Successful Application of Three-Dimensional Transcranial Power Doppler Imaging in Two Stroke Patients

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We applied a new technique of three-dimensional (3-D) transcranial power Doppler imaging to demonstrate the middle cerebral artery (MCA) in the 2 stroke patients. In the first patient, the 3-D power Doppler study clearly showed the horizontal portion, bifurcation, proximal portion of the upper and lower trunks, and the major branches of the lower trunk of the MCA. In the second patient, the 3-D power Doppler clearly revealed the proximal bifurcation of the left MCA. The 3-D transcranial power Doppler seems to be useful in making clear 3-D images of the MCA.

Key words: cerebral arteries, cerebral angiography, computer-assisted image processing, middle cerebral artery (MCA), ultrasonics

Introduction

Several imaging technologies are available to display cerebral arteries three dimensionally, such as helical computed tomographic angiography and magnetic resonance angiography. These techniques, however, are expensive and inapplicable at bed-side or for frequent examinations. We reported earlier that transcranial color-coded real time sonography can image the arteries at the skull base (1), which help to identify an occlusion in the horizontal portion of the middle cerebral artery (MCA) (2). This method offers us only two dimensional information, and often fails to demonstrate the details of the anatomical structures of the cerebral arteries.

The three-dimensional (3-D) ultrasound technology has been developed to image the anatomy and pathologic conditions in three dimensions (3-5). The power Doppler system is recent sonographic development for vascular structures. The image produced by power Doppler system resembles a map that indicates the density of red blood cells in the vessels. The power Doppler method is superior to the color-Doppler method for detecting blood flow signals, particularly in the intracranial cerebral and extracranial carotid arteries (6, 7). By a combination of the power Doppler method with the 3-D technology, it would be possible not only to image small vessels but also to construct a 3-D image of vascular structures (8, 9). The 3-D power Doppler technique seems to be useful in making clear 3-D images of the MCA from the M1 segment to major branches of M2.

Case Report

We applied the 3-D power Doppler method to evaluate the MCA in two patients with cerebral infarction by using the HDI 3000 (Advanced Technology Laboratories, Bothel, WA, USA). The transducer was operated at 2–3 MHz for B-mode imaging and Doppler functions.

The subjects were examined in the lateral decubitus position. The transducer was placed on the temporal surface. The blood flow signal was displayed in real time as color signals within a subsector of the black-and-white image by using color and power Doppler. Particular care was taken to obtain the blood flow signal clearly by means of tilting, rotating, or shifting the transducer. Then, the transducer was locked back and was tilted very slowly to examine the whole MCA from the M1 segment to M2 for 15 seconds to collect and store 74 images in computer memory. Subsequently, using a 3-D computed system, parenchymal data were subtracted and a composition of vascular anatomy was made. Then, 3-D power Doppler images of the MCA were reconstructed after rendering. In addition, 15 images from 15 angles within the spatial range of 110 degrees were displayed on a video monitor in dynamic partial rotation. We compared the 3-D power Doppler images with cerebral angiographic findings.
3-D Transcranial Power Doppler Imaging

Case 1
A 47-year-old man was admitted to our hospital because of left hemiparesis. Computed tomography (CT) demonstrated low a density area at the perforator territory of the right middle cerebral artery. We diagnosed him as lacunar infarction. We examined him initially with the 2-D power Doppler method to evaluate the cerebral arterial lesion. Although the horizontal portion of the right MCA was clearly shown, major branches (M2 segment) of the MCA were detected merely as dots of flow signals (Fig. 1A). On the other hand, the 3-D power Doppler method demonstrated not only the horizontal portion of the MCA, but its major branches (Fig. 1B, arrows). The findings of 3-D power Doppler imaging were compatible with those of cerebral angiography (Fig. 1C).

Case 2
A 48-year-old man developed right hemiparesis and was admitted to our hospital. CT revealed a low density area at the territory of the left anterior cerebral artery. The 2-D power, 2-D color Doppler and 3-D power Doppler ultrasonographic studies were performed on him on admission. The 3-D power Doppler method demonstrated that the horizontal portion of the left MCA was anomalously divided into double trunks (Fig. 2A). The 2-D power (Fig. 2B, B) and color Doppler (Fig. 2B, A) methods could not identify the anomaly. A routine anteroposterior view (AP view) of cerebral angiogram also failed to
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Figure 2. A) 3-D power Doppler of case 2. The double trunks (short and long arrows) at the MCA was clearly demonstrated. B) 2-D color Doppler (A) and power (B) images of the case 2. The double MCA trunks cannot be visualized by 2-D power and color Doppler images. Each arrow shows the single horizontal portion of the middle cerebral artery. C) Cerebral angiography of case 2. A: An antero-posterior view fails to demonstrate the anomaly of MCA. B: An antero-posterior oblique view shows the proximal bifurcation of the MCA (arrow), being compatible to the 3-D power Doppler image. F indicates frontal, O: occipital, L: lateral, M: medial.

Demonstrate the double trunks (Fig. 2C, A). An additional study with an antero-posterior oblique view (APO view) could visualize the anomalous bifurcation of the MCA (Fig. 2C, B). However, the left anterior cerebral artery was intact. Contrast transesophageal echocardiography revealed a right-to-left shunt through the patent foramen ovale. Therefore, we suspected him as paradoxical embolic stroke.

Discussion

Development of a 3-D ultrasound technique has enabled us to delineate fetal surface features, abdominal organs and coronary walls (3-5, 10, 11). The current study demonstrated that the 3-D power Doppler imaging provided an excellent visualization of the MCA, which was compatible with cerebral angiographic findings. To our knowledge, there were only two previous reports for 3-D power Doppler ultrasonography for the intracranial arteries. Lyden and Nelson performed 3-D power Doppler ultrasonography in normal volunteers but did not compare the ultrasonographic findings with the angiographic findings (8). Delcker and Turowski reported that a transpulmonary-stable ultrasound contrast agent could signifi-
cantly improve the success rate for 3-D power Doppler imaging of the intracranial arteries (9). But they did not compare 3-D power Doppler imaging with 2-D color and power Doppler imaging. Our study was the first report demonstrating the usefulness of 3-D power Doppler ultrasonography in Japanese stroke patients.

In case 1, the 2-D power and color Doppler methods could not demonstrate the MCA branches, but the 3-D power Doppler method clearly demonstrate the branches. We would like to emphasize that 3-D power Doppler imaging is more useful to obtain information of MCA structure than the 2-D power and color Doppler methods.

In case 2, the routine A-P view image of the cerebral angiography failed to demonstrate the anomaly of the MCA. Information obtained beforehand with the 3-D power Doppler ultrasonography led us to add the angiographic examination with an APO view, which confirmed the double trunks of the MCA. This experience indicated that the 3-D power Doppler study may be superior to routine cerebral angiography for evaluating intracranial vasculatures. The structure of intracranial arteries is three dimensional. In the evaluation of the anatomical structure of intracranial arteries, it seems better to use a 3-D method such as computed tomographic angiography, magnetic resonance angiography and 3-D power Doppler imaging compared with a 2-D method such as routine cerebral angiography, 2-D power and color Doppler imaging.

Although the 3-D power Doppler system offers useful information about the intracranial vascular structures, it seems to have some disadvantages from the practical and technical viewpoints. First, this system can not distinguish arterial flow signals from venous flow signals, and such signals may interfere with images of the arterial vascular network. Secondly, the 3-D power Doppler study is highly influenced by the operator’s skill.

By using the 3-D power Doppler technique, we may be able to 3-dimensionally detect an aneurysm, arteriovenous malformation, abnormal vasculature in a brain tumor and an occlusive disease at the horizontal portion or at major branches of the MCA in the near future. The 3-D power Doppler method has the potential to take the place of cerebral angiography for evaluating cerebrovascular disorders.

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