Ultrasonic Evaluation of the Site of Carotid Axis Occlusion in Patients With Acute Cardioembolic Stroke

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Purpose: We performed the present study to determine whether the site of cardioembolic occlusion in the carotid axis could be identified by end-diastolic velocity measurements of the common carotid arteries.

Summary of Report: Using duplex carotid ultrasonography, we measured the flow velocity in the common carotid arteries and calculated the side-to-side ratios of the end-diastolic velocity (ED ratio; the end-diastolic velocity of the nonaffected side divided by that of the affected side) in 46 patients with acute cardioembolic stroke. The velocity on the faster side was divided by the slower velocity to obtain the normal values of ED ratio in 30 controls. The ED ratios were compared with the angiographic findings, in which unilateral intracranial internal carotid artery occlusion was present in 20 patients (IC group), occlusion of the horizontal segment of the middle cerebral artery was present in 16 patients (M1 group), and branch occlusion of the middle cerebral artery was present in 10 patients (M1 Br group). The ED ratios of the control group were <1.3; those of the M1 Br group generally <1.3; the IC group >4.0, except in two patients with severe cerebral edema; and those of the M1 group between 1.3 and 4.0. Therefore, the IC group was easily distinguished from the other groups by an ED ratio >4.0, with an accuracy of 97%, and the M1 group by an ED ratio ≥1.3 and <4.0, with an accuracy of 93%.

Conclusions: We found the ED ratio useful to identify internal carotid artery and middle cerebral artery occlusion in patients with cardioembolic stroke unless severe cerebral edema was present. (Stroke 1992;23:420-422)

KEY WORDS • cardioembolic stroke • carotid artery diseases • ultrasonics

In acute cardioembolic stroke involving the carotid axis, the embolus is likely to lodge at the top of the internal carotid artery (ICA), the trifurcation of the middle cerebral artery (MCA), or in a branch of the MCA. It has been reported that size of infarct, degree of cerebral edema, and prognosis vary according to the site of occlusion. Therefore, it is of considerable importance to diagnose correctly the site of occlusion in patients with acute cardioembolic stroke. However, it is often difficult to differentiate the site of occlusion from neurological findings. The site of occlusion can be diagnosed by angiography, but this method is not applicable in elderly patients and has considerable risk during the acute phase of stroke.

The purpose of this study was to evaluate whether determination of common carotid flow velocity by Doppler ultrasound could aid in the detection and localization of occlusion in the ICA or MCA. Our results demonstrate that, at least in acute cardioembolic stroke, this simple determination can distinguish among M1 segment MCA occlusion, intracranial ICA occlusion, and normal vessels.

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Subjects and Methods

We studied 46 patients with acute cardioembolic stroke. In all cases, duplex carotid ultrasonography and bilateral carotid angiography were performed on the same day, within 7 days of the ictus. The patients included 25 men and 21 women (mean±SD age 64.4±10.2 years). Twenty patients had unilateral intracranial ICA occlusion (IC group), 16 patients had occlusion of the horizontal portion of the MCA (M1 group), and 10 patients had branch occlusion of the MCA (M1 Br group). On the angiograms, the carotid bifurcations were normal in 40 of the 46 patients and showed minor lesions (<25% stenosis) in the remaining six patients. None had severely stenotic lesions at the bifurcation, which affect the Doppler waveform of the common carotid artery (CCA). The control group comprised 30 patients with normal bilateral carotid angiograms.

The equipment used was a commercially available Toshiba SSA 250 A apparatus (Toshiba Inc., Tokyo, Japan). The duplex probe consisted of a 7.5-MHz imaging transducer and a 7.5-MHz pulsed Doppler transducer.

Patients were examined in the supine position. The head was turned away from the side being scanned, the neck was extended, and then the transducer was placed on the neck using the anterior oblique approach. On longitudinal scans, the sample volume (5 mm) was set in the CCA, which was displayed as linearly as possible.
Particular care was taken to keep the incident angle between the CCA and the beam at <60 degrees. The pulse repetition frequency was 3.0 or 3.5 KHz, and the low-pass filter was set at 70 Hz.

First, we measured the end-diastolic velocities of the bilateral CCAs (Figure 1) as a mean value obtained from five consecutive cardiac cycles. Next, the values were corrected by dividing them by the cosine of the incident angle. Then, the side-to-side ratio of the corrected end-diastolic velocity (ED ratio) was calculated by dividing the velocity of the nonoccluded side by that of the occluded side in the cardioembolic stroke patients and by dividing the faster velocity by the slower one in the control group. This ratio was used to study the diagnostic accuracy of the site of occlusion.

**Results**

The end-diastolic flow velocities in the bilateral CCAs were measured in all 76 subjects. The typical waveforms and the ED ratios are shown in Figures 1 and 2 according to the groups. In the control group, the ED ratio was $1.1 \pm 0.08$ (mean $\pm$ SD), and all values were <1.3. Those in MBr group were mostly <1.3. Therefore, these two groups could not be distinguished. In the IC group, however, the values were >4.0 in 18 of 20 patients, and 2.0 and 3.3 in the remaining two cases. These two patients had evidence of severely increased intracranial pressure manifested by severe midline shift. Ten of these 18 cases showed an infinite value because the end-diastolic velocity of the affected side was undetectable (zero). In M1 group, the ED ratio ranged between 1.3 and 4.0 in all but one case. Therefore, the IC and M1 groups were easily distinguished from other groups by an ED ratio $\geq 4.0$, with an accuracy of 97%, and by an ED ratio $\geq 1.3$ and $<4.0$, with an accuracy of 93%, respectively.

**Figure 2.** Graph showing side-to-side ratios of corrected end-diastolic velocities (ED ratios) in the IC, M1, MBr, and control groups. IC, unilateral intracranial internal carotid artery occlusion; M1, occlusion of the horizontal segment of the middle cerebral artery (MCA); MBr, branch occlusion of the MCA.
Discussion

The end-diastolic velocities are considered to reflect the peripheral resistance. The peripheral resistance in the IC group was higher than that in the M1 group, probably because flow in the anterior cerebral artery (ACA) reduced the peripheral resistance in the latter. The peripheral resistance in the MB group was considered to be lower than that of the M1 group and as low as that of the controls.

We used ED ratios, the side-to-side ratios of the end-diastolic velocities, to eliminate variability among patients because there is a considerable variation in Doppler velocity waveforms among patients with anatomically and physiologically similar CCAs. 4

In general, collateral circulation is not so well developed in cardioembolic stroke as in atherothrombotic stroke because of the abruptness of occlusion. 1 In atherothrombotic stroke, peripheral resistance may have greater variability because of potentially greater collateral flow in such cases. Therefore, we speculate that the end-diastolic flow velocity in the CCA is more influenced by cardioembolic occlusion of the distal carotid axis than by atherothrombotic occlusion.

In cases with severe cerebral edema with marked midline shift, the ED ratio remained low. This was probably due to the increased peripheral resistance on the nonaffected side, because of the high intracranial pressure caused by the severe cerebral edema. Thus, we should note that the ED ratio is prone to be low in such patients.

In evaluating the distal occlusion of the IC or M1 segment, a measurement of flow velocity at the ICA may be more useful than one at the CCA. However, it is difficult to obtain accurate flow velocity, corrected by incident angle, not only because the bifurcation is located too high to detect the signals in some cases, but also because the origin of the ICA is often not linear but curved. Our results showed that the ED ratio obtained at the CCA seems to be sufficient to evaluate the site of occlusion in the carotid axis. Therefore, we think that measurement of the flow velocity of the ICA is unnecessary.

We conclude that the CCA ED ratio is useful for identifying the site of occlusion in the ICA and M1 segment in patients with acute cardioembolic stroke unless severe cerebral edema is present.

References

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