Validation of the auscultatory method for diagnosing peripheral arterial disease

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Background. The Ankle brachial index (ABI) has been shown to be useful in diagnosing peripheral arterial disease (PAD). Ankle systolic blood pressures are measured by a Doppler device; however, general physicians cannot always use it in daily practice. The auscultatory method (AUS) is an alternative method and quite easy to perform, but has not yet been validated in diagnosing PAD.

Objective. To validate AUS for diagnosing PAD based on ABI, compared with Doppler method as gold standard.

Methods. Cross-sectional study. Study subjects were 119 patients aged 50 years and older, who were consecutively admitted to the division of general internal medicine in two community hospitals in Japan. We measured the systolic blood pressures of the brachial and the posterior tibial arteries by two methods. We calculated the ABI from the systolic blood pressure obtained by these two methods. PAD was considered to be present when ABI ≥ 0.90 by the Doppler method.

Results. PAD was diagnosed in 22 (18.5%) of 119 patients. Korotkoff sounds of legs were inaudible by AUS in 47 (39.5%) patients. The likelihood ratios for diagnosing PAD patients by AUS were 2.7 (95% CI 1.9 to 3.9) in cases with inaudible Korotkoff sounds, 0.7 (95% CI 0.2 to 1.9) when ABI ≥ 0.9 and 0.09 (95% CI 0.02 to 0.4) when ABI < 0.9.

Conclusions. While AUS is not efficient enough to confirm the presence of PAD based on ABI, it could be clinically useful in excluding PAD when ABI > 0.90. When measuring ankle blood pressure by AUS in the daily practice, it is important to realise its strengths and weaknesses.

Keywords. Ankle-brachial index, auscultation, Doppler, peripheral arterial disease, sensitivity and specificity, ultrasonography.

Introduction

The measurement of lower extremity blood pressure is important in the primary care setting, because the ankle-brachial index (ABI), which is calculated by dividing ankle systolic blood pressure (SBP) by brachial SBP, is useful for diagnosing peripheral arterial disease (PAD) and predicting cardiovascular events and overall mortality.1,2,3 Medical therapies are effective for patients with symptomatic PAD, since they can reduce leg pain and the risk of fatal and nonfatal ischemic events.4 Thus, when high-risk patients with atherosclerosis experience leg pain in daily practice, the possibility of PAD should be assessed by measuring the ankle blood pressure. In addition, JNC-VII recommends that blood pressure should be controlled more strictly for hypertension patients with PAD, regardless of symptoms, than for those without PAD.5 However, few general physicians measure lower extremity blood pressure in their daily practice6 for several reasons. Firstly, ankle blood pressure is usually measured with a Doppler device, but this is not always available to general physicians6 and, even if it is, few of them actually use this device.7 Secondly, the auscultatory method (AUS) is an alternative and has been advocated for measuring blood pressure in the lower extremities, such as in the
popliteal, the posterior tibial and the dorsalis pedis artery. However, to measure popliteal artery blood pressure, for example, a wide cuff for the lower thigh is necessary, but again this is not always available to general physicians.

Thirdly, blood pressure in the posterior tibial and dorsalis pedis artery can be measured with AUS using the standard cuff for measuring blood pressure in the brachial artery with the aid of a stethoscope. General physicians can therefore easily perform it in the daily practice or at bedside. However, the efficacy of AUS for measuring ankle blood pressure has not yet been compared with that of the Doppler method (DOP), nor has it been evaluated for diagnosing PAD based on ABI. Doubts about its efficacy could therefore discourage general physicians from measuring ankle blood pressure by means of AUS.

The objectives of this study were to compare AUS with DOP for measuring posterior tibial artery blood pressure and to investigate the potential and limitations of AUS for diagnosing PAD.

Methods

Subjects

Study subjects were patients aged 50 years and older, who were consecutively admitted to two community hospitals in Osaka and Kyoto, Japan, during the two periods of October 2001 and July 2002. We obtained informed consent from all these subjects.

Data collection

Three of the investigators, who were trained according to a standard protocol, took part in measuring blood pressure. SBP was measured twice by AUS in both the brachial and the posterior tibial artery and the average value was used to calculate ABI. Another of the investigators similarly calculated ABI by using DOP. Random digital numbers were used to assign one of the investigators to either method, as well as the sequence of measurements to minimize bias. All investigators were blinded to the results of other tests.

Ankle-brachial index measurement

At the outset, patients were asked to rest in the supine position for 5 minutes, after which the radial arteries were palpated bilaterally. After confirmation that the pulsations in the bilateral radial arteries were similar, the right brachial artery blood pressure was measured according to the method recommended by the American Heart Association. In order to measure the posterior tibial artery blood pressure, a 12 cm-wide standard cuff for the upper extremity was applied to the ankle, with the lower end of the cuff being placed about 3 cm above the malleoli and the contour adjusted to the conical shape of the lower leg. A hand-held 8-mHz Doppler device (ES-1000SPM, Hadeco R&D, Japan) for DOP and a stethoscope (Allen series 12/22; Allen Medical Instruments Corp., Newport Beach, CA, USA) for AUS were used.

Statistical analysis

A Student’s t-test was used to compare the difference in SBP of the brachial artery measured by DOP and AUS with the corresponding difference in SBP of the posterior tibial artery. We calculated likelihood ratios (LR) and 95% confidence intervals of ABI measured by AUS for diagnosing PAD with the gold standard by DOP. PAD legs were defined as legs with an ABI ≤0.90 as measure with the Doppler device. PAD patients were defined as those with an ABI of 0.90 or less in either leg. The difference in SBP of the posterior tibial artery when measured by DOP and AUS, was tested with analysis of variance among three investigators to examine the influence of clinical experience on the measurements. All of the statistical analyses were performed with the aid of STATA (Version 6; STATA Corp., College Station, TX, USA).

Results

Patient characteristics

Of the total 119 patients, 89 were admitted in October 2001 and 30 in July 2002. Because patient characteristics regarding age, gender and underlying disease were comparable, the data for the two groups were combined for analysis.

The average age of the subjects (119 patients, 238 legs) was 74.8 years (standard deviation: 9.8 years) and 50.4% of them were male. The percentages of patients with hypertension, hyperlipidemia, diabetes mellitus, history of stroke, history of coronary heart disease, and of those who were current smokers are described in Table 1. PAD (ABI ≤0.90 by DOP) was diagnosed in 33 (13.9%) of the 238 legs and in 22 (18.5%) of the 119 patients by DOP. The average ABI (SD) of participants was 0.99 (0.17). The percentages of patients with mild PAD (ABI 0.71–0.90), moderate PAD (ABI 0.41–0.70), and severe PAD (ABI <0.4) were 9.2%, 9.2% and 0%, respectively (Table 1).

Brachial blood pressures and ankle blood pressures

The mean brachial SBP was 127.7 mmHg for AUS and 131.1 mmHg as measured with DOP. The mean difference in brachial SBP, determined by subtracting the one measured by DOP from that measured by AUS, was −3.5 mmHg (95% CI −5.4 to −1.6).

Korotkoff sounds were inaudible by AUS in 76 (31.9%) of the 238 legs and 47 (39.8%) of the 119 patients. For those legs that the mean ankle SBP could be measured, it was 127.3 mmHg for AUS and 142.6 mmHg for DOP. The mean difference in ankle SBP, determined by subtracting SBP measured by DOP from that measured by AUS, was −15.2 mmHg (95% CI −17.8 to −12.7), which was significantly greater than the difference in SBP measured by AUS and DOP in the brachial artery (P < 0.001) (Fig. 1).

In legs where Korotkoff sounds were inaudible, the mean ankle blood pressure measured by DOP was

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To the best of our knowledge, this is the first published study to evaluate the auscultatory method, in comparison with the Doppler method, for measuring ankle blood pressure. We demonstrated that systolic blood pressures measured by AUS were significantly lower than those measured by DOP in both brachial artery (3.5 mmHg) and posterior tibial artery (15.2 mmHg).

Moreover, diagnosis of PAD by AUS showed that, when the value of ABI calculated by AUS is more than 0.9, the likelihood of PAD may be very small.

The difference in systolic blood pressure measured with the two methods was larger for the posterior tibial artery (119.6 mmHg, which was lower than for the legs where Korotkoff sounds were audible (142.6 mmHg) while there was no difference in systolic brachial blood pressures between inaudible (130.6 mmHg) and audible patients (131.5 mmHg).

There were no significant differences among the three observers in their measurements by AUS of posterior tibial artery blood pressure.

**Diagnosis of peripheral arterial disease with the auscultatory method**

The likelihood ratio (LR) for diagnosing PAD patients by AUS was 2.7 (95% CI 1.9 to 3.9) when Korotkoff sounds were inaudible, 0.70 (95% CI 0.2 to 1.9) for ABI  0.9, and 0.09 (95% CI 0.02 to 0.4) for ABI >0.9 by AUS. In addition, the LR for diagnosing PAD legs by AUS was 3.4 (95% CI 2.5 to 4.6) when Korotkoff sounds were inaudible, 1.0 (95% CI 0.4 to 2.2) for ABI  0.9, and 0.05 (95% CI 0.01 to 0.25) for ABI >0.9 by AUS (Table 2).

**Discussion**

To the best of our knowledge, this is the first published study to evaluate the auscultatory method, in comparison with the Doppler method, for measuring ankle blood pressure. We demonstrated that systolic blood pressures measured by AUS were significantly lower than those measured by DOP in both brachial artery (3.5 mmHg) and posterior tibial artery (15.2 mmHg). Moreover, diagnosis of PAD by AUS showed that, when the value of ABI calculated by AUS is more than 0.9, the likelihood of PAD may be very small.

The difference in systolic blood pressure measured with the two methods was larger for the posterior tibial
Auscultatory method for ruling out PAD

artery than for the brachial artery. One of the reasons seems to be the poor fit of the stethoscope on the curved skin surface of the lower extremity, making it more difficult to auscultate Korotkoff sounds in the ankle area than measure brachial blood pressure. Consequently, when the ABI value measured by AUS is more than 0.9, the one measured by DOP is also likely to exceed 0.9 (LR = 0.09).

In general, LR of >10 or <0.1 generates a large and often conclusive change in probability of PAD from pre-test to post-test. Based on our findings reported here, if the pre-test probability of PAD is 50%, the post-test probability becomes only 8% if the ABI value determined by AUS is more than 0.9. Thus, ABI >0.9 measured by AUS is useful for ruling out PAD in daily clinical practice. On the other hand, in patients with ABI ≤0.9 or blood pressure which cannot be auscultated, LR is not high enough to confirm the presence of PAD (LR = 2.7 and 0.7, respectively).

For general physicians, medical history and physical examinations are the major tools for suspecting or establishing a diagnosis of PAD. However, according to previous studies, history and physical examinations are not useful findings for lowering the probability of PAD. Stoffers et al. reported that the presence of a pulse in either or both the dorsalis pedis artery and posterior tibial artery was the most useful finding for lowering the probability of PAD (LR = 0.3). Our study showed that the LR (LR = 0.09) determined by AUS (0.09) was smaller than that by measured palpation, i.e. PAD was excluded more reliably by AUS than by palpation.

For calculating LR, we believe the inaudibility of the pulse in legs should not be interpreted as missing. The Standards for Reporting of Diagnostic Accuracy (STARD) reported that ignoring un-interpretable test results could produce biased estimates of diagnostic accuracy if these results occur more frequently in patients with the target condition than in those without it. The legs with inaudible pulse were more likely to be PAD legs than those in which the pulse was audible, because mean systolic ankle blood pressures of the former (119.6 mmHg) measured by DOP were significantly lower than that of the latter (142.6 mmHg), although there was no difference in systolic brachial blood pressures. That is why LR for PAD of legs with inaudible pulse was the highest among the three groups. If we ignore the results for inaudible legs, valuable information about AUS diagnostic test may be lost. We therefore analysed our data using the LR approach as three categorical results.

There are several limitations to this study. First, to determine the ABI by DOP, we used the posterior tibial, not the dorsalis pedis artery. However, the ABI value is usually calculated based on the value of either the posterior tibial or dorsalis pedis artery blood pressure, whichever is higher. If the ABI were calculated in that way, the ABI values could become larger than those reported here. Even in that case, therefore, when ABI >0.9 as determined by AUS, the ABI measured by DOP is also likely to exceed 0.9, i.e. the possibility of PAD remains miniscule. The usefulness of AUS for excluding PAD when ABI >0.9 is thus robust. Second, all subjects in this study were hospitalized patients. We selected these patients because the prevalence of PAD was likely to be higher among them than among ambulatory patients in Japan. This may somewhat restrict the generalizability of the current results in spite of the independent nature of the likelihood ratio from the prevalence of PAD.

In conclusion, mean SBP values measured by AUS were significantly lower than those measured by DOP in both brachial and posterior tibial arteries. Moreover, among the patients with audible pulse, AUS could be clinically useful for excluding PAD when ABI >0.9, although it is not efficient enough to confirm the presence of PAD. Thus, when physicians use AUS as a tool for measuring ankle SBP, it is important to be fully aware of its characteristics, strengths and weaknesses.

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Declaration

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Conflicts of interest: none

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