The Influence of Noninvasive Tests on the Selection of Patients for Carotid Angiography

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SUMMARY To assess the impact of noninvasive testing of the carotid vessels upon patient management, we analyzed the angiographic findings in 494 patients studied between 1978 and 1983 for suspected extracranial cerebrovascular disease. This longitudinal study revealed two changes in the pattern of angiographic results after introduction of noninvasive testing in the final months of 1979. The proportion of examinations that revealed less than 49% stenosis decreased significantly from 49% in 1978 to 19% in 1983 (p < 0.001). During the same time, the proportion of examinations identifying 75-99% stenosis increased from 20% to 62% (p < 0.001). The referring physicians and their patient population appeared to remain unchanged over these years. We believe the decline in patients with little or no disease is a consequence of better patient selection due to screening with noninvasive tests. We credit the increase in patients with 75-99% disease to additional patients identified by noninvasive tests. This study also points out that the role of noninvasive studies will necessarily be restricted because of inherent limitations in the techniques and that clinical judgement will remain the final arbiter with regard to the management of patients at risk for stroke.

NONINVASIVE tests for evaluating carotid atherosclerosis have proliferated in number and sophistication in the past decade, and studies have shown they can be quite accurate in detecting stenosis of greater than 50% of the lumen.1-10 Diagnostic capability does not assure clinical importance, however. Once the ability of a test has been determined, its role in the diagnostic process must be scrutinized.

While cerebral angiography remains the definitive diagnostic method for evaluating patients for atherosclerotic vascular disease, it is an invasive procedure that may cause permanent neurologic injury.11-14 Since noninvasive vascular tests are used in screening patients before performing carotid angiography, we looked at our angiographic population from 1978 to 1983. Our goal was to determine whether introduction of our noninvasive vascular laboratory in late 1979 actually changed the clinical profile of patients coming to carotid angiography.

Materials and Methods

Between January 1978 and December 1983, the staff of the New England Deaconess Hospital referred 494 patients with suspected extracranial cerebrovascular disease for selective carotid angiography. Results of these examinations formed the basis for our study. Patients referred by physicians whose primary affiliation was other than the Deaconess were excluded from this analysis.

Angiography was performed using standard Sel-dinger technique, and at least two views (1.6 X magnification) of the carotid bifurcation were routinely obtained. The percentage of stenosis was calculated by measuring the narrowest diameter on any view and dividing this by the maximal diameter of the vessel distal to the lesion. Patients were classified as showing mild stenosis (0-49%), moderate stenosis (50-74%), severe stenosis (75-99%) or occlusion (100% block).

In those patients having definite lateralizing symptoms, the category was based on measurement of the vessel of clinical concern; otherwise, the category was based on measurement of the vessel with the greatest stenosis.

The referring physicians remained constant during the study and, through conferences and normal clinical interaction, were exposed to the working of the noninvasive laboratory after its opening in late 1979. Clinical indications leading to angiography included transient ischemic attack, completed stroke, asymptomatic bruit, nonlocalizing neurologic symptoms and preoperative assessment. There were no changes in the angiography staff during 1978-1983.

For the first two years, few patients selected for angiography underwent prior noninvasive testing. The noninvasive vascular laboratory was established in the latter part of 1979, and from 1980 onward, an increasingly larger percentage of patients referred for angiography had first been studied noninvasively. During the last two years of the study, all patients scheduled for carotid angiography had prior noninvasive studies.

Initially, the noninvasive work-up consisted of oculoplethysmography, periorbital directional Doppler sonography, and direct Doppler imaging of the carotid bifurcation using a continuous wave Doppler system. Our techniques and results using this battery of tests have been described.15-16 Several different duplex systems combining pulsed Doppler and high resolution ultrasound imaging were tested from 1980 onward. In August 1981, a duplex system employing both 7.5 and 10-MHz transducer frequencies was incorporated into the routine. Spectral bruit analysis was added in 1982.17-18

The number of patients in each category were tallied for each year of the study. The chi-square test was used to determine the statistical significance of the differences observed among the categories. A probability of less than 0.05 as determined by chi-square (X²) analysis was considered to be statistically significant. The
X² test is performed to determine whether the observed changes in the proportion of cases in each disease category are statistically meaningful and not due to chance alone. The larger the X², the less likely the observed changes happened by chance. The strength of this likelihood is reflected in the p value. For example, when p is less than .001, the chance is less than one in a thousand that we are in error when we reject the null hypothesis that this is a random finding.

**Results**

Table 1 shows the number of patients examined each year noninvasively. Table 2 and figure 1 present the total number of angiographic studies performed each year and the proportion contributed by each category of disease. Overall, the total number of examinations grew almost every year, but several changes occurred in the proportion of examinations in each category.

The percentage of examinations showing mild stenosis (0–49%) was stable at 49% (27/55 and 37/76) of the total group during the first two years. In 1980, however, the proportion showing 0–49% stenosis began to diminish significantly, comprising 39% (32/83) in 1980, 36% (34/95) in 1981, 16% (13/79) in 1982 and 19% (20/106) in 1983.

The greatest increase in positive studies (50–100% disease) occurred not in those showing moderate carotid stenosis (50–74%) or total occlusion (100%) but rather in those with severe stenosis (75–99%). The percentage of examinations revealing 75–99% stenosis increased significantly from 20% (11/55) in 1978 to 62% (66/106) in 1983.

The percentage of examinations showing moderate stenosis (50–74%) remained essentially unchanged overall during the entire period although there were fluctuations from year to year. In the category of total occlusion, the percentage of patients declined over the six years.

**Discussion**

This six-year assessment demonstrates two significant changes in the amount of disease found by angiography in patients with suspected extracranial carotid atherosclerotic disease. While the total number of angiographic studies each year increased steadily, the percentage of examinations that showed no significant stenosis declined significantly. We believe this decline was a consequence of better patient selection due to the use of noninvasive tests to screen out patients with minimal or no disease. Over the same years, the number of studies showing 75–99% disease increased significantly. We believe this increase was almost exclusively due to patients identified by noninvasive testing.

Review of our angiographic study results over the six-year period immediately suggest division into three phases that further support this interpretation. In 1978 and 1979, only slightly more than half of all patients (51%) were found to have stenosis of 50% or greater. This corresponds to the period prior to the introduction of noninvasive testing. The following two years appear to represent a transition period during which the laboratory established itself as a clinically useful entity in the minds of referring clinicians. The impact of noninvasive testing upon patient selection for angiography appears to have stabilized during the last two years (1982 and 1983).

If the proportion of angiographic results found in 1978 and 1979 had remained constant and the same growth in total number of angiograms had occurred, an increase to 52 patients with 0–49% stenosis would have been expected in 1983 rather than the decrease to 20 actually seen. In contrast, 21 patients with 75–99% stenosis would have been expected in 1983 rather than the 66 actually found. Thus, only 32% of the 1983 volume in the severe category can be explained by the increased volume of total patient referrals.

It seems reasonable to expect that a certain percent-

<table>
<thead>
<tr>
<th>Year</th>
<th>Total pts</th>
<th>0–49%</th>
<th>50–74%</th>
<th>75–99%</th>
<th>100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1978</td>
<td>55</td>
<td>27 (49%)</td>
<td>6 (11%)</td>
<td>11 (20%)</td>
<td>11 (20%)</td>
</tr>
<tr>
<td>1979</td>
<td>76</td>
<td>37 (49%)</td>
<td>13 (17%)</td>
<td>15 (20%)</td>
<td>11 (14%)</td>
</tr>
<tr>
<td>1980</td>
<td>83</td>
<td>32 (39%)</td>
<td>8 (10%)</td>
<td>31 (37%)</td>
<td>12 (14%)</td>
</tr>
<tr>
<td>1981</td>
<td>95</td>
<td>34 (36%)</td>
<td>13 (14%)</td>
<td>39 (41%)</td>
<td>9 (9%)</td>
</tr>
<tr>
<td>1982</td>
<td>79</td>
<td>13 (16%)</td>
<td>8 (10%)</td>
<td>49 (62%)</td>
<td>9 (11%)</td>
</tr>
<tr>
<td>1983</td>
<td>106</td>
<td>20 (19%)</td>
<td>14 (13%) 66 (62%)</td>
<td>6 (6%)</td>
<td></td>
</tr>
</tbody>
</table>

The chi-square (X²) for the change in total number of patients over time was calculated without reference to any other column. The chi-squares for changes in columns denoting percentage of stenosis were calculated with reference to the total number of studies each year to correct for the confounding effect of the increasing total number of patients over time. NS = not significant at the p < .05 level.
Figure 1. The number of angiograms in each disease category over the six-year study period. Patients with mild stenoses are represented below the baseline; those with significant disease are represented above. The graph reveals that the number of studies failing to show significant disease decreased over time and that the number of positive angiographic results increased progressively. This increase occurs almost exclusively in the 75-99% disease category.

age of angiographic studies done in the future will continue to fail to reveal significant disease of the extracranial carotid system. Noninvasive studies even in the best of hands cannot expect to have an accuracy much better than 90% in detecting significant carotid stenosis. Thus, clinicians may well elect to proceed to angiography with highly symptomatic patients even when the noninvasive tests are normal. Also, although uncommon in our population, stenosis of the middle cerebral artery is impossible to detect noninvasively.

In some instances the different noninvasive tests may be in conflict, causing uncertainty in diagnosis. Certain physicians may in any instance never have confidence in noninvasive testing and invariably insist on the definitive answer supplied by angiography, accepting the risks inherent in this procedure rather than relying on more abstract methods.

Not all vessels classified as having no significant stenosis were entirely normal. Some of these studies demonstrated mild atheromatous disease at the carotid bifurcation, which is possible to identify noninvasively using a combination of real-time B-scan imaging and pulse Doppler techniques. In clearly symptomatic patients, angiography may still be required to look for possible ulceration. We recognize the great interest and controversy with relation to the identification of ulceration within atherosclerotic plaque by ultrasound. While we have occasionally identified plaque ulceration noninvasively, we cannot routinely confirm or exclude the possibility of ulceration within any given lesion. Therefore, we report the presence of ulceration only in the occasional instance when the finding is unequivocal. This entire issue is made more confusing by growing awareness of the limitations of angiography in accurately detecting ulceration, making comparisons with B-scan findings less reliable.

Normally, patients with totally occluded internal carotid arteries are not candidates for definitive surgical intervention and thus should be spared the risks of angiography. While the proportion of total occlusions decreased from 20% in 1978 to 6% in 1983, the diagnosis of complete occlusion by noninvasive means should not necessarily preclude angiography. As we and others have reported, it is impossible to distinguish between total and pseudo occlusion of the carotid artery noninvasively. Blood velocity distal to a high-grade stenosis may decrease to such an extent as to fall below a level that can be detected by standard Doppler and B-scan techniques. Symptomatic patients shown to have pseudo-occlusion may well benefit from carotid endarterectomy and are thus considered candidates for immediate carotid angiography. Noninvasive tests are helpful in this setting in that we specifically alter our angiographic technique in order to increase the possibility of detecting any residual patency of the internal carotid artery.

Thus, while noninvasive studies may indeed have significant impact upon the decision as to whether to proceed to carotid angiography, the final decision must still be based on clinical judgment. In our hands the clearest benefit growing out of the introduction of noninvasive testing is to spare patients without significant extracranial carotid disease the risks of angiography.

It is difficult in a retrospective study such as this to control for all variables. Multiple explanations for our findings could be offered, including more astute clinical triage, a shift in patient population to one containing a higher percentage of patients with disease, or some critical factor totally unrecognized by the investigators. Ideally, there should be a control population identical in all respects but for the intervention of the noninvasive studies. This was not possible in our clinical setting. We believe we have minimized the likelihood of such variables by limiting our data base to patients referred by the general staff at our hospital. Almost all patients sent for angiography within our institution are referred by a small group of neurologists and surgeons, and there has been no change in the composition of this group during this period. The population referred to these physicians has not altered for many years.

Our results may not describe precisely the response
that will occur in other hospitals. The trends are sufficiently strong, however, to believe that with some variations they will be duplicated elsewhere. For those who are considering addition of noninvasive imaging to their diagnostic routine, this study suggests that they can expect definite rewards in terms of patients spared unnecessary angiography. Similarly, the study indicates that utilization of noninvasive testing can result in a steady increase in the number and proportion of patients at risk of stroke who will be found to have severe disease at angiography.

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