Clinical Correlates of Doppler/Ultrasound Errors in the Detection of Internal Carotid Artery Occlusion

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One recognized limitation of carotid Doppler/ultrasound is its accuracy in differentiating occlusion from near-total occlusion of the internal carotid artery, which is a crucial issue in management decisions. Clinical histories were reviewed in 58 patients with apparent occlusion of an internal carotid artery diagnosed by Doppler/ultrasound who also underwent angiography. False-positive results were detected in eight patients, for an overall accuracy of 86%. Among a group of 25 patients with acute cerebral or ocular events ipsilateral to an apparently occluded artery, false-positive results occurred in seven (accuracy of 72%). Among a group of 33 patients with asymptomatic or remotely symptomatic apparent occlusions, only one false-positive occurred, for an accuracy of 97%. This difference in accuracy between groups was significant. Thus, a Doppler/ultrasound diagnosis of occlusion was most inexact in those patients for whom the detection of continued patency was most likely to influence management. (Stroke 1989;20:612–615)

Ultrasound examination of the carotid arteries has become a standard procedure for evaluating patients with suspected carotid or cerebrovascular disease. With increasing technical sophistication and clinical experience, carotid Doppler/ultrasound has become a substitute for carotid angiography in the minds of many who use the former. However, comparative studies of the two have demonstrated consistent limitations to the accuracy of Doppler/ultrasound. One problematic area has been the differentiation of an occluded internal carotid artery from one that is severely stenotic.1–4 Definition of different levels of accuracy for detecting internal carotid artery occlusion in varying clinical circumstances would allow the clinician attempting to base management decisions on Doppler/ultrasound information to know when to accept that information with reasonable confidence and when to regard it with suspicion.

Subjects and Methods

This study was conducted through the Neurovascular Laboratory of the Stroke Unit, Neurology Service, Veterans Administration Medical Center, West Haven, Connecticut. Clinical circumstances surrounding carotid Doppler/ultrasound examination were reviewed in all patients with internal carotid artery occlusion identified by Doppler/ultrasound who also underwent carotid angiography. Fifty-eight such men were identified in 5½ years. During this time, 123 patients were diagnosed by ultrasound as having internal carotid artery occlusion. The 65 who did not undergo angiography included patients in whom no possibility of surgical intervention existed, patients unwilling to undergo angiography, and patients whose referring physician believed angiography was not indicated.

Carotid Doppler/ultrasound examinations were performed using a mechanically aligned and electronically switchable real-time B-mode two-dimensional imaging system with a 7.5-MHz transducer (High Stoy SP1200B, Lake Success, New York) and a 4-MHz continuous-wave Doppler transducer. Thus, the Doppler beam was aimed in alignment with the B-mode image, although this was not a typical duplex system with B-mode and pulsed Doppler signals emanating from the same transducer. Ultrasound examinations were performed by either of two trained and experienced neurologists. Occlusion of the internal carotid artery was identified contingent on the recognition of a Doppler signal without diastolic flow in the common carotid artery, failure to obtain any Doppler signal from the vicinity of an internal carotid artery lumen identifiable on B-mode imaging, and longitudinal move-
ment of the artery coinciding with the cardiac cycle (Figure 1). Others have confirmed these criteria for identifying occlusion of the internal carotid artery.4,5

Angiographic examinations included selective carotid injections in all but three patients, in whom digital intravenous angiography was performed.

Results

Angiography confirmed the Doppler/ultrasound diagnosis of occlusion in 50 of the 58 patients (86%).

Among eight angiographically patent arteries that appeared to be occluded by Doppler, the presence of near-total occlusion was demonstrated by angiography in seven. Figure 2 illustrates a typical example. In the single patient without disease, the apparently occluded artery turned deep and away from the bifurcation at nearly a right angle. This anomaly, coupled with an absent diastolic signal in both carotid systems presumably related to low cardiac output, was believed to explain the Doppler/ultrasound error.

Correlations between the circumstances leading to a Doppler/ultrasound examination and the accuracy of a diagnosis of carotid occlusion are indicated in Table 1. Twenty-five of the 58 patients were referred for Doppler/ultrasound during the course of hospital admissions for acute ischemic events attributable to the vascular territory of the artery found to be occluded by noninvasive testing. The remainder were similarly distributed among patients with no history of cerebrovascular disease, patients who had been admitted for acute symptoms that could not be attributed to the apparently occluded artery, and patients who had experienced remote symptoms attributable to the apparently occluded artery. Patients with acute ipsilateral events were significantly more likely to receive a false-positive Doppler/ultrasound diagnosis of occlusion than other patients (p=0.016, Fisher's exact test). This appeared to be largely represented in those patients with acute hemispheric ischemic events (p=0.006, Fisher's exact test), while the false-positive rate in patients with acute ipsilateral ocular events was not significantly different from that in patients with no acute ipsilateral symptoms. One of the patients in the ocular-event subgroup was the one in whom angiography revealed no significant carotid disease. A more stringent comparison of patients with acute ipsilateral symptoms to those with no ipsilateral symptoms at any time still yielded a significant increase in false-positive results among the former (p=0.021, Fisher's exact test).

Discussion

Although the surgical approach to management of internal carotid artery disease has been subjected to recent criticism, it is widely practiced.6,7 The greatest unanimity surrounds a tightly stenotic internal carotid artery associated with ipsilateral mild or transient events. Even in an asymptomatic patient, the discovery of a very tight stenosis often results in endarterectomy. These tightest of carotid lesions are regarded as unstable and dangerous. Once an artery has occluded completely, however, it is regarded as less of a risk.8 At any rate, it is no longer certain to be amenable to surgical intervention.

If carotid surgery is to be considered, the sure differentiation of tightly stenotic from occluded inter-
nal carotid arteries becomes crucial. If noninvasive methods are expected to make this differentiation, their limitation must be known. In our hands, carotid ultrasound has been far from perfect in this regard. The reasonably consistent nature of mistakes made suggests that this reflects technical limitations, rather than human error. While it might be suspected that the use of continuous-wave Doppler rather than one of the currently popular pulsed-Doppler duplex devices influenced the results, previous comparisons of both techniques with angiography have indicated similar results with the two Doppler techniques or superior performance for this specific purpose with continuous-wave Doppler.

This report differs from previous comparisons of carotid Doppler/ultrasound and angiography by placing the detection of a specific error in a specific clinical context. The overall false-positive rate of 14% is consistent with that reported by others, yet division of patients into those with and those without acute events appropriate to the apparently occluded artery reveals distinct and very discrepant levels of accuracy. The data indicate that the differentiation of a minimally patent from a totally occluded internal carotid artery by Doppler/ultrasound is least reliable in the clinical situation in which that differentiation is most likely to affect management—in the setting of acute ipsilateral symptoms. On the other hand, when carotid occlusion is an incidental finding on ultrasound, it is very likely to be correct. The current results are consistent with the 97% accuracy in Doppler/ultrasound diagnosis of carotid occlusion achieved in the longitudinal study of asymptomatic patients reported by Roederer et al., in contrast to the general experience in unselected patients reported by that group and others. Presumably, very tight stenosis is difficult to differentiate from occlusion, regardless of the clinical circumstances, and it is the increased likelihood of encountering very severe stenosis in the setting of acute ipsilateral symptoms that leads to the discrepancy.

Without acute ipsilateral symptoms, the likelihood that a decision for angiography will prove beneficial to the patient with apparent occlusion by Doppler/ultrasound is very low. Nevertheless, angiography will always be necessary when the diagno-

<table>
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<th>Clinical circumstances</th>
<th>n</th>
<th>No.</th>
<th>%</th>
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<td>8</td>
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<tr>
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<td>2</td>
<td>18</td>
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<tr>
<td>No acute ipsilateral event</td>
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<td>3</td>
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<tr>
<td>Remote ipsilateral event</td>
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<td>0</td>
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</table>

% of n.

**Figure 2. False-positive Doppler/ultrasound diagnosis of occluded internal carotid artery.**

A: Common carotid artery Doppler flow signal with no diastolic component. No internal carotid signal was detected. Horizontal calibrations represent 0.1 second; vertical calibrations represent 1 KHz. Real-time two-dimensional image was similar to that in Figure 1B. B: Contralateral common carotid artery Doppler flow signal with well-defined diastolic Doppler shift. C: Angiography (antero-lateral view) revealing near-occlusion of internal carotid artery just above bifurcation.
sis of internal carotid artery stenosis must be made with certainty. The current results also provide a useful context for judging studies that seek to define the clinical correlates of carotid occlusion. Some such studies already have relied, at least in part, on Doppler/ultrasound alone in classifying carotid lesions. It is important to recognize that a group of acutely symptomatic patients with internal carotid artery occlusion so defined probably will include a significant portion with still-patent arteries, whereas a group of asymptomatic patients probably will not.

Acknowledgments
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References

KEY WORDS • carotid artery diseases • ultrasonics
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