# Office Doppler Techniques in Vascular Disease

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The Doppler ultrasonic velocity detector is the least expensive and most versatile instrument used to screen patients for peripheral arterial, cerebrovascular, and venous disease. The Doppler detector provides qualitative and quantitative estimates of arterial and venous flow velocity and segmental arterial pressure measurements. The device can become as clinically useful as the stethoscope to screen patients for vascular disorders. New audiovisual instructional aids may make this technique a routine complement to the clinician's diagnostic resources.

The prevalence of peripheral arterial, cerebrovascular, and venous disease exceeds the frequency of coronary artery disease, and such peripheral vascular disorders require proper diagnosis and management to prevent significant disability and death. Unfortunately, the clinical history and physical examination are usually reliable only in patients with advanced peripheral arterial occlusive disease. Carotid artery atherosclerosis and venous diseases are often clinically silent and, conversely, are frequently diagnosed when not actually present. Although invasive studies, including contrast arteriography and phlebography (venography), are the diagnostic standards for evaluation of peripheral vascular disease, the risk, discomfort, and expense of these procedures precludes their routine application for screening and follow-up studies. During the past decade there has been increasing emphasis on noninvasive diagnostic techniques for the detection of peripheral vascular disease.[1] The Doppler ultrasonic velocity detector is the least expensive and most versatile method to evaluate peripheral arterial, cerebrovascular, and venous diseases. Many of the routine diagnostic studies that are possible with this instrument may be carried out in the office, clinic, or at the hospital bedside, using portable equipment. It is the purpose of this article to review the practical instrumentation, indications, techniques, and limitations of Doppler ultrasonic evaluation of peripheral arterial, cerebrovascular, and venous disease.

## Instrumentation

The Doppler detector contains an oscillator that causes a piezoelectric crystal in a hand-held probe to emit a beam of ultrasound. By coupling the Doppler probe to the skin with acoustic gel, the ultrasound is transmitted into the tissues. Sound reflected from moving blood cells is shifted in frequency by an amount proportional to the velocity of blood flow. The backscattered ultrasound is received by a second crystal, and the frequency shift

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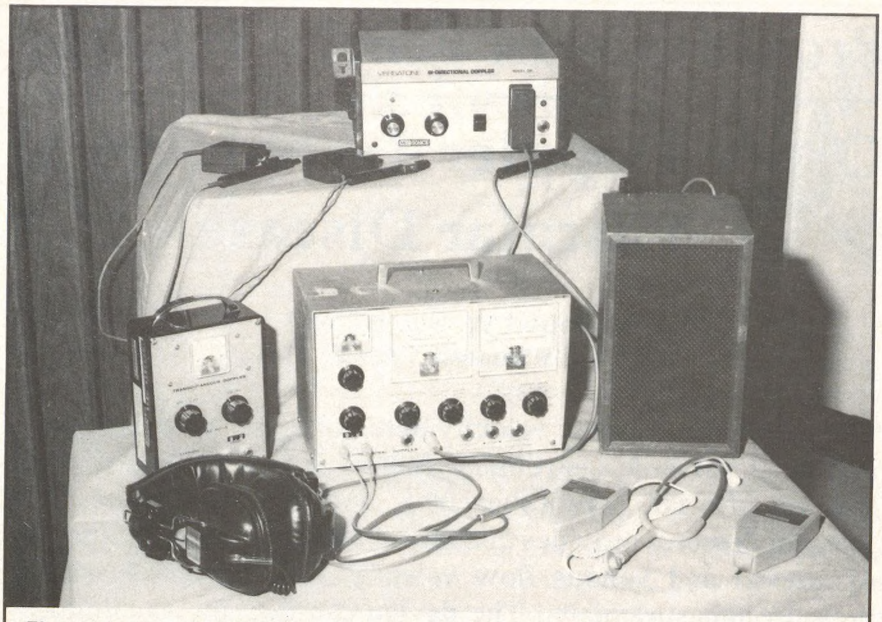

Figure 1. Portable nondirectional and directional Doppler ultrasonic velocity detectors

is detected and amplified by the instrument as an audible signal or a recordable analogue waveform. The least expensive Doppler devices are portable and are nondirectional; that is, they are incapable of determining whether the blood flow is moving toward or away from the Doppler probe. However, such portable instruments are very useful for screening for peripheral arterial and venous disease. Directional Doppler detectors are sensitive to the direction of blood flow velocity and are particularly useful for recording peripheral arterial signals and for performing Doppler cerebrovascular examinations. The portable nondirectional instruments are available for approximately $400, and such devices may be used with stethoscope-style ear pieces or with an accessory loudspeaker. Directional Doppler detectors cost between $850 and $2,000 and often are used with accessory strip-chart recorders. Such devices are particularly useful if a large number of patients will be screened, particularly for cerebrovascular or peripheral arterial disease, when permanent hard-copy recordings are desired. Figure 1 depicts various Doppler detectors that are useful for screening for peripheral vascular disease.

## Peripheral Arterial Evaluation

### *Indications*

Doppler screening is particularly useful to objectively confirm the presence of acute or chronic arterial occlusive disease. Patients with suspected arterial embolism or thrombosis may be rapidly screened for the presence and location of acute arterial occlusion and the severity of the circulatory impairment. Patients with suspected chronic atherosclerotic occlusive disease, including individuals with claudication, rest pain, ischemic ulceration, or gangrene, may be evaluated for the presence, location, and functional degree of arterial obstruction. The Doppler also permits screening of high risk patients such as those with diabetes mellitus, hyperlipedemia, known coronary artery disease, or hypertension for concomitant peripheral arterial occlusive disease. These techniques are also useful to predict the likelihood of success of arterial reconstruction, to monitor the peripheral circulation intraoperatively and in the early postoperative period, and to follow up the natural history or the influence of medical or surgical therapy on peripheral arterial occlusive disease.

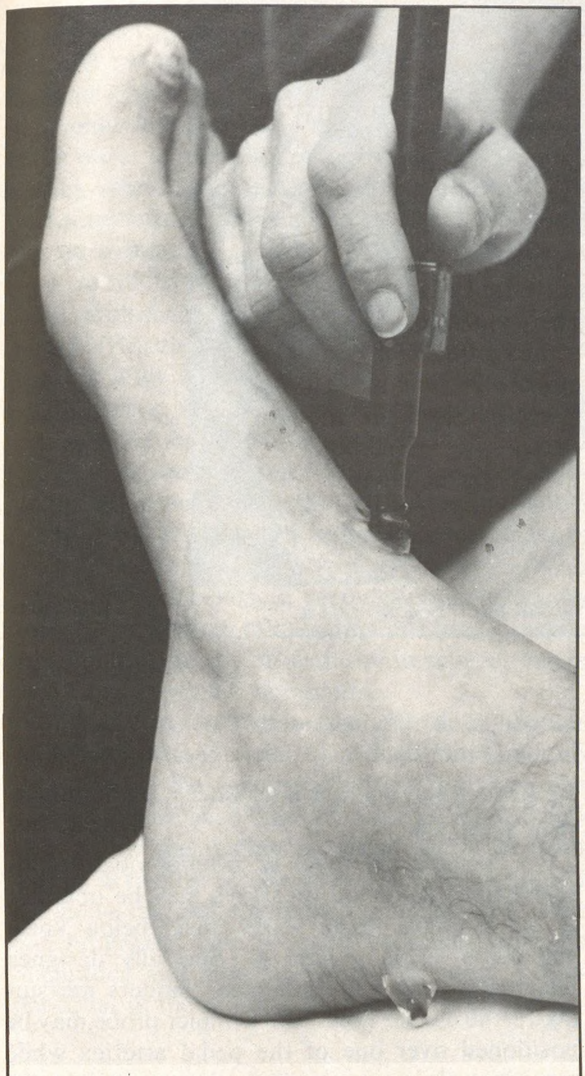

Figure 2. Doppler probe positioned over dorsalis pedis artery

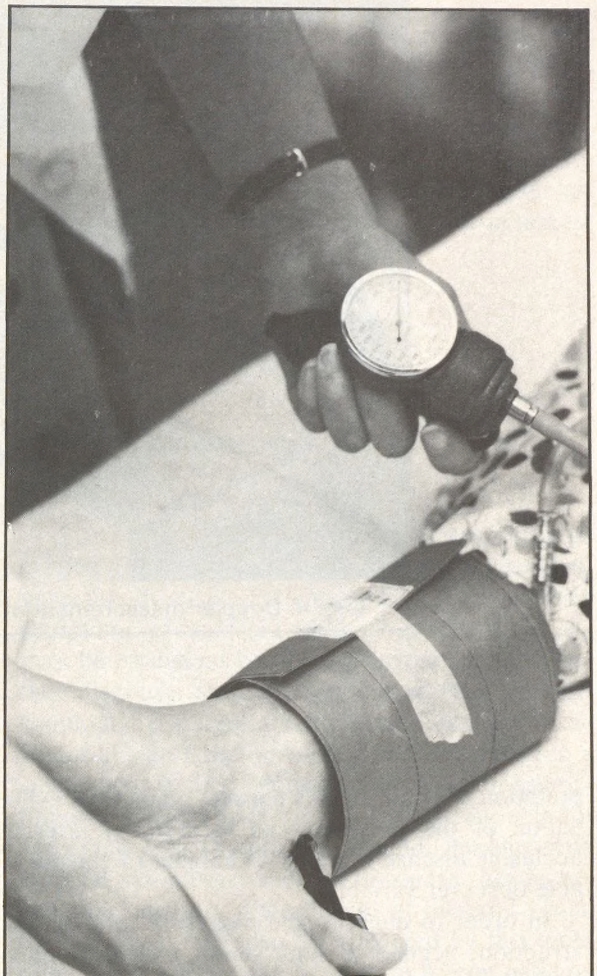

Figure 3. Doppler measurement of ankle systolic blood pressure

## *Technique*

Acoustic gel is placed on the skin overlying the artery at the usual site of palpation of peripheral pulses. The Doppler probe is coupled to the skin with the acoustic gel and is held at an angle of about 45 degrees with the skin surface (Figure 2). The probe is gently moved until the optimal arterial signal is elicited. The normal arterial signal is multiphasic with a prominent systolic component and one or more diastolic sounds. In the presence of arterial occlusive disease, the arterial signal distal to the obstruction will be attenuated and will be monophasic in character. Although the systolic sound may extend into diastole, the discrete diastolic sounds will be lost. Distal to severe arterial obstruction, there may be no audible Doppler arterial signal in the presence of severe ischemia. At the site of arterial stenosis, the arterial velocity signal will be of higher pitch. The Doppler arterial signals are elicited at the common femoral, popliteal, posterior tibial, and dorsalis pedis arteries in the lower extremity. In the upper extremity the subclavian, brachial, radial, ulnar, palmar arch, and digital arteries are examined. Audible inter-

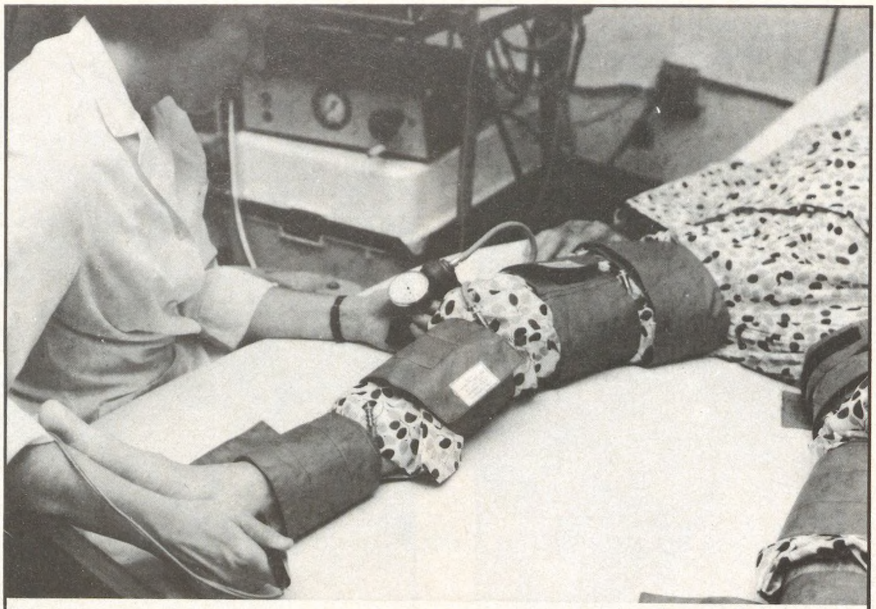

Figure 4. Doppler measurement of segmental leg blood pressure

pretation of these signals permits qualitative evaluation of the presence and location of arterial occlusive disease but may be subject to considerable observer variability.

In order to quantify the degree of arterial obstruction, segmental limb blood pressures may be measured by Doppler ultrasound. The best method to screen for peripheral arterial occlusive disease in the lower extremity is to measure the ankle blood pressure and relate it to that of the arm. A standard arm blood pressure cuff may be placed at the ankle and the Doppler probe positioned over one of the pedal arteries (Figure 3). The cuff is inflated until the arterial signal disappears. The cuff is then slowly deflated until the Doppler arterial signal returns at the systolic pressure of the ankle. The ankle pressure may be divided by the arm blood pressure to obtain the ankle pressure index (API). Normally the API is equal to or greater than 1.0. In the presence of arterial occlusive disease, the API will be less than 1.0 by an amount proportional to the degree of circulatory of impairment. Patients with claudication normally have an API between 0.5 and 0.9. Patients with rest pain, ischemic ulceration, or gangrene often have an API less than 0.5, and in such cases the absolute ankle pressure is often less than 50 mmHg.

To localize the level of arterial obstruction, segmental limb blood pressures may be obtained at the proximal thigh, above knee, below knee, and ankle levels (Figure 4). Specially designed pneumatic cuffs with inflatable bladders measuring 12×40 cm are used. The Doppler probe may be positioned over one of the pedal arteries while measuring the segmental limb pressures, since the pressure is determined by the location of the cuff being inflated, not by the location of the Doppler probe. Although the 12-cm-wide cuffs are relatively narrow, particularly on the thigh, the advantage of such cuffs is that proximal and distal thigh pressure measurements permit discrimination of aortoiliac (inflow) from superficial femoral (outflow) arterial occlusive disease.[2] Normally the proximal thigh pressure should be 20 to 30 mmHg above that of the arm, and there should be no more than a 20 to 30 mmHg pressure gradient between adjacent levels of pressure measurement on the limb. Aortoiliac obstruction is reflected by an abnormally low proximal thigh pressure measurement. Femoropopliteal artery occlusive disease is implied by an abnormal pressure gradient at the above knee or below knee level. Tibioperoneal (runoff) arterial occlusive disease of the calf is implied if there is an abnormal gradient between the below knee and the ankle cuffs.

In order to quantify the circulatory impairment during stress, the ankle blood pressure may be measured after a period of exercise, such as walking on a treadmill or standing repeatedly on the toes, or following temporary leg ischemia induced by a proximal thigh tourniquet (reactive hyperemia).[3] Normally the ankle blood pressure does not fall after a period of exercise at a standard walking pace. In the presence of arterial occlusive disease, the magnitude of the reduction in ankle pressure is proportional to the degree of circulatory impairment. The time taken for the ankle blood pressure to return to pre-exercise values is also related to the severity of the ischemia. With single vessel occlusion, recovery usually occurs within five minutes of cessation of exercise, while with multiple levels of occlusion recovery time is prolonged beyond five minutes.

During reactive hyperemia, after three minutes of leg ischemia induced by a thigh tourniquet inflated above the segmental systolic pressure, the ankle pressure should fall by no more than 35 percent below the resting level and should recover within 30 to 60 seconds. In the presence of arterial occlusive disease, the reduction in ankle pressure will be greater than is seen in normals while the magnitude and duration of the reduction is proportional to the severity of disease.

### *Limitations*

In advanced arterial occlusive disease, the Doppler arterial signals may be inaudible. In patients with vascular wall calcification, particularly in diabetes mellitus, the segmental limb blood pressures may be artifactually elevated. Indeed, the inability to compress the tibial arteries at the ankle by a pneumatic cuff, which makes ankle pressure measurement impossible, is pathognomonic of diabetes mellitus (terminal renal failure may also lead to tibial artery calcification). Patients with extremely obese legs may be impossible to evaluate for segmental limb pressures. Occasionally with severe inflow (aortoiliac) arterial occlusive disease, the presence of additional distal disease in the leg may be masked by the abnormally low proximal thigh pressure. There are few contraindications to screening for peripheral arterial occlusive disease with Doppler ultrasound, since this noninvasive technique is essentially without risk. Obviously patients with severe pain, ulceration, or inflammation may not be readily examined with a pneumatic cuff, but Doppler arterial signal analysis can be carried out in almost all circumstances.

## Cerebrovascular Evaluation

### *Indications*

A cerebrovascular Doppler examination may be carried out in any patient with suspected cerebrovascular disease. Patients who have suffered symptoms of transient ischemic attack or stroke may be evaluated by this technique, but the further diagnosis and management of such patients should not rest upon the findings of Doppler ultrasound alone. This limitation will be clarified in a subsequent section. Patients who have an asymptomatic cervical bruit are particularly suitable for screening with Doppler ultrasound. Patients with atypical symptoms, such as dizziness, headache, syncope, memory disturbance, or bilateral visual disturbances, may also be evaluated by this technique. The method can be used to screen patients at risk of having asymptomatic carotid lesions, such as those undergoing coronary artery bypass or major peripheral arterial reconstruction. Doppler examination also permits assessment of potential collateral hemispheric blood flow. Doppler ultrasound is particularly useful to monitor patients intraoperatively and in the early postoperative period following carotid endarterectomy. Finally, these techniques may be used to follow asymptomatic carotid disease or to assess the effect of medical or surgical therapy on known carotid lesions in patients who have suffered transient ischemic attack or stroke.

### *Technique*

The Doppler detector may be used to screen for carotid occlusive disease, both indirectly and directly. Indirect, or periorbital, Doppler examination involves the assessment of directional blood

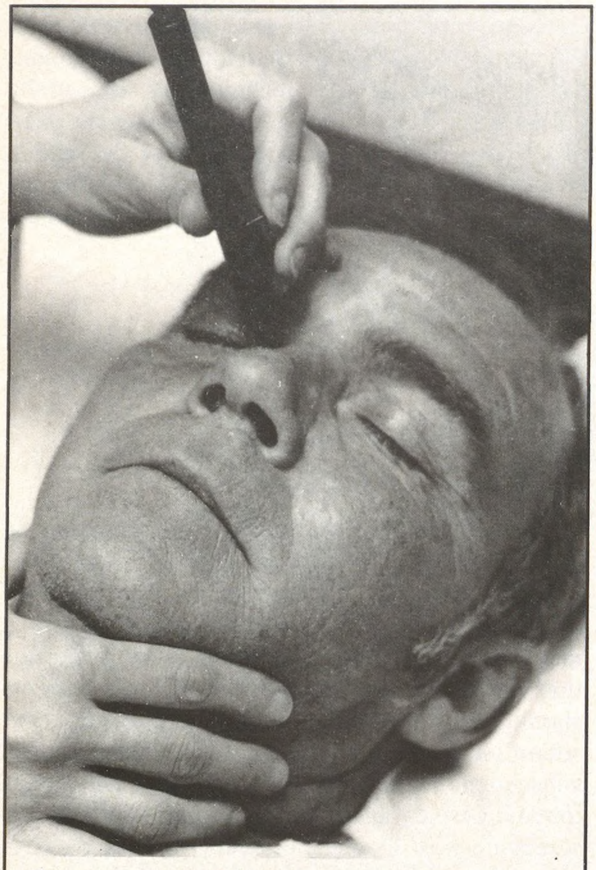

Figure 5. Periorbital Doppler evaluation of ophthalmic artery flow direction

flow in branches of the ophthalmic artery (Figure 5). A directional Doppler probe is positioned over the frontal artery immediately above the inner canthus of the eye. Normally this artery, which is a branch of the ophthalmic artery, carries blood flow antegrade out of the orbit. In the presence of severe stenosis (>75 percent) or occlusion of the extracranial internal carotid artery, flow may be reversed in the ophthalmic artery. This may be documented by compressing various branches of the external carotid artery, including the superficial temporal, infraorbital, and facial arteries. Normally the ophthalmic artery flow is unaffected or even augmented by such compression maneuvers. However, in the presence of reversed ophthalmic artery flow, the Doppler signal may be attenuated by compressing one of these extracranial sources of collateral circulation to the ophthalmic artery. Intracranial collateral via the circle of Willis may be assessed by transient common carotid artery compression low in the neck to avoid stimulating carotid baroreceptors or dislodging cerebral emboli from a diseased carotid bifurcation. Normally transient carotid compression should result in decreased ipsilateral ophthalmic artery flow. If the flow decreases, but remains antegrade during common carotid compression, good collateral hemispheric circulation (via the circle of Willis) is inferred.[4] If ophthalmic artery flow ceases or is reversed during carotid compression, poor hemispheric collateral flood flow is implied. If contralateral carotid artery compression attenuates ophthalmic artery flow, then intracranial collateral circulation from the opposite internal carotid artery is implied. If compression of each carotid artery in turn fails to attenuate ophthalmic artery flow, vertebrobasilar artery collateral circulation via the circle of Willis is inferred. The accuracy of the periorbital Doppler examination exceeds 90 percent in detecting severe stenosis or occlusion of the internal carotid artery.[5] However, the technique is insensitive to less than 75 percent stenosis, and it cannot distinguish a severe stenosis, which is operable, from an occlusion, which is generally considered inoperable by extracranial reconstructive techniques.

In order to detect less severe carotid occlusive disease and to distinguish carotid stensosis from occlusion, direct carotid Doppler examination in the neck may be performed (Figure 6). The directional Doppler probe is initially positioned over the common carotid artery, low in the neck, just above the clavicle. With the probe angled cephalad, a direction sensing switch may be depressed so that flow is heard only away from the probe, namely, in the common carotid artery, not in the adjacent internal jugular vein. The Doppler probe is then moved along the course of the carotid artery until the carotid bifurcation is reached. At this point there will be a slight change in pitch of the signal. The common carotid artery signal usually consists of prominent forward flow both in systole and diastole. When the internal carotid artery is reached, the Doppler pitch increases significantly because of the increased flow in the internal carotid artery supplying the low cerebral vascular resistance. The internal carotid artery is followed

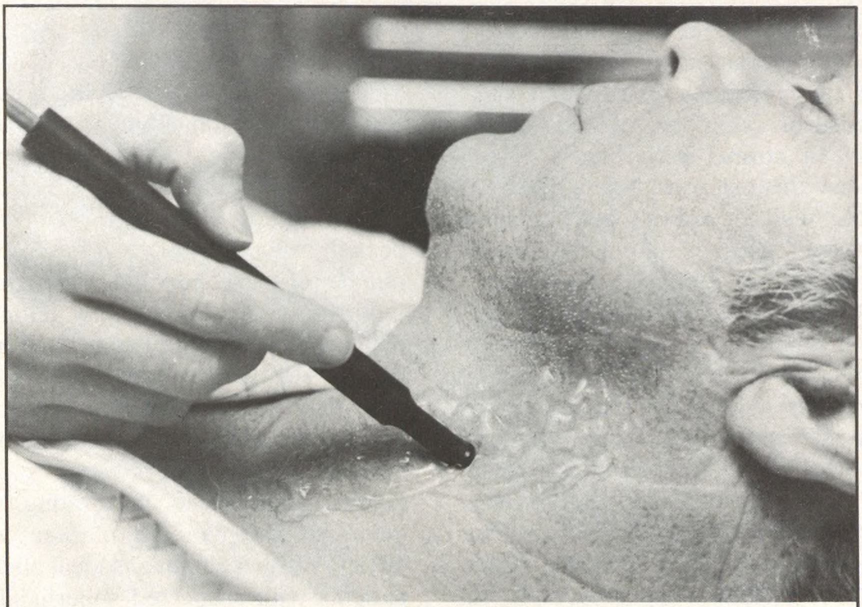

Figure 6. Direct carotid Doppler examination

along its course between the anterior border of the sternocleidomastoid muscle and the angle of the jaw. The Doppler probe is then repositioned over the carotid bifurcation, and the external carotid artery signal is elicited. Normally the external carotid artery carries lower flow velocity because of the increased peripheral vascular resistance of the face and scalp. The normal external carotid signal is multiphasic with a prominent systolic component and one or more diastolic sounds, with relatively low diastolic flow velocity.

Normally the carotid artery signals are smooth and pulsatile. At the site of carotid stenosis the Doppler pitch will increase in proportion to the severity of the stenosis. Distal to a stenosis the signal may become more "fluttery" or "bubbly" as a result of disturbed or turbulent blood flow. Occasionally a low pitched, gruff signal may be heard, which usually correlates with a carotid bruit. In the presence of occlusion of a carotid segment, no Doppler signal may be detected at the expected location. On the side of an internal carotid artery occlusion, the common carotid artery signal may be attenuated and have relatively low diastolic flow, similar to peripheral arterial signals. The ipsilateral external carotid signal may have increased pitch because of compensatory increased collateral flow to the ophthalmic artery. The contralateral common carotid artery may also carry increased collateral blood flow in the presence of internal carotid artery occlusion. The accuracy of direct carotid Doppler examination may exceed 90 percent in detection of greater than 50 percent stenosis or occlusion of the internal carotid artery. These two conditions should be distinguished in approximately 85 percent of cases. Occasionally less than 50 percent stenoses may be detected by this technique.

## Limitations

The periorbital Doppler examination is insensitive to carotid occlusive disease that does not result in at least 75 percent reduction in diameter of the internal carotid artery. It must be realized that the majority of hemispheric transient ischemic attacks or strokes are probably on the basis of emboli from a diseased carotid bifurcation.[6] Such emboli may occur from ulcerated carotid plaques or carotid stenoses, which do not significantly impair blood flow and thus would not be detected by periorbital Doppler screening. This limitation is emphasized by the fact that more than 50 percent of patients who are candidates for carotid endarterectomy because of symptoms of cerebral ischemia will have a normal periorbital Doppler examination.[7] Thus this test cannot be a basis for deciding upon the need for arteriography of such symptomatic patients. All such individuals should probably undergo cerebrovascular arteriography, particularly if they would be candidates for carotid endarterectomy if an appropriate extracranial vascular lesion were found. A second major limitation to periorbital Doppler screening is that an abnormal examination does not distinguish between operable carotid stenoses and inoperable carotid occlusion. This distinction is particularly important and can only be established with certainty by contrast arteriography. However, recently direct carotid Doppler examination has proved useful to distinguish these two carotid lesions.[8] This test also is more sensitive to nonobstructive plaques. However, direct carotid Doppler audio-examination still fails to detect a number of patients with nonobstructive plaques or ulcerated lesions, which may be the source of cerebral emboli. Furthermore, in the absence of ultrasonic imaging capability, errors of interpretation may result from anatomic variations or altered flow velocity due to changes in angle of the artery with respect to the ultrasonic beams. For this reason the physician must always consider contrast arteriography in any patient with suspected cerebral ischemia. In patients with asymptomatic carotid bruit or nonlateralizing cerebrovascular symptoms, a decision about management may rest upon the Doppler results of an experienced examiner. However, it should be realized that the natural history of such patients remains unknown.

## Venous Evaluation

### *Indications*

A Doppler venous examination is particularly useful to screen patients with suspected deep vein thrombosis. Patients who present with pain, tenderness, Homan's sign, leg swelling, inflammation, prominent superficial veins, or unexplained fever may be screened for possible leg vein thrombosis. It has become increasingly apparent that the clinical diagnosis of deep vein thrombosis is seldom more than 50 percent accurate.[9] The history and physical examination are both insensitive and nonspecific, and are accompanied by frequent false negative and false positive diagnoses. The Doppler is also useful to screen patients with suspected recurrent deep vein thrombosis, since a number of these individuals may have been previously misdiagnosed and may actually have a normal venous system. Patients with recurrent leg pain or edema after proven previous venous disease may actually have postphlebitic syndrome and not recurrent active venous thrombosis. The Doppler examination is useful to identify incompetence of the deep, perforating, and superficial veins in patients with chronic venous insufficiency.[10] The technique is ideal also for evaluating patients with suspected superficial thrombophlebitis[11] because such patients may actually have lymphangitis or cellulitis, which require different treatment. The Doppler can also screen patients with suspected pulmonary emboli for a site of venous thrombosis in the upper or lower extremities.[12] Finally, the Doppler technique is the most rapid and portable method to screen patients at risk of developing deep vein thrombosis,[13] such as those individuals suffering trauma, general surgery, orthopedic procedures, or patients with congestive heart failure.

### *Technique*[14]

The patient is examined in the supine position, preferably with the head of the bed elevated to permit pooling of blood in the lower extremities. Stockings and footwear are removed. The leg is positioned with slight flexion of the knee and hip and external rotation of the hip. The posterior tibial vein is initially examined at the ankle (Figure 7). The venous signal is phasic with respiration, although in the presence of cool, vasoconstricted extremities, no posterior tibial venous signal may be heard. In such instances, the venous velocity may be augmented by gently squeezing the foot. The competence of the deep venous valves are assessed by compressing the calf, which normally should interrupt posterior tibial venous flow. In the presence of deep venous incompetence, a reflux flow signal may be heard during calf compression.

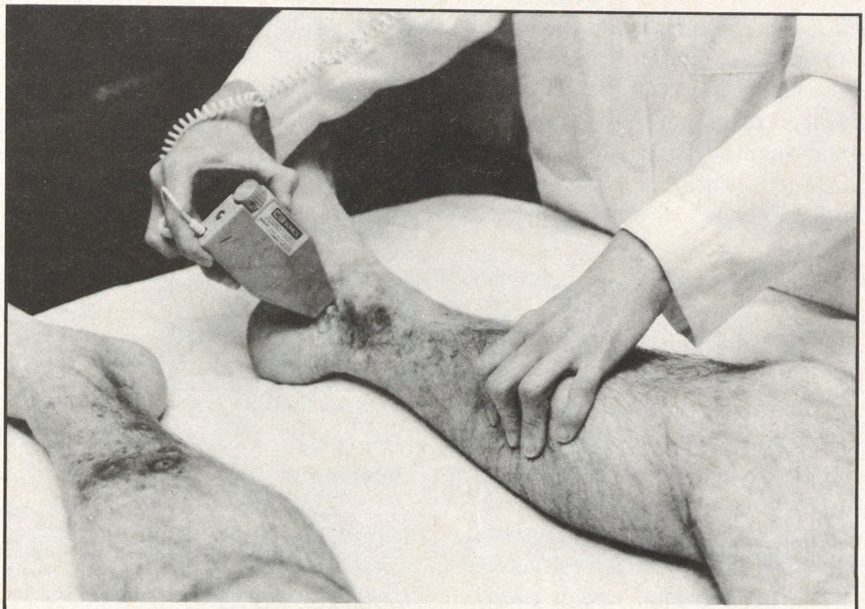

Figure 7. Doppler examination of deep calf (posterior tibial) veins

Release of calf compression should result in augmentation of posterior tibial venous flow. In the presence of calf vein thrombosis, this augmentation may be attenuated or absent. Next, the Doppler probe is positioned over the common femoral vein in the groin, just medial to the palpable common femoral artery pulse. The femoral venous signal should be phasic with respiration and sound like a cyclic low pitched windstorm. When the venous system is normal, the femoral venous signal should be augmented by calf or thigh compression, but such flow acceleration may be attenuated or absent in the presence of superficial femoral or calf vein thrombosis. A Valsalva maneuver or manual compression of the abdomen should interrupt venous flow unless the venous valves are incompetent, in which case a reflux venous flow signal will be elicited. Finally, the venous signal characteristics are elicited in the superficial femoral vein in the midthigh as well as the popliteal vein.

The Doppler is also useful to screen for subclavian or axillary vein thrombosis. The Doppler probe is positioned above the clavicle to elicit the subclavian venous signal, which may be pulsatile with each heart beat as well as cyclic with respiration. The axillary vein may be heard beneath the clavicle. Superficial veins in the lower extremities, particularly along the greater or lesser saphenous vein, may be heard by gentle application of the Doppler probe over the course of the vein. In the presence of vasoconstriction, the venous signal may not be heard spontaneously, but it may be elicited by distal limb compression. In the presence of varicose veins, incompetence of the saphenous veins may be documented by having the patient perform a Valsalva maneuver or by proximal compression along the course of the saphenous vein. Incompetent perforating veins in the lower leg, particularly on the medial aspect above the medial malleolus, may be examined with a Doppler probe.[15] The probe is positioned over the entire medial surface of the lower leg while compressing the calf above a rubber tourniquet, which prevents reflux in superficial veins. Incompetent perforating veins are implied if transient reflux flow signals are elicited in response to calf compression maneuvers.

Although the Doppler venous examination requires considerable practice in order to gain familiarity with the signal patterns in health and disease, an experienced examiner may eventually achieve a diagnostic accuracy exceeding 90 percent when compared to contrast phlebography in the assessment of deep venous thrombosis.

### *Limitations*

The greatest limitation of the Doppler venous examination is the subjective nature of the test, which requires many months of experience in order to recognize normal and abnormal venous flow signals. Such education may be enhanced by an audiovisual instructional program, which includes tape recordings of normal and abnormal venous flow signals. The technique is insensitive to nonobstructive venous thrombi, and it rarely detects minute calf vein thrombosis, which frequently occurs following operation, trauma, or orthopedic procedures. Nevertheless, major calf vein thrombosis can be determined by this technique.[16] The Doppler technique is somewhat nonspecific, inasmuch as any condition that extrinsically compresses the venous system may result in an abnormal Doppler signal. In such instances an abnormal signal is elicited, but the diagnosis of venous thrombosis cannot be established with certainty. Thus, in patients with trauma or malignant tumors, extrinsic venous obstruction can only be established by contrast phlebography. However, in most clinical circumstances the presence of an abnormal Doppler examination in a situation compatible with venous thrombosis is sufficient objective evidence to permit treatment of the patient with anticoagulants. In experienced hands, the use of a Doppler venous examination has proved to be cost beneficial.[17]

## Conclusions

The Doppler ultrasonic velocity detector permits both qualitative and quantitative documentation of the presence, location, and severity of peripheral arterial, cerebrovascular, and venous disease. The technique is most readily applied in peripheral arterial disease, although cerebrovascular and venous screening techniques may be learned, particularly through the aid of audiovisual instructional programs. These techniques are particularly helpful to establish the diagnosis in clinically suspected instances of vascular disease, to screen high risk patients, to predict therapeutic results, to monitor medical or surgical therapy, and to follow up the natural history or the influence of treatment of peripheral vascular disease.

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