Doppler Ankle Pressure

An Evaluation of Three Methods of Expression

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- We studied 133 patients with arteriographic evidence of lower limb arterial disease and 34 normal volunteers to determine the most useful means of expressing ankle pressure. Representative ranges were determined for each of six symptomatic categories. Receiver operating characteristic curve analysis showed that ankle index (ankle to brachial pressure ratio) and brachial-ankle pressure gradient were more valuable than absolute pressure in discriminating between normal and diseased extremities. In contrast, absolute ankle pressure was the best predictor of nonviability (limb requiring bypass for salvage or amputation). An absolute pressure cutoff of 60 mm Hg correctly identified 86% of viable limbs and 77% of nonviable limbs. Thus, the diagnostic accuracy of the three methods of expressing ankle pressure depends on the context in which they are to be used, and it appears that ankle index and gradient are most appropriate for defining the presence of disease, while absolute pressure correlates best with viability.

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Systolic BP measurement at the ankle level is a useful noninvasive technique in the diagnosis of peripheral arterial occlusive disease.1,2 There are three common ways of expressing the ankle systolic pressure. The most frequently used method is to calculate the ankle index as the ratio of ankle to brachial systolic pressure.3 A second method, and perhaps the simplest, is to report the absolute pressure in millimeters of mercury.3,4 The final method is to calculate the gradient across the arterial conduit, subtracting ankle systolic pressure from the brachial systolic pressure.5,6 All three methods have been used clinically as well as in noninvasive vascular studies. The accuracy in the determination of the presence and severity of disease may vary depending on how the ankle pressure measurements are expressed, but at the present time few data exist in this regard.

The receiver operating characteristic (ROC) curve was developed originally for use in the evaluation of the performance of radar apparatus. More recently, ROC curve analysis has been used to demonstrate the discriminative ability of a diagnostic test and its observer, who together represent the “receiver.”7 The relation between the false-positive rate and the true-positive rate is plotted as a continuous curve for a given test, and the position of the curve in the diagram determines the value of the test. The standard tests of sensitivity, accuracy, and specificity describe the diagnostic value of a test at only one specific cutoff point between what is to be declared “normal” and what is to be “abnormal.” In contrast, ROC curve analysis provides a method for describing the diagnostic value of a test over the spectrum of possible cutoff points, and may be used to test statistically for the significance of apparent differences between the diagnostic abilities of tests.8 The present study was undertaken to assess the diagnostic accuracy of each of the three methods of expressing ankle pressures in the diagnosis of arterial occlusive disease of the lower extremity, through the use of ROC curve analysis.

PATIENTS AND METHODS

Patient Selection

This study included 133 patients (260 limbs) with arteriographically proved peripheral arterial occlusive disease, who also underwent peripheral arterial assessment at the Noninvasive Vascular Laboratory of the University of Chicago. The patients' records were reviewed and a determination of limb viability was made. Nonviable limbs were defined as limbs requiring amputation or an arterial bypass procedure for rest pain, ischemic ulceration, or gangrene.

In addition, we examined 34 normal control subjects (68 limbs). In an effort to assure disease-free vasculature, all control subjects were healthy, with no clinical evidence of arterial disease.
Table 1.—Ankle Systolic Pressure, Ankle Index, and Brachial-Ankle Pressure Gradient in Various Patient Symptom Categories*

<table>
<thead>
<tr>
<th>Symptom Category</th>
<th>No. of Limbs†</th>
<th>Ankle Systolic Pressure, mm Hg</th>
<th>Ankle Index</th>
<th>Brachial-Ankle Pressure Gradient, mm Hg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>68</td>
<td>134 ± 3</td>
<td>1.09 ± 0.01</td>
<td>-11 ± 1</td>
</tr>
<tr>
<td>Asymptomatic, diseased‡</td>
<td>14</td>
<td>146 ± 7</td>
<td>1.05 ± 0.04</td>
<td>-5 ± 4</td>
</tr>
<tr>
<td>Claudication only</td>
<td>169</td>
<td>96 ± 3</td>
<td>0.65 ± 0.02</td>
<td>51 ± 3</td>
</tr>
<tr>
<td>Rest pain</td>
<td>62</td>
<td>55 ± 4</td>
<td>0.36 ± 0.02</td>
<td>95 ± 4</td>
</tr>
<tr>
<td>Ulceration</td>
<td>37</td>
<td>60 ± 5</td>
<td>0.41 ± 0.03</td>
<td>88 ± 6</td>
</tr>
<tr>
<td>Gangrene</td>
<td>18</td>
<td>66 ± 6</td>
<td>0.42 ± 0.03</td>
<td>91 ± 7</td>
</tr>
</tbody>
</table>

*Ankle index represents ankle-brachial pressure ratio. Values are mean ± SEM.
†Total number of limbs is greater than 260 because many limbs were the source of rest pain, ulceration, and/or gangrene concomitantly.
‡This group includes asymptomatic limbs with arteriographic evidence of disease.

Table 2.—Ankle Systolic Pressure, Ankle Index, and Brachial-Ankle Pressure Gradient, in Normal, Diseased but Viable, and Nonviable Limbs*

<table>
<thead>
<tr>
<th>Limb Viability</th>
<th>No. of Limbs</th>
<th>Ankle Systolic Pressure, mm Hg</th>
<th>Ankle Index</th>
<th>Brachial-Ankle Pressure Gradient, mm Hg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal limbs</td>
<td>68</td>
<td>134 ± 3</td>
<td>1.09 ± 0.01</td>
<td>-11 ± 1</td>
</tr>
<tr>
<td>Diseased, viable</td>
<td>204</td>
<td>93 ± 2</td>
<td>0.62 ± 0.02</td>
<td>56 ± 2</td>
</tr>
<tr>
<td>Nonviable</td>
<td>56</td>
<td>48 ± 3</td>
<td>0.53 ± 0.02</td>
<td>101 ± 5</td>
</tr>
</tbody>
</table>

*Ankle index represents ankle-brachial pressure ratio. Values are mean ± SEM; differences are all highly significant (P<.001).

were less than 30 years of age, and had no history of smoking or diabetes. Directional Doppler waveforms were triphasic (normal) in all controls.

**Technique**

Resting arm and ankle systolic blood pressures were measured using a sphygmomanometer and unidirectional Doppler ultrasound velocity detector. Brachial pressures were determined for each arm and the higher of the two was used. A 12-cm pressure cuff was applied just proximal to the malleoli and ankle pressures were measured using both the dorsalis pedis and posterior tibial Doppler signal. When the values for the two vessels differed, the higher of the two was used. Ankle index was calculated as the ratio of ankle systolic pressure to brachial systolic pressure, and ankle pressure gradient was calculated by subtracting ankle systolic pressure from brachial systolic pressure.

Transfemoral arteriograms of the aorta and lower extremity vessels to the level of the ankle were evaluated independently by an angiographer. Judgments were made as to the presence or absence of intimal irregularity, stenosis, or occlusion.

**Data Analysis**

Normal ranges for absolute ankle pressure, ankle index, and brachial-ankle pressure gradient were determined by calculating the 95% confidence interval about the control data. Sensitivities were determined by calculating the percentage of arteriographically diseased limbs that fell outside the normal range. Specificities were determined through calculation of the percentage of normal limbs that fell within the normal range.

The diagnostic value of absolute ankle pressure, ankle index, and brachial-ankle pressure gradient were assessed with ROC curve analysis. The ROC curve is generated by plotting percent false-positive (abscissa) vs percent true-positive (ordinate), and describes a test over the spectrum of individual cutoff values. The area underneath the curve is large whenever the percent true-positive is large for the corresponding percent false-positive. Thus, the area beneath the ROC curve is an index of the diagnostic performance of the test. While it is difficult to define statistical significance between two sensitivities or specificities, a test exists for the significance of differences between ROC curves. Two ROC curves may be compared, and P value generated for rejecting the null hypothesis that the tests are of the same diagnostic value.

**RESULTS**

Representative ranges for the absolute ankle pressure, ankle index, and brachial-ankle pressure gradient are illustrated in Table 1 for the various symptomatic categories. All three methods for expressing the ankle pressure detected differences between normal limbs and limbs with claudication, rest pain, ulceration, and gangrene (P<.001). However, limbs without symptoms but with arteriographic evidence of disease did not demonstrate significant differences in ankle systolic pressure, index, or brachial-ankle gradient when compared with normal limbs.

The mean absolute ankle pressure, ankle index, and brachial-ankle pressure gradient are illustrated in Table 2, for the control group, the diseased group with viable limbs,
and the diseased group with nonviable limbs. Each of the three methods of expressing the ankle pressure detected significant differences between the normal limbs, diseased but viable limbs, and nonviable limbs ($P<.001$).

The normal ranges for absolute ankle pressure, ankle index, and brachial-ankle pressure gradient were calculated for the 95% confidence intervals of the normal population (Table 3). In the discrimination between the presence or absence of disease, ankle index and brachial-ankle pressure gradient were sensitive (94% and 92%) and specific (99% and 100%) measures. Absolute ankle pressure appeared less sensitive (79%) and less specific (88%) than the other two measures.

The ROC curve analysis confirmed that ankle index and brachial-ankle pressure gradient were equivalent diagnostically in defining normal and arteriographically diseased extremities ($P<.04$); however, absolute ankle pressure was significantly less useful in this regard ($P<.001$; Fig 1). When ROC curve analysis was implemented for the determination of limb nonviability (Fig 2), absolute ankle pressure was the best discriminator ($P<.05$). An absolute pressure cutoff point of 60 mm Hg correctly identified 86% of viable limbs and 77% of nonviable limbs.

**COMMENT**

The noninvasive measurement of arterial pressures began with the studies of Korotkoff in 1905. This technique, referred to as the auscultatory method, remains in widespread use today and is useful for measuring pressures in large arteries with high pulse pressures. However, its application in limbs with arteriosclerotic disease is limited because of the small vessels and low pressures encountered.

Winsor used the tonosclillograph to avoid the limitations of the auscultatory method of pressure measurement, and was able to illustrate a correlation between low pressure and arterial obstruction. The advent of the Doppler ultrasonic flow detector has provided a simple and accurate test for the presence of arterial occlusive disease. Although most investigators express their data in terms of the ratio of ankle pressure to brachial pressure (ankle index), others have used absolute ankle pressure, and pressure gradient from a proximal reference point, usually the brachial artery, to the ankle.

There are two contexts in which these methods must be dealt with. The first is for the initial screening of the patient with suspected occlusive disease. The second is for the definition of limb nonviability, late in the course of the disease process when surgical intervention is indicated.

Our data indicate that ankle index and brachial-ankle pressure gradient are diagnostically more useful than the absolute ankle pressure for the detection of a flow-limiting lesion. The reason behind this observation becomes clear when one considers a patient with a brachial pressure of 100 mm Hg and an ankle pressure of 110 mm Hg, and a second patient with a brachial pressure of 200 mm Hg and a resting ankle pressure of 110 mm Hg. The first patient will not experience claudication; however, the second patient may be limited by claudication. Although both patients have identical absolute ankle pressures, when the second patient exercises, blood flow across the proximal high-resistance stenosis and collateral bed increases, distal perfusion pressure and flow drop, and ischemia results.

In contrast, our data indicate that the absolute ankle pressure is the best discriminator of nonviability. As long as
the tissues receive blood above a critical pressure, the brachial pressure is irrelevant. The majority of limbs appear to remain viable above an absolute ankle pressure of 60 mm Hg. This is not to say that ankle pressure measurements can be a substitute for clinical judgment. Concurrent disease processes such as diabetes and infection produce much variability, and several nonviable limbs were observed to have ankle pressures above 80 mm Hg, just as many viable limbs had pressures below 40 mm Hg. Clearly, the indications for operative intervention rest on clinical observations and not ankle pressure measurements alone.

None of the three methods of expressing ankle pressure was useful in differentiating asymptomatic limbs with arteriographic disease from normal limbs. These asymptomatic limbs characteristically had mild arteriographic abnormalities consisting of intimal irregularity or low-grade stenosis, and therefore they represented extremities with early hemodynamically insignificant lesions.

We conclude that the ankle index and the brachial-ankle pressure gradient are more useful than the absolute ankle pressure in discriminating between diseased and disease-free limbs. In contrast, absolute ankle pressure is more valuable than the other two measures in the prediction of limb nonviability. While operative indications should be based on signs and symptoms rather than pressure measurements, characteristic ranges do exist, and one should more thoroughly examine the patient when clinical characteristics and ankle pressures are in disparity.

References