Efficacy of the MRA-Based Road Mapping of the Para-Aortic Access Route before Mechanical Thrombectomy in Patients with Acute Ischemic Stroke

Satoshi Kobayashi\textsuperscript{a, b} Toshiya Osanai\textsuperscript{a} Noriyuki Fujima\textsuperscript{c} Akiyoshi Hamaguchi\textsuperscript{b} Taku Sugiyama\textsuperscript{a} Toshitaka Nakamura\textsuperscript{b} Kazutoshi Hida\textsuperscript{b} Miki Fujimura\textsuperscript{a}

\textsuperscript{a}Department of Neurosurgery, Faculty of Medicine and Graduate School of Medicine, Hokkaido University, Sapporo, Japan; \textsuperscript{b}Sapporo Asabu Neurosurgical Hospital, Sapporo, Japan; \textsuperscript{c}Department of Diagnostic and Interventional Radiology, Hokkaido University Hospital, Sapporo, Japan

Keywords
MRA-based road mapping · Access route · Aortic arch · Mechanical thrombectomy · Acute ischemic stroke

Abstract
Introduction: The aim of this study was to clarify whether magnetic resonance angiography (MRA)-based road mapping of the para-aortic transfemoral access route can reduce the procedural time of mechanical thrombectomy in patients with acute ischemic stroke. We further investigated the role of pre-procedural MRA-based road mapping in optimal initial catheter selection for rapid mechanical thrombectomy. Materials and Methods: We retrospectively reviewed 57 consecutive patients with acute ischemic stroke who underwent mechanical thrombectomy at our hospital between April 2018 and May 2021. Twenty-nine patients underwent MRA-based road mapping to visualize the para-aortic access route, whereas 28 patients only underwent routine head magnetic resonance imaging/angiography without MRA-based road mapping before neuro-interventional procedures. We then compared the basic procedural times required for mechanical thrombectomy, such as the time from femoral artery puncture to recanalization (“puncture to recanalization time”) and the time from the admission to recanalization (“door to recanalization time”), between the groups. Results: MRA-based road mapping significantly reduced the “puncture to recanalization time” (52.0 min vs. 70.0 min; \( p = 0.019 \)) and the “door to recanalization time” (146 min vs. 183 min; \( p = 0.013 \)). Conclusion: MRA-based road mapping of the para-aortic access route is useful to reduce the procedural time of mechanical thrombectomy in acute stroke patients, possibly by enabling optimal initial catheter selection during the procedure.

Introduction
The goal of acute revascularization in patients with acute ischemic stroke due to large-vessel occlusion is to achieve the shortest recanalization time. Indeed, acute revascularization by mechanical thrombectomy was demonstrated to be effective in a randomized controlled trial at the Interventional Stroke Conference in 2015 and in previous reports [1–5]. A sub-analysis of the Interventional Management of Stroke III trial suggested a 12% decrease in a favorable outcome for every 30 min (min) of delayed recanalization [6].
On the other hand, the procedural time of mechanical thrombectomy is significantly affected by the anatomical configuration of the aortic arch [7]. Especially in patients with type III aortic arch [7], the procedural time may be markedly prolonged due to the difficulty in catheter access; however, the exact correlation between the anatomical configuration of the aortic arch and the procedural time of mechanical thrombectomy remains unclear. We hypothesized that pre-procedural magnetic resonance angiography (MRA)-based road mapping of the para-aortic access route upon the diagnosis of acute cerebral infarction can optimize catheter selection and enable rapid mechanical thrombectomy with a shorter procedural time. In this study, we investigated whether pre-procedural MRA-based road mapping of the para-aortic transfemoral access route before neuro-interventional procedures. We defined the para-aortic area as that covering the entire aorta and common carotid artery (CCA). There were 28 patients who only underwent routine head magnetic resonance imaging (MRI) without MRA-based road mapping of the para-aortic area. We compared the basic procedural time required for mechanical thrombectomy, such as "puncture to recanalization time" and "door to recanalization time" between the groups with or without pre-procedural MRA-based road mapping. We also evaluated the time from femoral artery puncture to placing the guiding catheter at the ICA ("puncture to device placement time") and the time from admission to placing the guiding catheter at the internal carotid artery ("door to device placement time"). Finally, we evaluated the activity of daily living of the patients at transfer by modified Rankin Scale (mRS) in the group with MRA-based road mapping. In all patients, MRI and MRA were performed using a 1.5-Tesla system (GE Healthcare) without contrast material.

Material and Methods

Inclusion Criteria for the Patients

We retrospectively reviewed 57 consecutive patients with acute ischemic stroke who underwent mechanical thrombectomy at Sapporo Asabu Neurosurgical Hospital, Sapporo, Japan between April 2018 and May 2021. In total, 29 patients underwent MRA-based road mapping to visualize the para-aortic transfemoral access route before neuro-interventional procedures. We defined the para-aortic area as that covering the entire aorta and common carotid artery (CCA). There were 28 patients who only underwent routine head magnetic resonance imaging (MRI/MRA without MRA-based road mapping of the para-aortic area. We compared the basic procedural time required for mechanical thrombectomy, such as "puncture to recanalization time" and "door to recanalization time" between the groups with or without pre-procedural MRA-based road mapping. We also evaluated the time from femoral artery puncture to placing the guiding catheter at the ICA ("puncture to device placement time") and the time from admission to placing the guiding catheter at the internal carotid artery ("door to device placement time"). Finally, we evaluated the activity of daily living of the patients at transfer by modified Rankin Scale (mRS) in the group with MRA-based road mapping. In all patients, MRI and MRA were performed using a 1.5-Tesla system (GE Healthcare) without contrast material.

Assessment of Para-Aortic Area by MRA-Based Road Mapping

We classified the following three types of aortic arch by MRA-based road mapping as previously reported based on the vertical distance from the origin of the innominate artery to the top of the arch [8]. This distance was <1 diameter of the left CCA in a “type I arch,” between 1 and 2 diameters in a “type II arch,” and >2 diameters in a “type III arch.” In patients who did not perform MRA-based road mapping before the procedure, we retrospectively evaluated the type of aortic arch based on intraoperative aortography, surgical records, and chest computed tomographic scan.

Neuro-Interventional Procedures

All patients except one underwent mechanical thrombectomy under local anesthesia by a single surgeon (S.K.) at Sapporo Asabu Hospital. We selected the inner catheter according to aortic arch type by MRA-based road mapping of the para-aortic area upon the diagnosis of cerebral infarction. We were able to confirm the type of aorta in the original coronal image as soon as the image of the para-aortic area was completed. Briefly, we used a JB-2 type catheter® (Medikit, Tokyo, Japan) from initial treatment in patients with a type I or type II arch, and a Simmons type catheter from initial treatment for those with a type III arch as the inner catheter. We often used a 9-F Optimo guiding catheter® (Tokai Medical products, Aichi, Japan) as the guiding catheter and Silverway Guide Wire® (ASAHI INTECC, Aichi, Japan).

MR Protocol

All MRI was performed using a 1.5-Tesla unit (Signa HDxt Twin Speed 1.5 T version 23; GE Healthcare, Milwaukee, MI, USA) with a 12-channel receiver coil. We used the time-SLIP-based technique with short acquisition time MRA. This technique enables the visualization of arterial flow of the target field of view by using a selective inversion recovery pulse. First, a selective inversion recovery pulse is applied to invert all spins of protons in the imaging slab. Second, after a delay time of 1,600 ms, the imaging data are acquired. Within this duration of image acquisition, the high-signal fresh arterial spins are moving from outside to inside 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 was obtained under the following conditions: 3D fast imaging employing steady-state acquisition (FIESTA), repetition time = 3.5 ms, echo time = 1.7 ms, flip angle = 50°, field of view = 300 × 300 mm×, 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.

Statistical Analysis

Differences in the baseline clinical characteristics were compared using the Pearson χ2 test. Procedural times were assessed by the Wilcoxon two-sample test and analysis of variance for continuous variables, as appropriate. All statistical analyses were performed using JMP® Pro 12 (SAS Institute Inc., Cary, NC, USA). p values <0.05 were considered significant.

Results

The clinical characteristics of patients with acute ischemic stroke in this study are summarized in Table 1. There was a significant difference in sex, but there was no significant difference between groups in other factors. Cardioembolic stroke was 89.6% for the group with road mapping and 82.1% for the group without road mapping, and atherosclerotic stroke was 10.3% for the group with road mapping and 17.9% for the group without road mapping. There was no significant difference in stroke type between each group.
MRA-based road mapping significantly reduced the “puncture to recanalization time” (52.0 min vs. 70.0 min; \(p = 0.019\)) and the “door to recanalization time” (146 min vs. 183 min; \(p = 0.013\)), as shown in Table 2. In addition, it significantly reduced the “puncture to device placement time” (20.0 min vs. 35.0 min; \(p < 0.001\)) and “door to device placement time” (111 min vs. 153 min; \(p = 0.006\)).

The distribution of the type of aortic arch in the group with MRA-based road mapping was as follows: type I (27.6%), type II (34.5%), and type III (37.9%). This distribution of the aortic type did not statistically differ from that in the group without MRA-based road mapping as follows: type I (25%), type II (17.9%), and type III (17.9%), and unknown (39.2%). In patients who underwent pre-procedural MRA-based road mapping, the “puncture to device placement time” and “puncture to recanalization time” were almost consistent among patients with different aortic types, including the aortic arch type III (Table 3). As shown in Table 3, the “puncture to device placement time” was 16.0 min for type I, 25.5 min for type II, and 22.0 min for type III. Regarding the “puncture to recanalization time,” it took 50.0 min for type I, 62.5 min for type II, and 51.0 min for type III. Regarding the activity of daily living at transfer, incidence of the favorable outcome (mRS 0–2) in each aortic type was 71.4% for type I, 30.0% for type II, and 63.4% for type III (Table 3). There was no significant difference between each group.

### Representative Case

An 87-year-old woman presented with the sudden onset of dysarthria and left hemiparesis and was admitted to our hospital 3 h after onset. Initial MRA revealed right middle cerebral artery occlusion, and thus, we performed mechanical thrombectomy with rt-PA therapy 4.5 h after onset. MRA-based road mapping before the neuro-interventional procedure demonstrated aortic arch type III (Fig. 1a). Based on this para-aortic MRA finding, we selected a 6-F SY-6 catheter® (GADELIUS MEDICAL, Tokyo, Japan). We
used a 9-F Optimo guiding catheter® (Tokai Medical products, Aichi, Japan), 6-F SY-6 catheter, and Silverway Guide Wire® (ASAHI INTECC, Aichi, Japan). This enabled optimal recanalization of the affected middle cerebral artery at TICI3 with the Penumbra 3MAX® (Medico’s Hirata Inc., Osaka, Japan). The “puncture to device placement time” was 12 min and “puncture to recanalization time” was 30 min. The post-procedural course was uneventful, and the patient exhibited significant improvement in dysarthria and the left hemiparesis completely disappeared. She was discharged to home without permanent neurological deficit 3 weeks after the procedure.

**Discussion**

In the present study, we demonstrated that MRA-based road mapping of the transfemoral access route before mechanical thrombectomy can significantly reduce the neuro-interventional procedural times, such as “puncture to recanalization time,” in patients with acute ischemic stroke. In addition to the “puncture to recanalization time,” all other items significantly improved in patients who underwent MRA-based road mapping. MRA-based road mapping may enable us to promptly determine the approach route before the procedure and to select the optimal catheter by clarifying the aortic arch configuration. Indeed, we generally selected a standard JB-2 type catheter for aortic arch type I and II, whereas we chose the Simmons type catheter for aortic arch type III before mechanical thrombectomy based on MRA-based road mapping, resulting in a favorable procedural time for all aortic arch types.

There have been several reports of neuro-interventional techniques to facilitate catheter access, such as the

| MRA-based road mapping (+) | Aorta type | p value |
|---------------------------|------------|---------|
|                           | I (n = 8)  | II (n = 10) | III (n = 11) |
| P to D, min               | 16.0 (3.45–29.5) | 25.6 (12.9–36.2) | 22.0 (19.5–41.8) |
| P to R, min               | 50.0 (20.9–70.8) | 62.5 (49.9–94.5) | 51.0 (39.0–81.5) |
| mRS 0–2, %                | 71.4       | 30       | 63.4       |

P to D, puncture to device placement time; P to R, puncture to recanalization time; mRS, modified Rankin Scale. These items are the median time (95% confidence interval).

---

**Fig. 1.** Representative patient with aortic arch type III; MRA-based road mapping of the para-aortic transfemoral access route before mechanical thrombectomy. a MRA-based road mapping of the para-aortic access route. After confirming aortic arch type III shown by MRA-based road mapping of the access route, we selected a 6-F SY-6 catheter as the initial catheter. b X-ray during navigation of the 9-F Optimo guiding catheter up to the right CCA. A 6-F SY-6 inner catheter was placed in the right CCA. The 9-F Optimo guiding catheter was advanced along the 6-F SY-6 inner catheter. The “puncture to device placement time” was 12 min, and the “puncture to recanalization time” was 30 min. Arrowhead: 9-F Optimo guiding catheter, arrow: 6-F SY-6 inner catheter.
balloon inflation anchoring technique [9], carotid compression [10], and direct puncture [11], but most recent technical reports of mechanical thrombectomy focused on the best therapeutic modalities such as novel stent retrievers and/or combined techniques using both a stent retriever and aspiration catheter [12–15]. There is limited information regarding pre-procedural evaluation of the para-aortic access route. Rivo et al. [16] analyzed 130 acute stroke patients undergoing acute revascularization and found that type of the aortic arch significantly affects the median time from femoral artery puncture to device placement. Transfemoral catheter access was not possible in 5.1% of their cohort and patients with aortic arch type III was more prone to catheter access failure. Furthermore, patients in whom transfemoral catheter access was difficult had a lower recanalization rate and poorer prognosis [16]. Haussen et al. [17] also reported that 15 of 1,001 patients (1.5%) who underwent mechanical thrombectomy for acute ischemic stroke required a change in access route from a transfemoral artery approach to a trans-radial 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 a 50% mortality rate at 90 days. These studies suggest that changing the intra-procedural access route significantly compromises the outcome. In our series, we promptly achieved catheter access and completed mechanical thrombectomy in most patients, including those with aortic arch type III, as shown in Table 3. Based on our study, MRA-based road mapping may be advantageous to reduce the procedural time of revascularization in acute stroke patients, especially those with aortic arch type III. Therefore, we believe that pre-procedural MRA-based road mapping can facilitate optimal initial catheter selection at the initial stage of the procedure and minimize the procedural time, thereby improving the clinical outcome of acute stroke patients. Alternatively, if MRA-based road mapping suggests that access to the target vessel will be markedly difficult due to abnormal tortuosity and stenosis, direct puncture for CCA may be indicated to reduce the procedural time [11].

There are several limitations in this study. First, we only evaluated the para-aorta area by pre-procedural MRA; thus, we could not exclude the possibility that other anatomical variations in the different area of the access route could affect the results. Second, we could not perform aortography in all patients without MRA-based road mapping; thus, we do not completely rule out the potential bias of the distribution of aortic type between two groups. Finally, this study was a single-center study and the number of patients included in this series was limited. Further studies with a larger number of patients will clarify these important issues such as the optimal catheter for each aortic arch type.

**Conclusion**

MRA-based road mapping of the para-aortic access route is useful to reduce the procedural time of mechanical thrombectomy in acute stroke patients, possibly by enabling optimal initial catheter selection during the procedure.

**Statement of Ethics**

The Institutional Review Board of Sapporo Asabu Neurosurgical Hospital approved this study (IRB number, 24). We received written consent from all patients for their participation in this study.

**Conflict of Interest Statement**

The authors have no conflicts of interest to declare.

**Funding Sources**

There are no funding sources required for this study.

**Author Contributions**

Satoshi Kobayashi: conceptualization and study design. Satoshi Kobayashi and Akiyoshi Hamaguchi: acquisition of data. Satoshi Kobayashi and Miki Fujimura: analysis and interpretation. Satoshi Kobayashi, Miki Fujimura, and Noriyuki Fujima: drafting. Miki Fujimura, Toshiya Osanai, Taku Sugiyama, Toshitaka Nakamura, and Kazutoshi Hida: critical revision of the article. Miki Fujimura: study supervision.

**Data Availability Statement**

All data generated or analyzed during this study are included in this article. Further inquiries can be directed to the corresponding author.
References

1. Berkhemer OA, Fransen PS, Beumer D, van den Berg LA, Lingsma HF, Yoo AJ, et al. A randomized trial of intraarterial treatment for acute ischemic stroke. *N Engl J Med*. 2015; 372:11–20.

2. Campbell BC, Mitchell PJ, Kleing TJ, Dewey HM, Churilov L, Yassi N, et al. Endovascular therapy for ischemic stroke with perfusion-imaging selection. *N Engl J Med*. 2015; 372:1099–1109.

3. Goyal M, Demchuk AM, Menon BK, Eesa M, Rempel JL, Thornton J, et al. Randomized assessment of rapid endovascular treatment of ischemic stroke. *N Engl J Med*. 2015; 372:1019–30.

4. Saver JL, Goyal M, Bonafe A, Diener HC, Levy EI, Pereira VM, et al. Stent-retriever thrombectomy after intravenous t-PA vs. t-PA alone in stroke. *N Engl J Med*. 2015; 372:2285–95.

5. Jovin TG, Chamorro A, Cobo E, de Miquel MA, Molina CA, Rovira A, et al. Thrombectomy within 8 hours after symptom onset in ischemic stroke. *N Engl J Med*. 2015; 372:2296–306.

6. Sun CH, Ribo M, Goyal M, Yoo AJ, Jovin T, Cronin CA, et al. Door-to-puncture: a practical metric for capturing and enhancing system processes associated with endovascular stroke care; preliminary results from the rapid reperfusion registry. *J Am Heart Assoc*. 2014; 3:e000859.

7. Shen S, Jiang X, Dong H, Peng M, Wang Z, Che W, et al. Effect of aortic arch type on technical indicators in patients undergoing carotid artery stenting. *J Int Med Res*. 2019; 47:682–8.

8. Demertzis S, Hurmi S, Stalder M, Gahl B, Hermann G, Van den Berg J. Aortic arch morphometry in living humans. *J Anat*. 2010; 217:588–96.

9. Tokunaga S, Tsurusaki Y, Sambongi Y, Tsunamoto T. Balloon-inflation anchoring technique for insertion of a guiding catheter in acute mechanical thrombectomy. *J Neuroendovascular Ther*. 2017; 11(2):53–8.

10. Yoshimura S, Enomoto Y, Kitajima H, Yamada J, Kaku Y, Iwama T. Carotid-compression technique for the insertion of guiding catheters. *AJNR Am J Neuroradiol*. 2006; 27:1710–1.

11. JadHAV AP, Ribo M, Grandhi R, Linares G, Aghaebrahim A, Jovin TG, et al. Transcervical access in acute ischemic stroke. *J Neurointerv Surg*. 2014; 6:652–7.

12. Hesse AC, Behme D, Kemmling A, Zapf A, Hokamp NG, Frischmuth I, et al. Comparing different thrombectomy techniques in five large-volume centers: a “real world” observational study. *J Neurointerv Surg*. 2018; 10(6):525–9.

13. Goto S, Ohshima T, Ishikawa K, Yamamoto T, Shimato S, Nishizawa T, et al. A stent-retrieving into an aspiration catheter with proximal balloon (ASAP) technique: a technique of mechanical thrombectomy. *World Neurosurg*. 2018; 109:e468–e475.

14. Maus V, Behme D, Kabbasch C, Borggreve J, Tsogkas I, Nikoubashman O, et al. Maximising first-pass complete reperfusion with SAVE. *Clin Neuroradiol*. 2018; 28:327–38.

15. Almendoz JED, Kayan Y, Young ML, Fease JL, Scholz JM, Milner AM, et al. Comparison of clinical outcomes in patients with acute ischemic strokes treated with mechanical thrombectomy using either Solumbra or ADAPT techniques. *J Neurointerv Surg*. 2016; 8:1123–8.

16. Ribo M, Flores A, Rubiera M, Pagola J, Medocna N, Rodriguez-Luna D, et al. Difficult catheter access to the occluded vessel during endovascular treatment of acute ischemic stroke is associated with worse clinical outcome. *J Neurointerv Surg*. 2013; 5(1):i70–73.

17. Haussen DC, Nogueira RG, DeSouza KG, Pavford RN, Janjua N, Ramdas KN, et al. Transradial access in acute ischemic stroke intervention. *J Neurointerv Surg*. 2016; 8:247–50.