Noninvasive Diagnosis of Carotid Artery Disease

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THROMBOTIC STROKE is a major cause of death and disability in the United States today. Forty per cent of patients with thrombotic stroke have a lesion confined to the extracranial circulation, and another 33% have combined intracranial and extracranial lesions.[1] Extracranial cerebrovascular disease can present as an asymptomatic bruit, as a transient ischemic attack, or as chronic cerebral dysfunction. Asymptomatic bruit has been reported in one series to progress to frank stroke in up to 19% of cases and to TIA in 27% of instances. TIA's have been shown to progress to stroke within five years in approximately 30% of patients. Carotid endarterectomy can reduce the incidence of stroke to 3%-5% in the patient with asymptomatic bruit and to 2% in the patient with TIA's.[3]

Patients with cervical bruits and transient focal neurological defects have a clear-cut clinical indication for carotid angiography. There is another large group of patients, however, who have asymptomatic bruits, transient focal neurological defects without a bruit, or vague nondescript neurological symptoms. In this second group of patients, reliable techniques for the noninvasive diagnosis of cerebrovascular disease can be extremely valuable. By selecting the patients in this group who are likely to have significant cerebrovascular occlusive disease, arteriography (with its risks, inconvenience, and expense) can be reserved for those patients who are likely to have demonstrable pathology. Noninvasive cerebrovascular testing is also a useful tool for preoperative screening in individuals scheduled for major vascular or cardiac surgery and to follow the postoperative status of patients who have had carotid surgery.

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Noninvasive techniques for diagnosis of carotid artery disease are applicable to a large group of patients. The authors describe certain techniques and report their advantages.

Four distinct but complimentary techniques are utilized in the cerebrovascular examination in the UMC noninvasive vascular laboratory. Each technique is based upon separate and independent phenomena related to carotid artery stenosis.

Carotid phonoangiography (see Figure 1) is the electronic recording and visualization of the morphology and timing of a carotid bruit.[4] Bruits which extend into diastole are related to internal or common carotid stenosis, because the intracranial circulation is of relatively low resistance, and flow continues throughout the cardiac cycle. External carotid flow, however, is into a higher resistance system, and flow is almost exclusively during systole. Consequently, bruits related to the external carotid are generally confined to systole. Carotid bruits may be differentiated from transmitted murmurs, because sound related to the carotid bifurcation will be louder at the mid-neck position. False

positives occur when bruits are produced by non-stenotic tortuosity. False negatives occur because extremely high stenoses may have insufficient flow to generate an audible bruit. CPA is approximately 65% accurate, which is not sufficiently accurate to direct clinical decisions.

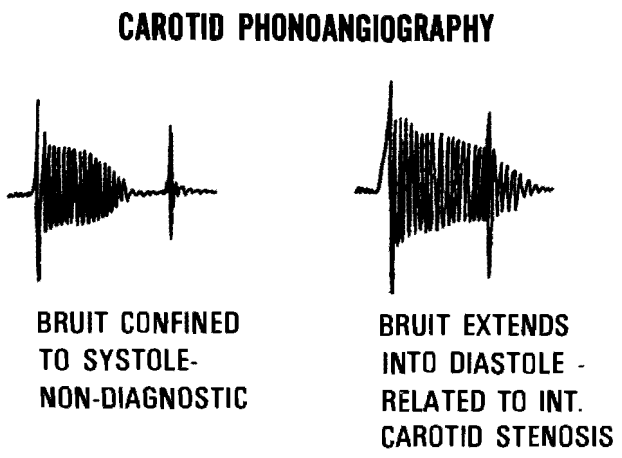

Figure 1. Carotid phonoangiography (CPA) shows the morphology of a carotid bruit.

Oculoplethysmography (see Figure 2) measures volume changes in the eyeball in order to detect the timing of the arrival of the systolic pressure pulse up the carotid system to the eyeball.[4] The volume of the eyeball increases slightly during systole. This method uses two plastic cups, similar to contact lenses, to time the changes in volume of the eyeball. A photoelectric probe on the earlobe is used to detect the pulse from the external carotid. A significant stenosis in the internal carotid causes the pulse wave to be slowed slightly. The timing of the two eye pulses, reflecting each internal carotid artery, and the earlobe pulse, reflecting the external carotid, are electronically recorded on a strip recorder. A fourth line, the differential, compares the two eye pulse signals. In the presence of unilateral internal carotid stenosis, the ipsilateral eye pulse signal will be delayed when compared to the eye pulse on the side of the normal internal carotid. Bilateral internal carotid disease will be reflected by both eye pulses occurring later than the earlobe pulse. The accuracy of OPG can be adversely affected by retinal artery disease, ophthalmic disease, poor cardiac output, or increased intracranial pressure. OPG as an independent diagnostic technique is 60% to 80% accurate.

The direction of blood flow through the periorbital collaterals (see Figure 3) is frequently altered in the presence of carotid stenosis.[5] The distribution of flow of the internal carotid artery is almost exclusively intracranial. The ophthalmic artery, the first branch of the internal carotid, is the exception. The ophthalmic artery has collateral connections with two branches of the external carotid, the facial and superficial temporal arteries. Blood flow is ordinarily from the internal system outward to the external system. In the presence of high grade stenosis, the blood flow is reversed and flows inward.

In the examination of periorbital collaterals, the examiner places a Doppler probe over the supraorbital artery and then alternately compresses the su-

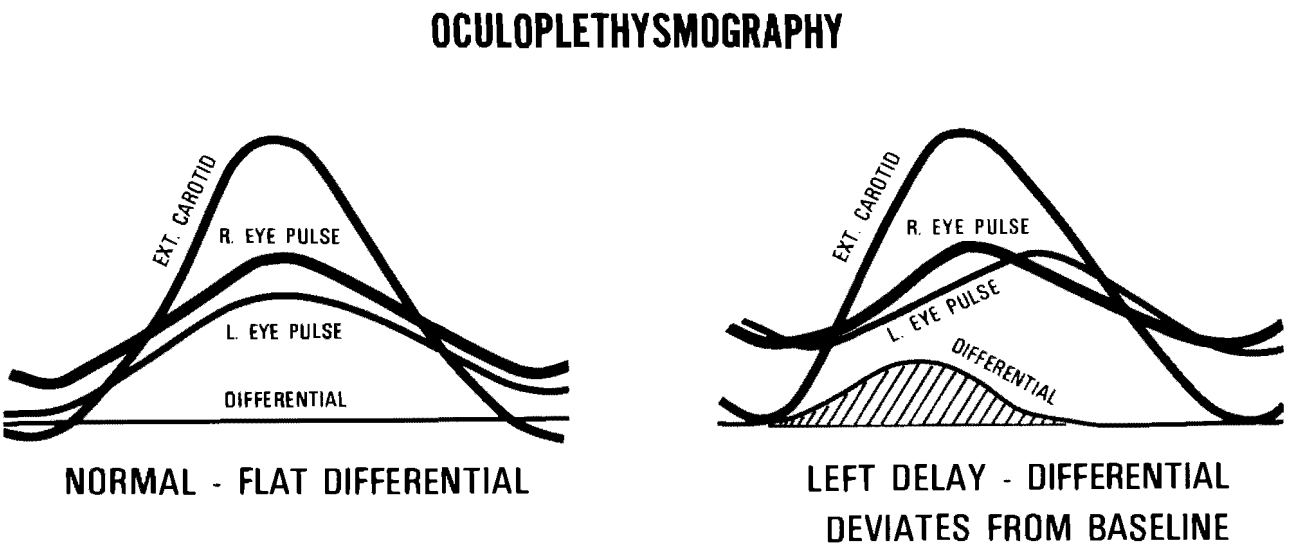

Figure 2. Oculoplethysmography (OPG) records changes in eyeball volume to time the pulse wave in each carotid artery.

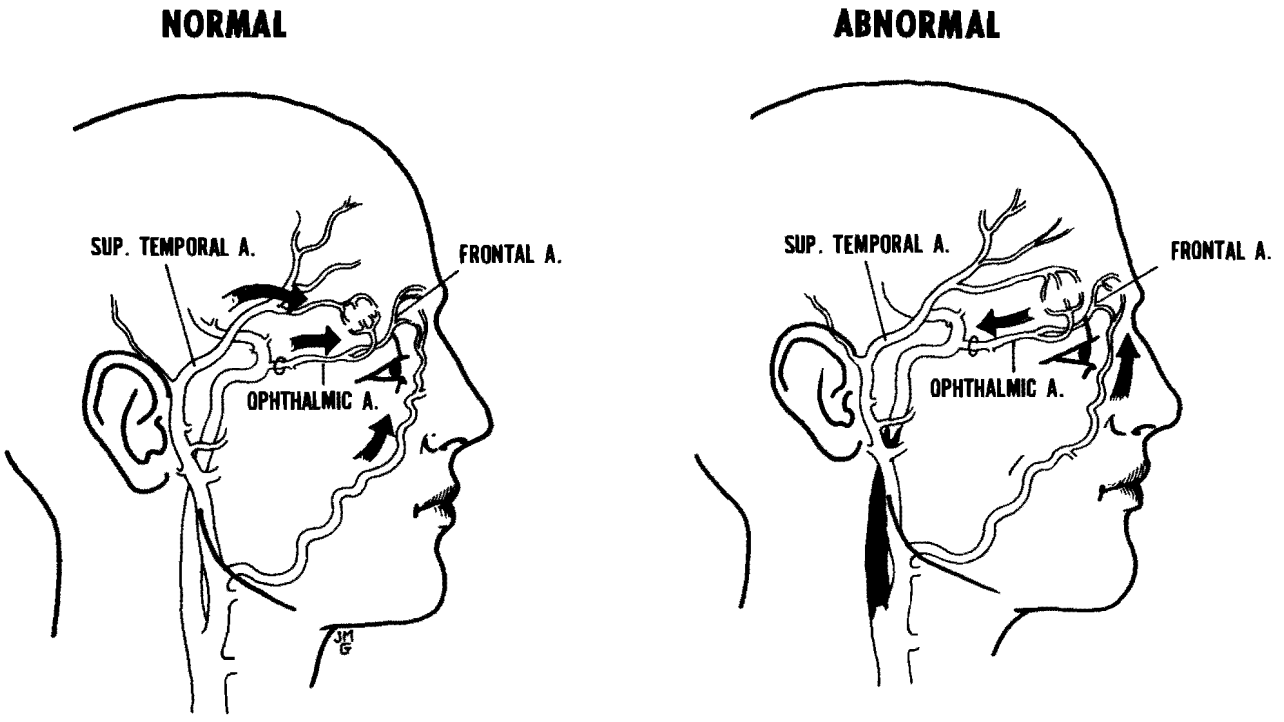

Figure 3. Periorbital collaterals are reversed with internal carotid obstruction.

perficial temporal and facial arteries. With a normal internal carotid system, the signal will increase in amplitude, because the extracranial pressure against which the outflowing blood must flow is reduced. In the presence of a significant internal carotid stenosis, compression of the superficial temporal or facial artery diminishes the signal because the flow is inward, from the external system to the internal system.

Direction of blood flow in the collaterals can also be directly monitored by placing the probe of a directional Doppler over the supraorbital artery and noting its direction of flow, and by placing the probe over the eyeball to detect the direction of flow in the ophthalmic artery. The use of these separate maneuvers to examine periorbital collateral flow significantly increases the accuracy of the method.

Reversal of the periorbital collaterals is a reliable indicator of high grade stenosis in 90% of instances when positive, but a negative examination is of little diagnostic value.

Doppler imaging and scanning of the carotid arteries uses ultrasonic waves to enable the operator to form a visual image of the extracranial carotid system on an oscilloscope and to estimate the degree of stenosis from the velocity of the blood flow (see Figure 4). In this technique, a Doppler ultrasonic probe is traced along the course of the common, external, and internal carotid arteries. The position of the probe is electronically sensed, and an image of the common, internal, external carotid is formed. The operator then moves the probe along the courses of these arteries, while listening to the frequency of the signal. Velocity of blood flow through a stenosis is higher than velocity proximal or distal to the stenosis. Changes in velocity of blood flow are heard as higher in frequency. In this manner stenosis of the common, internal, or external carotid can be accurately located and quantitated. Lesions of the intrathoracic carotid, or of the intracranial internal carotid cannot be detected. It is, however, highly reliable in detecting lesions of the cervical carotid system.

There are two significant benefits from using various techniques which are based upon totally different physiological and physical principles. First, we are able to increase our accuracy and minimize the errors due to artifact. In those patients who have had carotid

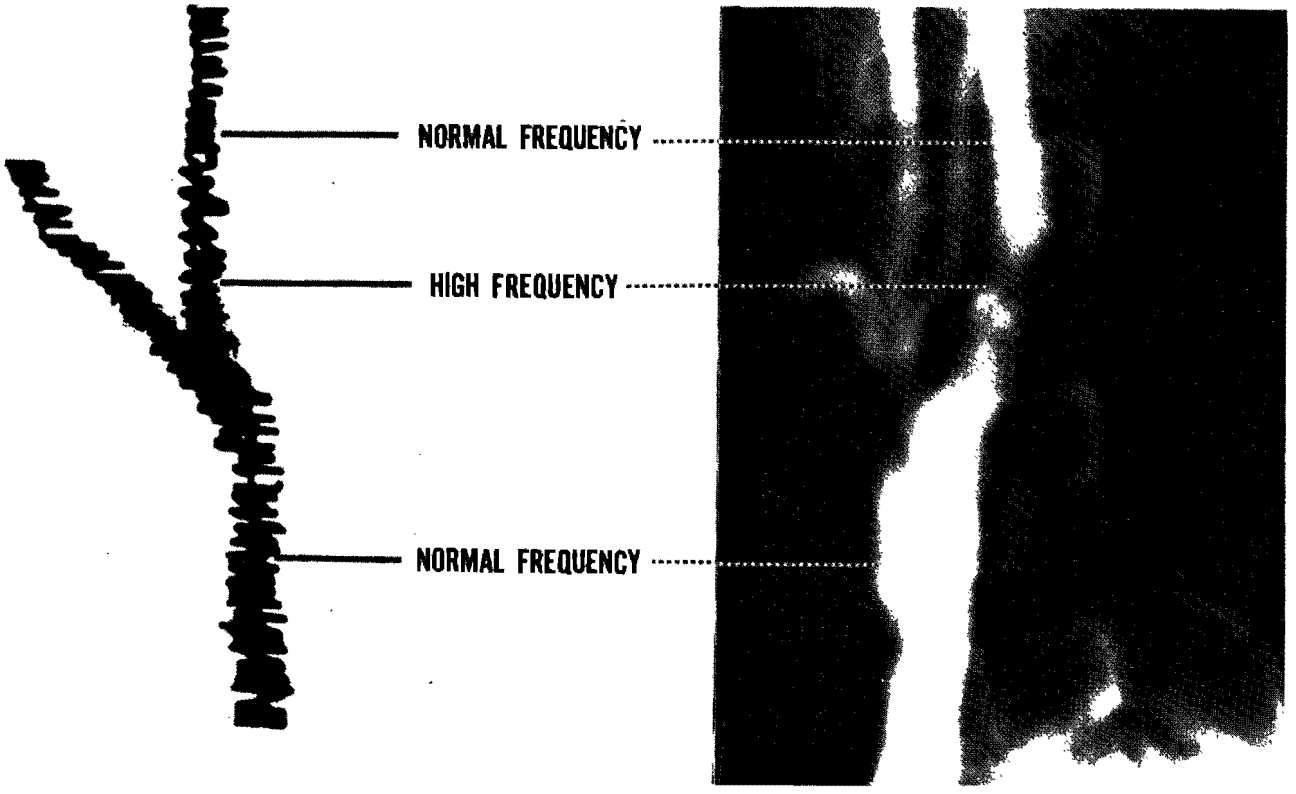

Figure 4. Dopscan image provides a guide for localization of high frequency Doppler signal associated with stenosis.

arteriography as well as noninvasive screening, we have been able to attain an overall accuracy of 93%.

Another advantage of multiple modality screening is that lesions can frequently be localized to a specific area in the carotid system. For example, a patient with a bilateral eye pulse delay and a cervical stenosis of one carotid artery probably has a contralateral carotid siphon stenosis.

Cerebrovascular atherosclerosis is a serious health problem. The noninvasive cerebrovascular examination can give important information to aid in the management of this condition. ★★★

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References

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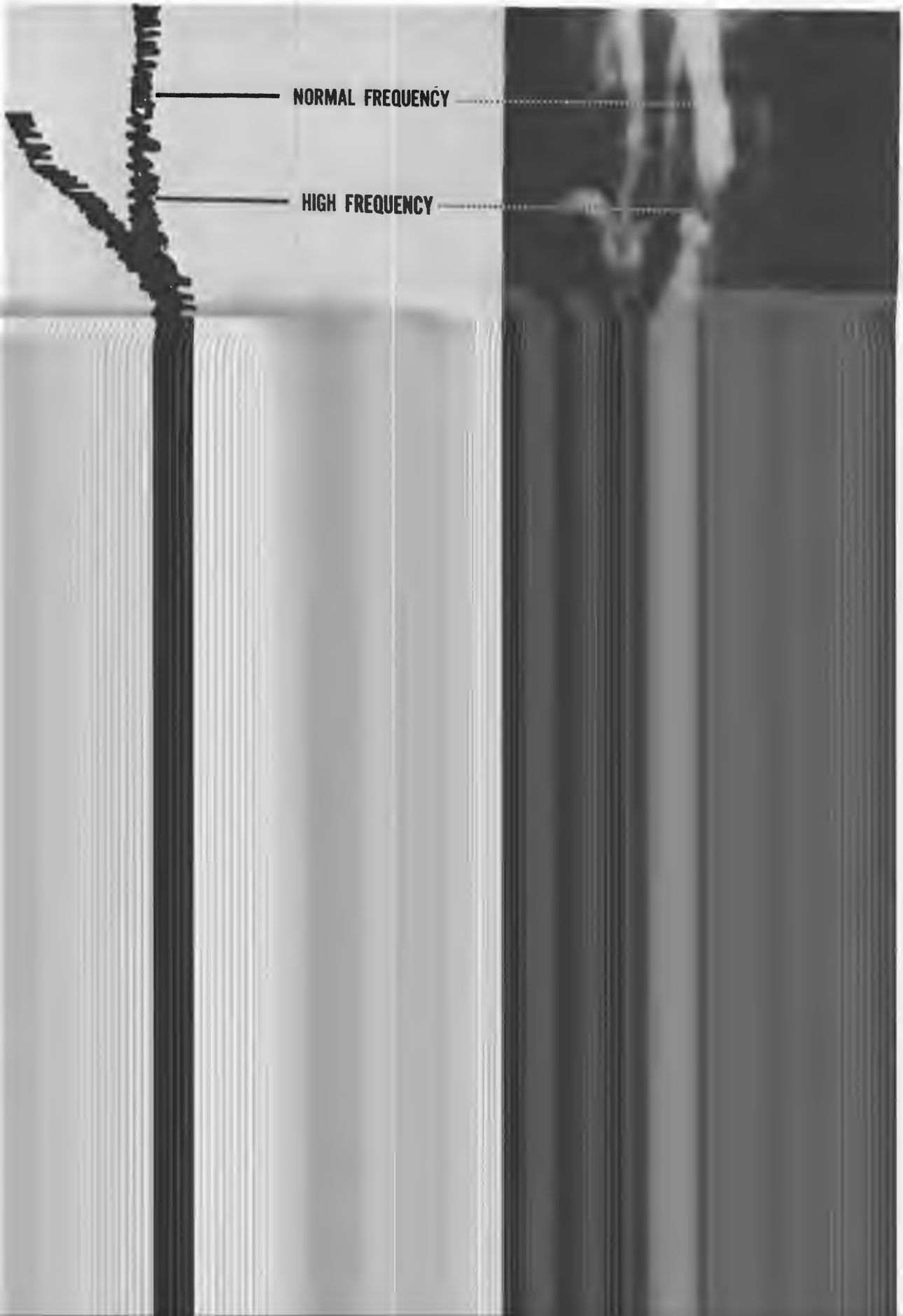
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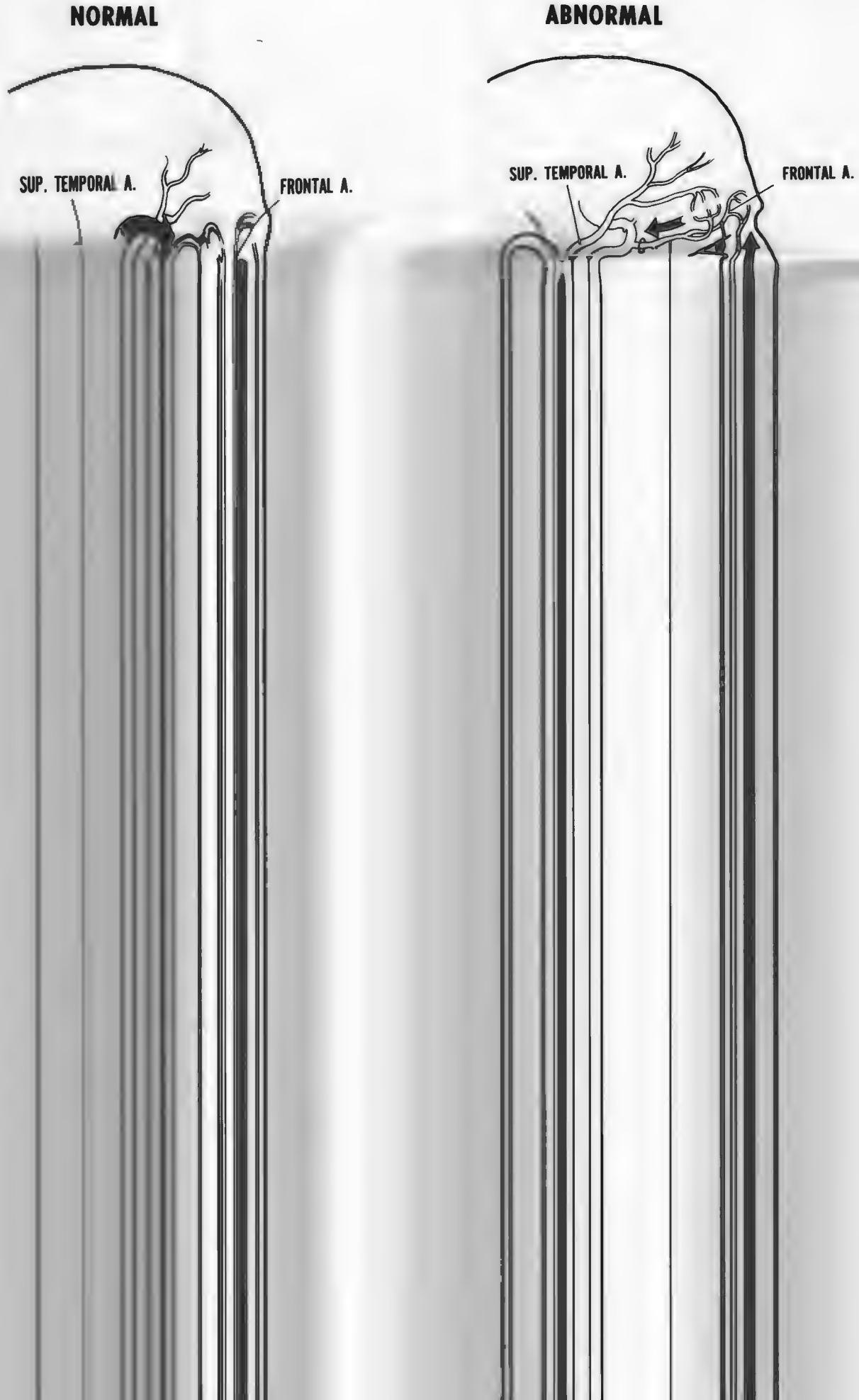
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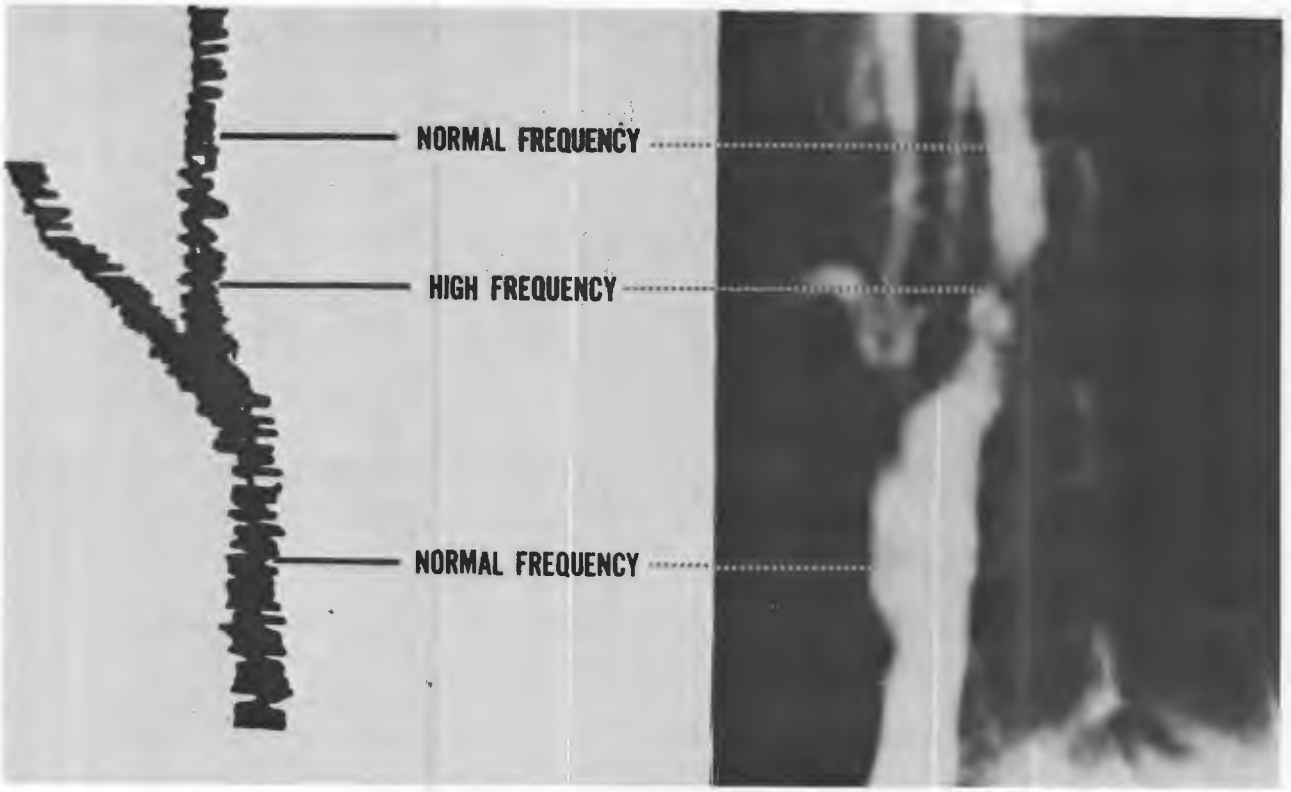

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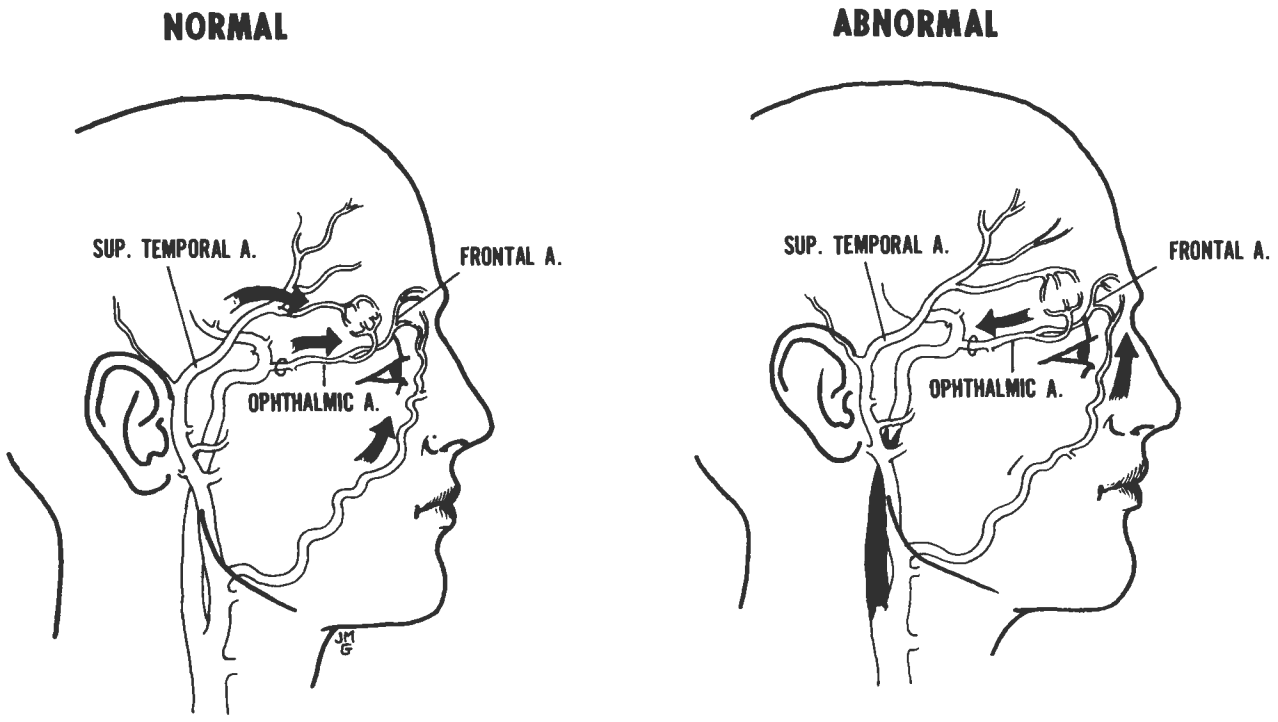

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