



Four-Limb Blood Pressure Measurement with an Oscillometric Device: a Tool for Diagnosing Peripheral Vascular Disease

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Abstract

Purpose of Review Traditionally, the term peripheral vascular disease (PAD) is restricted to the occlusive arterial disease in the leg, but now, the connotation of PAD is more widespread as it encompasses all extracoronary and extracerebral vascular disease. The incidence of PAD is increasing worldwide; therefore, it is necessary to diagnose PAD at an early stage.

Recent Findings Oscillometric BP device is widely used for four-limb measurement in clinical practice and provides several parameters for evaluating inter-limb BP difference, such as ankle-brachial index (OS-ABI), inter-arm BP differences (IAD), and inter-ankle BP difference (IAND). Using angiographic results as reference, the ABI, IAD, and IAND from an oscillometric BP device have been demonstrated having high accuracy for diagnosis of PAD. Meanwhile, combination of these parameters could further improve the accuracy of PAD, including the occlusive artery disease in the arm, leg, and aorta. For example, some patients with severe PAD in the leg have normal ABI; in this situation, an increased sIAND could confirm the diagnosis of PAD in the leg.

Summary Because ABI, IAD, and IAND from inter-limb oscillometric BP measurement can also predict adverse prognosis, we encourage the use of an oscillometric device to measure four-limb BP and to evaluate the inter-limb BP difference.

Keywords Peripheral vascular disease (PAD) · Oscillometric BP device · ABI · IAD · IAND

Introduction

Traditionally, the term peripheral vascular disease (PAD) is restricted to the occlusive arterial disease in the leg, but now, the connotation of PAD is more widespread [1–3] as it encompasses all extracoronary and extracerebral vascular disease. Although atherosclerosis is the most common, inflammatory disorders of the arterial wall and noninflammatory arteriopathies are included as the causes for PAD [4]. PAD is highly prevalent in the whole world [5] and an important

predictor for death, myocardial infarction, or stroke [6, 7]. However, most PAD patients are not diagnosed because only 10–20% of them have symptoms [2, 3]. At present, these patients are diagnosed by decreased ankle-brachial index (ABI of ≤ 0.90), a ratio of ankle systolic blood pressure (SBP) to brachial SBP [8, 9].

Previously, the ABI could only be detected with the Doppler method. As technical progress, automated BP monitors based on oscillometry have great feasibility to measure four-limb BP. In addition ABI, four-limb measurement could provide inter-arm BP difference (IAD) and inter-ankle BP difference (IAND). This review focuses the diagnostic value of ABI, IAD and IAND from oscillometric four-limb BP measurement for PAD based on the results of artery imaging.

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Inter-arm BP Differences

In 1915, Osler et al. [10] firstly reported IAD. Current guidelines for BP measurement recommend bilateral arm BP measurement to identify IAD. Generally, if the bilateral arm SBP difference is ≥ 10 mmHg, systolic IAD (sIAD) could be diagnosed [11–13, 14•]. sIAD is a useful marker for asymmetric

subclavian artery or brachial artery stenosis. The underlying mechanism of sIAD is that the arm with artery stenosis has lower SBP. The most common stenotic location is in the subclavian artery, and the next is in the brachial artery. The causes of artery stenosis include atherosclerotic plaque, aneurysm, syphilitic aortitis, coarctation, and aortitis syndrome [15].

A meta-analysis conducted by Clark CE [16] found that in the patients with proven > 50% subclavian artery stenosis, the mean sIAD was 36.9 mmHg (95%CI 35.4–38.4); meanwhile, a sIAD \geq 10 mmHg was strongly associated with subclavian stenosis (RR 8.8, 95%CI 3.6–21.2).

The diagnosis value of sIAD for subclavian and brachial artery stenosis based on five reports with angiography information is shown in Table 1 [17, 18, 19, 20]. Calligaro et al. [17] found that the sensitivity of sIAD \geq 10 mmHg for identification of subclavian \geq 50% stenosis is 75% and the specificity is 75%. In English's study [18], these values are 65% and 85%, respectively.

When the cutoff increases to 15 mmHg, Aboyans et al. [19] found that the sensitivity for identification of subclavian stenosis was 50%, but the specificity increased to 90% in 1778 patients. Osborn et al. [20] also reported that all patients with sIAD \geq 15 mmHg had subclavian stenosis, while in the 55 subjects with sIAD < 15 mmHg, no one had subclavian stenosis. Based on these results, we suggest that sIAD \geq 10 mmHg, especially \geq 15 mmHg is a strong predictor for subclavian artery stenosis of > 50%.

We also note that the sensitivity of sIAD for subclavian artery diagnosis is relatively low; one reason for this finding is likely associated with bilateral subclavian stenosis.

In addition, increased sIAD is a predictor for early diagnosis of aortic dissection in the patients with acute chest pain. Based on data from 111 cases with aortic dissection and 111 controls, Ohle et al. [21] suggest that sIAD > 20 mmHg may be a useful predictor for aortic dissection in the patients with acute chest pain.

our research team found the normal range of ankle SBP was 110–175 mmHg in the community population [28]. Recently, in the patients suspected with PAD in the leg, we found that the cutoff value of ankle SBP for > 50% artery stenosis of the leg was less than 110 mmHg in the patients with a report from computed tomography angiography (CTA). More interestingly, in the 90 legs with ankle BP reported with “error” by the oscillometric BP device, most had severe stenosis or complete occlusion. Thus, the “error” reported by the oscillometric BP device powerfully indicates 50% artery occlusive diseases in the legs, especially when the BP of the other ankle could be detected. Previously, a study also showed that when the SBP is lower than 50 mmHg, the oscillometric BP device could not report the exact BP value [29].

Like sIAD, the absolute difference between bilateral ankle SBP, sIAND, is a valuable predictor for artery stenosis in the leg. Based on the results from 1920 community populations, our team proposed that sIAND \geq 15 mmHg as an abnormal cut point [28]. Using ABI < 0.9 as reference, Herraiz et al. [30] pointed out that the specificity and the sensitivity of sIAND \geq 10 mmHg for diagnosing PAD in the leg was 85.1% and 69.6%, respectively. Meanwhile, a study demonstrated that sIAND \geq 15 mmHg is a strong predictor for PAD in the leg (RR, 11.87; CI 7.64–18.44) [31]. Using ultrasonic examination as reference, Su et al. [32] found that ABI < 0.9 was associated with an sIAND \geq 15 mmHg. Unfortunately, until now, no research used artery imaging as the gold standard to evaluate the values of sIAND for the diagnosis of PAD in the leg. Our unpublished data showed that in 187 patients with leg artery stenosis confirmed by CTA, sIAND \geq 15 mmHg has a specificity of 100% and sensitivity of 54.4% (Table 2). A reason for relative lower sensitivity of sIAND may be that majority of patients have bilateral leg artery stenosis. Another reason may be that when the ankle BP is too low, oscillometric device could not detect the BP and often show “errors” in both ankle.

Ankle BP and Inter-ankle BP Difference

Ankle BP is used more frequently in clinical practice at present as it could be easily taken using an oscillometric BP device [22–25]. In addition for calculating ABI [26, 27], a decreased ankle SBP itself indicates artery stenosis in the leg. Previously,

Oscillometric Ankle-Brachial Index

ABI is the ratio of ankle SBP to brachial SBP [8, 9]. Decreased ABI may occur in two situations: leg arterial stenosis or aorta coarctation [33].

Table 1 The value of sIAD for diagnosis of subclavian and brachial artery stenosis on the results of artery imaging

Author	Cutoff (mmHg)	Referring	population	N	Sensitivity (%)	Specificity (%)
Calligaro (1990)	\geq 10	angiography	Primary care and vascular consultant	40	75	75
English (2001)	\geq 10	angiography	Vascular clinic consultant	515	65	85
Osborn (2002)	\geq 15	angiography	Vascular surgery patients	59	100	100
Aboyans (2007)	\geq 15	angiography	Vascular clinic consultant	1778	50	90

Table 2 The results between sIAND and artery imaging

Author	Cutoff	Referring	Study population	N	Sensitivity (%)	Specificity (%)
Our team (2018)	≥ 15 mmHg	CTA	Vascular clinic consultant	187	56	100

Previously, the SBP of the dorsal and posterior tibial arteries could be measured only with the Doppler method. For the Doppler ABI, 1.00–1.40 is the normal range, 0.91–0.99 is the borderline, and < 0.90 is abnormal to indicate PAD in leg [34•]. However, there are several calculation methods of ABI at present. The ACC/AHA guidelines recommend that the higher SBP of the dorsal and posterior tibial arteries divide the higher SBP of brachial artery, because it has moderate sensitivity and high specificity [34•]. But, some researchers recommend that the lower SBP of the dorsal and posterior tibial arteries divide the higher SBP of brachial artery [35].

Recently, ankle BP can be measured with oscillometric method (OS-), the OS-ABI is calculated with the following formula: ABI = lower ankle-SBP of two ankles/higher SBP of two arms. Because of the different measurement method, many studies evaluated the value of OS-ABI for diagnosis of PAD in the leg against the Doppler ABI (DP-ABI).

On the existing reports, the coefficients between OS-ABI and DP-ABI are from 0.78 to 0.85 [36, 37, 38••]. Herráiz-Adillo et al. [38••] showed that OS-ABI had an acceptable sensitivity (78.2%) and excellent specificity (96%) when DP-ABI was used as reference. Subsequently, they confirmed OS-ABI an acceptable diagnostic parameter by a meta-analysis [39].

Until now, only four studies used CTA results as the gold standard [40•, 41•, 42•, 43•] to evaluate the diagnostic accuracy of OS-ABI for PAD in the leg. For example, Ichihashi et al. [40•] indicated that OS-ABI < 0.99 is optimal for diagnosis of PAD in the leg. Our unpublished data showed that OS-ABI < 0.9 had high specificity (100%) and relatively high sensitivity (84%) in 187 patients with leg artery stenosis confirmed by CTA. On the current data, the cutoff point for diagnosis of 50% stenosis is 0.95–1.02, which is higher than 0.9 for the DP-ABI (Table 3).

Table 3 The values of OS-ABI for diagnosis of PAD in leg on artery imaging

Author	Cutoff	Referring	Study population	N	Sensitivity (%)	Specificity (%)
Ichihashi (2014)	0.99	CTA	Vascular clinic consultant	108	90	85
Guo (2008)	0.95	DSA	Cardiology in-patient clinic	298	91	86
Clairotte (2009)	1.02	CTA	High risk	146	58.8	88.7
Our team (2018)	0.9	CTA	Vascular clinic consultant	187	84	100

Exercise ABI

However, a part of patients with leg symptoms concerning PAD have normal ABI. In this instance, exercise ABI should be detected. During exercise, the central aortic BP increases, but the BP in the leg with artery stenosis decreases because the arterial beds dilate to deliver more oxygenated blood to meet the metabolic demands of the leg muscles [44]. In healthy patients, ABI only slightly decreases in exercise. However, in the patients with PAD in the leg, the ABI obviously decreases in exercise. Aaron et al. found that exercise ABI < 0.90 exhibits a greater sensitivity for detecting PAD in the leg compared to resting ABI [45].

Inter-limb BP Difference

Based on the BP values of four limbs, a simple parameter of arm-ankle blood pressure difference (AAPD) could be calculated. Usually, the ankle SBP is higher than arm SBP by 20–40 mmHg, even in patients with hypertension. But this value is not suitable in newborns, as their BP levels between arm and leg were similar.

An increased systolic AAPD, especially when the two legs had similar SBP levels is a useful predictor for aortic coarctation [46], even in the newborns. Patankar et al. [47] found that the 46 newborns with aortic coarctation had a statistically significant higher systolic AAPD (6.8 ± 16.9 mmHg vs 1.2 ± 8.6 mmHg) and diastolic AAPD (6.6 ± 13.6 mmHg vs 1.3 ± 7.9 mmHg) against the 92 normal newborns.

Summary

The incidence of PAD is increasing in the world; therefore, it is necessary to diagnose PAD at an early stage. The oscillometric BP device is widely used in clinical practice for four-limb measurement and provides several parameters,

such as IAD, IAND, and ABI, to diagnose PAD. A combination of these parameters could improve the accuracy of PAD. For example, some patients with severe PAD in the leg have normal ABI. In this situation, the increased sIAND could identify most of these patients.

Because IAD, IAND, and ABI from inter-limb BP measurement can also predict adverse prognosis, we encourage the use of an oscillometric device to measure four-limb BP and to evaluate the inter-limb BP difference.

Compliance with Ethical Standards

Conflict of Interest The authors declare no conflicts of interest relevant to this manuscript.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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- Of major importance

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