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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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.

STANDARDS OF PRACTICE

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
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 0.5; 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 brachial 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**

<table>
<thead>
<tr>
<th>ABI</th>
<th>Comment</th>
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<tbody>
<tr>
<td>&gt; 1.3</td>
<td>Falsely high value (suspicion of medial sclerosis)</td>
</tr>
<tr>
<td>0.9-1.3</td>
<td>Normal finding</td>
</tr>
<tr>
<td>0.75-0.9</td>
<td>Mild PAD</td>
</tr>
<tr>
<td>0.4-0.75</td>
<td>Moderate PAD</td>
</tr>
<tr>
<td>&lt; 0.4</td>
<td>Severe PAD</td>
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API = ankle brachial index; PVR = peripheral arterial disease.