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Complementary Roles of a Noninvasive Test Battery and DSA in Evaluating Carotid Artery Disease

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Initial comparisons of the results of digital subtraction angiography (DSA) and a battery of tests for noninvasive diagnosis of carotid artery disease indicate the two techniques are complementary, rather than competitive. DSA provides important morphologic information at the carotid bifurcation and siphon, but the images are sometimes difficult to interpret with precision. Noninvasive testing gives discrete physiologic information related to hemodynamics, but the findings are less specific for the level of the lesion in the carotid/ophthalmic system. Noninvasive tests may be more useful than DSA for determining if a lesion is hemodynamically significant and whether advanced disease shows evidence of progression on sequential studies. The noninvasive tests are not definitive procedures, but are useful in selecting patients for a contrast study. They are the initial procedure of choice for the patient with asymptomatic bruit. Depending on the clinical situation and quality of the study, DSA can sometimes be a definitive procedure, but in some situations correlative noninvasive test results are necessary to assess whether the patient is a candidate for arteriography and/or surgery.

As the first neuroscience laboratory for noninvasive diagnosis of carotid disease, the Carotid Evaluation Laboratory (CEL) at Massachusetts General Hospital helped to define the prerequisites for appropriate noninvasive assessment. Our laboratory introduced the concept that a battery of tests was necessary to detect pathoanatomic and pathophysiologic changes at the common carotid bifurcation and pathophysiologic changes in distal circulatory beds [1–3]. We called the tests that examine the bifurcation itself *direct* tests and the tests that monitor distal circulatory beds *indirect* tests, stressing the importance of assessing not only different levels of the carotid/ophthalmic axis but also different functions at each level [3, 4]. Now we would like to introduce the concept of a nontraumatic battery, which would combine the noninvasive tests and digital subtraction angiography (DSA) in a complementary manner.

DSA has a unique place in the neurodiagnostic armamentarium. Whereas the noninvasive tests are always preliminary procedures and arteriography and computed tomography (CT) are essentially definitive tests, DSA is at times a preliminary test and at other times a definitive test. In certain instances information obtained by DSA must be augmented with physiologic data provided by noninvasive carotid evaluation, and in other situations the DSA data must be supplemented by the more precise information provided by cerebral arteriography.

We have performed noninvasive testing as a consultative service at Massachusetts General Hospital since 1974. DSA became operational in October 1981. Our experience over the past 8 years indicates that the noninvasive tests, when used in a battery, can provide discrete, graded information about the severity of bifurcation disease with about 90% accuracy. We use seven tests in our laboratory, although satisfactory assessment can be made with two or three. Our battery of tests is designed both to maximize our initial diagnostic capability and to follow the patients for evidence of progression. We use noninvasive studies to select patients for arteriography. Because the noninvasive tests are more sensitive to physiologic change distal to a bifurcation stenosis than is arteriography, our CEL battery has occasionally played a complementary role in our interpretation of the arteriographic findings; for example, in determining when advanced disease is hemodynamically significant. The precise role of the noninvasive tests relative to DSA has not yet been fully determined, but the initial data in our laboratory suggest that the CEL battery of tests and DSA are often important complementary procedures.

Records at Massachusetts General Hospital from June through August 1982, beginning about 9 months after the introduction of DSA, show that 200 investigative cerebral arteriographies, 189 DSA studies, and 321 CEL test series were performed during the 3 month period, which indicates that referring physicians still consider the noninvasive diagnostic tests useful. Sixty patients had both CEL and DSA studies, 23 had CEL and arteriography, 22 had DSA and arteriography, and 10 patients had all three tests. Because arteriography was done after DSA in the 10 patients who had all three studies, we can presume that there would be a relatively high rate of inconclusive results in these 10 cases; in fact, four of the DSA studies were inadequate. In two cases the internal carotid artery was interpreted as occluded on the basis of DSA, whereas the arteriogram showed it to be patent. In one case the DSA study was interpreted as showing moderate disease when in fact the atheromatous stenosis was quite severe. Of the CEL examinations done in these 10 patients, the noninvasive studies were interpreted as normal in one case in which a severe lesion was present. In a second case the noninvasive data were equivocally abnormal; a DSA study was recommended and was able to confirm a bifurcation stenosis. In this case DSA was a very important complement to the noninvasive battery of tests; in certain other situations the complementary role is reversed.

An example of the complementary role played by various methods for evaluating carotid disease is the case of a patient with an asymptomatic bruit whose digital study, as interpreted by three staff

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TABLE 1: **Recommended Initial Procedures in the Evaluation of the Stroke-Prone Patient**

Indications	Recommended Initial Procedures
Asymptomatic bruit	CEL > DSA
Multiple asymptomatic bruits	CEL > DSA or arteriography
Asymptomatic bruit, follow for progression	CEL
Equivocal TIA	CEL + DSA > CEL or DSA alone
Clear-cut TIA, single region	DSA > arteriography
Clear-cut TIAs, several regions	Arteriography > DSA
Clear-cut TIA, one territory, multiple bruits or multivessel disease by CEL	Arteriography > DSA
Known disease requiring monitoring for progression	CEL

Note.—CEL = Carotid Evaluation Laboratory noninvasive test battery; DSA = digital subtraction angiography; TIA(s) = transient ischemic attack(s); > = followed by.

neuroradiologists, suggested a residual lumen of less than 1 mm. Angiography showed a residual lumen of about 2–3 mm. It could not be determined from the arteriogram whether there was distal hemodynamic change, so noninvasive studies were ordered. The results of these tests were consistent with the moderate atheromatous disease at the bifurcation seen on arteriography, producing evidence of only early distal hemodynamic change. The patient was placed on aspirin therapy and has been monitored for 8 months without incident or change in the carotid lesion. Our experience over the past 8 years indicates that the noninvasive tests are more sensitive than arteriography in demonstrating distal hemodynamic change and that they are also a reliable method of following patients for evidence of disease progression. On the basis of longitudinal CEL studies, we have suggested that asymptomatic patients with no evidence of or only early distal hemodynamic change can safely be monitored (usually on aspirin) for evidence of progression [5, 6]. A patient is unlikely to encounter serious difficulties until distal hemodynamic change becomes very severe. These observations do not necessarily indicate that a subsequent stroke will be on the basis of a low flow, but rather that the tight carotid lesion is an appropriate substratum for both low flow and embolic stroke events.

Over the past year our experience has suggested the following scheme for combining noninvasive testing, DSA, and cerebral arteriography in evaluation of stroke-prone patients—namely, those with asymptomatic bruits or a history of transient ischemic attacks (TIAs) (table 1). Patients with asymptomatic bruits are best seen in the CEL. Patients who have clear-cut TIAs in one vascular region and evidence on bedside or noninvasive testing of only single-vessel disease are candidates for DSA. If the DSA in these patients is normal, we believe that endarterectomy can be done on the basis of the DSA study. In patients who have clear-cut TIAs in several vascular regions or TIAs in one territory but evidence on bedside or noninvasive testing of multivessel disease, arteriography is recommended. In summary, a high-quality DSA study can be a definitive test when the patient has TIAs in one cerebrovascular region without evidence of disease in other anterior or posterior circulatory regions. Such evidence might consist of bilateral bruits, bruits in the orbits as well as the carotids, CT demonstration of an infarct in another vascular territory, or signs or symptoms of multifocal brain lesions. In addition to the results of noninvasive testing, the DSA study is a preliminary test when it is of poor quality or fails to show the full extent of the possible vascular involvement that may have been suggested by bedside or noninvasive testing.

Current concepts in cerebrovascular disease emphasize the importance of assessing hemodynamic change in the management of patients with structural lesions. Intravenous DSA is not useful at this time for demonstrating physiology, especially at the variety of levels of the vascular axis permitted by noninvasive studies; however, DSA and noninvasive carotid evaluation together complement each other and comprise an important nontraumatic battery of tests for evaluation of the stroke-prone patient.

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