Ophthalmosonometry*
An Ultrasonic Method for Assessing Carotid Blood Flow

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In 1966, Stegall, et al., described an ultrasonic flowmeter, based on the Doppler effect, which could continuously record arterial or venous blood flow velocity through the intact human skin. Vascular surgeons found application for this instrument in the localization of arterial and venous occlusions of the extremities. Attempts to detect sites of obstruction in the extracerebral carotid arteries, however, have thus far been disappointing.

While using this blood velocity detector, we found that an arterial pulsation could be routinely detected with the transducer applied over the lid of the closed eye. Goldberg, et al., recently made this same observation, and after preliminary work on dogs they suggested that the use of this instrument might prove to be a practical, indirect method for assessing carotid and ophthalmic blood flow.

The purposes of this report are to establish that it is ophthalmic artery blood flow which is detected and to illustrate potential applications of this technique. It appears that the clinical indications for determining ophthalmic artery blood flow with ultrasound are similar to those for ophthalmo-dynamometry (ODM). We will, for convenience, use the term “ophthalmosonometry” (OSM) for this procedure.

Principles and Methods

A transcutaneous Doppler flowmeter with an attached velocity-amplitude convertor was used. Housed in a single handle are two D-shaped crystals which are the transmitting and receiving piezoelectric elements. The transmitting crystal generates a constant 5 mc beam of low intensity ultrasound in the range of 20-40 mw which can penetrate soft tissue and blood vessels; reflected ultrasound is detected by the receiving crystal. A frequency change occurs only when ultrasound is reflected from the moving tissue elements (blood, arterial wall); sound backscattered from motionless tissues has the same frequency as the transmitted signal and is filtered out. It is the change in frequency that occurs whenever the source of sound is changed in relation to a stationary observer that is called “the Doppler effect,” after the Austrian physicist, Christian Doppler, who first described the phenomenon in 1842.

Besides being converted to audible sound, the returning filtered signal is also processed by the velocity-amplitude convertor. This instrument yields DC voltages which are proportional to the frequency change and the amplitude of the Doppler signal. In the present studies these two components plus Lead II of the electrocardiogram were displayed on separate channels of a Honeywell Visicorder. The greater the frequency difference between the transmitted and the reflected sonic beam, the higher is the blood flow velocity. This is reflected by a greater deflection in the frequency channel and an increased pitch of the sound. It is impossible to determine accurately the absolute rate of blood flow because the frequency alteration varies markedly with changes in the angle formed by the crystals and the moving column of blood. Reproducible results, however, have been consistently obtained in the same patient over various intervals of time. The amplitude channel indicates the amount or quantity of backscattered ultrasound. This signal is related to the size of the blood column(s) and also the focusing arrangement of the transmitting crystals. We have not found this channel useful except for gross wave form analysis.

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All sonograms were obtained with the patient in the supine position. The transducer was held over the closed eyelid and Aquasonic‡ was used as the coupling agent. With little or no pressure, the transducer was moved over the eyelid until the position was found that produced the maximum auditory signal. A signal was detected with the transducer held over the medial, superior, or lateral aspect of the globe, but the maximal impulse was usually found when the transducer was placed over the medial canthus and directed toward the optic canal.

**Laboratory Studies**

To determine the source of the ocular Doppler signal experimentally, a monkey (*Macaca speciosa*) was chosen because the carotid flow and pressure characteristics in this animal are similar to those in the human.⁹ Under pentothal anesthesia, the right common, internal, and external carotid arteries were exposed in the neck. The ultrasonic transducer was then placed over the right eye and held in the position producing the maximal frequency change. Each of the exposed arteries was then alternately completely occluded and appropriate sonograms made. Following this, a right frontotemporal craniectomy was performed, and, with the aid of magnification, the internal carotid and ophthalmic arteries were clearly identified. While recording over the right eye with the Doppler instrument, the internal carotid artery immediately distal to the origin of the ophthalmic artery and the isolated ophthalmic artery were then alternately completely occluded with fine forceps.

Occlusion of the common carotid artery resulted in a dramatic decrease in the amplitude and frequency as recorded on the sonogram (Fig. 1). The impaired flow recorded after complete occlusion of the internal carotid in the neck was significant, but not as striking as that following common carotid ligation. This finding was not unexpected,

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**Fig. 1.** Continuous recording of the electrocardiogram (ECG), mean amplitude (AMP) and frequency (FREQ) of the ophthalmic Doppler signal in the monkey. A. Marked decrease in amplitude and frequency with occlusion (first arrow) of the common carotid. B. No change with external carotid occlusion. C. A significant decrease with internal carotid occlusion. D. Abrupt disappearance of a detectable signal with ophthalmic artery occlusion. (In this and all subsequent sonograms, the amplitude and frequency deflections are in millivolts.)