Asymptomatic Occlusion of an Internal Carotid Artery in a Hospital Population: Determined by Directional Doppler Ophthalmosonometry

BY MARK L. DYKEN, M.D.,* J. FREDERICK DOEPKER, JR., RICHARD KIOVSKY, AND ROBERT L. CAMPBELL, M.D.t

Abstract: Asymptomatic Occlusion of an Internal Carotid Artery in a Hospital Population: Determined by Directional Doppler Ophthalmosonometry

- Reversal of blood flow in an ophthalmic artery as determined by directional Doppler ultrasound (OSM) was present in nine (3%) of 310 patients over 50 years of age who did not have complaints, diagnoses or examination findings suggesting disease of the central nervous system, and was present in nine (12%) of 73 patients with neurological disease selected as technical controls. Twenty-two of the control patients had four-vessel angiography. Five with OSM evidence of reversal of flow had functional occlusion of the appropriate internal carotid artery, and 17 without reversal did not. This study presents evidence that occlusion of an internal carotid artery frequently occurs without producing recognizable clinical dysfunction.

Additional Key Words: cerebral angiography, thrombosis, ophthalmic artery, collateral circulation, cerebral infarction

Although many studies suggest a poor quantitative correlation between angiographical lesions and the clinical manifestations of cerebral vascular disease,¹ to these determinations have required that an invasive technique (angiography or surgery) or autopsy be performed. In our hands in the past, a noninvasive technique using directional Doppler ultrasound ophthalmosonometry (OSM) has determined reversal of flow through 32 ophthalmic arteries of 31 patients. In each case the reversal was verified by angiography and was associated with severe stenosis or occlusion of the ipsilateral internal carotid artery below the siphon. When verified by an experienced examiner, no false-positive reversals were noted except for two instances of temporary reversal in the immediate postoperative period following internal carotid endarterectomy. The mean age of these patients was 56.5 ± 6.8 years, and 24 of the 31 patients were males. Similarly, Muller⁹ reported reversal in 31 of 37 observed cases with occlusion and in nine of 20 cases with high-grade stenosis of an internal carotid artery.

To determine the presence of severe occlusive disease of the internal carotid arteries in a hospital population of patients over the age of 50 years without any neurological complaints or findings, all available patients answering these criteria in three different hospitals were studied by OSM.

Materials

All ophthalmosonometry was performed using a directional Doppler unit made by Parks Electronics Laboratory. The instrument is composed of a transmitter which sends a high frequency (10 MHz) sound wave to a transducer containing a transmitting and receiving crystal. The receiver converts any frequency shift to sound and also records increased frequency on one channel and decreased frequency on a second channel. Ultrasound waves reflected from moving blood particles change their frequency. If the movement is toward the transmitted sound, the frequency is increased, and if the movement is away, the frequency is decreased. The frequency shift is proportional to the velocity of the moving particles. Therefore, by observing from which channel the instrument is recording and the degree of frequency change, one can determine the direction of flow and the relative velocity.

The results of OSM on 310 consecutive hospitalized patients over 50 years of age without neurological symptoms or findings were reviewed. These were compared to those of 73 neurological patients who were selected as technical controls. The mean age of the asymptomatic patients was 63.5 ± 10.9 years, and of the controls 61.0 ± 10.7 years. Males predominated in both groups (208 or 67% of the study group and 56 or 77% of the controls). Blacks were in the minority (64 or 22% of the study group and nine or 12% of the controls). The general diagnostic categories for the
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Patients

Diagnostic Categories of Neurologically Asymptomatic Patients

<table>
<thead>
<tr>
<th>Disease</th>
<th>Neurologically Asymptomatic Patients</th>
<th>Reversal</th>
<th>Yes</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiovascular</td>
<td>59</td>
<td>2</td>
<td>61</td>
<td>(20%)</td>
</tr>
<tr>
<td>Skeletal or joint</td>
<td>46</td>
<td>0</td>
<td>46</td>
<td>(15%)</td>
</tr>
<tr>
<td>Metabolic</td>
<td>35</td>
<td>3</td>
<td>38</td>
<td>(12%)</td>
</tr>
<tr>
<td>Neoplasm</td>
<td>37</td>
<td>1</td>
<td>38</td>
<td>(12%)</td>
</tr>
<tr>
<td>Pulmonary</td>
<td>29</td>
<td>0</td>
<td>29</td>
<td>(9%)</td>
</tr>
<tr>
<td>Gastrointestinal</td>
<td>26</td>
<td>2</td>
<td>28</td>
<td>(9%)</td>
</tr>
<tr>
<td>Genitourinary</td>
<td>16</td>
<td>0</td>
<td>16</td>
<td>(5%)</td>
</tr>
<tr>
<td>Hematological</td>
<td>12</td>
<td>0</td>
<td>12</td>
<td>(4%)</td>
</tr>
<tr>
<td>Ophthalmological</td>
<td>3</td>
<td>1</td>
<td>4</td>
<td>(1%)</td>
</tr>
<tr>
<td>Other</td>
<td>38</td>
<td>0</td>
<td>38</td>
<td>(12%)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>301</td>
<td>9</td>
<td>310</td>
<td></td>
</tr>
</tbody>
</table>

Methods

After their first year of medical school, two medical students (F.D. and R.K.) were trained over a two-week period to perform directional Doppler ophthalmosonometry in the following manner: The patient is placed in a supine position and the transducer of the instrument is placed over the medial canthus of the closed eye and directed at the optic canal. The transducer is then moved slowly until the position is located in which the maximal arterial signal is obtained. The probe is then held steady and the values recorded from the toward and the away channels. As a double check and also to establish which branch of the external carotid artery was supplying the ophthalmic artery in cases of reversal of flow, a technique was performed that has been previously described, using a non-directional Doppler unit.11 Changes in ophthalmic artery blood flow during digital occlusion of each of the main accessible branches of the external carotid artery, which may provide collateral cerebral blood flow, were recorded. At the end of the training period, the students established by blind comparison with a senior author (M.L.D.) and by testing assigned patients with known lesions that they could determine reversal or absence of reversal of flow through the ophthalmic arteries. Permission was obtained to perform the procedure on every patient on medical and surgical wards in the participating hospitals. For the next ten weeks they consecutively went to each ward and reviewed all charts on patients over 50 years of age. All available patients who did not have complaints, diagnoses or examination findings suggesting disease of the nervous system were examined by OSM. The results were recorded, and in those cases where flow was reversed, the procedure was repeated by at least one additional examiner.

The neurological control group was selected by neurology staff and residents on the basis of a high likelihood of increased incidence of occlusive disease and an increased probability that cerebral angiography would be performed in the future. These patients were on the neurological services of all three hospitals and were not surveyed consecutively, but were examined upon request. All diagnoses and abnormal OSM findings were reviewed with the senior authors (M.L.D. and R.L.C.).

Results

Nine (3%) of the 310 neurologically asymptomatic patients had reversal of flow indicating occlusion or severe stenosis of the ipsilateral internal carotid artery. Not unexpectedly, nine (12%) of the 73 selected patients with neurological disease had reversed flow through the ophthalmic artery. In each of these 18 patients with reversed flow, compression of one of the branches of the external carotid artery produced a decrease in velocity of flow away from the probe, further supporting the directional change.

Twenty-two patients in the control group had four-vessel cerebral angiography. In five with OSM evidence of reversal of flow, the appropriate internal carotid artery was functionally occluded and the arteriogram revealed filling of the ophthalmic artery from external carotid artery branches (figs. 1 through 5). In 17 patients who did not have OSM evidence of reversal of flow, no internal carotid artery was obstructed more than 70%.

Comments and Conclusions

This study indicates that the technique of performing directional OSM can be learned in a short period of time. In our total experience, 37 instances of reversal of blood flow through an ophthalmic artery as determined by directional OSM, angiography demonstrated occlusion or severe stenosis of the ipsilateral internal carotid artery and filling of the ophthalmic artery from the external carotid artery system. In our experience only two possible instances of false-positive measurement were noted. These were transitory reversals in the early postoperative period following ipsilateral internal carotid endarterectomy. Therefore, the technique appears to be suitable to screen patients for occlusion or severe stenosis of the internal carotid artery.

The high incidence of reversal of flow in the ophthalmic arteries of asymptomatic patients was not completely unexpected. Faris et al.3 in 1963, compared angiograms of patients with cerebrovascular disease
Right carotid arteriogram of a 55-year-old white man with right hemisphere infarction. A: occlusion of right internal carotid artery. B-E: Demonstrates flow from external carotid artery system through ophthalmic artery to fill intracranial branches of internal carotid artery.
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FIGURE 2
Right carotid arteriogram of a 69-year-old white man with right cerebral hemisphere infarction. Demonstrates occlusion of right internal carotid artery.

FIGURE 3
Aortic arch arteriogram of a 44-year-old black man with a history of left hemisphere infarction four years before and episodes of transient weakness of left arm and leg for one month. Demonstrates occlusion of left internal carotid artery.

FIGURE 4
Right carotid arteriogram of a 73-year-old white man with a history of syncopal attacks which ceased after placement of a permanent transvenous cardiac pacemaker. Demonstrates more than 90% stenosis of the right internal carotid artery.
Aortic arch arteriogram of a 71-year-old white man with a history of transient ischemic attacks in the distribution of the right internal carotid artery and recent right internal capsule infarction. Demonstrates more than 90% stenosis of the left internal carotid artery.

and normal volunteer controls, and demonstrated no significant differences in angiographically demonstrated atherosclerotic disease. In none of their 43 male controls was occlusion of an internal or common carotid artery noted, but 33 were under 50 years of age. No attempt was made to quantitate the degree of atherosclerosis. Alter et al. also showed no clinical correlation between cerebral infarction and angiographical findings. Marshall and Wilkinson found no difference in the ultimate number of transient ischemic attacks or completed strokes in 64 consecutive patients with transient ischemic attacks in the distribution of one internal carotid artery which was angiographically normal compared to a group with demonstrated internal carotid artery stenosis. Gomensoro et al. reported that of 96 patients with lateralized transient ischemic attacks, 13 had occlusion of an appropriate artery and only two of these had further attacks. Dyken et al. found significantly less frequent post-hospitalization cerebrovascular events in 43 patients with occlusion of an internal carotid artery than in sex-matched and age-matched controls with less than 60% stenosis of any single artery. As pointed out in that communication, the lack of quantitative correlation of degree of stenosis or of occlusion and clinical symptomatic cerebrovascular disease does not mean that the atherosclerotic process has no relationship to ischemic disease. Although these studies make a hemodynamic factor less likely as a common cause of dysfunction, a relationship may be qualitative, and it is quite likely that changes related to atherosclerosis act as triggering factors for various hematological changes.

The present study demonstrated evidence for reversal of flow in an ophthalmic artery in nine of 310 (3%) of patients without any manifestation of neurological dysfunction, and one must conclude that occlusion of an internal carotid artery can occur not uncommonly without producing any recognizable dysfunction.

References

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Stroke. 1974;5:714-718
doi: 10.1161/01.STR.5.6.714

*Stroke* is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
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Print ISSN: 0039-2499. Online ISSN: 1524-4628

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