Diluted Contrast-enhanced Cone-beam CT during Acute-phase Recanalization Therapy for Occlusion of the Middle Cerebral Artery

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Objective: We here report the methods for and efficacy of C-arm cone-beam CT (CBCT) with diluted contrast medium during the recanalization therapy in acute ischemic stroke patients with middle cerebral artery occlusion.

Case Presentation: The subjects were 30 patients who underwent recanalization therapy for acute ischemic stroke with occlusion of the middle cerebral artery at our hospital between January 2015 and December 2016. Utilizing leptomeningeal anastomosis (LMA), 20-second CBCT with fourfold diluted contrast medium was performed, and 3D image processing was subsequently conducted. In 25 (83.3%) of the 30 patients, a blood vessel distal to the site of occlusion and the extent of thrombus were favorably visualized.

Conclusion: This procedure may be useful as an auxiliary examination that provides more detailed information to safely perform recanalization therapy for acute occlusion of the middle cerebral artery through the visualization of a blood vessel distal to the site of the occlusion.

Keywords ▶ thrombectomy, acute ischemic stroke, middle cerebral artery, cone-beam computed tomography

Introduction

Recently, randomized controlled trials demonstrated the efficacy of mechanical thrombectomy with a stent retriever for acute ischemic stroke with large artery occlusion,1–5) and it has been established as the standard treatment. However, blood vessels distal to the site of occlusion are not visualized on imaging, and blind microwire operations to the distal blood vessel may cause vascular dissection or perforation. To overcome these problems, we performed C-arm cone-beam CT (CBCT) with diluted contrast medium, utilizing leptomeningeal anastomosis (LMA), for patients with acute occlusion of the middle cerebral artery, which facilitated the visualization of a blood vessel distal to the site of occlusion and the extent of thrombus on 3D images. We report the methods and usefulness of this procedure.

Case Presentation

Of 55 patients who underwent endovascular recanalization therapy for acute ischemic stroke with occlusion of the middle cerebral artery between January 2015 and December 2016, CBCT imaging was performed in 30 patients under the following conditions immediately after a guiding catheter was guided into the internal carotid artery. After imaging, 3D image processing was conducted using Work Station to visualize a blood vessel distal to the site of occlusion and identify the extent of thrombus.

For angiography, an Artis zee BA Twin (SIEMENS, Munchen, Bayern, Germany) was used. For Work Station, Syngo X Workplace (SIEMENS) was adopted. Contrast medium was infused using a PRESS DUO injector (Nemoto Kyorindo, Tokyo, Japan). Nonionic iodine contrast...
medium, Iopamidol 300 (Bayer Yakuhin, Ltd., Osaka, Japan), was used as contrast medium, and physiological saline (Hikari Pharmaceutical Co., Ltd., Tokyo, Japan) was used to dilute the contrast medium.

CBCT was performed under the following conditions: tubal voltage, 70 kv; duration of imaging, 20 seconds; working angle, 200 degrees; and visual field size, 42 cm. The rate of contrast-medium infusion using an injector was established as 1 mL/s because contrast medium may maximally flow in the site of LMA with a restricted thrombus load. For image reconstruction using Work Station, the matrix size, image reconstruction function (Kemel type), and image reconstruction filter (Image Characteristics) were 256 × 256, Hounsfield Unit (HU), and Auto, respectively. Concerning the imaging conditions, fourfold diluted contrast medium was infused at a rate of 1 mL/s. After 10 seconds, CBCT imaging for 20 seconds was performed.

As a result, a blood vessel distal to the site of occlusion and the extent of thrombus, which were not visualized in any patient on preoperative MRA, were favorably visualized in 25 (83.3%) of the 30 patients (Table 1). Among the 55 patients, there was no complication of intraoperative perforation in any of 30 for whom CBCT was performed, whereas it occurred in 2 of 25 patients for whom CBCT was not conducted.

Case
A 50-year-old female with no medical history. As dysarthria and right hemiplegia suddenly appeared, she was brought to our hospital by ambulance 108 minutes after onset. The National Institute of Health Stroke Scale (NIHSS) score on arrival was 11. Diffusion-weighted imaging (DWI) revealed high signal intensity in the left insular cortex and precentral gyrus. The Alberta Stroke Programme Early CT Score on DWI (ASPECTS-DWI) was 9. On MRA, there was no visualization of the insular or a more distal portion (M2) of the left middle cerebral artery. Under a diagnosis of acute ischemic stroke with occlusion of the left middle cerebral artery, emergency recanalization therapy was performed. However, intravenous thrombolysis with recombinant tissue plasminogen activator (rt-PA) was not conducted because the platelet count on admission was 90000/µL.

Under local anesthesia, a 9Fr short sheath (Terumo Corporation, Tokyo, Japan) was inserted through the right femoral artery. The puncture was performed 48 minutes after arrival. A 90-cm 9Fr OPTIMO ST (Tokai Medical Products, Aichi, Japan) was guided into the left internal carotid artery, and complete occlusion of the distal horizontal portion of middle cerebral artery (M1) was observed on imaging (Fig. 1A). Subsequently, 20-second CBCT with fourfold diluted contrast medium confirmed the courses of the M2 superior and inferior trunks, and imaging was conducted at a working angle at which the M2 course was easily visualized (Fig. 1B and 1C). Using a 200-cm ASAHICHIKAI black (Asahi Intecc Co., Ltd., Aichi, Japan), the M2 inferior trunk was selected, and a Marksman microcatheter (Medtronic, Irvine, CA, USA) was guided to the distal site of occlusion. The extent of thrombus was estimated from 3D images (Fig. 1B), and a 4-mm × 20-mm Solitaire FR (Medtronic, Irvine, CA, USA) was deployed. After confirming immediate flow restoration, the internal carotid artery was blocked, and the stent was retrieved. Subsequent imaging demonstrated a slight delay in blood flow at the distal M2 inferior trunk, but thrombolysis in cerebral infarction (TICI) grade 2b recanalization was achieved after 1 pass (Fig. 1D). The interval from puncture until recanalization was 34 minutes. After surgery, the NIHSS score decreased to 2. On detailed examination for thrombocytopenia, pancreatic cancer was detected, leading to a diagnosis of embolism related to Trousseau syndrome. After continued rehabilitation, the patient was discharged on the 30th postoperative day. The modified Rankin Scale (mRS) score on discharge was 2.

Discussion
Previously, investigators attempted to visualize blood vessels distal to the site of occlusion during mechanical thrombectomy,6,7) but no study has reported the visualization of blood vessels distal to the site of occlusion on clear 3D images that can be applied as a roadmap while controlling the working angle. CBCT with fourfold diluted contrast

### Table 1 Patient characteristics

<table>
<thead>
<tr>
<th>Age, median (IQR)</th>
<th>74 (64.75–82)</th>
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<tbody>
<tr>
<td>Male, n (%)</td>
<td>15 (50)</td>
</tr>
<tr>
<td>NIHSS, median (IQR)</td>
<td>16 (10.5–19.25)</td>
</tr>
<tr>
<td>ASPECT-DWI, median (IQR)</td>
<td>8 (6.75–9)</td>
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<tr>
<td>Site of occlusion, n (%)</td>
<td></td>
</tr>
<tr>
<td>M1 proximal</td>
<td>4 (13)</td>
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<tr>
<td>M1 distal</td>
<td>12 (40)</td>
</tr>
<tr>
<td>M2</td>
<td>14 (47)</td>
</tr>
<tr>
<td>Visualization of distal vessels, n (%)</td>
<td>25 (83)</td>
</tr>
<tr>
<td>TICI 2b/3, n (%)</td>
<td>26 (87)</td>
</tr>
<tr>
<td>mRS 0–2, n (%)</td>
<td>18 (60)</td>
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</tbody>
</table>

ASPECTS-DWI: Alberta stroke program early CT score on diffusion-weighted images; IQR: interquartile range; mRS: modified Rankin Scale; M1: first segment of middle cerebral artery; M2: second segment of middle cerebral artery; NIHSS: National Institute of Neurological Disorders and Stroke Scale; TICI: thrombolysis in cerebral infarction; mRS 0–2, n (%): percentage of patients with modified Rankin Scale score 0–2; TICI 2b/3, n (%): percentage of patients with thrombolysis in cerebral infarction grade 2b/3; Visualization of distal vessels, n (%): percentage of patients with visualization of distal vessels; Site of occlusion, n (%): percentage of patients with occlusion of different segments of the middle cerebral artery.

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6. Iwasaki M, et al. Journal of Neuroendovascular Therapy  Advance Published Date: September 20, 2018
7. Iwasaki M, et al. Journal of Neuroendovascular Therapy  Advance Published Date: September 20, 2018
Diluted Contrast-enhanced Cone-beam CT in a Thrombectomy

In our procedure, a similar principle of peripheral blood vessel passage via diluted contrast medium was adopted, but angiography was performed using a thick 9Fr guiding catheter through the thin internal carotid artery adjacent to the intracranial space. In comparison with the method described by Amano et al., peripheral blood vessel passage may have been achieved with our method by initially diluting the contrast medium because circulating-blood-related diluting effects are less marked than on angiography through the aorta. As described by Amano et al., we also infused contrast medium at a rate of 1 mL/s and performed 20-second CBCT after 10 seconds.

For this procedure, the interval from the completion of imaging until image processing with Work Station was approximately 2 minutes. It was possible to complete the process while preparing an appropriate device after confirming vascular occlusion. The merits of this procedure are that the interval until recanalization can be shortened in comparison with aortic angiography or CT angiography by initially inserting a guiding catheter into the internal medium, which was adopted in this study, involves 3D image processing. Therefore, it is important for a large volume of contrast medium to reach a blood vessel distal to the site of occlusion through fine LMA; diluted contrast medium that can pass through resistant capillaries is necessary.

Although diluted contrast medium is advantageous with respect to capillary passage, it reduces the Gray Scale (GS) score and visualization capacity; therefore, the visualization of VR images, which are useful for selecting a working angle, is restricted. For this reason, we adopted CBCT, which is characterized by low-level contrast resolution, facilitating the visualization of 3D images with fourfold diluted contrast medium. Amano et al. infused contrast medium through the aortic arch to visualize a blood vessel distal to the site of occlusion and identify the extent of thrombus. They did not use diluted contrast medium, but the administration of contrast medium using a 4Fr catheter through the aorta may have resulted in the dilution of contrast medium in the presence of blood flow before reaching peripheral blood vessels, thereby contributing to the visualization of peripheral blood vessels.

**Fig. 1** (A) Anteroposterior view of angiogram showing left middle cerebral artery occlusion. (B) The cone-beam CT from the proper working angle clearly demonstrated the site of occlusion (arrow), the extent of thrombus and the M2 portion. (C) Angiogram from the proper working angle clearly showed the site of occlusion (arrow). (D) Postoperative angiogram showed the recanalization of the M2 portion (arrowheads).
carotid artery. In addition, the volume of contrast medium is limited. On the other hand, LMA-related contrast medium arrival in an area distal to the site of occlusion through the posterior cerebral artery may not be achieved in lesions other than the fetal-type, which is a limitation. In this study, it was possible to visualize a blood vessel distal to the site of occlusion in 25 (83.3%) of 30 patients for whom this procedure was performed. In the other five patients (16.7%) in whom it was difficult, an LMA-related collateral pathway was insufficient or body-movement-related artifacts were present, contributing to the difficulty. Because the anatomical structure of blood vessels distal to the site of occlusion varies in patients with distal M1 or M2 occlusion,11) the small M2 branches must be blindly selected with a wire. The visualization of a blood vessel distal to the site of occlusion using this procedure facilitates safe visualization of wire operations. In addition, a working angle at which the visual recognition of an access route to M2 lesions, which is difficult to confirm using two-directional (front and lateral) angiography, can be freely selected, increasing the safety of wire operations until the occluded blood vessel is captured. For recanalization therapy, promptness and safety are of the utmost importance. This procedure takes a few minutes, but the visualization of blood vessels may improve the safety and accuracy of the procedure.

**Conclusion**

For endovascular recanalization therapy for acute ischemic stroke with occlusion of the middle cerebral artery, C-arm CBCT with diluted contrast medium facilitated the visualization of a blood vessel distal to the site of occlusion and the extent of thrombus with high efficiency. This method may be useful as an auxiliary examination to obtain detailed information on blood vessels distal to the site of occlusion for safer treatment.

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**Disclosure Statement**

There is no conflict of interest regarding this article for the first author and coauthors.

**References**


