Value of the Non-Invasive Cerebrovascular Laboratory in Diagnosis of Extracranial Carotid Artery Disease

An Analysis of 159 Studies in 157 Patients

ARNOLD GORAN, M.D., AND GAIL MOORE, R.N.

SUMMARY Non-invasive vascular testing has proven to be an effective means of identifying patients with significant extracranial carotid artery disease. Such tests can yield valuable physiologic data in patients with TIAs and can identify patients with soft signs who may have significant carotid artery disease and who may be candidates for angiography. It may be an effective means of reducing the number of negative carotid angiograms.

STROKE is one of the leading causes of death and disability in the United States. It is, therefore, natural that the detection and prophylactic treatment of the persons at risk should continue to preoccupy clinicians.

Although angiography remains the single most important diagnostic modality in the evaluation of the patient with cerebrovascular insufficiency, the need exists for a less hazardous technique for screening. In the past 10 years, numerous reports have been made on the use of non-invasive techniques in the diagnosis of extracranial carotid disease.1-8

The proliferation of techniques has led to the development of non-invasive vascular laboratories (NIVL) in which a battery of tests are employed. Laboratories differ in the number and type of tests offered but, in general, all techniques are non-invasive. The purpose of these tests is to screen patients suspected of cerebral vascular disease, particularly carotid artery disease, in order to judge their need for cerebral angiography as angiography, even in its current refined state, still has a small element of risk. The value of the tests rests on the fact that the patient is not at risk and the examination can be repeated without danger.7

In many patients need for angiography is obvious without preliminary testing.8 Even in this group of patients valuable physiological data often can be obtained. The large group of patients with less specific cerebral symptoms, who may have significant carotid disease, often can be identified.

The development of neurovascular screening tests can be traced to the adaptation of the Doppler blood flow apparatus for the study of the cervical carotid artery. In 1954 Miyazaki and Kato9 first reported on the use of the Doppler ultrasonic directional flow meter in the study of the carotid artery. Goldberg10 recommended studying the supraorbital pulse with the Doppler to assess the degree of carotid collateral flow. Since then many authors have demonstrated the value of the Doppler in the study of carotid artery disease.1-8

Gee et al.17 described use of ocular pneumoplethysmography to measure retinal artery pressure in the study of carotid artery disease. The addition of carotid bruit audiofrequency analysis, as described by Boucher-Hayes et al.,18 has further extended the objective evaluation of carotid bruits.

The report of Spencer et al.19 in 1974 on cervical carotid imaging with a continuous-wave Doppler flow meter was a milestone in the study of the cervical carotid arteries by non-invasive means. Although reports continue to be received on this method, it is not generally used in community hospitals, but within the past year this equipment (DOPSCAN) has become commercially available.

Method and Material

The tests are modeled after those used at the Massachusetts General Hospital (MGH).20 We are particularly indebted to Jeffrey Rains, M.D.21 for his guidance and assistance in the establishment of our laboratory.

All tests were performed by the same R.N./techni-
cian and all tests were interpreted or reviewed by the
same physician.
A total of 159 examinations in 157 patients were
performed. The nurse/technician records a brief
neurological history. The examination includes:
1) Blood pressures in both arms.
2) Recording of carotid, facial, supraorbital and
temporal pulses.
3) Doppler examination of the carotid and
facial arteries.
4) Pneumoplethysmography of both eyes.
5) Carotid phonoangiograms bilaterally.19
6) Doppler ophthalmic test bilaterally.
7) Auscultation of carotid arteries.
The completed tests are reviewed by the physician
and the complete examination requires approximately
30 minutes.
Most of the patients tested were in the 40–80 year
age range (table 1) with equal distribution of males
and females. The majority of the patients was referred
by a neurologist or neurosurgeon and the next most
important source of referral was internists. Ap-
proximately 40% of those tested were out-patients.

Findings
To determine the clinical reliability of the testing
battery we studied in greater detail patients who had
angiography. Twenty-seven patients in the group had
angiography (17%).
Eighty-two percent of patients had angiographic
confirmation of the non-invasive vascular laboratory
findings.
In 11% (3 patients) the findings gave false positives
and in 7% (2 patients) there were false negatives.
Analysis of the false negative information is par-
ticularly helpful in understanding the limitations of
the non-invasive vascular studies (table 2). One patient
had a small carotid bifurcation atheroma which
resulted in stenosis of less than 25% of the vessel
lumen; the other patient had TIAs due to a small ul-
cerated plaque.

<table>
<thead>
<tr>
<th>Table 1 Age of Patients</th>
</tr>
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<tbody>
<tr>
<td>30–39 years</td>
</tr>
<tr>
<td>40–49 years</td>
</tr>
<tr>
<td>50–59 years</td>
</tr>
<tr>
<td>60–69 years</td>
</tr>
<tr>
<td>70–79 years</td>
</tr>
<tr>
<td>80–89 years</td>
</tr>
<tr>
<td>90–99 years</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>Table 2 False Negatives in Patients with Positive Angiograms and Negative NIVS</th>
</tr>
</thead>
<tbody>
<tr>
<td>#017 1) Small atheroma (2 mm × 3 mm) and less than 25% vessel stenosis.</td>
</tr>
<tr>
<td>#025 2) Small plaque with ulceration.</td>
</tr>
</tbody>
</table>

Stenosing lesions of less than 50%–75% may not
be detected by non-invasive diagnostic testing and ul-
cerating lesions will not be detected unless they are
associated with a significant stenotic lesion. Angiography may not always detect such lesions
either.
A more difficult problem is to reconcile the false
positives which occurred in 3 patients (11%) (table 3).
A false positive occurs when NIVS indicate a carotid
lesion and the carotid angiogram is normal. The most
reasonable explanation for false positive results is the
existence of a hemodynamic abnormality without
evidence of a structural lesion.
In the group in which there was agreement of non-
invasive vascular studies (NIVS) and angiographic
findings, 2 distinct subgroups emerged. One had a
diagnosis of carotid artery disease—made by both
NIVS and angiography (positive/positive, table 4)
and in the other the NIVS concluded there was no
arterial abnormality and this was confirmed by the
angiogram (negative/negative, table 5).
There are 2 answers to the question why the patients
with negative NIVS were subjected to arteriography.
First, the validity of the methods used is not yet es-
tablished. Second, the patients came from a variety of
referral sources, and it is the individual clinician who
must request angiography. As clinicians gain con-
fidence in the NIVL, fewer angiograms may be
ordered when the NIVS are negative. The total
number of angiograms may increase as patients with
"soft signs" are identified as having carotid artery dis-
ease.
In the negative/negative group the diagnoses ul-
timately found were emboli, small vessel occlusion,
seizure disorder, cataract and hysteria (table 6).
In the group of patients who had a carotid artery le-
sion diagnosed by NIVS and angiography (posi-
tive/positive) a particular profile emerged (table 7).
All patients were between 45 and 69 years of age
with the majority between 60 and 69 years.
Among the patients there was an unusually high in-
cidence of smoking. Only 38% of the patients in the
TABLE 4 Positive NIVS, Positive Angiograms and Patient Profile

<table>
<thead>
<tr>
<th>Age</th>
<th>Race/Sex</th>
<th>Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>67</td>
<td>white/male</td>
<td>ASHD; peripheral vascular disease; lower extremities, admitted for angina, triglycoerides increased, previous smoker, vertigo, syncope.</td>
</tr>
<tr>
<td>65</td>
<td>white/female</td>
<td>Amaurosis fugax, slightly elevated cholesterol; endarterectomy, smoker, hypertension, hyperlipidemia, headache, syncope, vertigo.</td>
</tr>
<tr>
<td>57</td>
<td>white/female</td>
<td>Left sided weakness, non-smoker, headache, hypertension, syncope.</td>
</tr>
<tr>
<td>47</td>
<td>white/female</td>
<td>Right sided weakness and numbness, aphasia, had endarterectomy; smoker, otoe, headache, vertigo.</td>
</tr>
<tr>
<td>68</td>
<td>white/female</td>
<td>Right endarterectomy, also right subclavian disease, previous smoker, hypertension, syncope, amaurosis fugax.</td>
</tr>
<tr>
<td>65</td>
<td>black/male</td>
<td>Admitted weakness RUE, smoker, hypertension, syncope.</td>
</tr>
<tr>
<td>64</td>
<td>white/female</td>
<td>Admitted right sided weakness &amp; speech disturbance, smoker, hypertension, syncope.</td>
</tr>
<tr>
<td>56</td>
<td>white/male</td>
<td>Admitted right TIA, atrial fibrillations, smoker, hypertension.</td>
</tr>
<tr>
<td>65</td>
<td>white/male</td>
<td>Admitted left sided weakness, smoker, hypertension, headache, syncope, TIA, speech disturbance.</td>
</tr>
<tr>
<td>67</td>
<td>white/male</td>
<td>Admitted for severe peripheral vascular disease, left TIA, amaurosis fugax, smoker, diabetic, headache, vertigo.</td>
</tr>
<tr>
<td>60</td>
<td>white/female</td>
<td>Admitted right paresthesias and dysphagia, smoker, hypertension, TIA, vertigo, syncope.</td>
</tr>
</tbody>
</table>

RUE = right upper extremity. Admitted = admitted to hospital.

entire series smoked, but 91% of the patients with positive NIVS and angiogram smoked. Hypertension was found in 73%. Many of the patients described some form of vertigo, syncope or light-headedness. Serious diabetes mellitus was an uncommon finding. All but one patient were Caucasian and there was no preponderance of males or females.

Many patients with symptoms of cerebrovascular insufficiency were investigated in the NIVL for a variety of reasons but from the outset were never candidates for angiography or surgery. The justification for their NIVL testing is the need to establish a diagnosis. This is important if inappropriate and unnecessary treatment is to be avoided.

Conclusions

1. The use of the non-invasive vascular studies is an effective means of screening patients for carotid angiography.

2. Non-invasive vascular tests are not a substitute for angiography. They give physiologic (hemodynamic) data while angiography, a form of imaging, yields morphologic and anatomic data.

3. Non-invasive vascular studies cannot detect stenosing carotid lesions of less than 50%, nor can they detect small but significant ulcerating lesions.

4. Non-invasive vascular studies are valuable in those patients who cannot have angiography.

TABLE 5 Negative NIVS, Negative Angiogram

<table>
<thead>
<tr>
<th>Chief Complaint</th>
<th>Diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>#047 Blurred vision</td>
<td>Cataract</td>
</tr>
<tr>
<td>#075 Confusion, aphasia</td>
<td>Small vessel occlusion; brain scan consistent with cerebral infarct</td>
</tr>
<tr>
<td>#116 Left hemiparesis, slurred speech</td>
<td>Small vessel occlusion; EEG diffusely abnormal</td>
</tr>
<tr>
<td>#125 Headache, blurred vision</td>
<td>Hypersia; CT negative</td>
</tr>
<tr>
<td>#135 Slurred speech, weakness LUE</td>
<td>Recovered, ? embolus</td>
</tr>
<tr>
<td>#140 Left hemiparesis</td>
<td>Low pressure hydrocephalus (CT); EEG abnormal</td>
</tr>
<tr>
<td>#144 Transient RUE weakness</td>
<td>Recovered, ? embolus; CT &amp; EEG negative</td>
</tr>
<tr>
<td>#150 TIA, slurred speech, left sided weakness</td>
<td>Recovered; brain scan &amp; EEG negative</td>
</tr>
<tr>
<td>#151 Seizures</td>
<td>Seizure disorder</td>
</tr>
<tr>
<td>#154 ?? left sided weakness</td>
<td>Hypersia; negative EEG &amp; brain scan</td>
</tr>
<tr>
<td>#159 Seizures, TIA</td>
<td>Seizure disorder, ?? embolus</td>
</tr>
</tbody>
</table>

LUE = left upper extremity. RUE = right upper extremity.

TABLE 6 Summary of Patients with Negative NIVS-Negative Angiograms

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cataract</td>
<td>1</td>
</tr>
<tr>
<td>Small vessel occlusion</td>
<td>3</td>
</tr>
<tr>
<td>Seizures</td>
<td>2</td>
</tr>
<tr>
<td>Hypersia</td>
<td>2</td>
</tr>
<tr>
<td>Probable emboli</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>11</td>
</tr>
</tbody>
</table>

TABLE 7 Positive/Positive Profiles. Patients with Positive NIVS and Positive Angiograms

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smokers</td>
<td>91%</td>
</tr>
<tr>
<td>Vertigo/Syncope</td>
<td>82%</td>
</tr>
<tr>
<td>Hypertension</td>
<td>73%</td>
</tr>
<tr>
<td>TIA</td>
<td>73%</td>
</tr>
<tr>
<td>Amaurosis fugax</td>
<td>27%</td>
</tr>
<tr>
<td>Peripheral vascular disease</td>
<td>27%</td>
</tr>
<tr>
<td>Speech disturbance</td>
<td>27%</td>
</tr>
<tr>
<td>Elevated serum lipid</td>
<td>18%</td>
</tr>
<tr>
<td>ASHD</td>
<td>18%</td>
</tr>
<tr>
<td>Diabetes</td>
<td>.09%</td>
</tr>
</tbody>
</table>

2. Non-invasive vascular tests are not a substitute for angiography. They give physiologic (hemodynamic) data while angiography, a form of imaging, yields morphologic and anatomic data.

3. Non-invasive vascular studies cannot detect stenosing carotid lesions of less than 50%, nor can they detect small but significant ulcerating lesions.

4. Non-invasive vascular studies are valuable in those patients who cannot have angiography.
Acknowledgment

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