The Detection of Carotid Artery Obstruction: A Correlation With Arteriography

BY GARY WISE, M.D.;* E. C. BROCKENBROUGH, M.D.;† RAYMOND MARTY, M.D.;‡ AND ROBERT GRIEP, M.D.*

Abstract:
The Detection of Carotid Artery Obstruction: A Correlation With Arteriography

Intravenous radioisotope arteriography, carotid compression ocular plethysmography, and supraorbital Doppler studies were more accurate than ophthalmodynamometry in the detection of the presence or absence of carotid artery obstruction in 35 patients. Abnormal results were present in patients with carotid obstruction who did not have a carotid bruit.

The isotope method provides information about relative blood flow through the two carotid arteries. Ocular plethysmography and supraorbital Doppler studies provide information about collateral circulatory pathways in patients with carotid obstruction.

Currently, they are most useful clinically in patients who are erroneously thought to have only intracranial vascular disease since abnormal results suggest an extracranial carotid lesion. These methods will not reveal abnormalities in patients with small, ulcerated carotid plaques which are a source of embolic material but which are not decreasing carotid blood pressure and flow.

ADDITIONAL KEY WORDS
extracranial arterial occlusion
ocular plethysmography
Doppler technique
intravenous radioisotope arteriography
ophthalmodynamometry

Atherosclerotic disease in the extracranial portion of the carotid artery is a frequent yet potentially preventable cause of stroke.1 Cerebral symptoms and infarction appear to be associated with severe stenosis or complete obstruction of the carotid artery, with a resultant decrease in carotid blood flow, and with emboli from ulcerated carotid plaques, even when carotid blood flow is not diminished.2

Recognition of carotid disorders before cerebral infarction occurs is sometimes difficult. Transient ischemic attacks in the distribution of the carotid and middle cerebral arteries suggest the possibility of extracranial carotid disease. A bruit over the carotid artery suggests carotid obstruction, increased carotid flow, or turbulence due to either tortuosity or roughening of the vessel by an atherosclerotic plaque.3

A difference in ophthalmodynamometric pressures suggests carotid or ophthalmic artery obstruction.

Since radiopaque contrast arteriography, the only definitive technique for the detection of carotid lesions, has a significant morbidity, it is desirable to develop diagnostic methods which are safe, easily performed, and relatively inexpensive, and which cause little patient discomfort. Serial studies with these methods may be of value in determining the natural history of obstructive disorders of the carotid artery and in assessing the results of medical and surgical treatment. It is possible that these techniques may be of some value as screening methods.

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This is a radioisotope arteriogram performed upon a pa-
tient without carotid artery obstruction. The amount  of
radioactivity detected from the right carotid artery re-
gion (A) is equal to the radioactivity from the left ca-
rotid region. Radioactivity detected from the right mid-
dle cerebral artery region (B) is equal to the
radioactivity from the left middle cerebral region. Ex-
posure of this photograph began nine seconds after in-
jection.

Intravenous radioisotope cerebral arteri-
ography,\textsuperscript{4} carotid compression ocular pleth-
ysmography / and supraorbital Doppler moni-
toring\textsuperscript{0} are diagnostic techniques which give
information regarding the functional signifi-
cance of anatomical lesions of the common and
internal carotid artery.

The results of these three techniques,
ophthalmodynamometry, and auscultation of the
neck in the evaluation of 35 patients with
cerebrovascular symptoms are presented in this
report. The anatomical status of the extra-
cranial carotid arteries was determined in each
patient by radiopaque four-vessel aortic arch arteriography.

**Description of the Techniques**

**INTRAVENOUS RADIOISOTOPE ARTERIOGRAPHY**
Fifteen millicuries of technetium 99m are
injected intravenously into the patient who is
seated facing the scintillation camera (Nuclear
Chicago Pho/Gamma III) to obtain an
anterior upright view of the head and neck.\textsuperscript{7}
Serial scintiphotographs of three seconds'

**CAROTID COMPRESSION OCULAR PLETHYSMOGRAPHY**
This test utilizes the ocular pulse to reflect
blood flow in the ophthalmic-carotid system.\textsuperscript{5}
The ocular pulse is obtained from modified
glaucoma cups which are placed over the
anterior surface of the eye and secured with
gentle negative pressure. Phasic changes in the
volume of the eye, coinciding with the arterial
pulse, are recorded from pressure transducers
connected to the glaucoma cups by fluid-filling
tubing. By briefly compressing each of the
carotid arteries in the neck and observing the
effect on the ocular pulse, one can determine
whether or not the carotid artery is severely
obstructed. In the normal individual when flow
through the carotid is interrupted by compres-
sion, the ipsilateral intraocular pressure falls
and the pulse largely disappears. Any residual
pulse is produced by collateral circulation.
Internal or common carotid artery obstruction
is thought to be present whenever contralateral
carotid artery compression produces a simulta-
neous drop in both ocular pulses (fig. 4).

External carotid and temporal artery
compression does not affect the ocular pulses
of a normal person but will decrease the
ipsilateral ocular pulse recording in cases of
carotid obstruction. Additional signs which
may be observed are delayed fall and pro-
longed recovery of the ocular pulse following
compression and release of compression.
Carotid sinus stimulation is sometimes a cause
of a drop in both ocular pulses.

**DOPPLER MONITORING OF THE
SUPRAORBITAL ARTERIES**
The external carotid artery is often a major
source of collateral blood flow whenever the
internal or common carotid artery is obstruct-
ed. One of the communications between the
internal and external carotid arteries is an
anastomotic loop formed by the superficial
DETECTION OF CAROTID ARTERY OBSTRUCTION

A. This is an illustration of a delay in the appearance of radioactivity in the left carotid region as compared to the right carotid region (A) and in the left middle cerebral artery region as compared to the right middle cerebral artery region (B). This is a three-second exposure which was started 12 seconds after intravenous injection of radioisotope.

B. This is a radiopaque arteriogram of the patient with the radioisotope study exhibited in figure 2A. The left internal carotid artery is completely occluded. There is a 30% stenosis of the right internal carotid artery.

temporal artery and the supraorbital branch of the ophthalmic artery (a branch of the internal carotid). When the pressure in the internal carotid is lowered by an obstruction in the neck, blood flow in the supraorbital artery is reversed because blood is supplied from the temporal vessel. This retrograde flow may be identified by placing a Doppler velocity detector* over the supraorbital artery and compressing the temporal artery. If retrograde flow exists, temporal artery compression will dampen or obliterate the reflected signal. Common or internal carotid artery obstruction is considered to be present if retrograde flow exists in the ipsilateral supraorbital artery.

*Ultrasonic blood velocity detector (Model 801, Parks Electronics Laboratory, Beaverton, Oregon). This detects relative blood velocities, based on the Doppler principle, by sending and receiving an ultrasonic signal.

Methods

Thirty-five patients with symptoms of cerebrovascular insufficiency were studied to determine the presence or absence of extracranial vascular disease (table 1). Most of these patients had recurrent attacks of dysfunction in the distribution of the carotid or middle cerebral arteries. There were 30 males and five females. The age range was from 35 years to 67 years. Nine were between 40 and 50 years of age; 18 were between 50 and 60 years of age. Diastolic hypertension (>90) was present in nine; systolic hypertension (>160) was present in three. Diabetes mellitus was present in two.

The isotope, plethysmographical and Doppler studies were performed and interpreted without knowledge of all other clinical features. Ocular plethysmography and Doppler studies were performed in the supine position. Ophthalmodynamometry and isotope studies were performed in the upright position. An average of three ophthalmodynamometric readings was taken for

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This is an illustration of an insignificant difference in the amount of radioactivity from the left carotid region a compared to the right carotid (A). There is a delay in the appearance of radioactivity in the left middle cerebral artery region as compared to the right middle cerebral region (B). Radiopaque arteriography revealed a 90% stenosis in the intracranial segment of the left internal carotid artery below the origin of the left ophthalmic artery.

Each eye. Differences were calculated from the formula:

\[
\frac{\text{diastolic pressure difference (scale units)}}{\text{larger diastolic pressure (scale units)}} \times 100 = \text{percent difference}
\]

A cervical bruit over the carotid artery was considered significant if it was louder over the midportion of the neck than over the proximal portion near the clavicle and radiated distally toward the jaw; this excludes transmitted cardiac and thoracic sounds. Arterial bruits of all intensities, frequencies and duration were included to make this method as sensitive as possible. Direct puncture radiopaque arteriography of the carotid was performed whenever carotid detail was not sufficient with the aortic arch study.

**Results**

This series includes 13 patients with extracranial carotid artery occlusive disease (greater than 50% stenosis), 17 patients with normal carotid arteries, four patients with minimum carotid occlusive disease, and one patient with intracranial internal carotid artery obstruction (patient 14, table 1).

**Patients with Extracranial Carotid Occlusive Disease**

The cerebral and ocular symptoms were on the side of the most significant carotid obstruction in 12 patients; the remaining patient had occlusion of both internal carotid arteries (table 2). Six had unilateral ocular ischemia or infarction. Significant bruits were present in eight of 13. A 15% difference in ophthalmic artery diastolic pressures was present in five of nine and a 10% difference was present in a sixth patient. The three patients with less than a 10% difference had predominantly unilateral carotid obstruction. Ophthalmodynamometry was not performed in two and could not be interpreted in two patients with retinal infarction and hemorrhage.

**Isotope**

The isotope method detected decreased flow on the side of carotid obstruction in 10 of 13 subjects. No detectable difference in the appearance of radioactivity was present in one patient with occlusion of both internal carotid arteries, in one with severe stenosis of both internal carotid arteries, and in one with approximately 60% stenosis of one internal carotid artery.

**Plethysmography**

Ocular plethysmography revealed evidence of carotid artery occlusive disease in 12 of 13 patients. Among these 13 patients, radiopaque arteriography revealed that occlusion or stenosis greater than 50% was present in 18 arteries. Abnormal plethysmographical findings were present in 15 of these 18 arteries (table 3).

**Doppler**

Supraorbital Doppler studies revealed evidence of carotid artery occlusive disease in 12 of 13 patients and in 16 of 18 arteries with occlusion or stenosis greater than 50%.

**EEG**

Carotid compression electroencephalography was performed upon three of these patients in whom the above techniques detected carotid
DETECTION OF CAROTID ARTERY OBSTRUCTION

<table>
<thead>
<tr>
<th>Patient</th>
<th>TIA (number)</th>
<th>Unilateral blindness</th>
<th>Transient manifestations</th>
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<td>4</td>
<td>R</td>
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<td>R</td>
<td>R homonymous hemianopia</td>
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<td></td>
<td></td>
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<td>33</td>
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<td></td>
<td>+</td>
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<tr>
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<td>L</td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>35</td>
<td>0</td>
<td>Physical findings of subclavian steal</td>
<td>Mild L paresis</td>
<td></td>
</tr>
</tbody>
</table>

Cerebrovascular Symptoms and Residual

- TIA: Transient ischemic attack
- Unilateral blindness
- R eye blindness
- R eye blindness
- Mild R paresis
- Moderate hemiparesis
- Expressive dysphasia
- Moderate R paresis
- Mild L paresis
- Milder hemiplegia

artery occlusive disease; normal results were obtained with compression of one-minute duration. Carotid compression electroencephalography was also normal in patient 13.

PATIENTS WITHOUT CAROTID OCCLUSIVE DISEASE

Seventeen patients had no evidence of carotid disease demonstrated by radiopaque arteriography. Minimal internal carotid atherosclerosis was present in four patients. Significant bruits were thought to be present over the carotid arteries in four of these 21 patients. The bruit was over an internal carotid artery with minimal atherosclerosis in one. The bruits were present for only a short while after transient cerebral ischemia in two; no carotid lesion was detected by radiopaque arteriography. The bruit was over an internal carotid artery which supplied the posterior circulation (demonstrated by radiopaque arteriography) in one patient with a "subclavian steal syndrome." A 15% difference in ocular diastolic pressures was present in three and a 10% difference in two of the 21. Systolic ophthalmic artery pressures in three of these...
This is a recording of the right ocular pulse (top) and the left ocular pulse (bottom) from a patient with left internal and external carotid artery obstruction. Preoperative results consisted of a drop in the right ocular pulsations with right common carotid artery compression; this also produced a delayed drop in the left ocular pulse. After release of compression, recovery of the right ocular pulse preceded the left ocular pulse recovery. Left common carotid compression did not alter either ocular pulse.

Postoperatively, the results were normal. Common carotid artery compression produced a drop in only the ipsilateral ocular pulse.

five patients revealed a 10% difference. Intraocular pressure measurements did not reveal any difference between the eyes which might explain these findings. Only two of the 21 patients had ocular symptoms. One of these had a 10% difference in ophthalmodynamometry; all other findings were normal in both of these patients.

ISOTOPE

The appearance of radioactivity in the carotid regions of 19 patients was equal. The isotope technique revealed a detectable difference in the extracranial carotid regions in two of these 21 patients. One of these (patient 15, table 1) had a significant bruit and a Doppler study suggestive of carotid obstruction. Ocular symptoms were not present. Ocular plethysmography and ophthalmodynamometry studies were normal. Minimal atherosclerosis was demonstrated at the origin of one internal carotid artery. The cranial portion of this carotid artery was not adequately visualized radiographically since there was no clinical indication for a selective carotid arteriogram. No additional transient ischemic attacks occurred after anticoagulation.

The other patient (patient 32, table 1) did not have a bruit or ocular symptoms but did have a 10% difference in ophthalmic artery...


**DETECTION OF CAROTID ARTERY OBSTRUCTION**

**TABLE 2**

<table>
<thead>
<tr>
<th>Patient</th>
<th>Cerebral symptoms</th>
<th>Significant bruits</th>
<th>Ophthalmodynamometry difference &gt;15%</th>
<th>Carotid artery obstruction</th>
<th>Ocular pleth.</th>
<th>Arteriogram</th>
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<td>LCC—occlusion</td>
</tr>
<tr>
<td>2</td>
<td>R</td>
<td>0</td>
<td>+</td>
<td>R</td>
<td>R</td>
<td>RIC—50% stenosis</td>
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<tr>
<td>3</td>
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<td>0</td>
<td>R, retinal A. obstruction</td>
<td>R</td>
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<td>RIC—occlusion</td>
</tr>
<tr>
<td>4</td>
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<td>R, L</td>
<td>R</td>
<td>RIC—80% stenosis</td>
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<td>R</td>
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<td>L</td>
<td>L</td>
<td>LIC—occlusion</td>
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<tr>
<td>6</td>
<td>L, R</td>
<td>L, R</td>
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<td>7</td>
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<td>L</td>
<td>L</td>
<td>LIC—occlusion</td>
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<tr>
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<tr>
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<td>LIC—occlusion</td>
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<td>LIC—occlusion</td>
</tr>
<tr>
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<td>+</td>
<td>O</td>
<td>R, L R, L</td>
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<td>13</td>
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<td>L</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>LIC—60% stenosis</td>
</tr>
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</table>

**diastolic pressure; supraorbital Doppler studies and ocular plethysmography were normal. Radiopaque arteriography revealed a normal common and internal carotid artery, middle cerebral artery, and anterior cerebral artery on the side with delayed appearance of radioactivity. Cerebral infarction had occurred with the last episode no additional ischemic attacks occurred.**

**PLETHYSMOGRAPHY**

Carotid compression ocular plethysmographic findings were normal in all 21 of these patients.

**DOPPLER**

Supraorbital artery Doppler studies demonstrated normal directional flow in 19 of 21 patients. Two patients were interpreted to have retrograde flow. The features of one of these patients (patient 15, table 1) have been referred to under the isotope results. The other (patient 30, table 1) had no bruits or significant difference in ophthalmic artery

**TABLE 3**

<table>
<thead>
<tr>
<th></th>
<th>Extracranial carotid obstruction</th>
<th>No carotid obstruction</th>
<th>Infracranial carotid obstruction</th>
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<tbody>
<tr>
<td>A. Patients</td>
<td></td>
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<tr>
<td>Bruits</td>
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<td>4/21</td>
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</tr>
<tr>
<td>Abnormal ophthalmodynamometry</td>
<td>5/9</td>
<td>3/21</td>
<td>1/1</td>
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<tr>
<td>Abnormal carotid isotope study</td>
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<tr>
<td>Abnormal plethysmography</td>
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<td>0</td>
<td>1/1</td>
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<tr>
<td>Abnormal Doppler study</td>
<td>12/13</td>
<td>2/21</td>
<td>1/1</td>
</tr>
<tr>
<td>B. Carotid arteries (35 patients)</td>
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<tr>
<td>&gt;50% stenosis</td>
<td>16/19</td>
<td>0/51</td>
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<tr>
<td>&gt;&lt;50% stenosis</td>
<td>17/19</td>
<td>2/51</td>
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*Stroke, Vol. 2, March-April 1971*
pressure; no carotid disease was detected by radiopaque arteriography.

**CRANIAL INTERNAL CAROTID STENOSIS**

One patient had 90% stenosis of his left internal carotid artery just below the cavernous sinus. There was a diastolic difference greater than 20% with ophthalmodynamometry. No cervical or cranial bruit was present.

The isotope study did not reveal any detectable difference between the extracranial carotid regions, but there was a delay in the accumulation of radioactivity in the left middle cerebral region (roughly corresponding to site of stenosis) (fig. 3). Ocular plethysmography and supraorbital Doppler studies revealed evidence of unilateral carotid artery obstruction.

**Discussion**

Isotope arteriography, ocular plethysmography, and supraorbital Doppler studies were more sensitive and accurate in the detection of carotid artery occlusive disease (greater than 50% stenosis) than ophthalmodynamometry or auscultation of the neck in these 35 patients. Carotid system symptoms without carotid occlusive disease are associated with normal results of the isotope, plethysmographical, Doppler, and ophthalmodynamometric studies but may be associated with a significant carotid bruit.

Radioisotope arteriography, ocular plethysmography, and supraorbital Doppler studies provide information about the functional effect of a carotid lesion upon the circulation; however, the sensitivity of these methods in the detection of a decrease in carotid blood flow is currently unknown. Carotid blood flow was not determined by direct measurement in any of these patients because we were concerned that this might increase morbidity. It is doubtful that a lesion obstructing less than 50% of the arterial lumen of an average-sized carotid vessel, in the case of unilateral carotid stenosis, could be detected by these techniques since it would produce little or no effect upon blood flow.8 Patient 13, with an estimated 60% unilateral carotid stenosis, had normal isotope, ocular plethysmographical, and Doppler studies; carotid compression electroencephalography and ophthalmodynamometry results were also normal. There was a slight systolic pressure gradient across the stenosis at the time of carotid surgery, suggesting that the obstruction was only of borderline significance.

The major deficit of the isotope method is that no detectable difference between the carotid regions may occur in cases with severe bilateral carotid obstruction. The plethysmographical and Doppler studies are as accurate for the detection of bilateral carotid occlusion as for unilateral disease.

An adequate explanation of the asymmetry in the appearance of radioactivity over the carotid regions in the isotope study in two of these patients without carotid obstruction is not known. The asymmetry was reproducible when the isotope studies were repeated. Carotid blood flow has been reported to be decreased ipsilaterally to a middle cerebral artery occlusion.4 This explanation is unlikely in this report since cerebral arteriography revealed normal intracranial vessels in one patient, and there were no permanent neurological signs in the other. The side with delayed accumulation of radioactivity was associated with a hypoplastic vertebral artery in both patients, but asymmetry in the size of vertebral arteries in other patients was unassociated with “carotid flow” asymmetry on the isotope study.

Possibilities of error in interpretation with the Doppler study occur whenever the examiner exerts too much pressure on the Doppler probe. This may obliterate the pulse. In addition, if the examiner places the probe over an orbital branch of the temporal artery rather than the orbital branch of the ophthalmic, temporal artery pressure will obliterate the signal and give the factitious impression of carotid obstruction. Repeat evaluation of one of the two patients with false-positive Doppler results revealed normal directional flow. This suggests a technical error in the first attempt. Failure of an increase, as contrasted to dampening, of the supraorbital Doppler signal pitch during temporal artery compression is not a sign of carotid obstruction. This occurs in a very small percentage of normal young individuals (personal observations).

Serial testing with these techniques may be beneficial in learning more about the natural history of carotid disorders and the efficacy of treatment. There is no risk with the isotope method since a small dose of radioactivity with no proved side effects is injected intravenously.
DETECTION OF CAROTID ARTERY OBSTRUCTION

Although severe cerebral complications as a result of carotid compression electroencephalography have occurred, brief compression (three to five seconds) with cardiac rhythm monitoring, such as used in this ocular plethysmographical technique, appears to have minimal risk. One of the authors (E.B.) has not had any permanent sequelae and only two transient cerebral ischemic attacks in approximately 3,500 compressions in 350 patient studies.

The plethysmographical and the Doppler equipment is inexpensive and the procedures are easily performed. The isotope study requires a gamma camera; however, many isotope departments now have this instrument.

Radiopaque arteriography is indicated in patients with symptomatic cerebrovascular disorders whenever any of the above methods suggest carotid obstruction unless surgical treatment is contraindicated by cerebral damage or cardiac disease. Radiopaque arteriography should be performed in cases who may have carotid disease even though all other diagnostic methods reveal normal findings, since these methods are not as sensitive as would be desirable. Currently, the clinical usefulness of these techniques is especially prominent in the patient who is thought to have intracranial vascular disease rather than an extracranial carotid disorder. The detection of carotid obstruction in such a case would suggest the possibility of a lesion amenable to surgical treatment.

References
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