ROLE OF NON-INVASIVE VASCULAR STUDIES

Thomas J. Chang, DPM

James Poindexter, M.D.

Peripheral vascular disease is a very common and debilitating disorder. As medical advances continue to improve and the population continues to live longer, the prevalence of vascular disease will also continue to increase. Successful treatment and timely referral of these disease states depends essentially on our ability to recognize vascular pathology. The podiatrist will routinely be the primary physician to encounter vascular disease and efforts to heighten clinical awareness plays an invaluable role in patient management.

Along with the clinical vascular examination, a more complete evaluation of both arterial and venous pathology can be assessed with non-invasive vascular studies. Non-invasive techniques performed within the office or in vascular laboratories can not only verify the presence of vascular disease but also define the extent of disease. These examinations can also indicate the most suitable form of therapy and suggest the predicted outcome. Non-invasive vascular studies provide an excellent method of identifying those patients who might require more invasive testing or who are possible candidates for surgery.

The discussion of vascular testing will be divided into the arterial system (Table 1) and venous system (Table 2). Peripheral arteries are assessed by several techniques, which include Doppler, plethysmography, and segmental pressure readings. The majority of venous studies are directed towards diagnosis and documentation of deep vein thrombosis. Recently, development in state of the art duplex scan imaging for arterial and venous pathology has shown promise and gained increased popularity.

A thorough history and physical is first obtained from the patient. The patient is then placed in a supine, recumbent position for at least 15 minutes prior to the examination. The extremities should be kept warm by maintaining a correct room temperature.

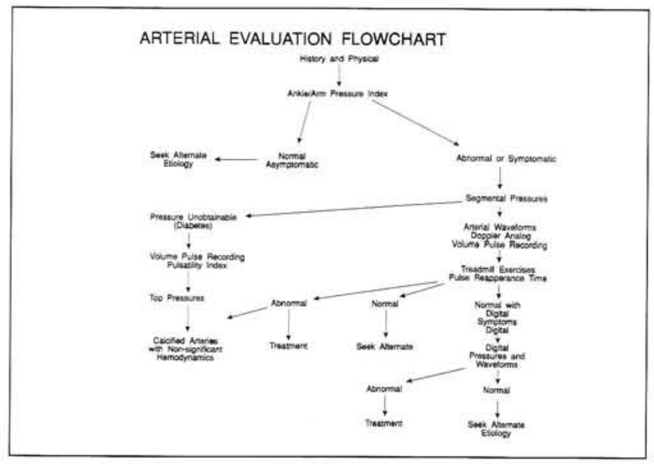

Table 1.

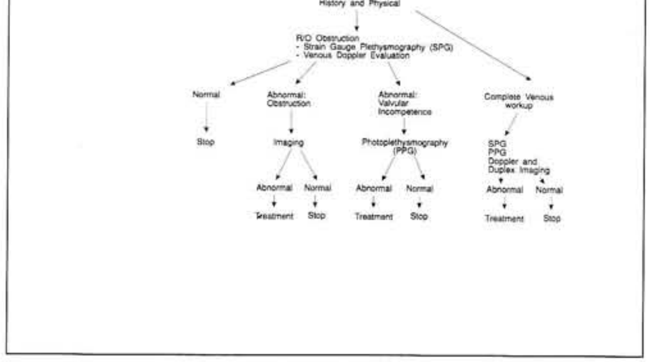

Table 2.

ARTERIAL EVALUATION

Ankle/Arm Index

Also known as the Ankle/Brachial Index, this is a simple and reliable index which defines the severity of arterial disease in the lower extremities. Each ankle pressure is divided by the highest brachial systolic pressure to obtain this ratio. Normal values are >=1, and abnormal <1. Values less than 1 have been separated into claudication (ABI 0.6-0.9) and severe occlusive (ABI <0.5) states. Claudication is seen in moderate stenosis and occlusive states, and generally presents with intermittent pain during exercise.

Segmental Pressures

While the ABI defines the severity of the disease, the segmental pressures localize the level of involvement. A four-cuff method is commonly employed at the following locations: ankle, below knee, above knee, and upper thigh. A Doppler probe is placed over either the DP or PT artery, whichever is stronger. Each cuff is inflated to a level above the systolic pressure. As the Doppler signal disappears, the cuff is slowly released and allowed to deflate. As the Doppler signal returns, the systolic pressure is recorded. Standard values for the segmental levels should follow the guidelines below. (Fig. 1)

Brachial systolic pressure - Reference point for indices. Bilateral pressures should be obtained without greater than a 10mm Hg discrepancy between the two. A discrepancy of these values greater than 10mm Hg indicates a possible upper extremity stenosis.

Upper Thigh systolic pressure - usually 20 - 30 mm Hg above the brachial pressure. Stenosis of the aorta, iliac artery, or common femoral artery can lower pressures at this level.

Above Knee systolic pressure - Usually 20 - 30 mm Hg below the upper thigh pressure and should be at least the value of the brachial pressure. Superficial femoral artery stenosis will lower this value.

Below Knee systolic pressure - usually 20 - 30 mm Hg below the above knee pressure. Low pressures are indicative of distal superficial femoral or popliteal artery obstruction.

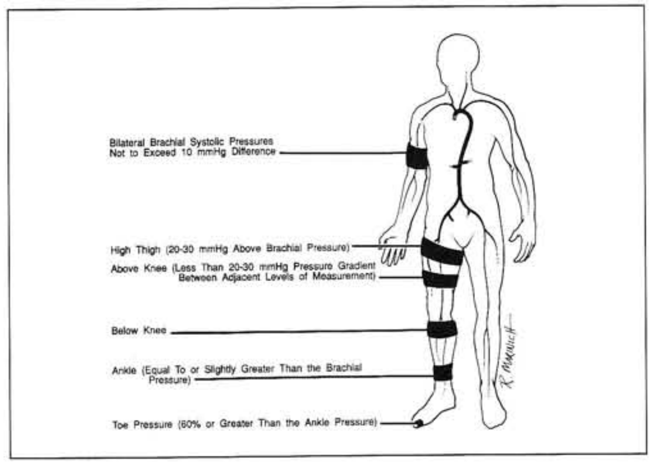

Fig. 1. Segmental Pressure Measurements

Ankle systolic pressure - greater than or equal to the brachial pressure. Abnormal values suggest tibio-peroneal occlusive disease usually involving two or three of the major vessels (posterior tibial, dorsalis pedis, anterior tibial).

Artifacts may cause erroneous readings and can occur for several reasons. Extreme obesity may distort the pressure measurements because of disproportionate placement. Calcified vessels seen in diabetic patients give falsely elevated values due to non-compressibility of the vessels. Multiple vessels at the recording site, or lack of vessels due to collateralization can also give inaccurate readings.

Doppler Waveform analysis

Doppler exams will provide wave morphology to correlate with segmental pressures. Proper positioning and localization is important for accurate evaluation due to the ability of the device to receive signals from all vessels in the field of view. The doppler probe will emit a certain wave frequency which is altered by any object moving faster than 6 cm/sec. The faster the blood flow, the stronger the reflected signals will become. The signal received can be processed in several forms, including audio signal, visual meter deflections, and analog waveform tracing. Doppler analysis is performed for the common femoral, superficial femoral, popliteal, posterior tibial, anterior tibial, and dorsalis pedis arteries. Recordings are obtained bilaterally for comparison and evaluation of both extremities.

Fig. 2A. Normal doppler signal flow with a "triphasic" waveform.

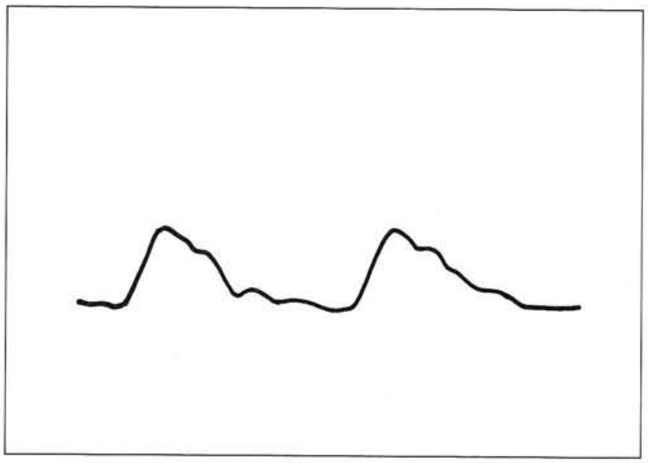

Fig. 2B. Abnormal doppler signal flow with a "monophasic" waveform.

The Doppler signal for a normal arterial flow is termed "triphasic" or "multiphasic". (Fig. 2A) The initial phase is the systolic phase of blood flow and actually represents the arterial pulse. Early diastolic reverse flow causes the second phase and is proportional to the elasticity and resistance of the vessel. This is actually a short proximal flow phase due to vessel resistance. The healthy vessel will recoil and produce a third phase which indicates good arterial compliance if present. If the limb is in mild Trendelenburg, there can be a fourth phase seen by gravity overcoming the weakening arterial pulse and causing mild proximal flow. In organic occlusive disease, the intima is narrowed and vessels are calcified. These are commonly "monophasic" due to the high resistance of the diseased vessel. (Fig. 2B)

Digital Pressures and Waveforms

In addition to assessing the circulatory status of the digits, digital analysis can prove useful when ABI's cannot be obtained. The digital waveforms are a simple and quick form of verifying arterial flow, especially in the pediatric patient. The toe cuff utilizes photo-plethysmography to record a similar waveform as described above. Unlike the other arteries, only one sound is heard within the digits because of the small diameter and higher resistance of the vessel.

Pressure recordings are performed by inflating a digital pneumatic cuff until the pulse disappears. The cuff is carefully monitored to record the reappearance of the pulse waveform (pulse reappearance time). Normal values of toe systolic pressure are less than brachial pressure and >=60% of the ankle pressure.

Sympathetic activity can also be demonstrated by digital analysis. The patient performs deep inspiration and expiration while waveforms are continuously recorded. Deep inspiration or vasoconstriction will cause a significant decrease in the pulse amplitude. The response returns to normal with expiration. In cases of Raynaud's or advanced arterial disease, there will be attenuation of this response.

VENOUS EVALUATION

Doppler Waveforms

This examination helps to determine the patency and valvular competency of particular veins. The veins to be examined include the deep venous (posterior tibial, popliteal, superficial femoral, and common femoral veins) and superficial venous (greater saphenous and perforating veins) systems. Each vein is examined for the following venous qualities:

Spontaneity - All veins except the posterior tibial should elicit a spontaneous signal. The posterior tibial may often be in a vasoconstricted state. A missing spontaneous signal with any other vein signifies pathology.

Phasity - Variation of pitch varies with respiration. In deep inhalation the venous sounds discontinue, yet augment with expiration.

Augmentation - Compression maneuvers (Valsalva or external compression) will increase venous flow in a patent vessel.

Competency - Proximal compression can demonstrate valvular competency by the recorded signal. Reflux from an incompetent vein will cause positive and negative deflections, whereas normal valves will only elicit a negative deflection.

Pulsatility - There should be no pulsatility noted with venous doppler sound. Chronic heart failure, venous hypertension, and fluid overload will cause this to occur.

Plethysmography

This area includes both Strain Gauge plethysmography and Photoplethysmography. These are described below:

Strain Gauge - This study measures volume changes in the limb induced by change in limb circumference. A fine elastic silicone rubber tube filled with an electrically conductive alloy (strain gauge) is gently stretched around the limb. The electrical resistance of the alloy is proportional to its length and area. Any change in the limb circumference will be recorded as a change in the electrical resistance. This technique is very accurate for determining patency of the major veins in the lower extremity and provides a safe, reliable method of screening DVT patients.

The parameters utilized to judge patency are venous capacitance (expansion) and maximum venous outflow. The maximum increase in calf volume during venous occlusion is termed venous capacitance. Normal values range from 2 - 3 mls/100 mls of tissue. Values below 1 ml/100 ml strongly indicate limited venous expansion. Maximum venous outflow is obtained by measuring the outflow between 0.5 - 2.0 seconds after release of the venous cuff. In the presence of DVT, the partial distension of the veins will decrease both of these parameters below normal.

Photoplethysmography - This test provides a qualitative measurement of the venous refilling time and assessing valvular incompetency. The photoelectric cell sensor is attached to the medial leg approximately 6 cm above the malleolus. The patient is instructed to exercise by dorsiflexing his feet for 10-15 seconds and then relax, venous refilling will then take place. The recovery time from the end of the exercise to the leveling of the refill time is calculated. In normal patients, >=20 seconds should be noted. Refilling time <20 seconds is considered valvular incompetency.

The procedure can be repeated with a tourniquet below the knees to occlude the superficial venous system. While inflated, the same test is performed to determine if the superficial or deep system is diseased. Primary valvular incompetency (superficial system) is present if the refilling time returns to normal with tourniquet application. If the refilling time is still abnormal, then secondary incompetency (deep system) is determined. This determination will aid in treatment and surgical procedures. As always, artifacts can occur with improper exercising, misplacement of the photoelectric cell, and tense muscles.

Bibliography

Bernstein EF: *Noninvasive Diagnostic Techniques in Vascular Disease.* C.V. Mosby Company, St. Louis, 1985.

Fronek A: *Noninvasive Diagnostics in Vascular Disease.* McGraw-Hill Book Company, New York, 1989.

Levin J, Zier BG, Grandinetti GM, Hoffman AF: Peripheral Vascular Disease. In Zier BG (ed) *Essentials of Internal Medicine in Clinical Podiatry.* WB Saunders, 1990.