Duplex Arterial Ultrasound for Podiatrists

Part 1: Physiology

BY JARROD SHAPIRO, DPM

Practice Perfect is a continuing every-issue column in which Dr. Shapiro offers his unique personal perspective on the ins and outs of running a podiatric practice.

One of the important imaging studies available to medicine is the arterial ultrasound (Figure 1). This non-invasive method is an excellent modality for the evaluation of peripheral arterial disease (PAD) because it evaluates both anatomical and physiological components of the arterial system. Venous ultrasounds are also available, but today we're going to focus on the arterial side of the tree.

Despite the importance of this test, there are many podiatrists who are unable to read and interpret the images and have only a rudimentary understanding of the reports that are generated. Now, podiatrists are not vascular surgeons, and we are not the ones to directly intervene when a patient needs an arterial procedure. However, it is important that we can interpret these tests, especially if we order them, to properly direct our patients. In the first of this three-part series, we are going to discuss the basic physiology of arterial blood flow as it pertains to the arterial ultrasound. In Part 2, we'll cover the images and report, and in Part 3, we'll review some case examples to build our skills.

One of the important imaging studies available to medicine is the arterial ultrasound.

Before we get into the details, let's quickly mention the physical examination. When it comes to PAD, there is no one single pathognomonic examination technique. Pulses can be present in a patient with proximal occlusion due to collateral flow, cool skin can occur in vasospasm, rubor can be present in a number of other disorders, and hair can be absent for any number of reasons. Similarly, the medical history is helpful but not definitive. Prior cardiac disease, smoking, and diabetes are all risk factors, but age is the most significant risk factor.

As a result of this variability, astute clinicians should examine multiple aspects of the history and physical to put together a composite picture consistent with PAD. You can also use the hand-held Doppler to get a better sense of the flow, with the same caveats about pulse palpation. Unfortunately, you can't always rely on the ankle brachial index (ABI) because of its false elevation in disorders with calcification (such as diabetes and renal disease). That brings us back to the arterial duplex ultrasound.

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Figure 1: Hand-held Doppler

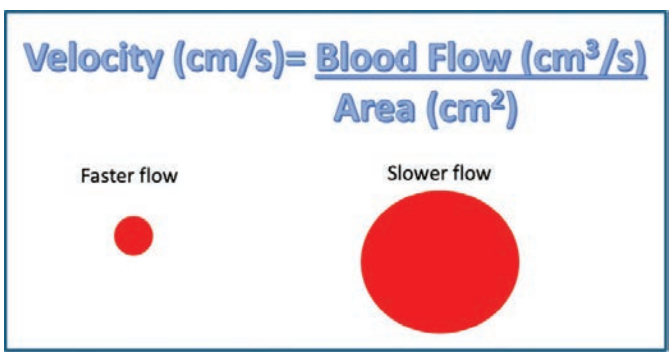

Figure 2: Equation for blood velocity

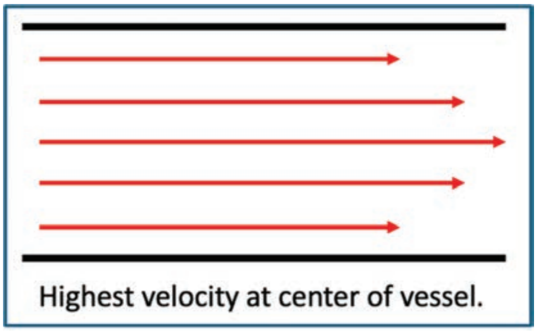

Figure 3: The highest velocity is towards the center of the vessel.

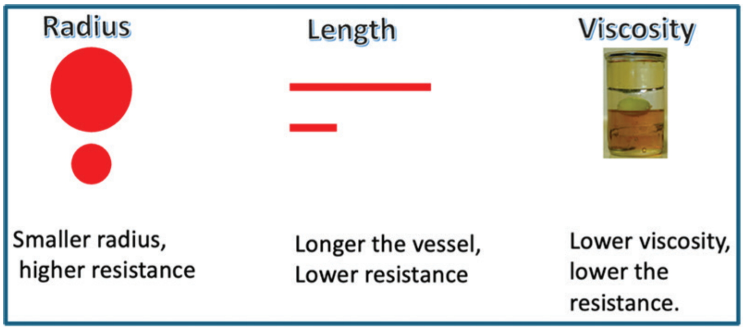

Figure 4: The resistance is affected by the radius of a vessel, its length, and the viscosity of the fluid flowing in it.

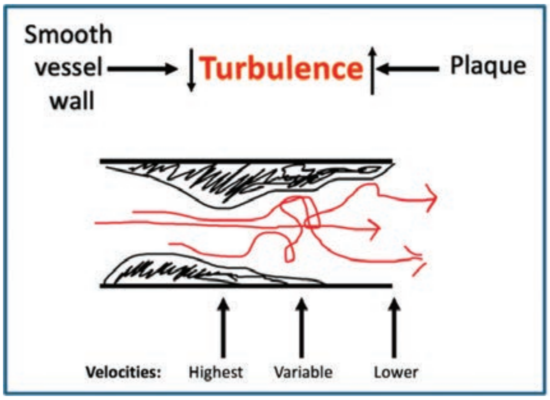

Figure 5: Irregular vessel walls increase turbulence.

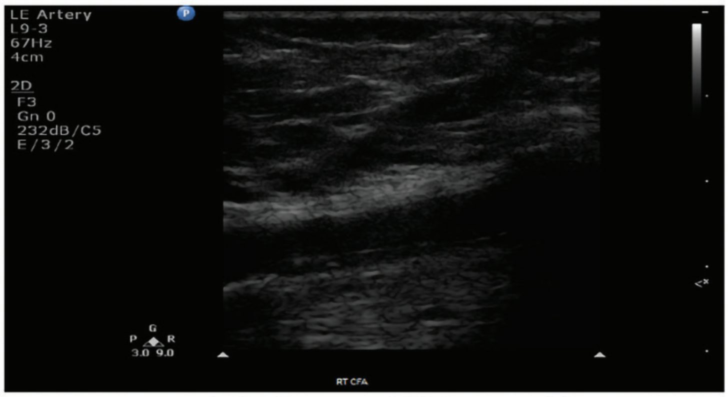

Figure 6: B Mode (brightness mode)

Ultrasound *(from page 58)*

Hemodynamic Principles

There are four hemodynamic principles pertinent to ultrasounds:

1) Blood is a non-Newtonian fluid
2) Velocity
3) Resistance
4) Turbulence

As shown in Figure 4, resistance is affected by the radius of a vessel, its length, and the viscosity of the fluid flowing in it.

The ultrasound image and report will be affected by these four principles.

Non-Newtonian Fluid

Blood is "non-Newtonian" in that it has a non-constant viscosity that changes with pressure. This is caused by the presence of the formed elements such as red and white blood cells and platelets in blood, among other proteins. Blood's ability to change viscosity under different conditions will greatly affect its behavior in the presence of diseased blood vessels and will also affect the other hemodynamic components.

Velocity

The velocity of blood, as indicated in the equation in Figure 2, is affected positively by how fast the blood flows through a vessel in a unit of time (this is actually termed volumetric flow rate) and inversely by the cross-sectional area of the vessel. As a vessel narrows, as seen in atherosclerotic disease, the velocity of blood flowing across that spot will increase.

Under ideal circumstances, the flow in an artery is laminar, i.e., straight in one direction, as shown in Figure 3. If the walls of the vessel were completely smooth and had no resistance, the velocity of the blood flowing through the vessel would be the same in all aspects. However, in real life this is impossible, and there is some resistance generated by the wall of a vessel, increasing the drag on the fluid nearest the wall. This is why the highest velocity is towards the center of the vessel (Figure 3).

Resistance

Resistance is opposition to blood flow in a vessel. As shown in Figure 4, resistance is affected by the radius of a vessel, its length, and the viscosity of the fluid flowing in it. And the greater the resistance, the slower the flow. Bifurcations in vessels increase resistance, causing drops in pressure and flow, and the greater number of bifurcations increases the surface area, increasing the pressure drop. This is why arterioles have slower flow rates and allow oxygen to be diffused into nearby tissues.

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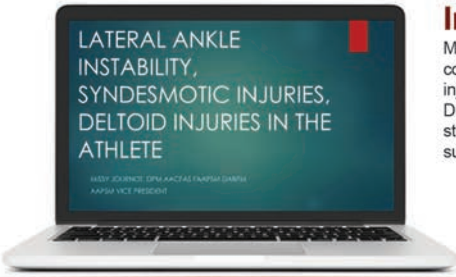
Featured Lecture

PRESENT e-Learning Systems

Lateral Ankle Instability, Syndesmotic Injuries, Deltoid Injuries in the Athlete

Melissa Journot, DPM, AACFAS, FAAPSM, DABPM
AAPSM Vice President
Kansas City, MO



0.5 CECH

In this Lecture...

Melissa Journot, DPM, AACFAS, FAAPSM, DABPM covers lateral ankle instability, syndesmotic, and deltoid injuries in athletes, emphasizing rapid rehabilitation. Dr Journot also discusses biomechanics, treatment strategies, and the importance of understanding subtalar joint involvement.

Scan to go to the lecture

Ultrasound *(from page 59)*

The actual appearance and interpretation of the ultrasound image will result from deviations of these principles as blood flows through normal and abnormal arteries.

Turbulence

If the walls of the blood vessel are irregular, then its interaction with the blood will increase (increased resistance), pulling irregularly on the fluid, causing that fluid to move in irregular patterns (Figure 5). This will, of course, have a snowballing effect as blood near the wall pushes irregularly on the rest of the blood in the vessel, causing increased turbulence.

The actual appearance and interpretation of the ultrasound image will result from deviations of these principles as blood flows through normal and abnormal arteries. Because the technology uses the Doppler effect, it can determine velocity of the blood as it comes toward and away from the probe. This is a "duplex" ultrasound because there are two modes, a brightness (B) mode (Figure 6) and a color Doppler mode (Figure 7). These modes are generally reported in the forms shown with a third spectral Doppler (Figure 8) that combines the color mode with waveforms (termed the spectral window) that provide a lot of useful information.

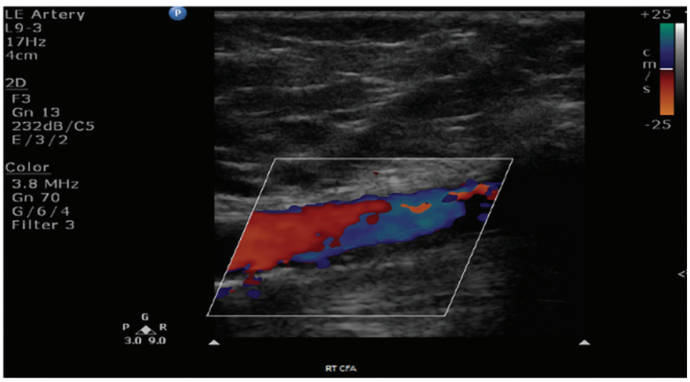


Figure 7: Color Doppler

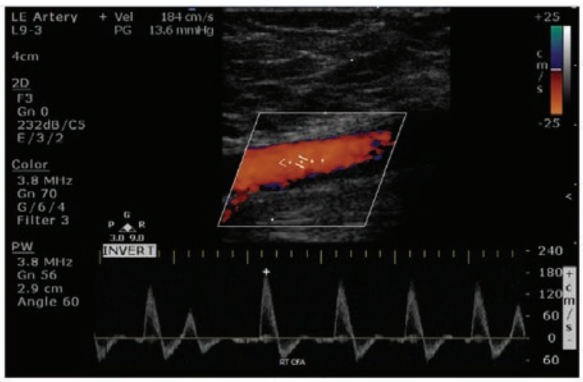


Figure 8: Spectral Doppler

There's even more complexity to the principles underlying Doppler ultrasonography, and those mathematically inclined can consider reviewing Poiseuille's law for laminar flow, Ohm's law of resistance, cardiac output, and systemic vascular resistance, and focus on the use of the basics of these principles when interpreting duplex arterial ultrasounds. PM

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