STANDARDS OF PRACTICE

Position Statement on Noninvasive Imaging of Peripheral Arterial Disease by the Society of Interventional Radiology and the Canadian Interventional Radiology Association

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ABBREVIATIONS

ABI = ankle-brachial index, PAD = peripheral artery disease, PSV = peak systolic velocity, PVR = pulse volume recording, TBI = toe brachial index

INTRODUCTION

Noninvasive evaluation of peripheral artery disease (PAD) has defined usefulness for patient screening and patient stratification. In addition, this evaluation also facilitates proper patient selection and objective outcome evaluation for PAD interventions (1,2). As part of the Affordable Care Act, alternative payment models have emerged to enact the intended paradigm shift from merit-based toward more value- and outcome-oriented delivery of medical care. Hence, the appropriate use of such noninvasive tools to improve preprocedure patient selection, as well as to objectively document postprocedure outcomes, deserves particular consideration. At the same time, no recent document is available that provides official Society of Interventional Radiology (SIR) guidance or comprehensively addresses the topic within the dedicated interventional radiology literature. Finally, use of noninvasive evaluation tools may vary considerably across specialties that are involved in the care of patients with PAD.

The present document therefore reviews and provides recommendations for noninvasive lower-extremity imaging of PAD, which includes two broad categories: (*i*) functional tests and (*ii*) anatomic tests. The functional or physiologic tests include the ankle-brachial index (ABI), segmental limb pressures, pulse volume recordings (PVRs), segmental Doppler waveforms, and oxygen testing. The anatomic tests include duplex ultrasound (US), computed tomography (CT), and magnetic resonance (MR) imaging. Because of the complexities and degree of discussion needed for each study, CT and MR imaging will be discussed in a future document. The intent of the present document is to outline the principles of noninvasive investigations for screening, pretreatment, and follow-up of PAD.

A noninvasive evaluation of patients with PAD is composed of a number of different testing modalities, each with specific purposes to identify various patient attributes. These components may differ among laboratories depending on local practice, availability of testing modalities, and training of the physicians and technologists. For instance, an ABI measurement alone does not constitute a complete noninvasive examination. A typical noninvasive examination should always include an ABI and may include PVRs, continuous-wave Doppler analysis, segmental pressures, and exercise testing. Many laboratories use all components to increase accuracy. Each of these tests has advantages and disadvantages. Together, with the use of each component, these noninvasive tests constitute a highly reproducible and accurate examination.

STANDARD TESTING MODALITIES

ABI

The ABI is the ankle systolic blood pressure divided by the brachial artery systolic blood pressure. Both upper-extremity brachial pressures should be taken, and, if there is more than a 15-mm Hg difference between the two sides, hemodynamically significant disease should be considered to be present proximal to the brachial artery with the lower pressure. If there is a brachial pressure discrepancy, the higher pressure should be used. The greater of the dorsalis pedis or posterior tibial artery blood pressure from each side is taken for the ankle reading. The blood pressure readings can be obtained by stethoscope auscultation or

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by a Doppler US probe. Because auscultation is generally less accurate and less reproducible, Doppler reading is the preferred method (3,4).

The range for a normal ABI is between 1.0 and 1.1 (5–8). There is an association between increasing severity of lower-extremity symptoms caused by PAD and a decreasing ABI (9). Although there is overlap between intervals, early work by Yao (9) has suggested the following thresholds for the practical classification of the severity of PAD: no symptoms, ABI more than 1.0; claudication, ABI between 0.5 and 1.0; rest pain, ABI between 0.25 and 0.50; and impending tissue loss, ABI less than 0.25 (9). The sensitivity and specificity rates of ABI for the diagnosis of PAD are 72% and 96%, respectively (4,10,11).

An alternative classification of ABI ranges is included in Table 1. One of the limitations of the ABI is the possible underestimation of the degree of disease in the case of tissue loss, such as a nonhealing arterial ulcer, as the higher of the two ankle blood pressures are taken for the calculation. Hence, ABI reporting should take the clinical scenario into context and also include absolute ankle pressures. If one were to use the lower of the pressures between the dorsalis pedis and the posterior tibial artery, the sensitivity would increase but the specificity in detecting disease would decrease. This is performed by some laboratories when PAD is known and the examination is not being performed for screening or detection of new disease. In fact, if the ABI is obtained as a prognostic marker for cardiovascular disease, the lower value should be used (4).

Another limitation of the ABI is its false elevation in patients with calcified arterial vessels. If the patient has heavily calcified vessels, a toe brachial index (TBI) can be taken with a pressure reading from the great toe, in which vessels rarely show calcification. An index > 0.65 is considered normal for the TBI. Generally, severe PAD is present with a TBI of less than 0.40. It is important to note that ABI does not localize disease within the lower extremities. The ABI measurement serves as a preliminary test to determine if the patient's symptoms are related to PAD. The ABI is also used as part of a surveillance test for patients as a follow-up study. Finally, it is well documented that decreasing ABIs are associated with increased morbidity and mortality from cardiovascular disease (12–14).

PAD is an independent risk factor for coronary artery disease. Therefore, discovery of PAD with a decreased ABI often mandates a further workup for patients and should lead to assessment of cardiovascular risk factors. In fact, cardiovascular risk screening is often performed by measuring an ABI.

Recommendations. Bilateral ABI calculations should be performed, which include bilateral brachial arteries and bilateral ankle pressures. The ABI should take the clinical situation into context to avoid false-negative calculations. The absolute ankle pressures should also be included in conjunction with the ABI calculation. Finally, in heavily calcified arteries, a TBI should be considered.

Segmental Limb Pressures

Because the ABI does not localize disease within the lower extremities, segmental limb pressures can be used. Segmental pressures are similar to the ABI, with the addition of two or three appropriately sized blood pressure cuffs placed in the high and/or low thigh and in the upper calf. The blood pressure cuff is inflated to occlude the arterial inflow; the cuff is then slowly deflated while detecting the pressure at which blood flow resumes distal to the cuff. Doppler instrumentation or plethysmography can be used to determine the resumption of blood flow. Additional cuffs are placed just below the knee, and one large cuff or two narrow cuffs are placed above the knee and at the upper thigh. The cuffs are then inflated to greater than systolic blood pressure and then slowly deflated. A gradient of greater than 30 mm Hg between two consecutive ipsilateral segments or a gradient of greater than 20–30 mm Hg from one limb to the other at the same level suggests significant arterial stenosis (15). Segmental limb pressures serve as a preliminary test to determine if the patient may have PAD. It can also be used as a separate test after the ABI, if the ABI is abnormal, to further localize the diseased area in the affected extremity. Segmental pressures may be difficult to interpret when significant proximal disease is present. The use of segmental pressures is helpful as an adjunct to PVRs, which are much more sensitive in detecting multilevel disease.

Table 1. ABI-Based Grading of PAD

ABI	Comment
> 1.3	Falsely high value (suspicion of medal sclerosis)
0.9–1.3	Normal finding
0.75–0.9	Mild PAD
0.4–0.75	Moderate PAD
< 0.4	Severe PAD

Source–Stiegler H, Brandl R. Importance of ultrasound for diagnosing peripheral artery disease. Ultraschall in Med 2009; 30:334–363.

ABI = ankle brachial index; PAD = peripheral artery disease.

Recommendations. An ABI is a mandatory part of a physiologic examination. For segmental pressures, four cuffs can be used. The recommended location of the blood pressure cuffs are the upper thigh, lower thigh, upper calf, and ankle.

Segmental PVRs

Similar to segmental limb pressures, segmental PVRs use dedicated pressure cuffs at the different limb segments. A PVR is an air plethysmographic study used to detect segmental volume changes in the limb during the cardiac cycle (16). The cuffs are typically inflated to 65 mm Hg to occlude venous return while maintaining arterial flow. Cuffs are placed at the superior thigh, inferior thigh, calf, ankle, and transmetatarsal levels. Toe PVR can be performed as well. An ankle PVR cuff is left in place during exercise, and the PVR tracings at the ankle are repeated after exercise along with the ABI. The pneumoplethysmographic waveform signals, which are derived from the segmental volume changes of blood flow, are recorded. Waveforms are generated as air is displaced in the nonoccluded cuff. These waveforms are markedly different than Doppler arterial waveforms and should not be confused with arterial waveforms. The normal waveform typically consists of four phases: (*i*) a rapid systolic upstroke, (*ii*) a rapid diastolic downstroke, (*iii*) a prominent dicrotic notch, and (*iv*) normalization to baseline before the next rapid systolic upstroke occurs. With PAD, when significant occlusive disease is present, the waveforms may first lose the dicrotic notch, and then, as the upstroke and downstroke slow, the waveform becomes more rounded and the amplitude decreases. The amplitude of the waveform will decrease with distal stenosis and will become flat in occlusive disease. Interpretation of PVRs should be performed quantitatively and qualitatively. Comparison of each limb's waveforms is an important element of interpretation. When blood flow is normal, the calf waveform augments as much as 30% more than the high thigh waveform. If augmentation is not present, even with a qualitatively good waveform, disease in the femoral popliteal segment should be suspected (17).

Segmental PVRs are part of the complete noninvasive examination. The indications for segmental PVRs as a component of noninvasive testing are to evaluate whether a patient's symptoms are related to arterial insufficiency or as surveillance in patients who have undergone revascularization to determine if additional intervention is needed. Advantages of segmental PVRs include the ability to identify and localize segmental disease. In addition, segmental PVRs are not altered by calcium and are highly reproducible. This is probably the most reliable and accurate component of the noninvasive examination, and is considered a standard portion of the complete examination in many laboratories (17,18).