

UNDERSTANDING THE ANKLE BRACHIAL PRESSURE INDEX TO TREAT VENOUS ULCERATION

Measuring ankle systolic blood pressure and calculating an ankle brachial pressure index (ABPI) is crucial for the non-invasive assessment of peripheral vascular disease (PVD). More recently, the technique has become an important aspect of lower limb wound management, helping clinicians to assess patients with venous ulceration to establish suitable treatment options.

KEY WORDS

- ▶▶ Ankle brachial pressure index (ABPI)
- ▶▶ Venous ulceration
- ▶▶ Doppler principle
- ▶▶ Systolic pressure
- ▶▶ Diastolic pressure

The measurement of ankle systolic blood pressure and the calculation of an ankle brachial pressure index (ABPI) is one of the fundamental non-invasive techniques used to assess peripheral perfusion. The methodology was established in the 1960s (Vowden et al, 1996; Caruana et al, 2005) and has, for nearly 50 years, been an integral part of vascular assessment, defining the physiological consequences of atherosclerotic arterial disease, in terms of peripheral perfusion pressure.

More recently, the technique has become one of the key elements of lower limb wound management, determining treatment options for patients with venous ulceration (Royal College of Nursing, 1998; SIGN, 2010).

The technique does have limitations but when correctly applied has been shown to offer a valid, reliable and reproducible measure of lower limb arterial disease (Vowden et al, 1996; Caruana et al, 2005).

REST THE PATIENT

Before undertaking any blood pressure measurement, the room should be quiet and at a comfortable temperature and the patient should be relaxed, comfortable and have rested for at least five minutes (O'Brien et al, 2003).

When taking lower limb systolic pressure readings, the resting period may need to be longer. For patients with severe arterial disease the resting period may need to

be as long as 25 minutes (Yao, 1970), as muscle metabolic activity during exercise results in local vasodilation induced by the release of chemical mediators.

In normal individuals there is an increase in total limb blood flow without a fall in pressure. However, in the presence of arterial stenotic disease, pressure in the distal vascular bed falls and remains low until the vasodilators are cleared from the limb. Therefore, mild-to-moderate peripheral vascular disease causes a fall in the ABPI after exercise, the recovery period reflecting the severity of the arterial disease (Caruana et al, 2005). For a normal subject who has not exercised, a resting period of five minutes will usually suffice but if the systolic pressure is reduced and the ABPI of less than 1, readings should be repeated after a further period of five minutes rest or until results are stable.

CHOOSE A SENSOR

A number of different sensors can be used to detect the onset of blood movement during occlusive blood pressure measurement. These include:

- ▶▶ A traditional stethoscope
- ▶▶ An ultrasonic detector using the Doppler principle to detect blood cell movement
- ▶▶ A strain gauge which calculates blood flow and, hence, pressure by measuring electrical resistance changes. It uses an extendable band placed around a limb or digit to detect small changes in volume (Nielsen and Rasmussen, 1973)
- ▶▶ Detectors that register changes

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Figure 1. How to perform a Doppler assessment

- ▶ Explain procedure (reduce anxiety) – anxiety may falsely elevate systolic pressure
- ▶ Position subject (supine) – limb elevation or dependency in relation to heart level will affect systolic pressure
- ▶ Rest subject (20 minutes) – exercise can lower leg systolic pressure in claudicants and patients with asymptomatic arterial disease

- Measure systolic pressure in both arms using Doppler ultrasound probe (8MHz) and a sphygmomanometer cuff. Remember:
- ▶ Systolic pressure can vary between arms so record both and use highest
 - ▶ Inappropriate cuff size can affect accuracy
 - ▶ Brachial pressure measurement method can produce slight variation in systolic reading
 - ▶ An irregular pulse and/or too rapid deflation of cuff can affect accuracy of reading



Locate ankle pulses (AT/DP and PT). Measure systolic pressure in both vessels using Doppler ultrasound probe (8MHz) and an appropriately sized sphygmomanometer cuff.

Using contact gel, position probe at 60° to skin surface and in line with the artery. Record pressure for each vessel and use the highest pressure at the ankle to calculate the ABPI for that leg. Repeat the process for the other limbs. Remember:

- ▶ Systolic pressure can vary between ankle vessels so record both pressures and sound type (e.g. monophasic)
- ▶ Cuff size, position and wound padding can affect accuracy of reading – position at ankle with only film covering wound
- ▶ Non-compressible vessels will falsely elevate pressure; be cautious in diabetics and patients with renal failure
- ▶ Limb dependency will falsely elevate pressures
- ▶ Select 5MHz probe for deeper vessels and large limb size.



- ▶ Document results – record systolic pressure, calculate ABPI, using formula (right)
- ▶ Discuss results with patient – consider if patient requires healthy living advice
- ▶ Clean equipment – follow infection protocol

$$ABPI_L = \frac{\text{Highest left ankle systolic pressure}}{\text{Highest brachial systolic pressure}}$$

$$ABPI_R = \frac{\text{Highest right ankle systolic pressure}}{\text{Highest brachial systolic pressure}}$$

in tissue oxygen (pulse oximetry). These have been used to calculate the Lanarkshire Oximetry Index (LOI), which is derived from pressures recorded from cuffs at the elbow and ankle using oximetry sensors placed on the finger and toe to detect restoration of pulsatile flow as the cuffs are deflated. This method has been suggested as a possible alternative to measuring the ABPI using Doppler equipment (Khalili et al, 2002; Bianchi et al, 2008).

No matter which sensor system is used, all these methods record the occlusion pressure at the site of the cuff, not the pressure at the sensor, and all are subject to the same limitations, in terms of vessel compressibility, pulse pressure variability, patient position and the need to rest subjects before conducting readings (Vowden and Vowden, 2006).

All of the methods allow estimation of systolic pressure, but not all register diastolic pressure measurement.

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Figure 2: This image shows the location of the posterior tibial artery.

Figure 3: These markings indicate where the tibial artery continues as the dorsalis pedis in the foot.

Figure 4: This marking shows the site at which the distal peroneal artery can be accessed at the ankle.



Figure 5: Toe pressure measurement is taken by placing a cuff around the base of the toe and using a Doppler probe to detect blood flow in the digital artery.

Whichever technique is used to measure blood pressure, readings should be obtained with the sphygmomanometer equipment at heart level to eliminate the effect of hydrostatic pressure on the pressure measurement (O'Brien et al, 2003; Pickering et al, 2005).

When a comparison is to be made between upper and lower limb pressures, readings should be taken with the patient supine to eliminate pressure variations caused by the hydrostatic pressure difference between the higher and lower limbs in relation to the heart (Vowden, 2001a; Vowden, 2001b).

The difference between the blood pressure measured in the arms and that measured in the legs is normally less than 10mmHg, pressure in the lower limb generally being higher because of augmentation of the pressure by the muscular peripheral arteries and the summation of reflected pressure waves (Caruana et al, 2005). But, the difference may be increased in the presence of coarctation of the aorta (Markham et al, 2004) or occlusive lower limb arterial disease or following exercise, especially in the presence of occult or symptomatic arterial disease (Vowden et al, 1996; Vowden and Vowden, 2001b). An appropriate cuff size should be chosen for each limb when undertaking blood pressure readings (Caruana et al, 2005).

USING DOPPLER FOR SYSTOLIC BLOOD PRESSURE

When using the hand-held Doppler equipment to measure systolic blood pressure (Figure 1) the same basic methodology set out above for the conventional measurement of blood pressure using a sphygmomanometer should be followed, remembering that the pressure measured relates to the cuff position and not to the position of the sensor. Cuff position and size errors may result in inappropriate clinical decision making (Caruana, 2005).

With the subject rested, relaxed and supine, the correct size cuff should be secured around the limb in question. For the arm, the cuff should be located just above the elbow. A variety of probe types are available that emit ultrasound at a specific frequency. In general, an 8mHz probe is used to evaluate flow in peripheral arteries as they tend to be

superficial. In oedematous limbs or obese patients, a 5mHz probe may occasionally be necessary as there is greater depth penetration of the ultrasound at that frequency (Vowden et al, 1996).

The brachial pulse should first be located by palpation and ultrasonic gel placed over the identified artery. The gel acts as a coupling medium, allowing transfer of the ultrasound from the probe into the tissues. The probe should be held in contact with the skin at an angle of about 60° to the line of the vessel but no pressure should be applied. Once a good signal is obtained, the cuff should be inflated to above systolic pressure and then slowly released, the pressure at which the signal returns equates to the systolic pressure. It is important not to move the probe away from the vessel and to deflate the cuff slowly to obtain an accurate reading.

To obtain lower limb systolic blood pressure, the patient is measured at the ankle with the cuff placed immediately above the malleoli. This allows access to the posterior tibial, the anterior tibial and its continuation the dorsalis pedis, and the peroneal arteries. The peroneal can be difficult to identify and, therefore, the posterior and anterior tibial arteries are most commonly used for pressure readings (Vowden et al, 1996; Caruana et al, 2005). Figures 2-4 demonstrate the anatomical location of these vessels. Whether two or three vessels are used, pressure readings are obtained and recorded for each artery tested.

Differences in pressure of greater than 15mmHg between crural arteries can be taken as indicating significant occlusive arterial disease in the vessel with the lower pressure (Vowden and Vowden, 2001b). This may be relevant when considering a patient for compression therapy, particularly if the pressure is lowest in the anterior tibial artery, as the area over the tibialis anterior tendon is more vulnerable to pressure damage.

In some patients, lower limb systolic pressure may appear grossly elevated due to the non-compressible nature of their arteries. In such a situation it may be possible to estimate lower limb systolic pressure by performing a pole test (Smith et al, 1994; Pahlsson et al, 1999). In this test a reference pulse is identified in a resting supine patient

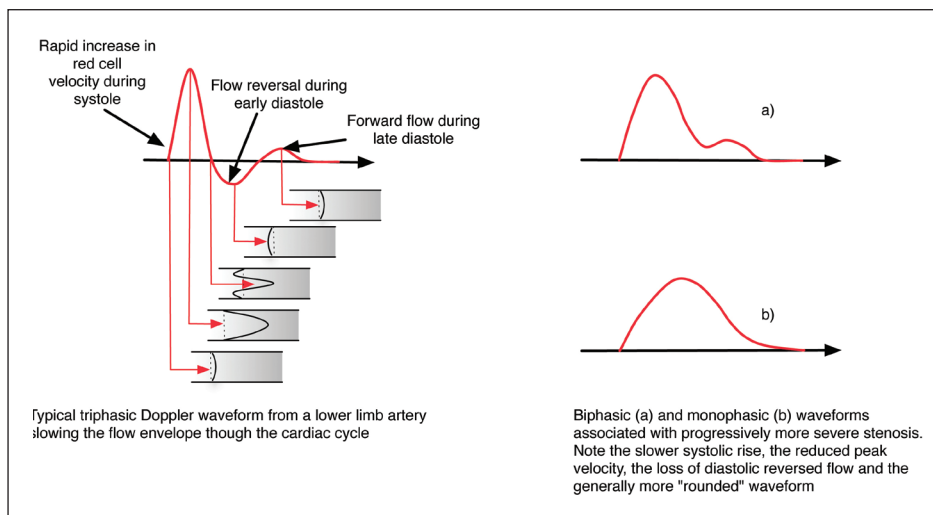


Figure 6: Increasing atherosclerotic stenotic arterial disease produces an altered waveform, producing first a biphasic and then a monophasic waveform.

and the limb elevated with the Doppler probe held over the artery. The height at which the reference pulse disappears above the neutral position in centimetres is recorded. Multiplying this figure by 0.735 (to convert from millimetres of blood to millimetres of mercury) gives the equivalent ankle systolic pressure in mmHg (Vowden et al, 1996), but the range of values is clearly limited by limb length and hip mobility. Although not frequently undertaken, pressures derived by leg elevation provide a more accurate index of severe leg ischaemia than sphygmomanometry, although the technique is limited to assessing pressures of less than approximately 60mmHg (Smith et al, 1994).

An alternative is to measure toe systolic pressure, which is regarded as a more reliable measure in diabetics as digital vessels are less likely to be non-compressible. The technique is, however, more difficult. A neonatal or penile blood pressure cuff is placed on the great toe and blood flow detected in the terminal phalanx. Figure 5 shows a Doppler probe being used to detect blood flow in the digital artery. An alternative is to place the probe over the tip of the toe. It is often useful to connect headphones to the Doppler unit to allow more accurate detection of flow onset and, therefore, systolic pressure.

Toe pressures are lower than arm or ankle systolic pressure and the 'normal' range much narrower. It has been found that cuff width can greatly affect the obtained

systolic blood pressure reading and it has been proposed that readings should be taken with a 2.5cm wide cuff (Pahlsson et al, 2007).

The definition of critical limb ischaemia and the likelihood of wound healing, particularly in the diabetic foot, have been related to absolute systolic pressure at both the ankle and toe and such readings may, therefore, have value in treatment planning (Apelqvist et al, 1989; Dormandy et al, 1991).

OBTAINING THE ABPI

Systolic blood pressure can vary widely and to compensate for this and allow a meaningful comparison of results for an individual over time, a ratio can be derived that compares the highest arm systolic pressure, taken as the best estimate of central systolic pressure, with the highest pressure obtained at the ankle. These readings should, ideally, be taken synchronously and give a separate ABPI for each leg. Table 1 highlights some of the potential sources of error in systolic pressure measurement and, therefore, in ABPI calculation.

Al-Qaisi et al (2009) have reviewed the literature relating to ABPI and provide an update for practitioners, exploring the rationale for the technique and its limitations.

Automated systems such as the Huntleigh Dopplex ABILITY (Huntleigh Healthcare), which uses an integrated pneumatic sensor system rather than traditional Doppler,

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KEY POINTS

- ▶▶ Before undertaking a blood pressure measurement, the room should be quiet, at a comfortable temperature and the patient should be relaxed, comfortable and have rested for at least five minutes.
- ▶▶ Mild-to-moderate peripheral vascular disease causes a fall in the ABPI after exercise, the recovery period reflecting the severity of the arterial disease.
- ▶▶ All methods allow estimation of systolic pressure but not all methods allow diastolic pressure measurement.
- ▶▶ Cuff position and size errors may result in inappropriate clinical decision making.

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or systems which use the oscilometric method to record systolic pressure (ABPI MD[®]; Mesi), are available to synchronously measure limb systolic pressure in all four limbs and calculate the ABPI. These have been shown to be reliable in clinical use but do not all give full information on the pulse waveform and pressure at the three ankle vessels obtained with the standard Doppler method (Lewis et al, 2010).

WAVEFORM AND SOUND, SPECTRAL ANALYSIS

Blood cell velocity varies during the cardiac cycle and across the sample zone within a blood vessel, with cells in the centre of the blood vessel moving faster than those on the periphery. Ultrasound is reflected from all these cells but as the cell velocities vary so does the frequency shift that occurs in the reflected ultrasound. The velocity profile for a normal peripheral artery produces a characteristic triphasic waveform and sound. Increasing atherosclerotic stenotic arterial disease produces an altered waveform, producing first a biphasic and then a monophasic wave profile and sound (Vowden et al, 1996). *Figure 6* illustrates this and demonstrates the waveforms produced.

Signal analysis in its simplest form involves operator interpretation of the audible signal derived from the hand-held Doppler. More complex analysis of the generated Doppler waveform can be undertaken and a Pulsatility Index (PI) derived, the lower the PI the greater the degree of proximal arterial stenosis (Sumner, 1989; Burns, 1993).

ABPI AND GENERAL CARDIOVASCULAR RISK

A reduced ABPI is associated with a general increase in cardiovascular risk (Leng et al, 1996; Jonsson and Skau, 2002) with increasing morbidity rates, and reduced survival, being linked directly to a reduction in the ABPI (Donnelly et al, 2000). Finding a reduced ABPI should, therefore, feed in to an associated cardiovascular risk assessment and management strategy and if symptoms of peripheral vascular disease are present, referral to a vascular surgeon for further assessment.

ABPI AND LOWER LIMB ARTERIAL DISEASE

In a normal subject the ABPI is usually between 1.3 and 0.95, with a ratio of <0.92 taken as indicating arterial disease. An ABPI of >1.3 is usually taken to indicate a

degree of non-compressibility in the lower limb vessels. If such a result is obtained, check for possible technical errors that may have falsely elevated the lower limb systolic pressure, such as using too small a sphygmomanometer cuff or measuring ankle pressure with the limb dependent.

In a young and otherwise fit patient with no symptoms of peripheral arterial disease such readings are unlikely to be of significance. In the elderly, in people with diabetes and in patients with possible symptoms of arterial disease an alternative technique should be used to check lower limb perfusion.

Individuals with symptoms of intermittent claudication usually have an ABPI between 0.4 and 0.9, while patients with rest pain or arterial ulceration usually have an ABPI of <0.4. In patients with mild arterial disease, particularly that involve the iliac vessels, Doppler systolic pressure measurement combined with exercise testing can be of value in revealing occult arterial disease (Vowden et al, 1996).

Segmental pressure measurements along a limb, comparing pressures in the thigh, upper calf and at the ankle can also be useful in locating the site of any significant arterial occlusive disease. The systolic pressure is usually higher in the thigh than the brachial, with a pressure gradient down the leg (Hirai and Shionoya, 1978), and a pressure difference of >30mmHg between adjacent cuffs indicating significant arterial disease (Sumner, 1989). Anderson (2002) demonstrated a statistically different systolic pressure and ABPI between measurements taken in the upper and lower calf although the differences may not have always been clinically significant. Some subjects also found the upper cuff position more uncomfortable.

Variations in systolic pressure can also influence ABPI and may be important in longitudinal measurement of ABPI. ABPI is relatively higher in hypotensive patients and low in hypertensive patients (Hugue et al, 1988; Belcaro and Nicolaidis, 1989; Carsier, 2001).

ABPI, LEG ULCERATION AND COMPRESSION THERAPY

Taken in isolation an ABPI does not establish a diagnosis or define the aetiology of a leg ulcer. The role of ABPI in leg ulcer management and compression

Table 1
Sources of error in blood pressure measurement and ABPI (Vowden et al, 1996; Khalili et al, 2002; Markham et al, 2004)

Some causes of arm blood pressure error	Systolic effect
Cuff too small	+10-40 mmHg
Cuff too large	-5-25 mmHg
Artery line not centered	+4-6 mmHg
Arm above heart level	-2 mmHg/inch
Arm below heart level	+2 mmHg/inch
Cuff placed over clothing/bulky dressings	+/- 10-40 mmHg
Patient not rested	+10-20 mmHg
Patient in pain	+10-20 mmHg
White coat syndrome	+11-20 mmHg

	Lower limb systolic pressure	ABPI
Insufficient period of rest	Reduced	Reduced
Limbs dependent	Elevated *	Elevated
Irregular pulse	Variable	Variable but usually reduced
Leg cuff too small	Elevated	Elevated
Leg cuff to large	Reduced	Reduced
Probe errors	Reduced	Reduced

* Allowance can be made for this by taking the height difference between arm and ankle pulse in centimetres $\times 0.735$ from the systolic pressure recorded. This should correct systolic pressure and allow more accurate estimation of the true ABPI.

therapy is two-fold. The first is to support the diagnostic process and evaluate the presence of arterial disease, and the other is to help define the appropriate level of compression therapy. In a clinimetric analysis of the measurement of ABPI by Doppler ultrasound, Keen (2008) concluded that the method was, 'valid and reliable if the practitioner is competent and able to interpret the result within the context of a full clinical assessment'

Caruana et al (Caruana et al, 2005) emphasise this need for caution in their review in which they discuss possible causes of inappropriate compression therapy in chronic venous leg ulcer patients. An ABPI of ≥ 0.8 is taken as broad indicator that a patient will tolerate high compression bandaging (sub-bandage resting ankle pressure of 40mmHg) or hosiery (European Class 2). Concern is often expressed about applying compression to limbs with an ABPI >1.3 as such readings may mean that the arterial tree is non-compressible. Male et al (2007), however, emphasise that, for the otherwise healthy adults in the 20–40 year age range a 'normal' ABPI should not be

considered a fixed figure, the mean ABPI in their study population being 1.14 (SD 0.06).

ABPI readings should, therefore, be interpreted in light of the patient's age, limb size and symptoms of peripheral arterial disease. Decisions about the appropriateness of hosiery, for example as part of post deep vein thrombosis limb management, or compression bandaging, should be made accordingly. The International Leg Ulcer Guidelines (European Wound Management Association [EWMA], 2003) describe appropriate management strategies stratified according to ABPI. ABPI readings may also indicate appropriate bandage type selection and several bandage systems having now been designed to offer compression therapy to patients with reduced ABPI (Vowden et al, 2011).

CONCLUSION

Providing the Doppler assessment principles are followed and the common pitfalls avoided, the ABPI test provides a simple method for assessing and monitoring peripheral arterial disease. **WUK**

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