Diagnosis of middle cerebral artery occlusion with transcranial color-coded real-time sonography.

K Kimura, Y Hashimoto, T Hirano, M Uchino and M Ando

AJNR Am J Neuroradiol 1996, 17 (5) 895-899
http://www.ajnr.org/content/17/5/895

Diagnosis of Middle Cerebral Artery Occlusion with Transcranial Color-Coded Real-Time Sonography

Kazumi Kimura, Yoichiro Hashimoto, Teruyuki Hirano, Makoto Uchino, and Masayuki Ando

PURPOSE: To determine the usefulness of transcranial color-coded real-time sonography in detecting occlusion of the horizontal portion of the middle cerebral artery. **METHODS:** Using transcranial color-coded real-time sonography, we measured the end-diastolic flow velocity with incident angle correction and the side-to-side ratio of the end-diastolic flow velocity (the end-diastolic ratio) in both middle cerebral arteries in 44 patients with or without occlusive disease. Cerebral angiography was carried out in all patients before or within 1 week after sonography. The subjects included 4 patients with unilateral stenosis of the extracranial internal carotid artery (≥75%; ICS group), 6 with unilateral occlusion of the extracranial internal carotid (ICO group), 6 with occlusion of the horizontal portion of the middle cerebral artery (M1 group), and 28 without stenotic (<75%) lesions in the internal carotid artery (control group). **RESULTS:** In the control group, the end-diastolic flow velocity was 40.4 ± 16.8 cm/s (mean ± SD) and the end-diastolic ratio was 1.28 ± 0.27. In the ICS and ICO groups, the end-diastolic flow velocities on the affected side and the end-diastolic ratios were 33.4 ± 9.0 cm/s and 1.35 ± 0.24, and 29.6 ± 10.2 cm/s and 1.67 ± 0.58, respectively. In the M1 group, the end-diastolic flow velocity (16.7 ± 4.29 cm/s) on the occluded side was significantly lower than that in the other groups. The end-diastolic ratio (3.53 ± 1.47) in the M1 group was significantly higher than that in the other groups. **CONCLUSION:** The M1 group could be easily distinguished from the other groups on the basis of the end-diastolic ratio. Measurement of the end-diastolic flow velocity and the end-diastolic ratios in the middle cerebral artery by means of transcranial color-coded real-time sonography may help to identify an occlusion in the horizontal portion of the middle cerebral artery.

Index terms: Arteries, cerebral, middle; Arteries, stenosis and occlusion; Arteries, ultrasound; Ultrasound, Doppler

AJNR Am J Neuroradiol 17:895–899, May 1996

In 1982, Aaslid et al (1) demonstrated that Doppler signals could be obtained from the arteries at the skull base by using the temporal bone as the acoustic window. Transcranial Doppler sonography has been reported to be useful in evaluating intracranial hemodynamic alterations, vasospasm that follows subarachnoid hemorrhage, intracranial arterial stenosis, and arteriovenous malformations (2–4). However, the diagnosis of occlusion of the horizontal portion of the middle cerebral artery with transcranial Doppler sonography is difficult because precise placement and proper angulation is necessary. In 1991, our research group reported that transcranial color-coded real-time sonography was useful for obtaining images of the arteries at the skull base and that flow velocity could be measured accurately after the incident angle was corrected (5). Our objective in this investigation was to determine whether it was possible to detect an occlusion in the horizontal portion of the middle cerebral artery with Doppler sonography by measuring the end-diastolic flow velocity and the end-diastolic ratio (the side-to-side ratio of the end-diastolic flow velocity).

Received July 6, 1995; accepted after revision November 7.

From the Departments of Cerebrovascular Disease (K.K.) and Neurology (Y.H.), Kumamoto City Hospital, and the First Department of Internal Medicine, Kumamoto University School of Medicine (T.H., M.U., M.A.), Japan.

Address reprint requests to Kazumi Kimura, MD, Department of Cerebrovascular Disease, Kumamoto City Hospital, 1-1-60 Kotoh, Kumamoto City, Kumamoto 862, Japan.

AJNR 17:895–899, May 1996 0195-6108/96/1705–0895

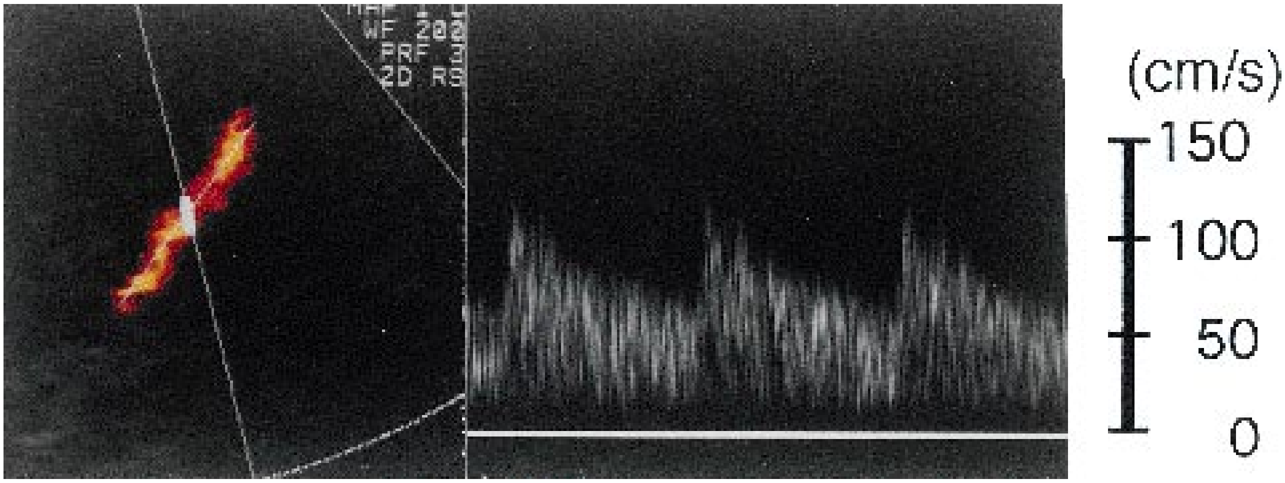


Fig 1. Transcranial color-coded real-time sonogram of the right middle cerebral artery in a patient in the control group. At *left,* the right middle cerebral artery is displayed in red, indicating flow toward the transducer. The sample volume is situated in the middle cerebral artery. The angle between the Doppler beam and the course of the vessel is adjusted (48°). At *right,* the Doppler waveform of the middle cerebral artery flow pattern is seen. The end-diastolic flow velocity is 63 cm/s.

Subjects and Methods

Transcranial color-coded real-time sonography was performed in 73 patients from June 1 to September 30, 1994. We routinely obtained B-mode scans and measured flow velocity by pulsed-Doppler sonography in both middle cerebral arteries. Cerebral angiography was carried out in 44 of the 73 patients before or within 1 week after the sonographic examination, and these 44 patients (37 men and 7 women; mean age, 62 ± 13 years) were entered into the present study.

The 44 patients were divided into four groups on the basis of their angiographic findings. Group 1 was the internal carotid artery stenosis (ICS) group; it included 4 patients with unilateral stenosis of the extracranial internal carotid artery (≥75%). Group 2 was the internal carotid artery occlusion (ICO) group; it included 6 patients with unilateral occlusion of the extracranial internal carotid artery. Group 3, the M1 group, included 6 patients with an occlusion of the horizontal portion of the middle cerebral artery. Group 4 was the control group, which comprised 28 patients without stenotic (<75%) lesions on bilateral carotid angiograms. In this study, patients with occlusion of the middle cerebral artery close to the internal carotid artery bifurcation were excluded because flow images of the middle cerebral artery were not obtainable.

Of the 16 patients with stenosis or occlusion of the carotid artery, 10 had suffered acute thrombotic stroke, 4 had had an acute occlusion of the central retinal artery, and 2 had had transient ischemic attacks. In the control group, 18 had lacunar infarction, 5 had cerebral embolism, 3 had transient ischemic attacks, 1 had cerebral hemorrhage, and 1 had encephalitis.

The equipment used was a commercially available transcranial color-coded real-time sonographic scanner. The transducer was operated at 2.25 MHz for both B-mode imaging and Doppler functions. The pulse repetition frequency was mainly 3700 Hz, and the low-pass filter was 50 Hz.

The subjects were examined first in the left lateral decubitus position and then in the right lateral decubitus position. The transducer was placed on the temporal surface. Blood flow velocity and direction were displayed in real time as color signals within a subsector of the black-and-white image. Particular care was taken to obtain a long axis view of the desired vessel, especially of the horizontal portion of the middle cerebral artery, by means of tilting, rotating, or shifting the transducer.

A range-gate pulsed Doppler sample volume, 2 mm in size, was used to measure the blood flow velocity in the middle cerebral artery. Particular care was taken to keep the incident angle between the middle cerebral artery and the beam at 60° or less (Fig 1).

First, we measured the end-diastolic flow velocity of both middle cerebral arteries and determined its mean value during five consecutive cardiac cycles. These velocities were then corrected with the incident angle. Then, the side-to-side ratio of the end-diastolic flow velocity (the end-diastolic ratio) was calculated by dividing the velocity of the unaffected side by that of the affected side in the ICO, ICS, and M1 groups. In the control group, the end-diastolic ratio was obtained by dividing the velocity on the faster side by the slower velocity.

The age and flow velocity data for each group were expressed as mean ± SD. For the analysis of velocity data, we used the unpaired *t* test. A value of $P < .05$ was accepted as indicating a significant difference.

Results

The end-diastolic flow velocity in both middle cerebral arteries was measured in 44 patients. The typical waveforms in the control, M1, and

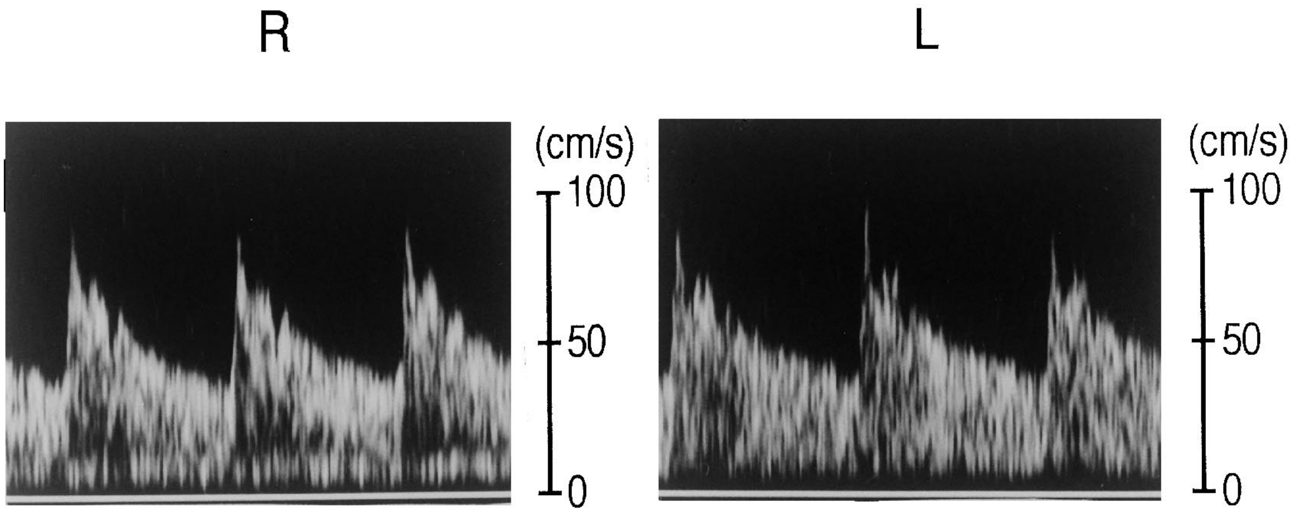
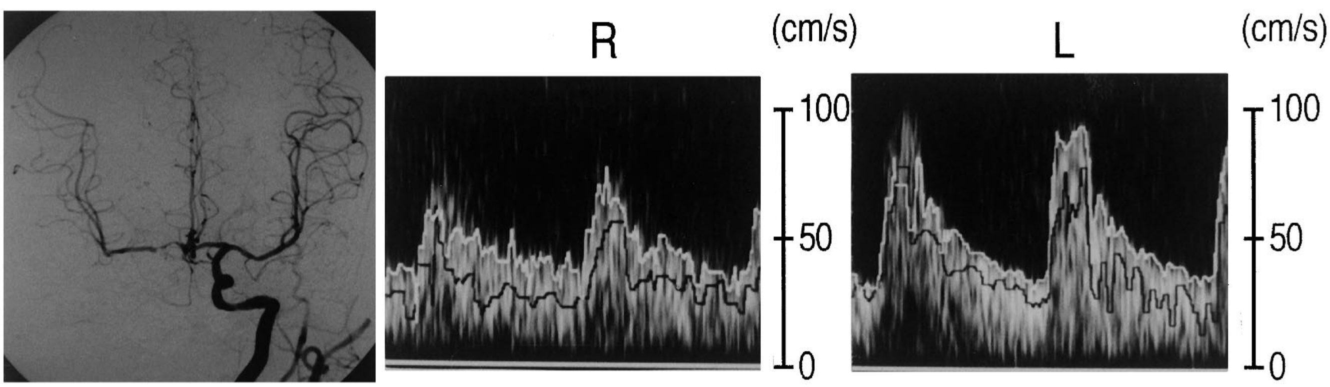


Fig 2. Doppler flow waveforms of a patient in the control group. The right middle cerebral artery end-diastolic flow velocity is 39 cm/s, the left middle cerebral artery end-diastolic flow velocity 41.5 cm/s, and the side-to-side ratio of the end-diastolic flow velocity (the end-diastolic ratio) is 1.06.



A B

Fig 3. *A,* Angiogram of a patient with right internal carotid occlusion.

B, Doppler waveforms show that the right middle cerebral artery end-diastolic flow velocity is 29 cm/s, the left middle cerebral artery end-diastolic flow velocity is 37.2 cm/s, and the side-to-side ratio of the end-diastolic flow velocity (the end-diastolic ratio) is 1.28.

ICO groups are shown in Figures 2 through 4. The end-diastolic flow velocity and the end-diastolic ratio in each group are shown in Figures 5 and 6.

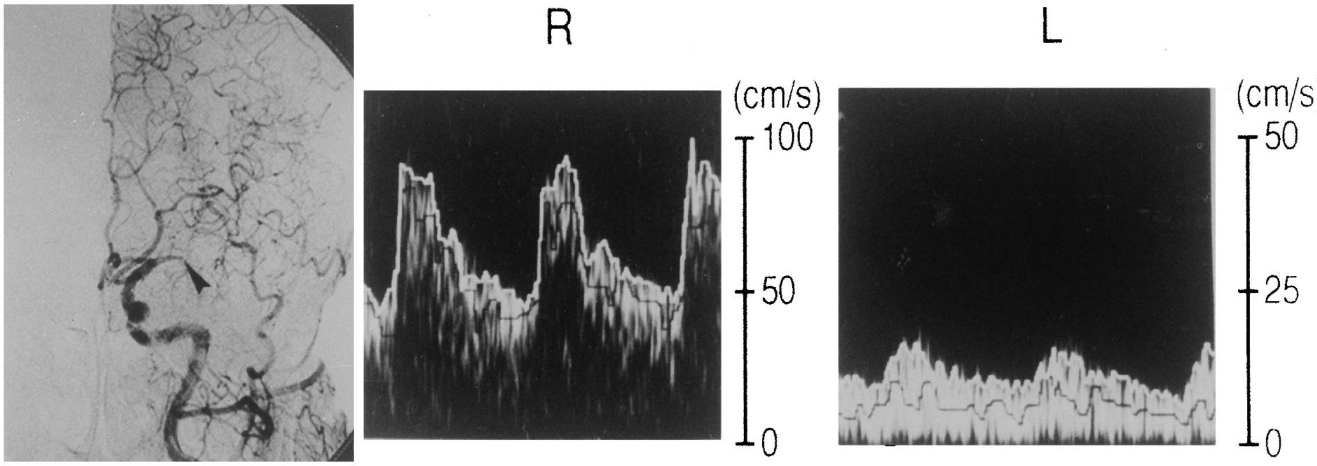
In the control group, the end-diastolic flow velocity was 40.4 ± 16.8 cm/s and the end-diastolic ratio was 1.28 ± 0.27. All values were less than 1.9 (mean value + 2 SD).

In the ICS and ICO groups, the end-diastolic flow velocity on the affected side and the end-diastolic ratio were 33.4 ± 9.0 cm/s and 1.35 ± 0.24, and 29.6 ± 10.2 cm/s and 1.67 ± 0.58, respectively. Therefore, these three groups could not be distinguished.

In the M1 group, however, the end-diastolic flow velocity (16.7 ± 4.29 cm/s) on the occluded side was significantly lower than that in the control, ICS, and ICO groups ($P < .01$). The end-diastolic ratio was 3.53 ± 1.47; all values were 1.9 or greater. Therefore, the M1 group could be easily distinguished from the other groups by the end-diastolic flow velocity and the end-diastolic ratio (≥1.9) ($P < .01$).

Discussion

Transcranial Doppler sonographic recordings of flow velocity have been reported to be useful in evaluating the intracranial hemodynamic alterations as determined from outside the skull (1). When measuring blood velocity, Doppler imaging presents several problems. Precise placement of the sample volume as well as angle correction are not possible when using the



A B

Fig 4. *A,* Angiogram of a patient with occlusion *(arrowhead)* of the M1 segment of the left middle cerebral artery.

B, Doppler waveforms show that the right middle cerebral artery end-diastolic flow velocity is 43.8 cm/s, the left middle cerebral artery end-diastolic flow velocity 12 cm/s, and the side-to-side ratio of the end-diastolic flow velocity (the end-diastolic ratio) is 3.65.

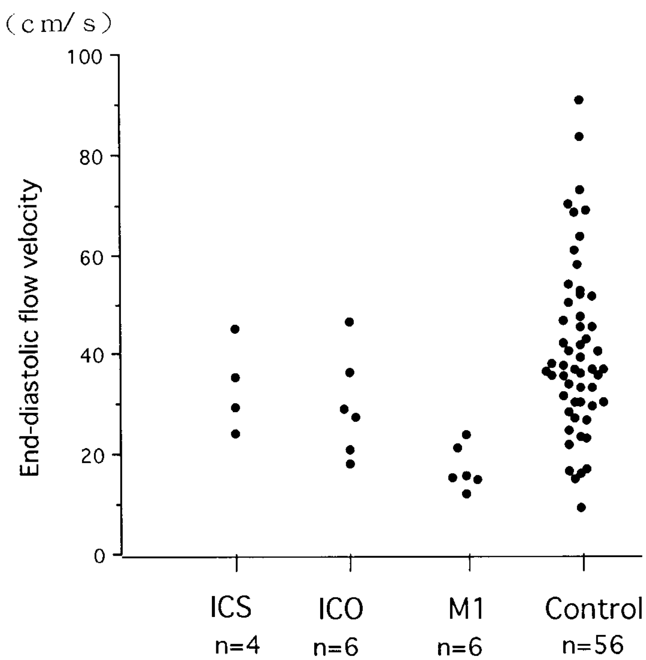


Fig 5. End-diastolic flow velocity in the ICS, ICO, M1, and control groups. In the M1 group, the end-diastolic flow velocity was significantly lower than that in the control, ICS, and ICO groups ($P < .01$). (The ICS group includes patients with unilateral stenosis [≥75%] of the extracranial internal carotid artery; the ICO group includes patients with unilateral occlusion of the extracranial internal carotid artery; and the M1 group includes patients with occlusion of the horizontal portion of the middle cerebral artery.)

transcranial Doppler sonographic technique, and therefore it cannot be used to measure absolute flow velocities. Using transcranial color-coded real-time sonography, however, it is possible to image the horizontal portion of the middle cerebral artery and to measure the absolute flow velocity (4). Transcranial color-coded real-time sonography is a more useful method for determining the accurate flow velocity of the middle cerebral artery than is transcranial Doppler sonography.

In a previous study using transcranial Doppler sonography, the diagnosis of occlusion of the horizontal portion of the middle cerebral artery was based on the absence or the severe reduction of detectable Doppler signals at a depth of insonation corresponding to the middle cerebral artery. At the same time, the flow velocity of the anterior cerebral artery increased because of collateral flow over leptomeningeal anastomoses (6, 7). However, these findings are not consistently present. In patients with chronic occlusion of the middle cerebral artery, normal-appearing transcranial Doppler signals can occasionally be detected. Thus, it is very difficult to attempt to diagnose occlusion of the M1 segment of the middle cerebral artery by using transcranial Doppler sonography.

In our study, the end-diastolic flow velocity in the M1 group was lower than that in the other groups. The end-diastolic flow velocity is considered to reflect the peripheral resistance. The peripheral resistance in the M1 group was higher than that in the other groups, probably because flow in the middle cerebral branch arteries reduced the peripheral resistance in subjects in the ICS, ICO, and control groups. Using only the end-diastolic flow velocity, we could

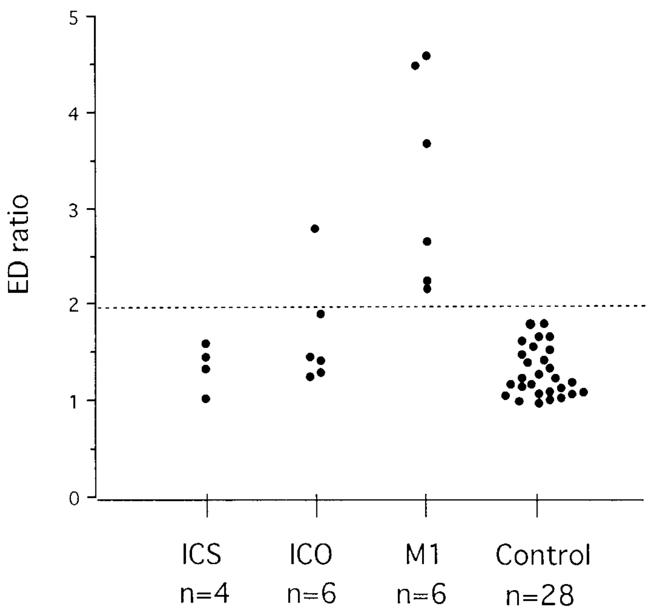


Fig 6. Side-to-side ratios of corrected end-diastolic velocity *(ED ratio)* in the ICS, ICO, M1, and control groups. The M1 group could be easily distinguished from the other groups by the end-diastolic ratio. The *dotted line* indicates the mean ± 2 SD value of the end-diastolic ratio (1.9) in the control group. (The ICS group includes patients with unilateral stenosis [≥75%] of the extracranial internal carotid artery; the ICO group includes patients with unilateral occlusion of the extracranial internal carotid artery; and the M1 group includes patients with occlusion of the horizontal portion of the middle cerebral artery).

not distinguish the M1 group from the control group, because the end-diastolic flow velocity in some of the patients in the control group was as low as that in the patients in the M1 group.

Because of this, we used the side-to-side ratio of the corrected end-diastolic ratio. The M1 group was easily distinguished from the other groups by an end-diastolic ratio of 1.9 or greater. It seems that marked side-to-side difference is a characteristic sonographic finding in patients with occlusion of the horizontal portion of the middle cerebral artery.

We could not distinguish the ICO group from the control group by the end-diastolic flow velocity. In five patients in the ICO group, angiographic examination disclosed occlusion of the extracranial internal carotid artery and rich collateral flow through the anterior communicating artery and the ophthalmic artery. Their end-diastolic ratio was 1.9 or less. The presence of a rich collateral flow may have led to an increase of the cerebral blood flow on the affected side and may have been responsible for the inability to distinguish the ICO group from the control group. But, in the ICO group, there was one patient with an end-diastolic ratio similar to that in the M1 group. We think his collateral flow was so poor that the end-diastolic ratio might have increased more than 1.9.

We conclude that the end-diastolic flow velocity and the end-diastolic ratio in the middle cerebral artery may help to identify the site of occlusion in the horizontal portion of the middle cerebral artery. Transcranial color-coded real-time sonography should be used routinely in addition to cervical carotid artery sonography for noninvasive vascular evaluation in patients who have had a stroke.

Acknowledgment

We express our cordial thanks to Akiko Furukawa for assistance.

References

1. Aaslid R, Markwalder TM, Nornes H. Noninvasive transcranial Doppler ultrasound recording of flow velocity in basal cerebral arteries. *J Neurosurg* 1982;57:769–774
2. Lindegaard KF, Bakke SJ, Grolimund P, et al. Assessment of intracranial hemodynamics in carotid artery disease by transcranial Doppler ultrasound. *J Neurosurg* 1985;63:890–898
3. Aaslid R, Huber P, Nornes H. Evaluation of cerebrovascular spasm with transcranial Doppler ultrasound. *J Neurosurg* 1984;60:37–41
4. Wechslder LR, Ropper AH, Kistler JP. Transcranial Doppler in cerebrovascular disease. *Stroke* 1986;17:905–912
5. Tsuchiya T, Yasaka M, Yamaguchi T, et al. Imaging of the basal cerebral arteries and measurement of blood velocity in adults by using transcranial real-time color flow Doppler sonography. *AJNR Am J Neuroradiol* 1991;12:497–502
6. Mattle H, Grolimund P, Huber P, et al. Transcranial Doppler sonographic findings in middle cerebral artery disease. *Arch Neurol* 1988;45:289–295
7. Kaps M, Damian MS, Teschendorf U, et al. Transcranial Doppler ultrasound findings in middle cerebral artery occlusion. *Stroke* 1990;21:532–537