Illuminating Circulation

Plethysmography offers enhanced accuracy and other advantages in PAD and CVD diagnostics.

BY WINDY COLE, DPM

Peripheral vascular disease (PVD) is a significant and escalating public health concern, contributing to high rates of morbidity and mortality while placing substantial financial strain on healthcare resources worldwide. Vascular disorders result from dysfunction in the circulatory system, often caused by damage, blockage, or inflammation of the arteries and veins. Among the various types of PVD, peripheral arterial disease (PAD) and chronic venous disease (CVD) which includes chronic venous insufficiency (CVI) and deep vein thrombosis (DVT) are particularly common in the lower extremities.[1]

Patients at risk for atherosclerotic cardiovascular disease (ASCVD) often develop PAD in the lower extremity characterized by the narrowing or blockage of arteries due to the accumulation of fatty deposits or plaque, known as atheroma.[2] This condition deprives the tissues supplied by the impaired artery of oxygen-rich blood and essential nutrients, leading to severe complications such as gangrene and the potential for amputation.[2] PAD affects approximately 10–15% of the general population, with prevalence rising to nearly 20% among individuals aged over 60.[3] In 2019, the global prevalence of PAD was recorded at 1,466 diagnoses per 100,000 individuals. In comparison, the prevalence in 1990 was 1,299 diagnoses per 100,000, indicating a 13 percent increase in prevalence over the 29-year interval.[4]

Early diagnosis and management of PAD is essential to mitigating the significant rates of mortality and morbidity associated with this condition. Unfortunately, approximately 50% of individuals are asymptomatic, which often results in a lack of medical consultation and vascular assessment in the absence of a prior diagnosis.[5] However, evaluating the burden of PAD in at-risk patients provides clinicians with a clinically useful, evidence-based foundation to guide the development of medical care algorithms and to implement strategies for the prevention of amputations. Nevertheless, vascular assessments for PAD continue to be substantially underperformed across various clinical environments, leading to significant health disparities in marginalized populations.[6]

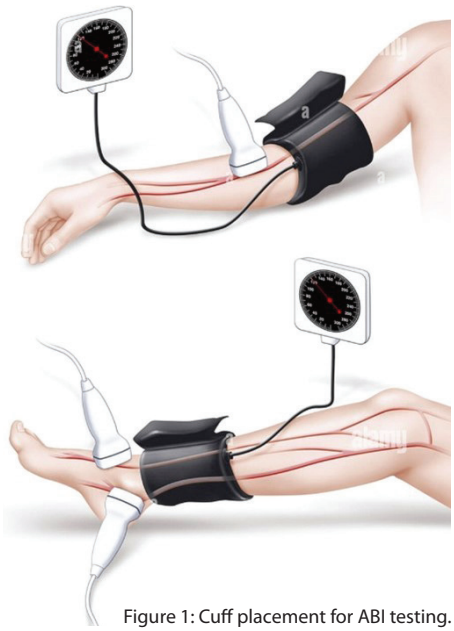

Figure 1: Cuff placement for ABI testing.

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ASCVD Guidelines

According to the American Heart Association evidence-based guidelines for assessing patients at risk for ASCVD include several key components:[7]

1) Risk Assessment Tools: Utilizing established tools like the ASCVD risk calculator, which incorporates factors such as age, sex, blood pressure, cholesterol levels, smoking status, and diabetes, can estimate the patient's 10-year risk of ASCVD events. (To access tool, scan QR code at right.)

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New Concepts and Studies

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2) Patient History: Conducting a thorough medical and family history is imperative to identify risk factors. This may include a personal and/or family history of heart disease, hypertension, diabetes, hyperlipidemia, and family history of premature cardiovascular disease.

3) Physical Examination: Assessing vital signs such as blood pressure, body mass index (BMI), and other physical symptoms like shortness of breath, heart arrhythmia, ankle swelling and fatigue can be signs of cardiovascular risk.

FIGURE 2

Ankle Brachial Index Results and Associated PAD Severity

ABI MEASUREMENT	INTERPRETATION
≥1.3	Abnormal calcification
≥1.0	Normal Value
0.9 – 0.99	Borderline PAD
0.7 – 0.89	Mild PAD
0.5 – 0.69	Moderate PAD
<0.5	Severe PAD with impending gangrene

Figure 2: Ankle brachial index results and associated PAD severity

Invasive methods to assess PAD such as angiography, venography, ambulatory venous pressure, and intravascular ultrasound are known for their high accuracy.

4) Laboratory Tests: Recommendation include obtaining lipid panels to evaluate cholesterol levels, fasting glucose or HbA1c for diabetes assessment, and other relevant biomarkers as indicated.

5) Lifestyle Factors: Discussions of lifestyle habits such as diet, physical activity, alcohol consumption, and tobacco use, and educating patients on the impact these factors have on cardiovascular risk should be performed on a regular basis.

6) Consideration of Specific Populations: Consider patient age, gender, ethnic background, and co-morbidities while assessing risk, as these factors may influence the likelihood of ASCVD.

7) Management Recommendations: Based on risk assessment, provide appropriate interventions, such as lifestyle modifications, medications (like statins), and regular follow-ups.

8) Shared Decision-Making: Involving patients in the decision-making process regarding their care, emphasizing the importance of adherence to prescribed therapies and lifestyle changes is a way to improve communication and concordance with treatment protocols.

9) Staying updated with the latest guidelines from reputable organizations such as the American Heart Association (AHA) and the American Podiatric Medical Association (APMA) is crucial for accurate patient assessment and management.

Figure 3: PPG probe placement on the toe.

Vascular Assessments for PAD

Invasive methods to assess PAD such as angiography, venography, ambulatory venous pressure, and intravascular ultrasound are known for their high accuracy. However, they also present significant drawbacks: they are expensive, must be performed at specialized medical centers, can cause discomfort for patients, and carry inherent risks.[8] The risks and discomfort associated with these methods render them unsuitable for routine vascular assessments, which is vital for the early diagnosis of diseases where preventive care could provide the greatest benefits.[8] These techniques are generally reserved for situations that require precise measurements, such as in pre-surgical planning, during intervention procedures, or within virtual surgery systems. In contrast, non-invasive PAD vascular assessment methods present as an alternative, allowing for more frequent diagnosis and effective monitoring of treatment.[9] Although these methods do have their limitations, their continuous development is essential for improving diagnostic accuracy and clinical application.

Non-invasive lower extremity studies are typically indicated for the evaluation of arterial disease in patients who present with the following conditions:[9]

- Claudication: This condition is characterized by discomfort or pain that arises during physical exertion and is alleviated with rest; it may also manifest as pain that diminishes when the legs are positioned off the side of the bed.
- Ischemic rest pain
- Nonhealing lower extremity wounds.

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- In patients with advanced diabetes, the symptoms may also include leg fatigue.
- Recurrent stenosis or occlusion of the tibial vessels.
- Peripheral neuropathy.

Ankle Brachial Index (ABI)

The Ankle-Brachial Index (ABI) is a simple, non-invasive test used to assess PAD by comparing the blood pressure in the patient's ankle with the blood pressure in the arm (Figure 1). This ratio helps to determine how well blood flows to the limbs and can indicate the presence of narrowed or blocked arteries. A normal ABI value ranges from 1.0 to 1.3, while values below 0.9 may suggest PAD, indicating a potential risk for cardiovascular diseases (Figure 2).[10]

The Ankle-Brachial Index (ABI) is a beneficial diagnostic tool; however, it does have certain limitations. One primary concern is that the ABI may yield false-positive or false-negative results, particularly in individuals with diabetes or those who have calcified arteries, which can lead to overestimation of the blood flow.[11] Additionally, certain patient factors, such as body position during the test or the presence of vascular anomalies, can affect the accuracy of the measurements.[11] ABI is also less effective in patients with severe lower extremity edema or other conditions that might alter blood flow dynamics.[11]

Furthermore, while the ABI is a useful vascular assessment tool, it does not provide comprehensive details regarding the location or extent of arterial blockages. Therefore, additional imaging studies may be necessary for a more thorough evaluation of vascular health. While it is crucial to establish effective and efficient non-invasive PAD diagnostic algorithms to accurately assess vascular competence, enabling earlier identification and intervention for patients at risk, ABIs can fall short.

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Plethysmography

ABI and plethysmography are both diagnostic tools employed in the assessment of peripheral arterial disease

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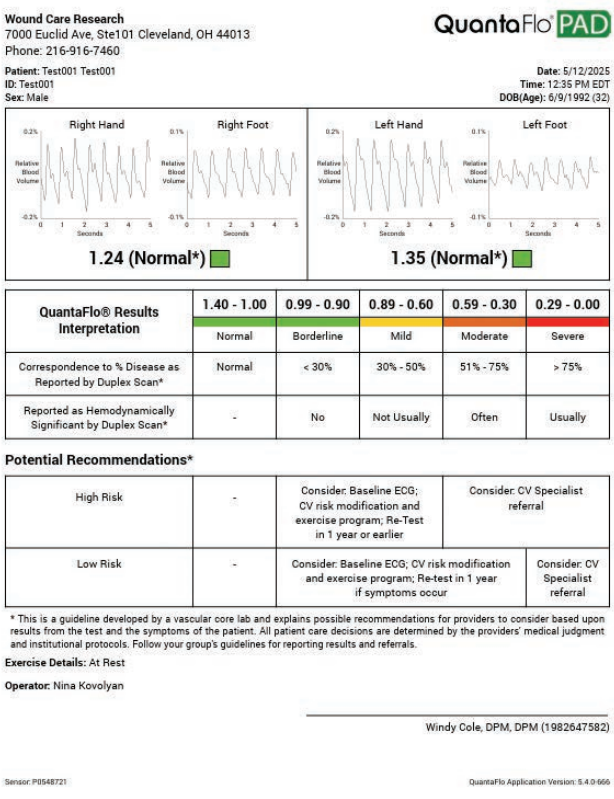
(PAD); however, they differ in their methodologies and certain advantages. Commercially available devices such as QuantaFlo utilize volume plethysmography to evaluate blood flow in the lower extremities, while ABI involves the measurement of blood pressure in the ankles and arms. QuantaFlo is generally characterized by a more efficient and straightforward execution process, and studies indicate that it may offer superior accuracy compared to ABI, particularly in the early detection of PAD.[12]

The principle of plethysmography for the measurement of limb volume was first introduced by Francis Glisson in 1677 using water displacement.[13] Over time, water plethysmography method was modified to other measures of volume to reduce the complexity of the measurement and improve accuracy.[13]

Modern plethysmography (PPG) devices like QuantaFlo measure blood volume changes within the vessels of the lower extremities via light. In PPG, infrared light is emitted from and reflected to a probe that has been placed on a digit (Figure 3). The blood volume affects how much light is reflected, which produces a waveform measuring the variation of blood volume that is recorded and plotted on a graph.[14] In other words, the pulsatile waveform (AC) produced by PPG is superimposed on a slowly varying baseline (DC).[15] The AC component is utilized to measure fluctuations in blood volume due to arterial pulsation, while the DC component reflects changes in total blood volume.[15] The derived arterial pulse wave allows clinicians to diagnose arterial incompetence.



Wound Care Research
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Phone: 216-916-7460

QuantaFlo PAD

Patient: Test001 Test001
ID: Test001
Sex: Male

Date: 5/12/2025
Time: 12:35 PM EDT
DOB(Age): 6/9/1992 (32)

Right Hand | Right Foot | Left Hand | Left Foot

1.24 (Normal*) 1.35 (Normal*)

QuantaFlo® Results Interpretation	1.40 - 1.00	0.99 - 0.90	0.89 - 0.60	0.59 - 0.30	0.29 - 0.00
	Normal	Borderline	Mild	Moderate	Severe
Correspondence to % Disease as Reported by Duplex Scan*	Normal	< 30%	30% - 50%	51% - 75%	> 75%
Reported as Hemodynamically Significant by Duplex Scan*	-	No	Not Usually	Often	Usually

Potential Recommendations*

High Risk	-	Consider: Baseline ECG; CV risk modification and exercise program; Re-Test in 1 year or earlier	Consider: CV Specialist referral
Low Risk	-	Consider: Baseline ECG; CV risk modification and exercise program; Re-test in 1 year if symptoms occur	Consider: CV Specialist referral

* This is a guideline developed by a vascular core lab and explains possible recommendations for providers to consider based upon results from the test and the symptoms of the patient. All patient care decisions are determined by the providers' medical judgment and institutional protocols. Follow your group's guidelines for reporting results and referrals.

Exercise Details: At Rest

Operator: Nina Kovolyan

Windy Cole, DPM, DPM (1982647582)

Sensor: P0548721 QuantaFlo Application Version: 5.4.0-666

Figure 4: Sample QuantaFlo result readout

Interpretation

The typical peripheral artery waveform presents a distinctive pattern: a steep upslope, a clear systolic peak, a dicrotic notch, and a smooth, bowing downslope returning to baseline. However, within diseased vessels, this waveform becomes significantly dampened, exhibiting a wider upslope and the absence of the dicrotic notch, which are critical indicators of vascular health.[16]

The QuantaFlo device enhances diagnostic accuracy by generating a score ratio that evaluates blood flow in the extremities compared to the arms (Figure 4). A lower score can indicate potential peripheral artery disease (PAD), prompting timely intervention. Moreover, this score not only highlights possible issues but also provides tailored treatment and assessment recommendations, empowering healthcare professionals to make informed decisions for optimal patient care.

Modern plethysmography (PPG) devices like QuantaFlo measure blood volume changes within the vessels of the lower extremities via light.

Clinical Use Cases

Plethysmography (PPG) offers several valuable applications in podiatry, aiding in the assessment and management of foot and ankle conditions.[17]

Lower Extremity PAD Assessments and Monitoring

PPG can non-invasively measure blood flow in the lower extremities, helping podiatrists identify patients with PAD, a condition characterized by reduced blood flow due to narrowed arteries. By monitoring changes in blood volume, podiatrists can determine the severity of PAD and implement early interventions, which are crucial for preventing serious complications, such as non-healing ulcers and potential amputations.

PPG can serve as an educational tool for patients, helping them understand the importance of monitoring circulation and overall foot health. By demonstrating real-time blood flow data, podiatrists can empower patients to take proactive steps in their care, including regular foot inspections and lifestyle modifications that promote good vascular health.

Wound Care

For patients receiving wound care, the ability to monitor blood flow through plethysmography (PPG) is invaluable for identifying obstacles to healing and recognizing early signs of potential complications. This advanced technology allows podiatrists to continuously assess blood circulation in the feet, offering crucial insights into

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perfusion levels. By utilizing PPG, healthcare professionals can detect subtle indications of compromised blood flow, enabling timely interventions that can significantly lower the risk of amputations. This proactive approach not only enhances patient safety but also leads to better overall outcomes in wound healing. Furthermore, the data obtained from PPG can substantiate the medical necessity for employing advanced wound therapies, such as cellular and acellular matrix products (CAMPs), thereby optimizing treatment strategies for improved recovery results.

Conclusions

In conclusion, peripheral vascular disease (PVD), particularly in the form of peripheral arterial disease (PAD) and chronic venous disease (CVD), represents a significant public health challenge that necessitates urgent attention. The rising prevalence of PAD, especially among aging populations, underscores the importance of early diagnosis and intervention. With approximately 50% of affected individuals remaining asymptomatic[5], there is a critical need for improved assessment strategies, particularly non-invasive methods like the Ankle-Brachial Index (ABI) and plethysmography.

This article emphasizes the essential role of both ABI and plethysmography in the early detection and monitoring of PAD. While ABI remains a standard tool, plethysmography offers notable advantages in accuracy and ease of use, thereby enhancing diagnostic capabilities in clinical settings. As highlighted throughout this discussion, timely detection can significantly reduce the risk of severe complications, including limb loss, by facilitating appropriate therapeutic interventions.

Ultimately, addressing the disparities in the assessment and treatment for PAD, particularly in marginalized populations, is crucial to improving outcomes. As the landscape of peripheral vascular disease continues to evolve, ongoing research and innovations in diagnostic technology will be instrumental in shaping effective healthcare strategies aimed at improving vascular health and patient quality of life. **PM**

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