

Clinical Approach to Vascular Ultrasound Peripheral Arterial Studies - Lower

Shipra Arya MD, SM, FACS

Associate Professor of Surgery, Stanford University School of Medicine,
Section Chief, Vascular Surgery, VA Palo Alto Healthcare System



STANFORD
UNIVERSITY

Objectives

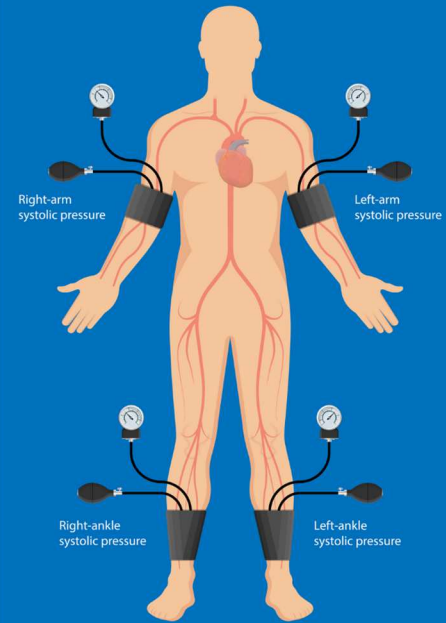
- Arterial Physiologic Testing
 - Ankle Brachial Index (ABI)
 - Toe Brachial Index (TBI)
 - Pulse Volume Recordings
 - Segmental pressure and Waveforms
 - Exercise ABI
 - Transcutaneous oxygen measurement
- Arterial Duplex Scanning

Ankle Brachial Index (ABI)

- Main non-invasive diagnostic test for Peripheral Artery Disease (PAD)
- Ratio of the systolic blood pressure (SBP) measured at the ankle to that measured at the brachial artery
 - Taking the higher pressure of the 2 arteries at the ankle: Dorsalis Pedis (DP) and Posterior Tibial (PT)
 - The higher of the two brachial systolic pressure measurements is used.

$$\text{Right ABI} = \frac{\text{Highest Pressure in Right Foot (DP/PT)}}{\text{Highest Pressure in Both Arms}}$$

Ankle-brachial pressure index (ABPI)
detecting for peripheral artery disease (PAD)



Ankle Brachial Index (ABI)

- Normal range 0.9-1.4
- >90% sensitivity and specificity to detect PAD compared with angiography
 - In diabetics, high specificity but lower sensitivity (at best <80%)
- The 2016 AHA/ACC PAD guideline recommends screening of PAD with ABI in high-risk populations (eg, older adults, ever-smokers, patients with diabetes).
- However, the US Preventive Services Task Force does not recommend ABI screening in asymptomatic adults.

ABI	Interpretation
1.0-1.4	Normal
0.9-1.0	Acceptable/Borderline
>1.4	Artificially elevated or Non compressible
0.7-0.9	Mild PAD
0.4-0.69	Moderate PAD
<0.4	Severe PAD

Time scale: 25 mm/s

HR:72 FP:37 1mV/V

Normal

Moderate obstruction

Severe obstruction

PPG AC

With photoplethysmography (PPG), infrared light is emitted onto a defined area of skin. More or less light is absorbed depending upon changes in blood volume, which is determined by measuring the light reflected from the skin. A normal PPG waveform consists of a short rise in the upstroke during systole (A), a gradual decline during diastole (B), and a dicrotic notch in the diastolic downstroke (C). Moderate arterial obstruction results in loss of the dicrotic notch, flattening of the upstroke and downstroke, and rounding of the peaks of the waveform. Severe obstruction flattens the waveform.

mV: millivolts; V: volts; PPG: photoplethysmography; HR: heartrate; FP: finger pressure.
 Reproduced with permission from: Kesselman P. Non-Invasive Arterial Vascular Testing: Providing these diagnostic services benefits both the patient and your bottom line. Podiatry Management Nov/Dec 2006. Copyright © 2006.

UpToDate

Toe Brachial Index (TBI)

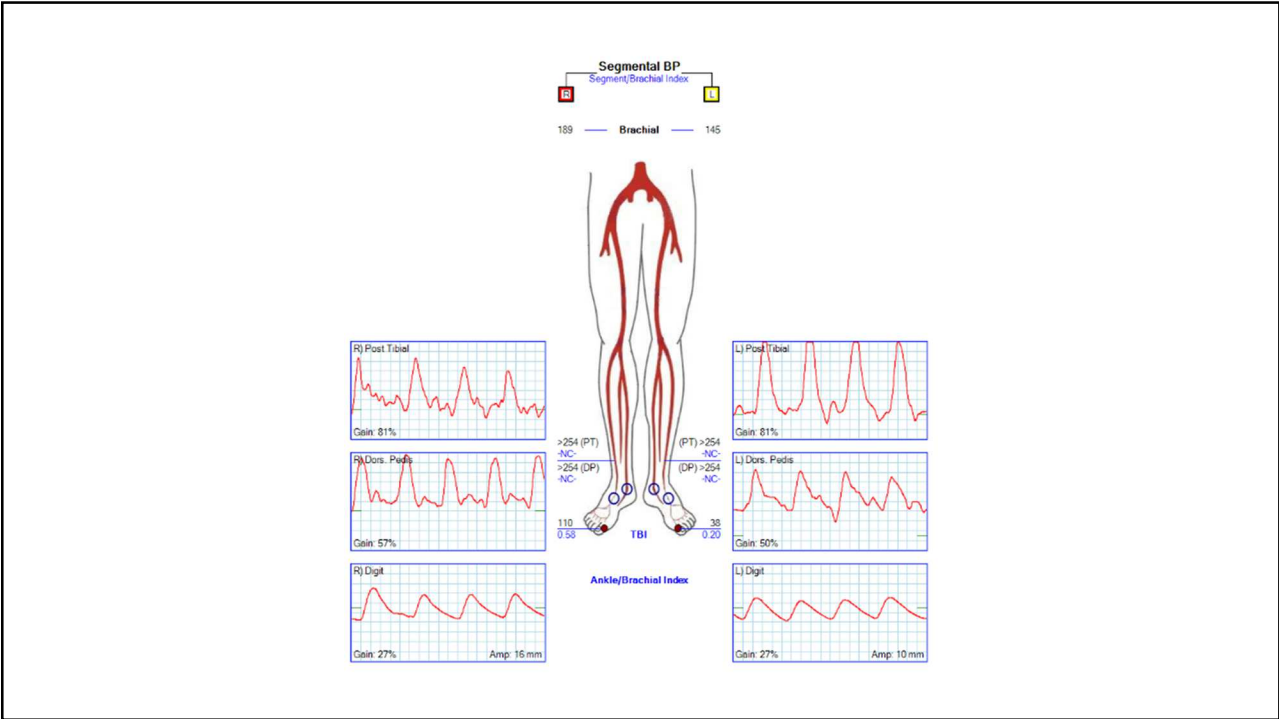
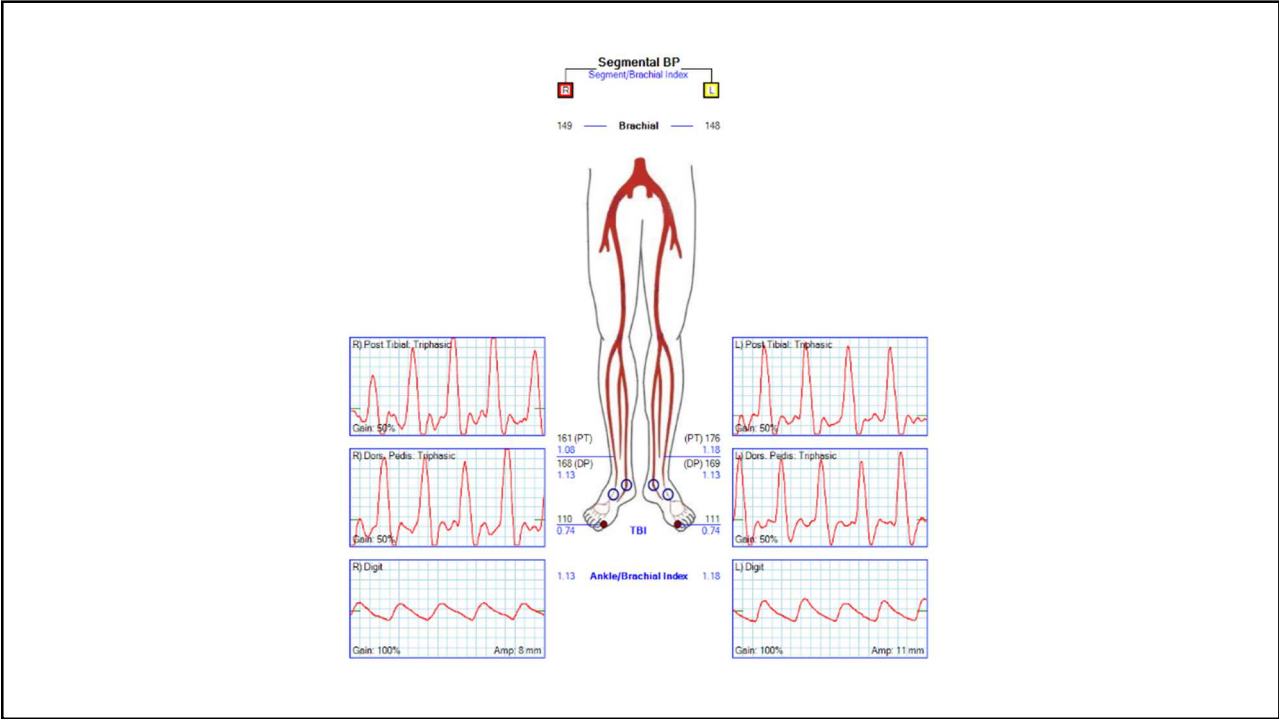
- Ratio of systolic BP measured in the hallux or second digit by the systolic brachial BP.
- Useful in patients with ABI >1.4 or noncompressible as the digital arteries are much less likely to be affected by medial calcification
- Pneumatic cuff on great toe usually
 - In case of amputation, the second or other toe is used.
- A photo-electrode is placed on the end of the toe to obtain a photoplethysmographic (PPG) arterial waveform using infrared light

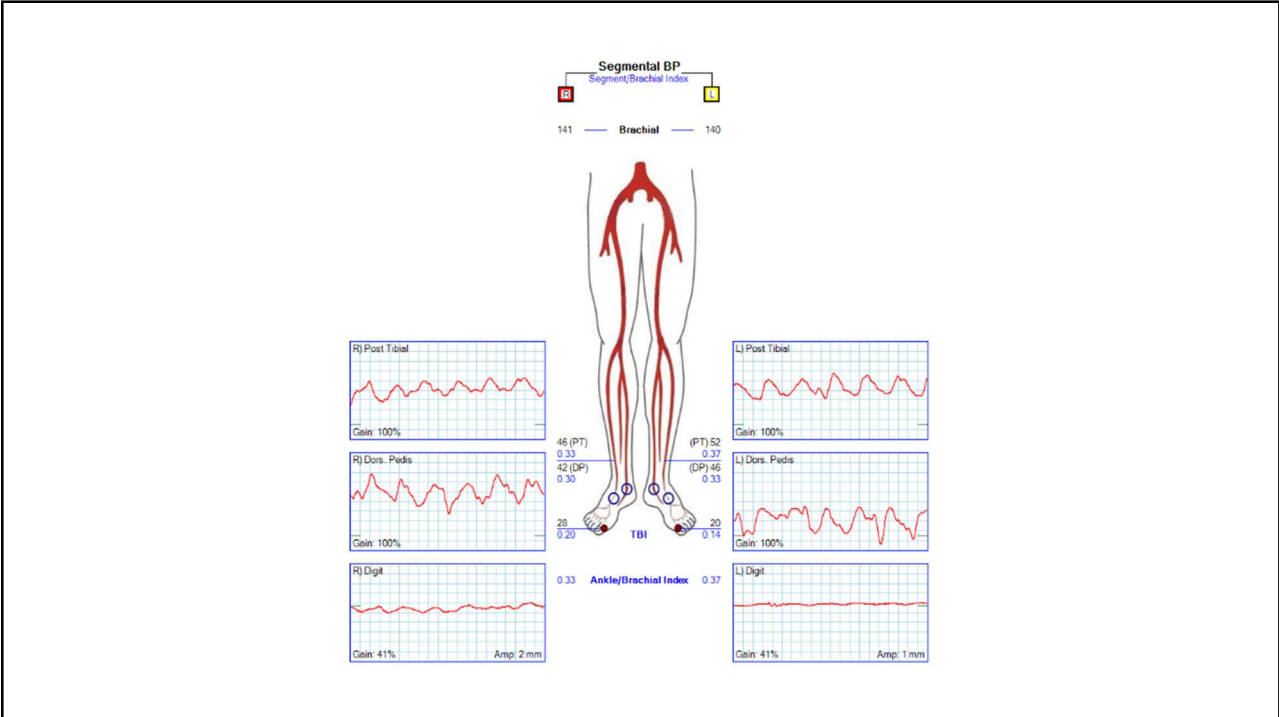
Mitchell Uptodate 2019

Toe Brachial Index (TBI)

- Lack of a well-established grading system
 - Normal TBI is 0.8 – 0.9
 - Abnormal < 0.7
 - Toe pressure <30 mmHg or TBI <0.2 is considered severely ischemic
 - Lower TBI correlates with decreased wound healing potential
 - Toe pressures >45 to 55 mmHg may be required for healing in patients with diabetes.

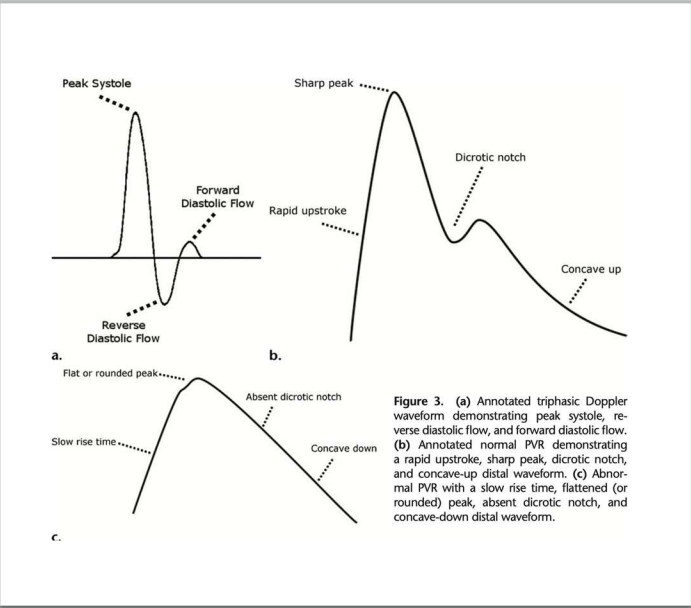
Sibley, Radiographics 2017; Tehan Vasc Med 2016, Mitchell UpToDate 2019





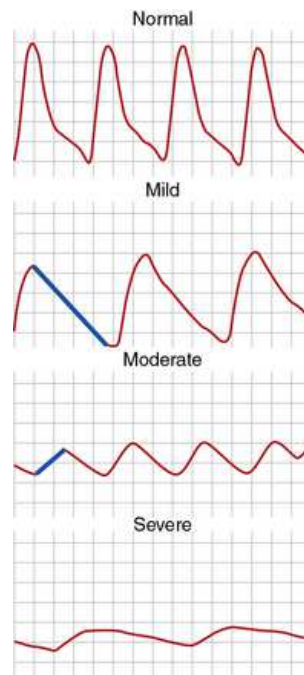
Pulse Volume Recordings (PVR)

- PVRs obtained with partially inflated segmental blood pressure cuffs that detect *volume* changes sequentially down limbs.
- Volume changes beneath the cuffs resulting from systole and diastole cause small pressure changes within the cuffs, which, with the use of appropriate transducers, can be displayed as arterial waveforms.
- Different from Doppler waveform



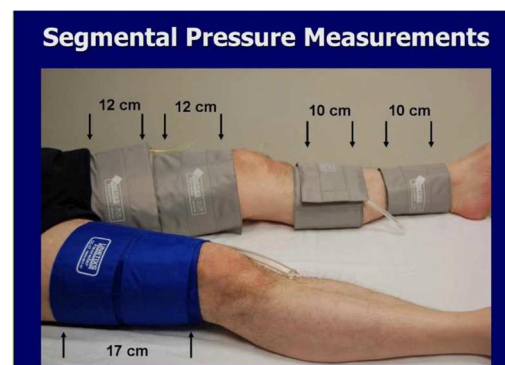
Pulse Volume Recordings (PVR)

- Normal *waveform*: sharp systolic upstroke and peak, and a prominent dicrotic notch on the downward portion of the curve.
- Proximal arterial occlusion: the dicrotic notch is lost and the pulse wave peak becomes rounded with loss of amplitude, and there are nearly equal upstroke and downstroke times.
- Severe PAD: the pulse wave may be completely absent.
- PVRs are generally evaluated in a qualitative fashion

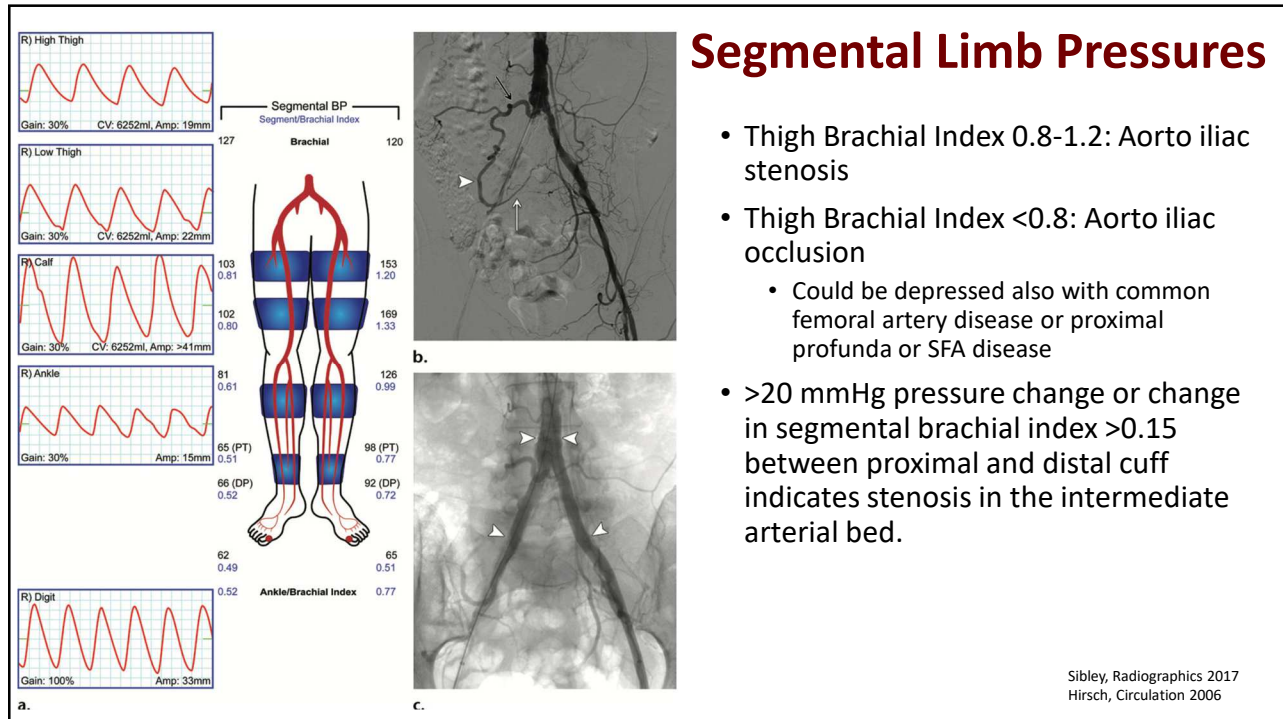


Segmental Limb Pressures

- Multiple pneumatic cuffs to measure arterial pressure in different segments of the limb.
- 3 versus 4 cuff methods
- These segmental leg pressures are compared to each other and to the higher brachial artery pressure.
- Each cuff width should be 20% greater than the diameter of the limb at the point of application or 40% of the circumference of the limb

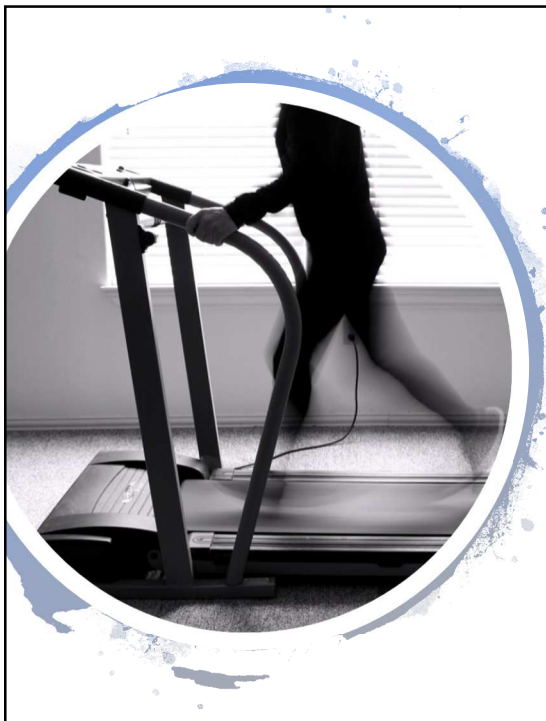


Segmental Limb Pressures



- Thigh Brachial Index 0.8-1.2: Aorto iliac stenosis
- Thigh Brachial Index <0.8: Aorto iliac occlusion
 - Could be depressed also with common femoral artery disease or proximal profunda or SFA disease
- >20 mmHg pressure change or change in segmental brachial index >0.15 between proximal and distal cuff indicates stenosis in the intermediate arterial bed.

Sibley, Radiographics 2017
Hirsch, Circulation 2006



Exercise ABI

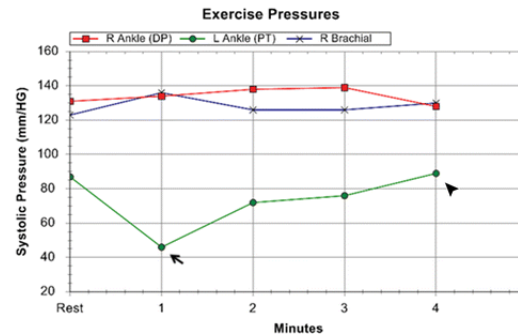
- Useful when history/ presentation is divergent from resting ABIs/ waveforms.
- Differentiating true claudication from other walking pains
- Relative contraindications
 - ABI<0.5
 - Chronic Limb Threatening Ischemia (CLTI): rest pain/ tissue loss
 - Chest pain/ shortness of breath
 - Inability to ambulate on treadmill speed
- Alternatives: Toe ups, reactive hyperemia testing

Exercise ABI

- Protocols vary: patient walks for specified time and specific grade or stops with symptoms occurring
 - E.g. 5 minutes at 12% incline at 2mph
- Measure ABI immediately after stopping and every minute until ABIs normalize to pre-exercise values.
- ↓ ABI after exercise > 0.2 indicates PAD.
- Return to Baseline
 - <2 minutes normal
 - 2–6 minutes: single-segment disease
 - 6–12 minutes: multisegment disease

Exercise Pressures		Rest	1	2	3	4	5	6	7	8	9	10
R Ankle (DP)	131	134	138	139	128							
L Ankle (PT)	87	46	72	76	89							
R Brachial	123	136	126	126	130							
R ABI	1.07	0.99	1.10	1.10	0.98							
L ABI	0.71	0.34	0.57	0.60	0.68							

PATIENT WALKED ON TREADMILL FOR 3 MINUTES AT 2 MPH AT 12% INCLINE



Mohler Arch Int Med 2003
Sibley, Radiographics 2017

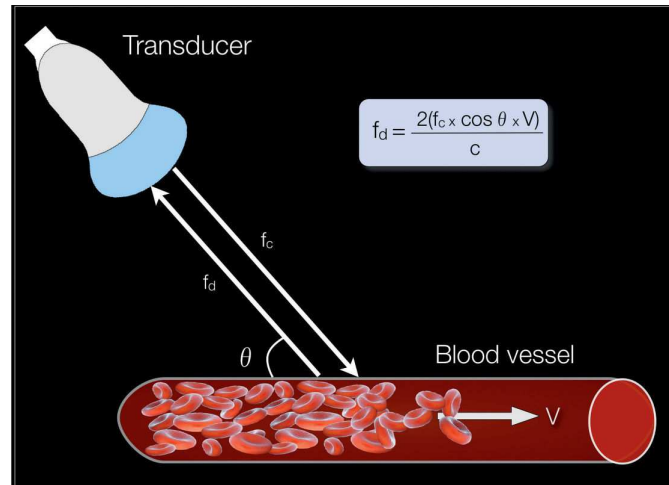
Transcutaneous oxygen measurement (TcPO₂)

- Provide supplemental information regarding local tissue perfusion
- Platinum oxygen electrodes are placed on the chest wall and legs or feet.
- The absolute value of the oxygen tension at the foot or leg, or a ratio of the foot value to chest wall value, can be used.
- A normal value at the foot is 60 mmHg, and a normal chest/foot ratio is 0.9.
- Wounds likely to heal if TcPO₂>40mmHg



Duplex Ultrasonography

- Mainstay for vascular imaging
- Utilizes both B-mode (brightness) and pulsed doppler ultrasound
 - Location and extent of vascular disease
 - Arterial hemodynamics
 - Lesion morphology
- Uses Pulsed Wave Technology



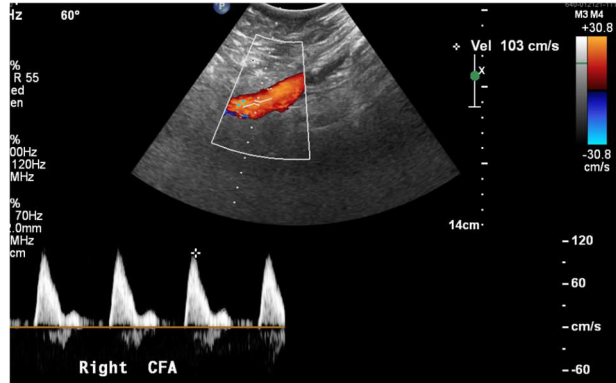
B-Mode

- The B-mode provides a grayscale image useful for evaluating anatomic detail.
- The quality of a B-mode image depends upon the strength of the returning sound waves (echoes).
- Echo strength is attenuated and scattered as the sound wave moves through tissue.
- Angles of insonation of 90° maximize the potential return of echoes.
- Higher-frequency sound waves provide better lateral resolution compared with lower-frequency waves.
- Thus, high-frequency transducers are used for imaging shallow structures at 90° of insonation.



Duplex imaging

- The identification of vascular structures from the B-mode display is enhanced in the color mode, which displays movement (blood flow) within the field.
- The shift in sound frequency between the transmitted and received sound waves due to movement of red blood cells is analyzed to generate velocity information (Doppler mode).
- Flow toward the transducer is standardized to display as red, and flow away from the transducer is blue; the colors are semiquantitative and do not represent actual arterial or venous flow.



Peripheral artery stenosis

- The severity of stenosis is best assessed by positioning the Doppler probe directly over the lesion.
- An angle of insonation of 60° is ideal; however, an angle between 30° and 70° is acceptable.
- The ratio of the velocity of blood at a suspected stenosis to the velocity obtained in a normal portion of the vessel is calculated.
- Velocity ratios >4.0 indicate a >75 percent stenosis in peripheral arteries

Table: Lower Extremity Arterial Duplex Diagnostic Criteria for PAD

Degree of Stenosis	Peak Systolic Velocity (cm/s)	Velocity Ratio
<20%	<150	<1.5
20-49%	150-200	1.5-2.0
50-80%	200-300	2.0-4.0
>80%	>300	>4.0
Occlusion	No flow detected in lumen	N/A

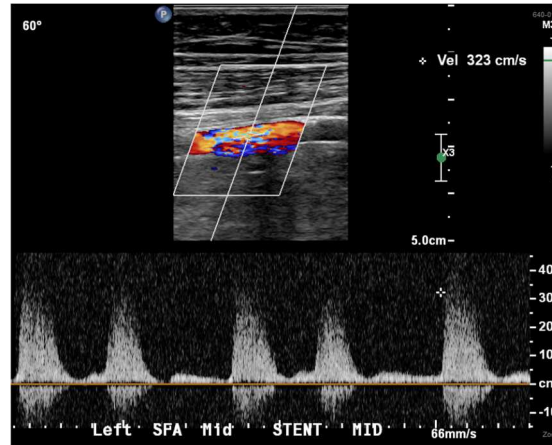
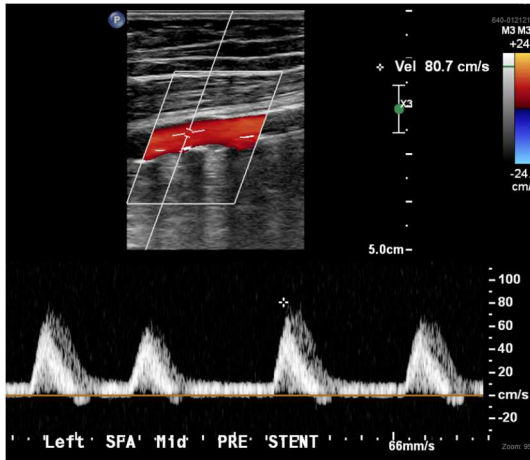
Adapted from: [Hodgkiss-Harlow KD & Bandyk DF. Semin Vasc Surg 2013;95-104](#)

Table 17 Diagnostic criteria for vein graft lesions using peak systolic velocity

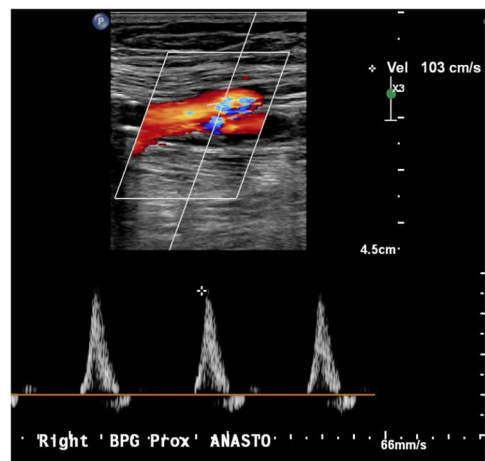
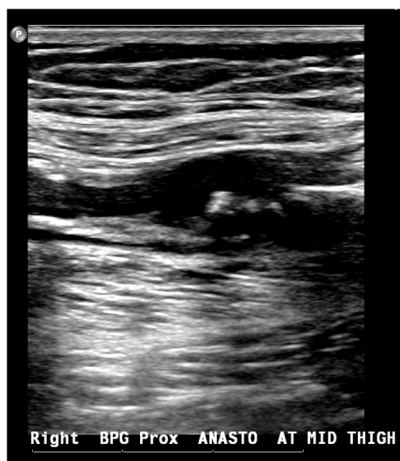
- Minimal stenosis <20% with PSV ratio < 1.4 and < 125 cm/s
- Moderate stenosis of 20% to 50% with PSV ratio 1.5 to 2.4 and a PSV <180 cm/s
- Severe stenosis 50% to 75% with PSV ratio 2.5 to 4 and a PSV >180 cm/s
- High-grade stenosis > 75% with PSV ratio > 4 and PSV > 300 cm/s

PSV, Peak systolic velocity.

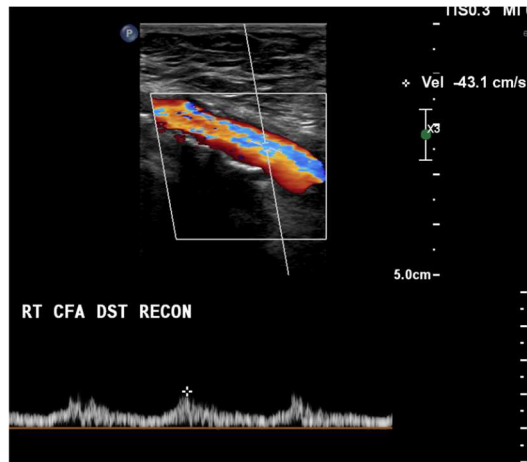
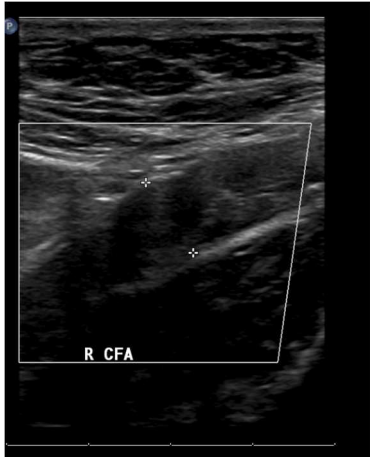
Stent Stenosis



Bypass Graft Anastomosis



Occluded vessel



Thank you