LOI: an alternative to Doppler in leg ulcer patients

Doppler Ankle Brachial Pressure Index (ABPI) is the recommended method of arterial screening (RCN, 1998; SIGN, 1998; CREST, 1998) when assessing patient eligibility for compression therapy. However, in this paper, Janice Bianchi details the potential shortcomings of this technique and describes a newer, simpler test using a pulse oximetry Lanarkshire Oximetry Index which has been shown to be a feasible way to assess whether compression can safely be applied (Lucke et al, 1999; Bianchi et al, 2000; Zamiri et al, 2004) in patients with leg ulcers.

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KEY WORDS
Doppler ABPI
Pulse oximetry
LOI
Vascular assessment
Leg ulcers

Systematic reviews suggest that compression systems improve the healing of venous leg ulcers and should be used routinely in uncomplicated venous ulcers (Fletcher et al, 1997; Cullum et al, 2002). Compression treatment of the leg can, however, be hazardous in limbs with occult arterial disease (Callam et al, 1987a). In order to exclude significant peripheral arterial disease before applying compression, Doppler Ankle Brachial Pressure Index (ABPI) has become the accepted test recommended in recent years (Callam et al, 1987a,b; CREST, 1998; RCN, 1998; SIGN 1998).

However, the technique requires considerable skill, particularly when locating foot arteries and maintaining the correct probe angle (Ray et al, 1994). Strandess et al (1967) suggested that in order to ensure reproducibility of the signal when measuring Doppler ABPI, it is important to maintain a constant angle between the probe and the vessel being examined. Others have noted variability between right and left legs, suggesting observers may experience more difficulty measuring one leg than the other due to the position of the patient and the position of the observer's hand (Fowkes et al, 1988; Kaiser et al, 1999). Even vascular technicians with specialised skills in Doppler ABPI have had difficulty with the technique, particularly in individuals whose arterial flow was difficult to detect (Fowkes et al, 1988). Additionally, Bianchi et al (2002) noted that in patients with oedema or lympoedema the signal can be difficult to detect.

The appropriate period of training in Doppler ABPI has not been determined, however, Ray et al (1994) found that an intensive training programme over a 6-week period produced less errors in Doppler ABPI examination than a single educational session. However, this extended period of training may only be available to a few practitioners.

Maintaining Doppler ABPI skills may also prove difficult for nurses who carry out the test on an irregular basis. Kaiser et al (1999) identified experienced recorders of ABPI as those who carry out the procedure more than 10 times a week and the less experienced as those who perform Doppler assessment 5 to 15 times a month. Vowden and Vowden (2002) suggested that anxiety over Doppler assessment is, perhaps, an indication that a change in service management is needed.

The history of pulse oximetry

In reports from as early as 1874, oxygen consumption and arterial occlusion were measured by spectroscopy. According to Severinghaus et al (1998), von Vierordt measured oxygen consumption using transmitted light in a crude experiment. Wrapping a rubber band around his wrist to cut off the circulation and shining a light on his hand, he saw that two bands of oxyhaemoglobin disappeared and a band of deoxyhaemoglobin appeared. Using reflected light from a spectrometer, he measured the oxygen consumption of the living tissue by noting the time that elapsed as oxyhaemoglobin changed to deoxyhaemoglobin.

Fifty-five years later and with better equipment, Nicolia resurrected von Vierordt's work. Nicolia added photo-electric light detection and his student, Kramer, introduced the new German barrier-layer photocells to record saturation *in vivo* by transilluminating the arteries of animals (Ridlen, 1998).

In 1935, Mathers built the first device that continuously measured human blood oxygen saturation. He ▸▸

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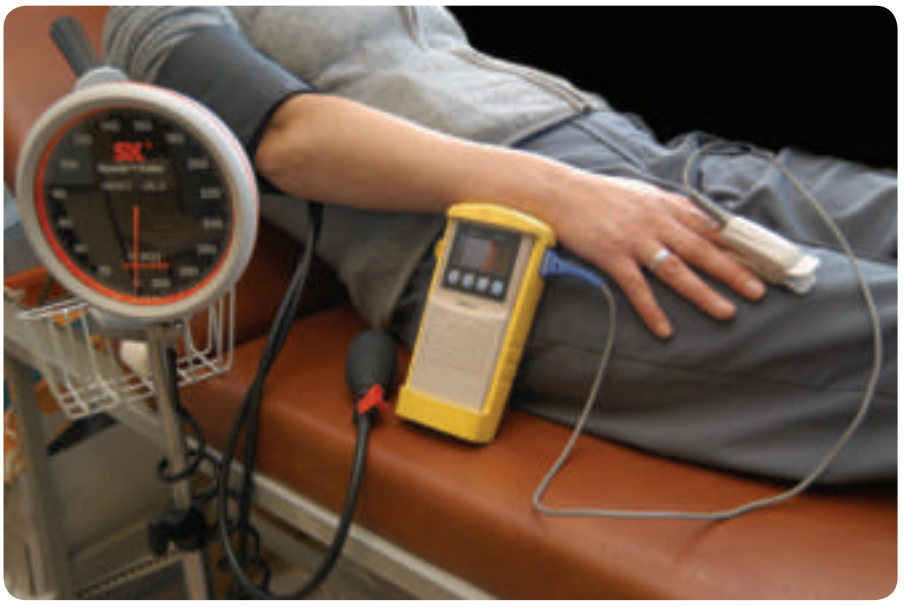

Figure 1. Pulse oximetry sensor placed on the finger.

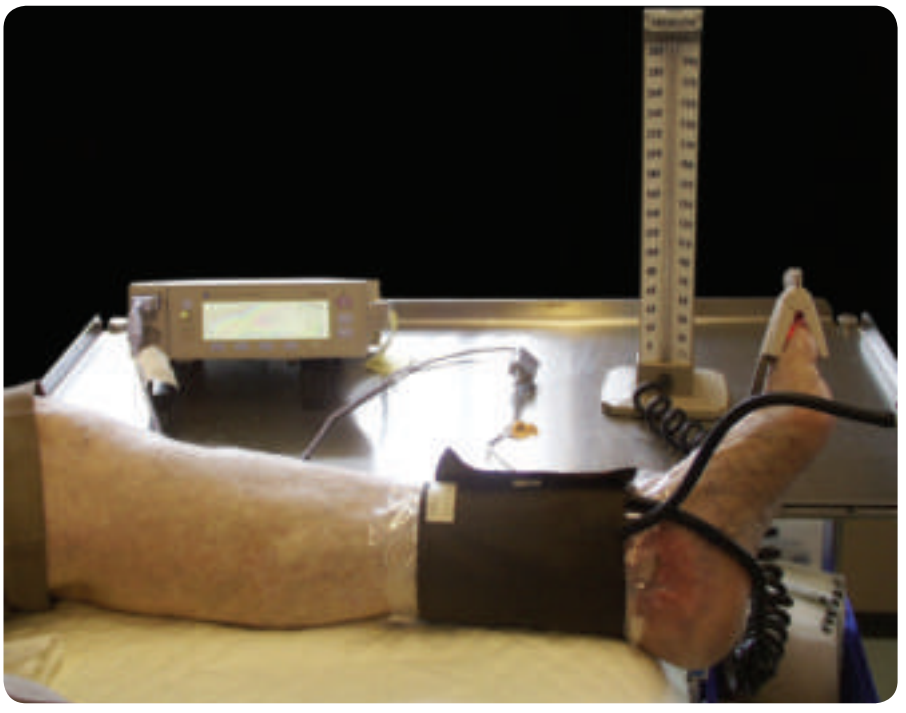

Figure 2. Pulse oximetry sensor placed on the toe.

used two wavelengths of light, one that was sensitive to changes of oxygenation and another that was not. This device could follow trends in saturation but was difficult to calibrate (Tremper and Barker, 1989). Squires developed a similar device that was calibrated by compressing the tissue to eliminate the blood (Squire, 1940).

In the early 1940s, Millikan coined the term 'oximeter' to describe a lightweight device he developed for aviation research (Millikan, 1942). Later, when Wood and others used oximeters similar to Millikans in the operating room, they were noted to detect significant desaturation even during routine anaesthetics (Wood and Geraci, 1949; Stephen et al, 1951). Surprisingly, despite being developed over half a century ago, pulse oximeters were only commercially marketed from 1981 onwards (Woodrow, 1999).

Initially the pulse oximeter was confined to use in anaesthetics, intensive care and other emergency situations (Ridlen, 1998), but, by 1986, they were recommended as a standard of care for every patient undergoing general anaesthetia in the USA (Eichorn, 1986).

More recently, their ability to detect tissue perfusion and arterial occlusion pressure has been exploited and has seen them being increasingly used in new and novel ways, from the detection of peripheral neuropathy (Modi et al, 1997) to the viability of tissue after surgery (Lindsay et al, 1991; Yilmaz et al, 1999), and in the diagnosis of peripheral vascular disease (Joyce et al, 1990; Couse et al, 1994; Jawahar et al, 1997: Johannson et al, 2002).

Mode of action

The mode of action of the pulse oximeter is based on Lambert Beer's Law. The law defines the correlation between light transmission and optical density, relating the concentration of a solute to the intensity of light transmitted through it (Ridlen, 1998). The pulse oximeter measures the oxygen saturation of haemoglobin in blood or tissue. The device passes light at two different frequencies – visible red (660nm) and infrared (900nm) – through a sensor to a photodetector.

Sensors are available as either transmission or reflectance models. Transmission models have separate light sources and photodetectors, and measure light passing through the subject (e.g. digit or earlobe). Reflectance probes have the light source and photodetector mounted in the same probe. These are used over bony areas, such as the anterior tibia, and measure reflected light. For measurement of LOI, the transmission models are more appropriate.

The amount of oxygenated haemoglobin (which absorbs more infrared light), and deoxygenated haemoglobin (which absorbs more red light) are measured (Ahrens and Tucker, 1999). The ratio of red to infrared light absorbed determines the oxygen

saturation detected by the pulse oximeter. More importantly, pulse oximetry – like Doppler – depends on the presence of pulsatile blood flow, therefore, occlusion of the arteries by a pressure cuff will result in signal loss.

Development of the Lanarkshire Oximetry Index

Arterial screening by pulse oximetry Lanarkshire Oximetry Index (LOI) was developed as a vascular assessment tool for leg ulcer patients. The technique involves simply placing the transducer on a digit which may make it less dependent on operator technique than Doppler ABPI. The following section outlines a protocol to determine suitability for compression therapy.

The Lanarkshire Oximetry Index

Explain the procedure to the patient. Ensure he/she is lying comfortably in a semi-recumbent position.

Stage 1

Measurement of finger oximetry pressure

- An appropriately sized blood-pressure cuff is placed around the upper arm
- The pulse oximetry sensor is placed on any finger (***Figure 1***). When the sensor is placed on the digit, the oximetry will display two numbers; the first represents the patient's heart rate, the second the percentage of circulating oxygenated haemoglobin (SpO_2). Pulsatile blood flow is also displayed either by waveform or a column of lights. A baseline pulse oximetry reading is recorded
- The sphygmomanometer cuff is inflated to 60mmHg, then inflated in 10mmHg increments with approximately 10 seconds between incremental changes. Once the pressure measured reaches 100mmHg, incremental changes can be increased to 20mmHg
- When the pulse oximetry signal is lost[1], the pressure reading one below is recorded, e.g. if the signal is lost at 180mmHg, a pressure of 160mmHg is noted.
- If 180mmHg is reached before loss of signal, the cuff is not inflated further and a maximum pressure of 180mmHg is recorded
- The measurement is repeated on the other arm and the higher of the two readings is used to calculate LOI.

Measurement of toe oximetry pressure

- An appropriately sized cuff is placed around the ankle immediately above the malleoli. It is important that any fragile skin or ulcer tissue is protected beforehand
- The oximetry sensor is placed on one of the first 3 toes *(Figure 2)*
- The cuff is inflated as outlined (*Stage 1*) and the pressure at which the signal lost, or 180mmHg if this is reached without loss of signal, is recorded.

Stage 2

Calculate toe/finger oximetry index (ratio)

- The LOI for each leg is calculated by dividing toe pressure by finger pressure and expressing it as a decimal. For example:
  Toe pressure=140mmHg
  Finger pressure=120mmHg
  LOI = toe pressure/finger pressure
  =140/120 = 1.17.

Values are similar to those of Doppler ABPI. Patients with a ratio of 0.8 or above can have full compression applied.

Stage 3

- Apply an appropriate graduated compression bandage or stocking to the leg and then place the sensor on one of the first three toes *(Figure 3)*. The signal is checked with the leg horizontal, then elevated for approximately 30 seconds.

The pulse oximetry test is carried out with patients in a semi-recumbent position, not supine as recommended for Doppler ABPI. Clinical experience shows that many elderly patients with co-morbidities affecting their cardiovascular or respiratory systems find lying flat particularly uncomfortable. Thus, pulse oximetry testing may be beneficial in this patient group.

In a pilot study, the test was evaluated and Lucke et al (1999) demonstrated, by satisfactory healing rates and the absence of bandage damage, that compression could be safely applied to a group of patients with reduced Doppler ABPI, but occlusion pressures of more than 80mmHg. Subsequently, Bianchi et al (2000) found that there was no difference in healing rates in 77 venous ulcer patients selected for suitability for compression by pulse oximetry, irrespective of whether Doppler ABPI was reduced or normal. The study also indicated fair agreement between ABPI and LOI with a weighted kappa of 0.39. The study found no evidence of ischaemia in patients where toe pulse oximetry reading was normal; however, the sample size used was small so needs interpreting with caution.

In a further study by Zamiri et al (2004), 108 patients (200 legs) had ABPI and LOI measurements recorded. The results indicated a fair agreement between

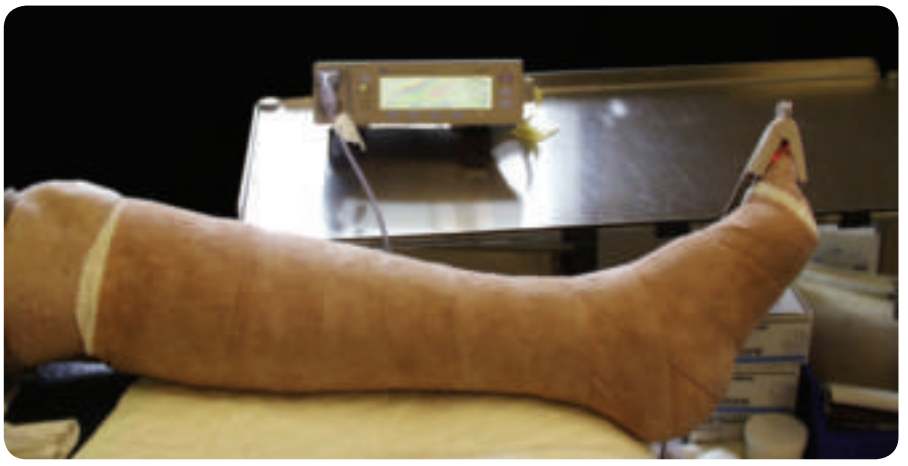

Figure 3. Pulse oximetry sensor after bandaging.

[1]Loss of signal is indicated by flattening of the waveform or loss of the column of lights on the oximeter.

the two tests (weighted kappa = 0.484). Of the 200 legs assessed, neither ABPI or LOI could be recorded in 1 case, and in 9, LOI was recordable but ABPI was not. A Bland-Altman plot indicated neither LOI or ABPI consistently over- or under-read compared to the average of both values, i.e. that neither is clearly a better measure than the other. The authors suggested that pulse oximetry LOI was a simple alternative to Doppler ABPI.
Further studies comparing pulse oximetry LOI to angiography are currently being undertaken.

Limitations of LOI vascular assessment

The pulse oximetry signal may be difficult to detect if the patient has grossly dystrophic toe nails, extreme cyanosis, or, in conditions where there is peripheral vasoconstriction, such as Raynaud's disease. Additionally, LOI will not detect localised arterial disease where there is adequate collateral circulation. If it is necessary to assess blood flow to individual arteries, Doppler ABPI should be used.

These limitations apply to a small percentage of patients but should be considered when carrying out vascular assessment using pulse oximetry.

Conclusion

Studies have suggested that pulse oximetry LOI is at least as effective as Doppler ABPI in the vascular assessment of leg ulcer patients. It may offer advantages in that the instrument is widely available, appears to be simple to use and is less operator-dependent than Doppler. Additionally, the signal can be picked up easily in situations where Doppler ABPI can be problematic, such as in patients with oedema/lymphoedema.

Our own experience and the current literature suggest that where Doppler is used on a regular basis, there may be little need for an additional vascular assessment tool. However, where there is technical difficulty with locating arteries with Doppler ABPI, or where vascular assessment is carried out less frequently, pulse oximetry LOI may provide a suitable, yet simpler, alternative. WUK

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