Physical Examination and Chronic Lower-Extremity Ischemia

A Critical Review

Steven R. McGee, MD; Edward J. Boyko, MD, MPH

Objective: To determine the clinical utility of physical examination in patients with suspected chronic ischemia of the lower extremities.

Data Sources: MEDLINE search (January 1966 to January 1997), personal files, and bibliographies of textbooks on physical diagnosis, surgery, and vascular surgery.

Study Selection: Both authors independently graded the studies as level 1, 2, or 3, according to predetermined criteria. Criteria deemed essential for analysis of sensitivity, specificity, and likelihood ratios were (1) clear definition of study population, (2) clear definition of physical examination maneuver, and (3) use of an acceptable criterion standard test for comparison.

Results: The following positive findings help clinicians diagnose the presence of peripheral arterial disease: abnormal pedal pulses, a unilaterally cool extremity, a prolonged venous filling time, and a femoral bruit. Other physical signs help determine the extent and distribution of vascular disease, including an abnormal femoral pulse, lower-extremity bruits, warm knees, and the Buerger test. The capillary refill test and the findings of foot discoloration, atrophic skin, and hairless extremities are unhelpful in diagnostic decisions. Mathematical formulas, derived from 2 studies using multivariate analysis, allow clinicians to estimate the probability of peripheral arterial disease in their patients.

Conclusion: Certain aspects of the physical examination help clinicians make accurate judgments about the presence of peripheral arterial disease and its distribution.

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In his book The Circulatory Disturbances of the Extremities, published in 1924, Buerger introduced to clinicians several new physical signs of peripheral vascular disease. Whereas earlier writers on vascular disease had confined themselves to descriptions of gangrene, Buerger stressed the importance of certain "prodomal" findings, including absent pulses, toe and foot ulcers, impaired nail growth, soft tissue atrophy, poor capillary refill (the "expression test"), foot pallor with elevation, and a deep-red color of the limb in the lowered position ("erythromelia").

Modern clinicians have accepted Buerger's findings as characteristic of chronic arteriosclerosis, a somewhat surprising inference because Buerger considered them most characteristic of thromboangiitis obliterans, a rare form of small-vessel vasculitis now known as Buerger disease. Moreover, other prominent physicians, writing soon after the appearance of Buerger's book, argued that some of Buerger's findings were unreliable and clinically unhelpful, especially capillary refill and dependent rubor.

Chronic arterial disease usually affects 3 distinct segments in the lower limbs: the aortoiliac segment (especially the infrarenal abdominal aorta and common iliac arteries), the femoropopliteal segment (especially the superficial femoral artery in the adductor canal, a tunnel amid muscle groups of the middle third of the thigh), and the peroneotibial segment (below the knee). Most patients have femoropopliteal disease, aortoiliac disease, or both. Significant peroneotibial disease is uncommon unless the patient has diabetes or thromboangiitis obliterans. According to traditional teachings, disease in each of these segments causes specific claudication symptoms and pulse abnormalities, and requires different surgical approaches.

The ankle-to-arm systolic pressure index (AAI), the most common criterion standard used in studies of physical diagnosis, is obtained by measuring the highest systolic blood pressure at the ankle...
MATERIALS AND METHODS

One of us (S.R.M.) performed a MEDLINE search of articles published between January 1966 and January 1997 to retrieve all relevant publications on the bedside diagnosis of peripheral vascular disease (the specific strategy was arterial occlusive diseases/di AND physical examination OR peripheral vascular disease/di OR intermittent claudication/di OR pulse/), all limited to the English language and human subjects. Based on review of titles and abstracts, relevant publications were retrieved, including all articles that determined interobserver variability and all that compared physical signs with an objective criterion standard. To complete the search, the bibliographies of these articles and those of textbooks on physical diagnosis, surgery, and vascular surgery were reviewed.

Both of us independently examined the selected studies for the following criteria: (1) clear definition of the study population, (2) clear definition of the physical examination maneuver, (3) use of an acceptable criterion standard test (calculation of AAI, direct pressure measurement, angiography), (4) unbiased selection of patients (ie, consecutive patients or population-based sample), (5) predefined abnormal thresholds for the criterion standard, and (6) blinded comparison of test and criterion standard results. Studies satisfying all 6 criteria were graded level 1; those with fewer than all 6 but satisfying at least 1, 2, and 3 were graded level 2; and all others were graded level 3. We discussed and resolved any disagreement in classification by consensus.

Of the 17 studies identified, 7 were graded level 1.9,12,15 5 were graded level 2,16-20 and 5 were graded level 3.21-25 Four studies10,11,16,21 were excluded from the analysis of the pulse examination because each defined as abnormal the absence of only 1 of the 2 pedal pulses, a common finding in healthy individuals (see below) and a biologically implausible sign of disease (lower-extremity ischemia, in any of the upper 2 segments, should cause both pedal pulses to disappear). Level 3 studies and other citations may appear in the discussion if they provide original data that support findings from level 1 and 2 studies. However, we used only level 1 and 2 studies for calculations of sensitivity, specificity, and likelihood ratios (LRs).

Data were expressed as sensitivity, specificity, positive and negative LRs, and the κ statistic according to traditional definitions.26 If a particular LR, positive or negative, has a value close to 1, that outcome of the test is unhelpful in making diagnostic decisions at the bedside.27

(dorsalis pedis and posterior tibial arteries) with a handheld Doppler flowmeter and dividing it by the blood pressure in the brachial artery. In healthy individuals, the AAI is greater than 0.97 (this cutoff represents the lower 2.5% of measurements from large numbers of young, non-smoking, asymptomatic individuals).6-9 Values less than 0.97 identify patients with angiographically proven occlusions or significant stenoses with a sensitivity of 96% to 97% and specificity of 94% to 100%.6,8 Most patients with claudication have AAs between 0.5 and 0.8 and disease in a single segment; those with rest pain and gangrene have AAs less than 0.5 and disease in at least 2 segments.5,8

This review addresses the diagnostic accuracy of many of Buerger’s prodromal findings, compared with the AAI and other criterion standard measures, and whether certain aspects of the physical examination actually help clinicians accurately determine the location of the patient’s arterial occlusions and stenoses, as suggested in Table 1.

RESULTS

DIAGNOSIS OF PERIPHERAL ARTERIAL DISEASE

Examination of the Pedal Pulses

To best understand the diagnostic value of the pulse examination, it is important to first address interobserver variation and the normal variations in the vascular perfusion of the foot. When deciding whether a particular pulse is present or absent, clinicians demonstrate fair to almost perfect agreement (κ=0.20-0.92) (Table 2), although attempts to distinguish the normal and reduced pulse cause considerable dissent (κ=0.01-0.15) (Table 2). Table 3 reveals that, in studies of large numbers of healthy individuals, the dorsalis pedis, posterior tibial, and femoral pulses are palpable 8.1%, 2.9%, and 0% of the time, respectively (Table 3),37 findings that are consistent across all age groups.35 Even when a physician cannot palpate one of the pedal pulses of a healthy individual, however, it is usually audible by a Doppler flowmeter, the dorsalis pedis artery being congenitally absent in only 2% of extremities and the posterior tibial in 0.1%.39,40 Anatomists dissecting normal feet have found that when the dorsalis pedis artery is small or absent, the posterior tibial artery is prominent; when the posterior tibial artery is small, the dorsalis pedis is prominent.41 These normal patterns of collateral circulation not only help explain why clinicians use whichever pedal pulse has the highest blood pressure to calculate the AAI, but also why only 0.7% of normal extremities are missing both pedal pulses (Table 3).

Consistent with these anatomic studies and investigations in healthy subjects, the absence of both pedal pulses has been shown to be a powerful predictor for the presence of vascular disease (AAI<0.9) in the extremity examined (LR+=9.0-44.6; Table 4). For definitions of disease that include only the most severe cases (AAI<0.5), however, the positive LRs are lower (LR+=3.0-3.8), probably because of diminished specificity (ie, many patients with AAs between 0.5 and 0.9 also lack pedal pulses).

Nevertheless, up to about one third of patients with disease, sometimes at limb-threatening levels (ie, AAI<0.5),12 have at least 1 palpable pedal pulse (sensitivity, 0.63-0.95) (Table 4). Although some correlation
exists between an arterial blood pressure and whether its pulse is palpable, this relationship is variable. In the dorsalis pedis artery, for example, the range of systolic pressures associated with palpable pulses (mean ± SD, 151±27 mm Hg; range, 64-220 mm Hg) overlaps significantly with those that are nonpalpable (mean, 112±56 mm Hg; range, 42-300 mm Hg). No absolute pressure threshold exists below which the pulse becomes nonpalpable, suggesting that other variables such as a highly flexible vessel wall, high rate of arterial runoff distal to the pulse, high cardiac output, superficial location of artery, low viscosity of blood, or certain distributions of disease, may preserve a palpable pulse despite low pressure.

In some patients with false-negative examination results (ie, disease is present but pedal pulses are palpable), the pedal pulses disappear during exercise. Just as exercise testing uncovers significant coronary artery stenoses, exercise of the extremities presumably results in a disproportionate distribution of blood to better-perfused muscle and away from poorly perfused distal tissue, causing the extremity to become symptomatic, the pressure to fall, and the pedal pulse to disappear. Exactly what proportion of diseased extremities with false-negative examination findings become positive with exercise has never been investigated, but a related series of investigations has shown...

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### Table 1. Diagnosis and Management of Chronic Arterial Disease of the Lower Extremities: Classic Approach

<table>
<thead>
<tr>
<th>Anatomic Segment</th>
<th>Location of Claudication</th>
<th>Pulse Examination</th>
<th>Usual Surgical Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aortoiliac</td>
<td>Buttock, thigh, calf†</td>
<td>Absent</td>
<td>Aortofemoral bypass with bifurcated prosthetic graft‡</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Absent</td>
<td>Femorofemoral bypass (if patient cannot tolerate abdominal procedure and other iliac widely patent)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Absent</td>
<td>Axillofemoral bypass (if patient cannot tolerate abdominal procedure and both iliac arteries diseased)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Absent</td>
<td>Femoropopliteal bypass with saphenous vein</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Absent</td>
<td>Femorotibial or femoroperoneal bypass with saphenous vein (if disease limited to proximal-mid calf and good distal runoff)</td>
</tr>
</tbody>
</table>

*A"Femoro" of "femoropopliteal" indicates superficial femoral artery and of "femoral pulse," common femoral artery.
† May cause erectile dysfunction if internal iliac arteries are involved.
‡ In the aortoiliac segment, percutaneous transluminal angioplasty is preferred for stenoses (not occlusions) of short segments (<10 cm).
§ Disease in this segment usually causes no claudication in patients with diabetes but causes foot pain in those with thromboangiitis obliterans.

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### Table 2. Palpation of Pulse: Interobserver Agreement

<table>
<thead>
<tr>
<th>Study‡</th>
<th>No. of Patients</th>
<th>No. of Examiners</th>
<th>Pulses Examined</th>
<th>Findings†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lawson et al28</td>
<td>63</td>
<td>3</td>
<td>Posterior tibial, dorsalis pedis (graded 0-4)</td>
<td>Weighted k: 0.20-0.72 (before training); 0.58-0.87 (after training)</td>
</tr>
<tr>
<td>Myers et al29</td>
<td>22</td>
<td>6</td>
<td>Femoral, popliteal</td>
<td>Pulse present or absent: k = 0.53 (femoral); 0.52 (popliteal)</td>
</tr>
<tr>
<td>Breaerly et al30</td>
<td>5</td>
<td>2</td>
<td>Femoral, popliteal, anterior tibial, posterior tibial, dorsalis pedis</td>
<td>Pulse present or absent: k = 0.92</td>
</tr>
</tbody>
</table>

*Studies that expressed data as simple agreement31-33 are not included in this table, unless raw data were available to calculate the k statistic.30
† Conventional interpretation of k statistic: 0-0.2, slight agreement; 0.2-0.4, fair agreement; 0.4-0.6, moderate agreement; 0.6-0.8, substantial agreement; and 0.8-1.0, almost perfect agreement.34

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### Table 3. Absent Pedal Pulses by Palpation in Healthy Subjects

<table>
<thead>
<tr>
<th>Study</th>
<th>No. of Extremities</th>
<th>Age, y</th>
<th>Dorsalis Pedis (DP)</th>
<th>Posterior Tibial (PT)</th>
<th>Both DP and PT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morrison35</td>
<td>2000</td>
<td>70+</td>
<td>6.1</td>
<td>10.1</td>
<td>1.9</td>
</tr>
<tr>
<td>Silverman36</td>
<td>2028</td>
<td>20 (mean)</td>
<td>12.5</td>
<td>2.8</td>
<td>0.2</td>
</tr>
<tr>
<td>Stephens37</td>
<td>400</td>
<td>35 (mean)</td>
<td>3.0</td>
<td>0.3</td>
<td>. . .†</td>
</tr>
<tr>
<td>Barnhorst and Barber38</td>
<td>2000</td>
<td>1-10</td>
<td>8.7</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Nuzzaci et al39</td>
<td>720</td>
<td>14-79</td>
<td>13.8</td>
<td>2.6</td>
<td>. . .†</td>
</tr>
<tr>
<td>Robertson et al40</td>
<td>1094</td>
<td>93-30</td>
<td>4.5</td>
<td>1.3</td>
<td>. . .†</td>
</tr>
<tr>
<td>Mean %</td>
<td>NA†</td>
<td>NA†</td>
<td>8.1</td>
<td>2.9</td>
<td>0.7</td>
</tr>
</tbody>
</table>

* The femoral pulse was present in every limb.
† Ellipses indicate no data were available from these studies; NA, not applicable.
that 2% to 13% of abnormal AAI s occur only after stress.8,11 (Most of these patients, however, never underwent angiography, raising the question whether they all represent true-positive findings.) Still, many vascular surgeons regard pulses that disappear with stress as a significant phenomenon that occurs relatively commonly (in 16 patients over a 2-year period in 1 surgical practice).47 These surgeons propose a variety of simple bedside maneuvers to detect this phenomenon, all carried to the point of claudication (running in place, walking, toe-stands, or ankle flexing repeatedly against resistance).44,45,47

The presence of color abnormalities (pale, red, or blue color) were weak predictors of disease (LR+=1.6-2.8), but in both of the studies that investigated this finding,12,15 foot discoloration added nothing to the clinical prediction after multivariate analysis. Table 4 also shows that an abnormal capillary refill time, absent distal lower-extremity hair growth, and atrophic skin are all unhelpful to the clinician. Another level 3 study also found no difference in hair loss among the lower limbs of 40 patients with vascular disease and 40 control subjects.23

### DISTRIBUTION OF VASCULAR DISEASE

One study, graded level 3 because it omitted explicit instruction on the physical examination maneuvers performed, showed that vascular surgeons using traditional bedside methods (similar to those in Table 1) accurately predicted the distribution of occlusions and stenoses in 96% of 102 symptomatic patients (the predictions preceded measurement of the AAI or angiography).22 In another study, the finding of a severely reduced or absent femoral pulse in patients with suspected vascular disease confirmed the diagnosis of aortoiliac disease (LR+=4.7-5.7). Because the test is insensitive (sensitivity, 0.20-0.29), however, the absence of a femoral bruit does not meaningfully change the probability of disease (LR=0.7-0.8) (Table 4). Two other positive findings that are useful, although both are insensitive (sensitivity, 0.10-0.25), are an abnormally prolonged venous filling time (LR+=3.6-4.6) (see Table 5 for definition) and a limb that is cooler when compared with the contralateral limb (LR+=5.8) (Table 4). In a different study,12 the finding of a foot cooler than the ipsilateral calf was unhelpful (LR+=1.2-1.5), but this is not surprising because the cutaneous blood flow, the main determinant of skin surface temperature, often diminishes toward the feet to conserve body heat, causing the toes of normal extremities to be 2°C to 6°C cooler than the ipsilateral groin.48 A unilaterally cold foot, however, is abnormal and usually indicates arterial disease.45

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### Table 4. Physical Diagnosis for Presence of Vascular Disease: Sensitivity and Specificity

<table>
<thead>
<tr>
<th>Physical Finding</th>
<th>Study</th>
<th>Study Level†</th>
<th>No. of Patients</th>
<th>Abnormal Finding</th>
<th>Disease</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>LR+</th>
<th>LR−</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abnormal pedal pulses</td>
<td>Christensen et al13</td>
<td>1</td>
<td>132</td>
<td>Both PT/DP pulse absent</td>
<td>AAI&lt;0.9</td>
<td>0.63</td>
<td>0.99</td>
<td>44.6</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>Stoffers et al15</td>
<td>1</td>
<td>2455</td>
<td>PT/DP pulse: absent/absent or absent/weak</td>
<td>AAI&lt;0.9</td>
<td>0.73</td>
<td>0.92</td>
<td>9.0</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td>Boyko et al12</td>
<td>1</td>
<td>631</td>
<td>PT/DP pulse: absent/absent, absent/weak, or absent/weak</td>
<td>AAI&lt;0.9</td>
<td>0.65-0.80‡</td>
<td>0.78-0.79</td>
<td>3.0-3.8</td>
<td>0.3-0.4</td>
</tr>
<tr>
<td>Femoral arterial bruit</td>
<td>Criqui et al10</td>
<td>1</td>
<td>613</td>
<td>Femoral bruit present</td>
<td>AAI&lt;0.8</td>
<td>0.20</td>
<td>0.96</td>
<td>4.7</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>Stoffers et al15</td>
<td>1</td>
<td>2455</td>
<td>Femoral bruit present</td>
<td>AAI&lt;0.9</td>
<td>0.29</td>
<td>0.95</td>
<td>5.7</td>
<td>0.7</td>
</tr>
<tr>
<td>Venous filling time</td>
<td>Boyko et al12</td>
<td>2§</td>
<td>631</td>
<td>&gt;20 s</td>
<td>AAI&lt;0.5</td>
<td>0.22-0.25</td>
<td>0.94-0.95</td>
<td>3.6-4.6</td>
<td>0.8</td>
</tr>
<tr>
<td>Cool skin</td>
<td>Stoffers et al15</td>
<td>1</td>
<td>2455</td>
<td>Unilateral cooler skin</td>
<td>AAI&lt;0.5</td>
<td>0.10</td>
<td>0.98</td>
<td>5.8</td>
<td>0.9</td>
</tr>
<tr>
<td></td>
<td>Boyko et al12</td>
<td>1</td>
<td>631</td>
<td>Dorsal foot cooler to touch than ipsilateral calf</td>
<td>AAI&lt;0.5</td>
<td>0.65-0.80</td>
<td>0.46-0.47</td>
<td>1.2-1.5</td>
<td>0.4-0.7</td>
</tr>
<tr>
<td>Color abnormality</td>
<td>Stoffers et al15</td>
<td>1</td>
<td>2455</td>
<td>Pale, red, or blue color</td>
<td>AAI&lt;0.9</td>
<td>0.35</td>
<td>0.87</td>
<td>2.8</td>
<td>0.7</td>
</tr>
<tr>
<td></td>
<td>Boyko et al12</td>
<td>1</td>
<td>631</td>
<td>Blue, purple color</td>
<td>AAI&lt;0.5</td>
<td>0.24-0.32</td>
<td>0.84-0.85</td>
<td>1.6-2.0</td>
<td>0.8-0.9</td>
</tr>
<tr>
<td>Capillary refill time</td>
<td>Boyko et al12</td>
<td>1</td>
<td>631</td>
<td>&gt;5 s</td>
<td>AAI&lt;0.5</td>
<td>0.25-0.28</td>
<td>0.84-0.85</td>
<td>1.6-1.9</td>
<td>0.8-0.9</td>
</tr>
<tr>
<td>Trophic changes</td>
<td>Boyko et al12</td>
<td>1</td>
<td>631</td>
<td>Absent distal lower-extremity hair growth</td>
<td>AAI&lt;0.5</td>
<td>0.47-0.48</td>
<td>0.70-0.71</td>
<td>1.6</td>
<td>0.7</td>
</tr>
</tbody>
</table>

*LR+ indicates positive likelihood ratio; LR−, negative likelihood ratio; PT, posterior tibial; DP, dorsalis pedis; and AAI, ankle-arm index.
†See "Materials and Methods" section for definitions.
‡Data from Boyko et al12 were derived from examination of both limbs. Because the findings in the right leg were not independent of those in the left leg of the same patient, the data for each were presented separately, yielding 2 values for each finding.
§In contrast to all the other physical examination maneuvers in the study by Boyko et al12 the venous filling time was performed after the measurement of the AAI, which potentially affects the blinding of the comparison and lowers the grade for this finding to level 2.

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patients with 2 of these 3 clinical features, 83% had aortoiliac disease in one study, and in those with all 3 features, 100% had aortoiliac disease. In another study of 50 patients with suspected vascular disease and intact popliteal pulses (patients unlikely to have total vascular occlusions), the finding of any limb bruit was a predictor of significant stenoses on angiography (LR+ = 3.2) (Table 6), which has important therapeutic implications because these patients may be candidates for angioplasty (Table 1).

A negative Buerger test result (Table 5) excluded disease distal to the adductor canal in a study of 55 limbs with symptomatic vascular disease (LR− = 0; sensitivity, 1.0; 95% confidence interval, 0.72-1.0; Table 6). Furthermore, a positive Buerger test result indicated more severe and extensive disease. Patients with a positive test result had lower AAsIs (mean ± SD, 0.37 ± 0.29 vs 0.62 ± 0.23), more rest pain (60% vs 8%), and more gangrene (23% vs 0%).

One level 3 study reported the intriguing finding that about one half of patients with arterial disease confined to the femoropopliteal segment had unilaterally warm knees in the same limb, whereas no patient with disease in the aortoiliac segment had warm knees. Subsequent studies, mostly case series that sometimes included infrared thermography, have confirmed this finding. Presumably, femoropopliteal occlusions induce collateral vessels to develop just beneath the skin surface around the knee, thus raising its temperature. Table 6 reveals the “warm-knee sign” to be a predictor of superficial femoral artery occlusions or stenoses ending at the adductor hiatus (LR+ = 2.9, LR− = 0.4). Important questions about the warm-knee sign, however, are whether popliteal occlusions are important to the finding (some investigators stating it is a prerequisite while others stating it is unnecessary) and whether this sign actually influences clinical decisions (ie, how many of these patients have obvious femoropopliteal disease from the classic combination of calf claudication, normal femoral pulses, and absent popliteal pulses).

**Table 5. Glossary of Terms**

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capillary Refill Test</td>
<td>A maneuver similar to the Allen test, this method purportedly estimates the ankle blood pressure when Doppler equipment is unavailable. After placing the blood pressure cuff around the ankle and elevating the patient's foot, the clinician inflates the cuff and returns the limb to the horizontal position. As the pressure in the cuff is slowly decreased, 5 mm Hg every 10 seconds, the first appearance of pink flush on the sole of the foot indicates the systolic pressure. In a study of 156 lower limbs with a mean age of 78 years, 85% of the AAIs by the visual flush method were within 0.1 of the conventional AAI.</td>
</tr>
<tr>
<td>Venous Filling Time</td>
<td>After positioning the patient supine and identifying a prominent pedal vein, the clinician elevates the patient's leg 45° above the table surface for 1 minute. The patient then sits up and dangles the legs over the side of the examining table, and the clinician records the time in seconds until the previously identified vein rises above the level of the skin surface. A delay greater than 5 seconds before return of the usual skin color is regarded as delayed refill.</td>
</tr>
<tr>
<td>Visual Flush Method</td>
<td>A maneuver similar to the Allen test, this method purportedly estimates the ankle blood pressure when Doppler equipment is unavailable. After placing the blood pressure cuff around the ankle and elevating the patient's foot, the clinician inflates the cuff and returns the limb to the horizontal position. As the pressure in the cuff is slowly decreased, 5 mm Hg every 10 seconds, the first appearance of pink flush on the sole of the foot indicates the systolic pressure. In a study of 156 lower limbs with ankle-to-arm systolic pressure indexes (AAIs) between 0.3 and 1.4, 85% of the AAIs by the visual flush method were within 0.1 of the conventional AAI.</td>
</tr>
</tbody>
</table>

**INCREMENTAL VALUE OF COMBINATIONS OF SYMPTOMS AND SIGNS: MULTIVARIATE ANALYSIS**

The goal of multivariate analysis is to identify diagnostic factors that are redundant, to identify the minimal number of useful findings. Using multivariate analysis, 2 studies have identified which clinical findings are independent predictors of peripheral arterial disease (Table 7). Although the studies enrolled different populations (100% vs 10.2% were patients with diabetes), investigated slightly different findings (Table 7), and defined disease differently (AAI < 0.5 vs AAi < 0.9), they both dealt with large numbers of elderly individuals of whom only 9% to 16% had claudication and 8% to 9% had peripheral arterial disease. Importantly, both studies showed that certain historical items were important predictors and that physical examination added significantly to any predictive model based on history alone.

Independent predictors from the physical examination were abnormal pedal pulses, a prolonged venous filling time, a unilaterally cool extremity, and a femoral artery bruit. The findings of foot discoloration, prolonged capillary refill time, a hairless limb, and atrophic skin were all unhelpful diagnostically.

Both models included mathematical formulas (Table 8) that allow precise predictions of the probability of disease. Boyko et al validated the results of their regression model using bootstrap methodology. Stoffers et al did not validate their regression model, but it is unlikely that their final model overfit the data because they considered only 19 potential predictors of low AAI in 2455 patients. According to the model by Stoffers et al, which yields a range of probabilities of 0.4% to 98%, the probability of an AAI less than 0.9 in a 75-year-old man who smokes and has claudication, abnormal pedal pulses, a femoral artery bruit, and a unilaterally cool leg is 93%. In such a patient, further diagnostic testing with a Doppler flowmeter is unnecessary. Using the model of Boyko et al, which yields a range of probabilities of 0.02% to 93%, the clinician would determine that the probability of an AAI less than 0.5 in a 80-year-old with diabetes, no history of peripheral vascular disease, normal pulses, and a venous filling time of 5 seconds is only 3%. Further testing is again unnecessary. Only
individuals with intermediate probabilities require further testing—for example, the 29% probability of an AAI less than 0.9 in a 64-year-old woman who smokes and has claudication, weak pedal pulses, no unilateral limb coolness, and no femoral artery bruit.15

Although the mathematical formulas in Table 8 are complicated and too burdensome for general clinical use in individual patients, clinicians can generate simple-to-use figures, examples of which appear in one of the original studies.12

Clinicians should suspect chronic arterial occlusion in patients who present with claudication, gangrene, rest pain that is relieved by dangling the limb, or ulcers with a necrotic base involving the distal foot. Lumbar spinal stenosis also may cause claudication, but the limb discomfort in these patients characteristically worsens with extension of the spine (eg, standing), improves with flexion of the spine (eg, sitting), and varies in severity from...
day to day much more than the discomfort of vascular claudication.52,55

Since the AAI is the diagnostic criterion standard for peripheral arterial disease, clinicians who have Doppler equipment should use flowmeters, not physical examination, to make the diagnosis in most of their patients. Primary care physicians, however, do not always have easy access to Doppler equipment, and this review has confirmed the value of the traditional approach to diagnosis, combining information from both the patient interview and physical examination. The important physical signs—presence or absence of pedal pulses, a unilaterally cool extremity, prolonged venous filling time, and femoral artery bruit—help clinicians determine the estimated probability of disease in their patients, which, in turn, appropriately influences decisions about the need for further testing.

Even clinicians who have a Doppler flowmeter, however, still benefit from examining the patient carefully. Some patients with diabetes have calcified distal arteries that are noncompressible, causing the AAI to be falsely high (ie, >0.9) even though the clinical evaluation still suggests disease.4 Furthermore, in patients whose AAI’s are less than 0.9, the presence or absence of thigh claudication, femoral pulse abnormalities, lower-extremity bruits, warm knees, and a positive Buerger test all help determine the extent of the patient’s disease, its distribution, and, if the patient is a candidate for surgery, the necessary procedure.

Other findings from the examination, although traditionally thought to be useful, do not help the diagnostic process. Lewis3 and Pickering,2 writing soon after publication of Buerger’s book,1 showed that the capillary refill test was unreliable because the capillary blood expressed by firm pressure from the examiner’s hand could return from adjacent veins, allowing prompt refill even in a limb rendered completely ischemic experimentally. Our review also finds capillary refill unhelpful, along with some of Buerger’s other prodromal findings, including hairless legs, atrophic skin, and foot discoloration.

Unresolved in this review are the clinical utility of the warm-knee sign, the diagnostic value of the abnormal popliteal pulse (as a sign of femoropopliteal disease when the femoral pulse is present), the importance of exercising patients with suspected disease and palpable pedal pulses, and the merit of the “visual flush method,” a potentially important maneuver (Table 5) that allows calculation of the AAI without a Doppler flowmeter. Even without answers to these questions, however, the physical examination remains a powerful diagnostic tool for clinicians who have patients with suspected chronic lower-extremity arterial disease.

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