Automated Oscillometric Determination of the Ankle–Brachial Index Provides Accuracy Necessary for Office Practice

Joshua A. Beckman, Caitlin O. Higgins, Marie Gerhard-Herman

Abstract—Peripheral arterial disease (PAD) remains underdiagnosed by primary care and cardiovascular physicians. The office-based assessment of PAD is limited by the need for specialized equipment and the time required for performance of the ankle–brachial index (ABI). We explored whether the accuracy of automated ABI measurement by oscillometry compared favorably with the gold-standard method using continuous-wave Doppler ultrasound. Consecutive patients referred to our university hospital noninvasive vascular laboratory for ABI measurement were invited for participation. Of 205 patients, 201 participated, including 55 with PAD. The ABI was measured by automated oscillometry and Doppler ultrasound. The test of trends revealed a correlation coefficient of 0.78 in the left leg and 0.78 in the right leg \( (P<0.01 \text{ for both}) \). The mean ABI difference between methods was 0.04 ± 0.01 and 0.06 ± 0.01, respectively, in the left and right legs. The differences between the methods followed a normal distribution. Oscillometric determination of the ABI provides an accurate determination of the ABI in an outpatient population. Our findings show automated oscillometry to be a reliable and easier method of ABI measurement, lowering the barrier to incorporation of this diagnostic test into clinical practice. \( (\text{Hypertension.} \ 2006;47:35-38.)\)

Key Words: vascular diseases ■ atherosclerosis

Peripheral arterial disease (PAD) remains the least recognized and treated form of atherosclerosis. It is present in 5 to 12 million Americans\(^1,2\) but is diagnosed in less than half of these patients.\(^3\) The diagnosis of PAD has important prognostic implications and requires institution of therapeutic lifestyle changes and medical therapy to reduce cardiovascular morbidity and mortality. One important reason that the diagnosis of PAD is made infrequently is the lack of an easy-to-perform diagnostic test.

The ankle–brachial index (ABI) is the ratio of the systolic pressure at the ankle compared with the brachial artery pressure. When the ABI is \( \leq 0.9 \), a diagnosis of PAD is made with up to a 90% accuracy.\(^4\) Measurement of the systolic pressure in both brachial arteries and pedal pulses is performed with a continuous-wave Doppler ultrasound. The greatest barrier to office-based ABI measurement is the time required for testing.\(^5\) A test that is automated, easy to perform, and less reliant on specialized skills may facilitate measurement of the ABI, increasing the diagnosis of PAD in susceptible populations. Oscillometric (automated) determination of blood pressure is approved for blood pressure measurement and is commonly available, reliable, and simple to use.\(^6\) Oscillometers measure the magnitude of the pressure vacillation in the limb as the cuff is deflated from suprasystolic pressures. As the pressure in the cuff decreases and approaches systolic blood pressure, oscillation rapidly increases and eventually reaches a peak after which decrease of the cuff pressure causes the oscillation to decrease. Systolic blood pressure is calculated when the oscillation increases rapidly and the diastolic pressure when the oscillation decreases rapidly. Accordingly, we compared the automated, oscillometric measurement of the ABI to the Doppler ultrasound measurement of the ABI to determine whether there is a simple, fast, and accurate method suitable for common use in the office.

Methods

Patient Selection

All of the men and women aged 18 years or older referred to the Brigham and Women’s Noninvasive Vascular Laboratory between May 1 and August 20, 2004, for evaluation of PAD were asked to participate. Subjects were excluded if they were unable to consent. Each subject provided written, informed consent. This study was approved by the Human Research Committee of Brigham and Women’s Hospital.

Study Procedures

Demographic information was acquired after consent was obtained. Doppler pressure measurements and automated oscillometric pressure measurements were performed using sphygmomanometric cuffs that were appropriately sized to the diameter of the arms and ankles. The subject rested supine for 10 minutes before measuring pressures.

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Doppler pressure measurements were made with a commercially available machine (Parks Medical Electronics, Inc). A cuff was inflated to suprasystolic pressure and deflated slowly until a flow signal was detected by Doppler over the dorsalis pedis and posterior tibial arteries, indicating the systolic pressure at the ankle. Brachial artery systolic pressure was determined similarly. The ABI for each extremity was calculated as the higher of the 2 pedal pressures divided by the higher of the 2 arm pressures. Oscillometric measurements were made using a standard automated blood pressure cuff system (Cas 740, Cas Medical Systems, Inc). This model has a reported accuracy to within 5 mm Hg and a SD of $\pm 8$ mm Hg. Hospital standard calibration of the device was performed just before study initiation and halfway (4 weeks) through recruitment by the hospital Biomedical Engineering department. Using a cuff sized for the arm, blood pressures were obtained in both arms and ankles. ABI was calculated as the quotient of the ankle pressure and the higher of the 2 arm pressures after both sets of measurements were made. Subjects with incompressible ankle arteries (ABI $\geq 1.4$) were excluded.

Statistics
Demographic variables are presented as mean±SD and computed measures as mean±SE. Correlation between measures was determined by linear regression adjusted for demographic variables. For each method of measurement, agreement between standard ABI measurements and oscillometric measurements was investigated using the Bland and Altman method. A correlation analysis between the difference of the two methods was performed to see whether these measures varied systematically over the range of ABI. Sensitivity, specificity, positive predictive value, and negative predictive value of the oscillometric measurements to predict an abnormal ABI of $<0.9$ were determined using the Doppler ultrasound ABI measurement as the gold standard. Kolmogorov–Smirnov analysis was performed to determine normality of differences between both measures. To avoid the effect of interrelated measures within each subject, we analyzed each leg separately, thus making each leg an independent observation.

Results
Of the 205 subjects that were approached, 201 participated. The subjects were typical of those referred to a vascular laboratory. Subjects mean age was $66 \pm 11$ years, 53% were female, 78% were white, and 36% had diabetes mellitus. Twenty-eight subjects (14%) were excluded from the analysis because of lower extremity vascular calcification artifact, leaving 173 evaluable subjects. Vascular calcification prevents compression of the artery, thus artificially raising the detection of flow by Doppler ultrasound well beyond normal. Of the remaining subjects, 55 had an abnormal ABI ($<0.9$), and 118 had a normal ABI (0.9–1.39) (Figure 1). The oscillometric determination of blood pressure reliably measured arm systolic blood pressure, differing by a mean of $2.8 \pm 13.6$ mm Hg from Doppler ultrasound determination of arm systolic blood pressure.

There was a strong association between types of measurement in each leg tested separately (Figure 2). A test of trends revealed a $\beta$ coefficient of 0.78 in the left leg (Figure 3) and 0.78 in the right leg ($P<0.01$ for both). Diabetes, end-stage renal disease, age, sex, and race did not impact on the association. The mean difference between the methods was $0.04 \pm 0.01$ in the left leg and $0.06 \pm 0.01$ in the right leg. The
surprisingly, Doppler ultrasound determination of the ABI is a time-intensive diagnostic test.  

The need to perform a primary care and specialty medical services for a number of reasons, an important one of which is the need to perform a more thorough physical examination, and a directed examination of the lower extremities. Diagnosis of PAD changes medical recommendations, requiring the institution of antiplatelet therapy, risk factor modification, and a directed examination of the lower extremities. Thus, oscillometric determination of the ABI would allow for greater office-based diagnosis of PAD.

**Perspectives**

Peripheral arterial disease is present in as many as 20% of the Medicare population but diagnosed in <50% of the patients with the disease. Because of the attendant risk of cardiovascular morbidity and mortality, making the diagnosis of PAD may impact significantly on patient outcomes. An important barrier to diagnosis is the lack of an easy, office-based method. This investigation demonstrates that automated, oscillometric determination of the ABI correlates well with Doppler ultrasound measurement of the ABI. Because of the decreased time and training required for ABI determination, the barriers to ABI measurement are lowered, enhancing the possibility of PAD diagnosis.

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