes. We had studied using electrocardiogram-triggered angiography non-contrast-enhanced (TRANCE) imaging regarding the access route.[1)] However, TRANCE is not suitable for the treatment of AIS, because it is too time-consuming.

Time-spatial labeling inversion pulse (Time-SLIP) MRA is an imaging method that relies on non-contrast MRA, although the usefulness of Time-SLIP MRA as a method of evaluating access routes for patients with AIS is unclear. The aim of this study was to evaluate the feasibility of using Time-SLIP MRA as a preliminary access route study prior to mechanical thrombectomy for AIS by comparing it with contrast-enhanced (CE) MRA.

Materials and Methods

This study was approved by the Institutional Review Board of Sapporo Azabu Neurosurgical Hospital (approval

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number: 0121). We obtained written consent from all patients for their participation in this study. The inclusion criterion was the patients who admitted to our hospital between October 2018 and December 2018 for any cerebral infarction and agreed with this study. The exclusion criterion was the patients who had advanced renal dysfunction (estimated glomerular filtration rate ≥30 mL/min/1.73 m^2) and in whom MRI was not performed for any reason such as a pace maker and claustrophobia. We retrospectively reviewed 31 patients who met the criteria of the present study. In this study, no patients were eligible for mechanical thrombectomy. The access route examined was from the aorta to the common carotid artery (CCA). A radiologist, blinded to the clinical information, evaluated the quality score and the vascular properties, such as stenosis, classification of aorta type, and degree of tortuosity. We also compared the imaging time between Time-SLIP MRA and CE MRA. Both of them were performed simultaneously on the same patient.

The quality scores for Time-SLIP MRA and CE MRA were assigned by a radiologist. A three-point score rating for image quality was used as follows: score 1 (the entire arterial morphology completely visible), score 2 (arterial morphology incompletely but visible), and score 3 (arterial morphology not visible and not diagnosable).[2,3] The difference between complete and incomplete is defined as whether the entire arterial morphology is completely visible or not. If it appeared unclear, it was defined as incomplete. Stenosis was classified into three types as follows: no stenosis (0%), insignificant stenosis (1%–49%), and significant stenosis (>50%). Less than 50% was considered a negative result and more than 50% a positive result. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were evaluated. The sensitivity, specificity, PPV, NPV of stenosis, and the corresponding 95% confidence intervals were calculated. Aorta type was defined based on the distance from the origin of the innominate artery to the top of the aortic arch.[4] In type 1, this distance is less than the diameter of the CCA; in type 2, the distance is between 1 and 2 times the CCA diameter; and in type 3, the distance is more than double the CCA diameter. Tortuosity was measured using tortuosity index.[5] The index was calculated as the ratio of the length of the median line to the length of a straight line from the origin of the brachiocephalic artery to the origin of the CCA. Tortuosity was classified into three types as follows: mild was less than 1.15, moderate was between 1.15 and 1.2, and severe was greater than 1.2.

Time-SLIP MRA protocol

All MRI was performed using a 1.5T unit (Signa HDxt Twin Speed 1.5T version 23; GE Healthcare, Milwaukee, MI, USA) with a 12-channel receiver coil. We used a Time-SLIP-based technique with a short acquisition time MRA. This technique enables the visualization of arterial flow of the target field of view (FOV) by using a selective inversion recovery (IR) pulse. First, a selective IR pulse is applied to invert all spins of protons in the imaging slab. Second, after a delay time of 1600 ms, the imaging data are acquired. Within this duration of image acquisition, the high-signal flesh arterial spins are moving from outside of the imaging slab into inside of the imaging slab, whereas the static tissue signal within the imaging slab remains low because those tissues are within the T1 relaxation process, and the signal has not recovered sufficiently. Time-SLIP-based MRA were obtained under the following conditions: 3D fast imaging employing steady-state acquisition, repetition time = 3.5 ms, echo time = 1.7 ms, flip angle = 50°, FOV = 300 × 300 mm^2, matrix = 224 × 288 with 512 × 512 reconstruction, slice thickness = 6 mm, slab thickness = 60 mm, array spatial sensitivity encoding technique (ASSET) factor = 2, and scanning time = 45 s.

CE MRA protocol

CE MRA was also performed using a spoiled gradient-echo imaging sequence with the following acquisition parameters: FOV = 280 × 280 mm^2, matrix = 288 × 256 pixels with 512 × 512 reconstruction, repetition time = 5.1 ms, echo time = 1.0 ms, flip angle = 45°, slice thickness = 1.6 mm, slab thickness = 96 mm, coronal slab orientation, ASSET factor = 2, and acquisition time = 40 s. Gadoterate meglumine (0.1 mmol/kg, Magnescope; Terumo, Tokyo, Japan) was used as the contrast agent in each patient and was injected as a bolus at a rate of 2.5 mL/s for 8 s; the contrast agent was followed by a 30-mL saline flush by using a power injector (Sonic Shot GX; Nemoto, Tokyo, Japan).

Statistical analysis

All statistical analyses were performed using JMP Pro 12 (SAS Institute, Cary, NC, USA).

Results

Table 1 shows the basic characteristics of the patients included in our study, including age, sex, and past history. Time-SLIP MRA and CE MRA were performed in all patients.

Table 1 Patient clinical findings

Characteristic	Findings
Mean age (years)	78.3
Sex	
Female (%)	61.2
Male (%)	38.7
Cardiovascular risk factors	
Diabetes mellitus (%)	19.4
Hypertension (%)	67.7
Hyperlipidemia (%)	41.9
Arrhythmia (%)	38.7

Table 2 Quality score for Time-SLIP MRA and CE MRA by one reader

	CE MRA		
	1	2	3
Time-SLIP MRA			
1	28	0	0
2	1	2	0
3	0	0	0
Quality score	1	2	3
Sensitivity (%)	96	100	

CE: contrast enhanced; Time-SLIP: time-spatial labeling inversion pulse

Table 3 Sensitivity, specificity, PPV, and NPV and kappa statistic for stenosis of Time-SLIP MRA compared to CE MRA by one reader

	Values
Sensitivity (%)	83
Specificity (%)	96
PPV (%)	83
NPV (%)	96

Date are given as mean (95% CI). CE: contrast enhanced; CI: confidence interval; NPV: negative predictive value; PPV: positive predictive value; Time-SLIP: time-spatial labeling inversion pulse

With regards to the quality score, there were no Time-SLIP MRA and CE MRA images graded as "non-diagnostic" (**Table 2**). The sensitivity of the quality score was 96% for score 1 and 100% for score 2.

With Time-SLIP MRA, the reader diagnosed stenosis with a sensitivity of 83%, specificity of 96%, PPV of 83%, and NPV of 96%, as compared with CE MRA (**Table 3**).

The sensitivity of the classification of aortic shape was 100% for all types of aorta (**Table 4**).

The sensitivity for mild tortuosity was 93%, for moderate tortuosity was 100%, and for severe tortuosity was 100% (**Table 5**).

The imaging time of CE MRA was about 40 s for scanning, and images could be seen immediately after scanning. Time-SLIP MRA took 45 s to scan, and it took about 10 min to reconstruct the maximum intensity projection (MIP).

Table 4 Quality score for aorta-type classification assessed by Time-SLIP MRA and CE MRA

	CE MRA		
	1	2	3
Time-SLIP MRA			
1	23	0	0
2	0	5	0
3	0	0	3
Aorta type	1	2	3
Sensitivity (%)	100	100	100

CE: contrast-enhanced; Time-SLIP: time-spatial labeling inversion pulse

Table 5 Quality score for grading of tortuous artery by Time-SLIP MRA and CE MRA by one reader

	CE MRA		
	1	2	3
Time-SLIP MRA			
1	14	0	0
2	0	11	0
3	1	0	5
Tortuosity	1	2	3
Sensitivity (%)	93	100	100

CE: contrast-enhanced; Time-SLIP: time-spatial labeling inversion pulse

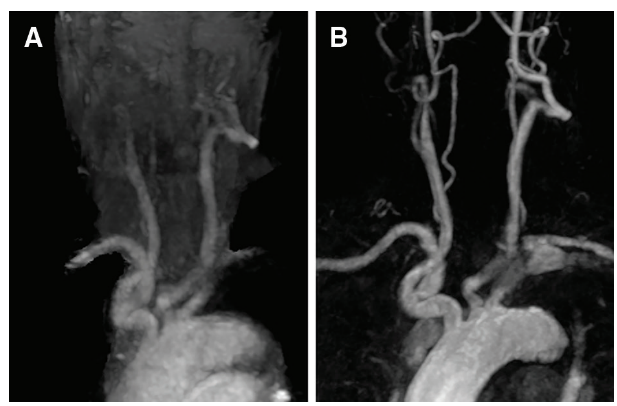

Fig. 1 Case presentations comparing Time-SLIP MRA and CE MRA. (**A**) Time-SLIP MRA and (**B**) CE MRA. In this case, the quality scores between Time-SLIP MRA and CE MRA were different. The quality score estimated by Time SLIP was 2, whereas that by CE MRA was 1. CE: contrast enhanced; Time-SLIP: time-spatial labeling inversion pulse

Case presentation

We show representative case with mismatched quality scores between Time-SLIP MRA and CE MRA. Time-SLIP MRA estimated a quality score of 2 (**Fig. 1A**), whereas that estimated by CE MRA was 1 (**Fig. 1B**). CE MRA conferred better visibility than Time-SLIP MRA in this case. The other vascular properties were evaluated: no stenosis, aorta type 2, and severe tortuosity for both Time-SLIP MRA and CE MRA. In contrast, the second case showed quality score of 1 for both Time-SLIP MRA and CE MRA; however,

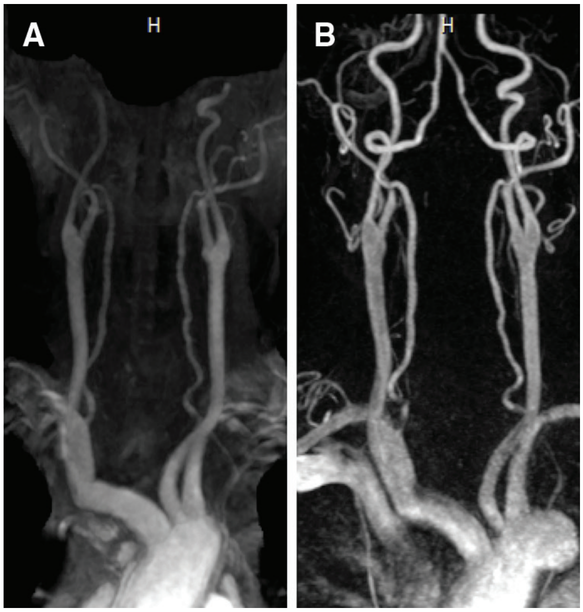

Fig. 2 Case presentations comparing Time-SLIP MRA and CE MRA. (**A**) Time-SLIP MRA and (**B**) CE MRA. In this case, stenosis and tortuosity observed between Time-SLIP MRA and CE MRA appeared different. A radiologist reported stenosis and moderate tortuosity with Time-SLIP MRA, whereas mild tortuosity was reported with CE MRA. CE: contrast enhanced; Time-SLIP: time-spatial labeling inversion pulse

the reader reported stenosis and mild tortuosity after assessment of Time-SLIP MRA results (**Fig. 2A**), whereas moderate tortuosity in CE MRA (**Fig. 2B**). Stenosis was present and was type 3 for both modalities.

Discussion

In this study, we compared the image quality and the imaging time of access routes in Time-SLIP MRA and CE MRA. Our results indicate that Time-SLIP MRA can evaluate the visibility, stenosis, aortic arch shape, and tortuosity to a similar level to that observed with CE MRA, and also the access routes well.

With regard to stenosis, non-contrast MRA is generally susceptible to turbulence that causes false stenosis,[6] but our study did not show any significant difference in stenosis between the two imaging modalities. That is, Time-SLIP MRA can diagnose stenosis. Therefore, the approach can be changed when severe stenosis is identified in the preoperative access route. It may help to avoid cholesterin syndrome, one of the complications due to catheter manipulation for atherosclerotic lesions.

The imaging time of Time-SLIP MRA is relatively short, with the completion time being 45 s. This short imaging time may allow imaging prior to mechanical thrombectomy. As for recanalization time of mechanical thrombectomy, a subanalysis of the Interventional Management of Stroke III trial suggested a 12% decrease in favorable outcome for every 30 min of delayed recanalization.[7] From this report, it should be completed in the shortest possible time from diagnosis to treatment. However, there are several factors that can take time in the treatment approach. One of them is the configuration of aorta. Type 3 aortic arch is generally more difficult to attempt prompt access, generally requiring longer procedural times.[8–11] Haussen et al. also reported that 15 of 1001 patients (1.5%) who underwent mechanical thrombectomy for AIS required a change in the access route from a transfemoral artery approach to a transradial artery approach during the procedure, but the access route change was decided approximately 120 min after the puncture, which resulted in a favorable outcome in 13% and 50% mortality rates at 90 days.[12] It is possible to confirm the original image with a coronal image immediately after scanning. It takes approximately 10 min to complete the MIP, but it can be confirmed on the monitor when the patient is transferred to the angiography room before starting thrombectomy. Therefore, depending on the type of aorta, the site of puncture and the catheter to be used can be determined before the surgery, which may contribute to shortening the recanalization time.

Many reports have described the efficacy of MRA for evaluating vascular disease, such as peripheral vessel stenosis. For peripheral artery disease, CTA is typically used, but there are facilities that use CE MRA. The gold-standard method in patients with renal dysfunction is DSA with non-contrast MRA.[13–20] Non-contrast MRA is used in preoperative evaluations for bypass surgery, balloon angioplasty for lower limb arteries, and stent placement.

The results of this study showed that the resolution of Time-SLIP MRA was not inferior to that of CE MRA. Therefore, it may be used for these preoperative examinations. Time-SLIP MRA may also be useful as a postoperative or follow-up imaging evaluation to avoid repeated use of contrast media due to CE MRA.

The main limitation of this study was the small number of cases, the lack of cases with aneurysms, and the absence of motion artifacts or metal artifacts from the stent. MRA does not confirm calcification and may recognize them as stenosis. This method is restrictive because of out of range of scanning from the femoral artery to the descending aorta. In the future, larger studies addressing this important issue need to be performed.

Conclusion

Time-SLIP MRA can be an alternative to CE MRA in access route assessment for patients with cerebral infarction who are not eligible for acute thrombectomy therapy.

Disclosure Statement

The authors have no conflicts of interest to declare.

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