Internal Carotid Artery Occlusion Diagnosed by Doppler Ultrasound

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Abstract:
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Using a transcutaneous Doppler ultrasonic blood velocity detector, retrograde ophthalmic artery blood flow was demonstrated in four patients, all of whom had angiographically confirmed occluded internal carotid arteries. In three, compression of the facial artery obliterated the ophthalmic artery signal. In a fourth patient compression of the superficial temporal artery produced the same result.

The technique presently used to monitor ophthalmic artery blood flow and to detect retrograde ophthalmic flow is described. This simple method appears to be at least as useful as ophthalmodynamometry in the routine evaluation of patients for extracranial occlusive disease, is easier to perform, and has a wider range of application.

ADDITIONAL KEY WORDS ophthalmic artery collateral blood flow blood velocity cerebral angiography ophthalmodynamometry

The Doppler ultrasonic blood velocity detector was first used clinically to localize transcutaneously the precise site of vascular occlusion in peripheral arteries. Because of the relationship of extracranial carotid occlusion to strokes, it seemed that this atraumatic diagnostic method might also be used to evaluate these patients.

Brinker, Landiss and Croleyn, Grossman and Wood, while recording directly from the carotid vessels, found recognizable changes in the frequency of the Doppler signal in patients with carotid occlusion. We, and others, however, have not found direct recording over the carotid artery in the neck reliable. With our equipment, we could not identify the carotid bifurcation, distinguish internal from external carotid blood flow, or localize angiographically demonstrated complete or partial carotid occlusions.

Recently, we have demonstrated that by comparing the relative velocity of blood flow through the ophthalmic arteries, valuable clinical information could be obtained in patients with carotid artery occlusion, carotid cavernous sinus fistula, ophthalmic artery thrombosis and intraorbital tumor.

Our preliminary laboratory and clinical experience with surgical or disease-induced acute occlusion of the internal or common carotid artery suggested that this diagnostic procedure, termed ophthalmosononometry (OSM), was a safe and simple method for evaluating patients for extracranial carotid occlusion. However, a few patients with angiographically complete occlusion of the internal carotid artery had no demonstrable OSM changes in the ipsilateral ophthalmic artery blood flow. In these patients, a well-developed collateral circulation between the external carotid and the ophthalmic artery was angiographically demonstrated. Since the direction of blood flow cannot be determined with this technique, collateral circulation severely limited the clinical application of this procedure.

We subsequently have discovered that in patients with a well-developed external carotid-ophthalmic collateral circulation, digital occlusion of a main collateral branch of the external carotid produced a dramatic decrease in
INTERNAL CAROTID OCCLUSION

ophthalmic artery blood flow velocity. This simple technique for demonstrating retrograde ophthalmic artery blood flow thereby provides *prima facie* evidence for occlusive disease of the internal carotid artery and significantly expands the clinical applicability of the procedure.

The purpose of this article is to describe the technique currently used to record ophthalmic artery blood flow and also to illustrate the results obtained in patients who have occluded carotid arteries with retrograde ophthalmic artery blood flow.

**Method**

A commercially available Doppler flowmeter* with an attached velocity-amplitude converter is presently being used to record ophthalmic artery blood flow. The instrumentation is described in detail elsewhere.\(^6\) Basically, an ultrasonic beam generated by a piezoelectric crystal is reflected from moving erythrocytes passing through the ophthalmic arterial system. The reflected ultrasound is picked up by a similar crystal mounted in the same transducer. The frequency change between the transmitted and the reflected sound waves is converted to an audible signal which is heard through a loud-speaker. The pitch of the audible signal is directly related to the velocity of blood flow. Since the ophthalmic artery is a branch of the internal carotid, a decrease in carotid blood flow will result in a diminished audible signal from the ophthalmic artery provided there is not a well-developed collateral circulation.

After the patient is in a comfortable position, the small transducer of the instrument is gently placed over the medial canthus of the closed eye and directed at the optic canal. Since air is a poor conductor of ultrasound, Aquasonic\(^5\) or water is used as a coupling agent. The transducer is then slowly moved until the position is located in which the maximal arterial auditory signal is obtained. The same procedure is then repeated over the opposite eye and the signals are compared.

If there is no significant difference between the signals obtained from the two sides, additional maneuvers are performed to determine if there is retrograde ophthalmic artery blood flow. The main accessible branches of the external carotid which may provide collateral cerebral blood flow via the ophthalmic artery and which are susceptible to isolated digital compression are: (1) the facial artery, (2) the infraorbital branch of the internal maxillary artery, and (3) the superficial temporal artery.

While ophthalmic artery blood flow is being monitored, each of these arteries is respectively digitally occluded: the facial artery as it crosses the mandible, the infraorbital artery as it exits from its foramen, and the superficial temporal artery in the temporal fossa above the zygomatic arch. Permanent recordings (sonograms) are made by displaying the frequency component of the Doppler signal on a multichannel recorder.

**Case Histories**

**CASE 1**

A 54-year-old white man was admitted to the Robert Long Hospital in March 1968 because of persistent left supraorbital headaches and a subjective cranial bruit. These symptoms were not relieved by bilateral carotid endarterectomy six years previously. The patient stated that the exacerbations of the headache frequently coincided with mild intermittent weakness in his right arm.

On physical examination the blood pressure was 140/80 mm Hg bilaterally and the heart rate was 90 per minute and regular. No bruits could be heard over the head or carotid areas and both carotid arteries pulsed normally. The only significant neurological finding was a minimal right hemiparesis.

**Diagnostic Procedures**

Ophthalmodynamometry revealed pressures of 120/70 and 60/35 in the right and left eyes, respectively. Ophthalmosonometry revealed that

![Figure 1](http://stroke.ahajournals.org/)

**FIGURE 1**

Ophthalmic artery sonograms. Case 1—obliteration of normal pulse pattern upon compression of superficial temporal artery (arrow) on the side of the internal carotid occlusion and return to normal after release of pressure. Similar results in cases 2-4 with compression of the respective facial artery.
the left ophthalmic artery signal was obliterated with compression over the ipsilateral superficial temporal artery (fig. 1). Carotid arteriography showed the left internal carotid artery to be occluded just above the bifurcation, and there was a very well-developed collateral flow to the ophthalmic artery via the superficial temporal artery (fig. 2).

CASE 2
A 58-year-old Negro man was admitted to the Robert Long Hospital on June 5, 1969, because of a sudden onset of left hemiparesis and left hemihypesthesia. He was in apparent good health until June 2, 1969, when the symptoms developed. He had no other complaints and denied any history of headaches, visual disturbances or neurological problems.

On physical examination, the blood pressure was 230/115 mm Hg bilaterally. The pulse was 92 per minute and regular. The carotid arteries pulsed normally and no cervical bruits were heard. Sensorium and speech were normal, but there was constructional dyspraxia. Other pertinent neurological findings included a left hemiparesis affecting the arm more than the leg, a left hemihypesthesia, and impaired position sense and astereognosis on the left. The muscle stretch reflexes were increased on the left and the left plantar response was extensor.

Diagnostic Procedures
Ophthalmodynamometry revealed a diastolic pressure of 90 in the left eye and 87 in the right. A gamma scan demonstrated decreased arterial perfusion in the distribution of the right middle cerebral artery and a delay in venous filling suggesting collateral blood flow to that area. Ophthalmosonometry initially revealed no difference between the ophthalmic artery blood flow. With digital occlusion of the facial artery, however, there was a dramatic decrease in the audible signal from the right ophthalmic artery (fig. 1). Angiography demonstrated occlusion of the right internal carotid artery at its origin.

CASE 3
A 53-year-old white man was admitted to the Marion County General Hospital on June 23, 1969, because of the sudden onset of confusion and unusual behavior approximately three weeks before admission. He was previously in good health, except for diabetes mellitus which was controlled with diet and oral hypoglycemic medication.

Physical examination revealed a blood pressure of 130/80 and 122/70 mm Hg in the right and left arms, respectively. The right carotid artery was barely palpable, whereas the left pulsed normally. No bruits could be heard. Pertinent neurological findings included a left

**FIGURE 2**
Left carotid arteriogram demonstrating occlusion of the internal carotid artery and the well-developed collateral superficial temporal-ophthalmic artery circulation. (Reproduced with permission from J Neurosurg 30: 244, 1969.)
central facial weakness, mild paresis of grip in the left hand, weakness of plantar and dorsiflexion of the left foot, and constructional apraxia. Astereognosis and sensory extinction were present on the left. The muscle stretch reflexes were slightly increased in the left arm and leg and the plantar response was flexor bilaterally.

Diagnostic Procedures
Ophthalmodynamometry showed pressures of 55/22 and 110/55 in the right and left eyes, respectively. Ophthalmosonometry was normal, but with compression of the right facial artery a dramatic decrease in blood flow through the right ophthalmic artery was detected (fig. 1). A gamma brain scan demonstrated abnormal perfusion with a decrease in the distribution of the right middle cerebral artery. Bilateral carotid angiography showed occlusion of the right internal carotid artery.

CASE 4
A 46-year-old white man was transferred to the Robert Long Hospital on June 18, 1969, for evaluation of left hemiparesis which developed eight days before admission. Previously, he was in
good health except for essential hypertension for which he sporadically took medication.

On physical examination the blood pressure was 150/88 mm Hg bilaterally. Carotid pulsation was full bilaterally and no bruits were heard. Pertinent neurological findings included left central facial weakness, dense left hemiparesis, and complete left hemihypesthesia. Muscle stretch reflexes were increased on the left and the left plantar response was extensor.

**Diagnostic Procedures**

Ophthalmodynamometry could not be performed because of the lack of patient cooperation. Ophthalmosonometry demonstrated a marked decrease in right ophthalmic artery blood flow when the right facial artery was compressed (fig. 1). The gamma brain scan demonstrated decreased perfusion in the distribution of the right middle cerebral artery with delayed venous emptying. Four-vessel angiography showed occlusion of the right internal carotid artery.

**Discussion**

Retrograde ophthalmic artery blood flow may occur when there is a decreased pressure in the carotid siphon caused usually by arteriosclerotic occlusive disease of the carotid arteries in the neck. The most common anastomotic channels which shunt blood from the external carotid to the ophthalmic artery are the facial, superficial temporal, and maxillary arteries (fig. 3).

As illustrated by these cases, retrograde ophthalmic artery blood flow may now be demonstrated with Doppler ultrasound by digitally occluding the external carotid anastomotic vessel(s). A marked reduction in the ophthalmic Doppler signal occurred when the facial artery was compressed in three patients and when the superficial temporal artery was compressed in a fourth patient.

There are three possible conditions, however, when ophthalmosonometry may fail to demonstrate collateral circulation to the ophthalmic artery, i.e., normal OSM readings are obtained, even though the common or internal carotid artery is occluded: (1) the main collateral circulation may be via the anterior deep temporal branch of the maxillary artery which is inaccessible to isolated digital compression. We have seen two patients with internal carotid occlusion and this anastomotic pattern who had normal sonograms (fig. 4); (2) no significant pressure gradient may develop when there is good cross circulation via the circle of Willis; (3) although rare, the ophthalmic artery may arise from the middle meningeal, which is also inaccessible to digital occlusion.

Preliminary experience with ophthalmosonometry indicates that it is at least as reliable as ophthalmodynamometry for routine evaluation of patients with suspected carotid occlusion, and it is more easily performed with virtually no patient discomfort. Furthermore, false negative results are frequently encountered with ophthalmodynamometry when the collateral channels are sufficient to maintain the ophthalmic artery pressure (see case 2). With OSM this collateral circulation may be demonstrated even in uncooperative patients (see case 4).

The blood velocity detector itself is quite simple to operate, is transistorized and battery-powered, and can be conveniently transported. The absence of complications in more than 300 patients now studied with this technique, plus the results of extensive laboratory and clinical studies involving low-intensity ultrasound, indicate that OSM is a safe diagnostic procedure.

**References**

INTERNAL CAROTID OCCLUSION

9. Maroon JC, Pieroni DW, Campbell RL: Effects of low intensity ultrasound on the eye. To be published
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