

## Instructor's Digital Curriculum Resource- For Techniques in Noninvasive Vascular Diagnosis-4<sup>th</sup>. edition.

by Robert J. Daigle, BA, RVT, RVS, FSVU, FSDMS

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## Chapter 10. Arterial Physiologic Testing- Lower Extremities

### Techniques In Noninvasive Vascular Diagnosis-4th edition

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### Definitions for this chapter

- **Basal state**
  - A steady-state in metabolism of systemic blood pressure
- **ABI**
  - Ankle to Brachial Index (ankle pressure divided by brachial pressure)
- **Palpation**
  - Palpation is a method of feeling (pulses) with the fingers or hands during a physical examination.

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### Definitions for this chapter

- **Segmental pressures**
  - blood pressures obtained from cuffs palced around the ankles, calves and thighs
- **Pseudo-claudication**
  - Pain when walking that mimics vascular claudication but is due to some other cause.
- **Infrainguinal-** below the groin

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### Definitions for this chapter

- **AHA** - American Heart Association
- **PAD-** peripheral arterial disease (atherosclerosis occlusive disease in the legs (and arms)

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### Arterial Physiologic Testing Purpose-goals:

- Evidence for arterial occlusive disease?
- Responsible for the patient's symptoms?
- Arterial disease and neurospinal compression, which condition is causing the symptoms?
- If disease is present, how severe?
- To assess increasing or decreasing limb perfusion during serial follow-up exams.

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## Advantages of Physiologic Testing

- Simple to perform
- Short exam time (20-45 Minutes)
- Accurate for hemodynamically significant disease
- Provided objective, quantitative information
- Relatively inexpensive equipment

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## Indirect Physiologic Tests

1. **Pressure assessment**
  - ABI and/or segmental pressures
2. **Plethysmography**
  - Pulse volume recording (PVR)
  - Photoplethysmography (PPG)
3. **Doppler waveform analysis**
4. **Exercise stress test**

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## Pertinent history questions should include:

- Do you have leg pain when you walk, and if so, is it in both legs?
- Which leg is the worse?
- In what part of the leg is the pain (calf, thigh, buttock, or hip)?
- Is the pain progressive and does it stop you from walking?

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## Pertinent history questions should include:

- How many blocks can you walk before you cannot go on?
- Does the pain go away when you stop walking?
- Have you ever had a bypass graft or arterial operation, and if so, what type?

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## Risk Factors for PAD?

- Is the patient a smoker, and if so, how many packs are smoked per day and for how many years?
- Does the patient have diabetes mellitus (DM) and does he/she take insulin?
- Has the patient ever had a stroke (CVA), transient ischemic attack (TIA), or myocardial infarction (MI)?

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## Risk Factors for PAD?

- Is there a family history of CVA, or MI?
- Does the patient have hypertension (HT)?
- Does the patient have hyperlipidemia (high cholesterol levels)?

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### Palpation of limb pulses (optional)

- 0 = no pulse.
- 1+ = weak pulse.
- 2+ = normal pulse.
- 3+ = very strong pulse or aneurysmal pulses (this is when you can observe your hand moving up and down with each pulsation).

Pulses may be obtained at the following sites:

- Groin - distal EIA or CFA.
- Popliteal fossa - Popliteal artery.
- Ankle - DPA & PTA.

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### Physical Signs of Disease

- Note the physical signs of disease that may be apparent:
  - Pallor, pain, paresis, pulselessness.
  - Coldness.
  - Dependent rubor.
  - Cyanotic toes.
  - Ulceration.
  - Non-healing wound.

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### Manifestations of PAD: Mild Disease

- Asymptomatic
- Bruit ?
- Emboli?
- Following Exercise = some decrease in ankle pressure

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### Moderate Disease

- Asymptomatic at rest
- Claudication
- Exercise = significant decrease in ankle pressure

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### Claudication = to limp

- Progressive pain with exercise in the calf, thigh, buttock or hip
- Relieved by rest

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### Severe Disease

- Night pain in feet- toes
  - relieved by dependency
- Dependant rubor
  - Redness, light purple or deep red-violet color that develops on the foot when it hangs in a dependent position

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## Severe Disease

- Ischemic rest pain ( in feet and toes)
- Ulceration
- Tissue necrosis
- Gangrene



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## Arterial vs. Venous

progressive SX	acute onset SX
intermittent pain when walking	persistent pain calf or thigh
no swelling	limb swelling
limb pallor	limb cyanosis
limb coolness	limb warm
rest pain	local tenderness

Do not perform an arterial exam on someone suspected of having acute deep venous thrombosis. If an arterial exam is necessary, an ankle to brachial index exam should suffice.

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## 1. Patient Preparation

- Introduce yourself to the patient.
- Explain the examination.
- Palpate pulses (optional, and not necessary).
- Apply blood pressure cuffs.

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## Segmental Pressure Principle

- In a normal individual in a supine position, ankle systolic pressure is  $\geq$  brachial pressure.
- Pt. should be in a basal state in a warm room prior to pressure acquisition

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## Blood Pressure Cuff Size:

- Bladder should be 20% wider than limb diameter
  - thigh = 18 x 36 cm
  - arms, calf, ankle = 10 or 12 x 23 cm
  - metatarsal (child-size) = 9 x 20 cm
  - digit = 2 or 2.5 x 5 cm
- 12 cm cuffs are used on the thigh in the 4-cuff method. High-thigh pressure artifact is likely (but not always) to occur.

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## Blood Pressure Cuff Size:

- Bladder should be 20% wider than limb diameter
  - thigh = 17 or 18 x 36 cm
  - Arms + ankle = 10 or 12 x 23 cm
  - Calf = 12 x 23 cm
  - Metatarsal (child-size) = 9 x 20 cm
  - Digit = 2 - 2.5 x 5 cm
- Non-uniform limb sizes = variations in pressures.



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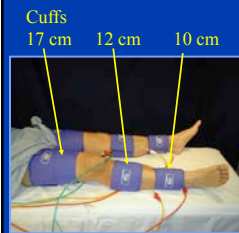
## Cuff wrap demo you-tube

When in PowerPoint Show, click on link below for video demo on youtube.

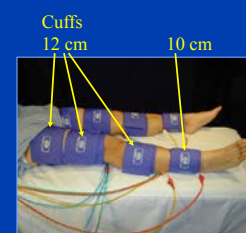
<http://youtu.be/7eTkmOh1a8E>

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## 2. Cuff Application



3-cuff method

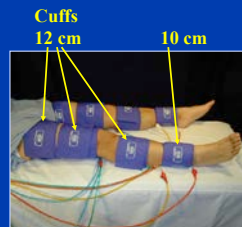


4-cuff method

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## Segmental Pressures: 4- Cuff Method

- Used to identify region of disease
- 2-thigh cuffs useful for differentiating AI from SFA disease
- High-thigh cuff artifact may occur; artificially elevated thigh pressure



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## Helpful Hints

- The AHA recommends that the cuff width be 20% wider than limb diameter, or 40% of the circumference.
- Don't let the patient lift their leg in an attempt to assist you when applying leg cuffs; as soon as they relax their muscles, the cuff becomes loose.
- Place the high (proximal) thigh cuff as proximal as possible.
- Place the calf (below knee) cuff below the bony structures of the knee, otherwise, excessively high pressures may be recorded.

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## Helpful Hints

- Plastic wrap placed over a wound or ulcer will keep pressure cuffs clean.
- Manufacturers will recommend either a 10 or 12 cm cuff for the arms and ankles based on their system configuration.

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## 3. Obtain bilateral arm systolic pressures with CW-Doppler and compare.

- A pressure gradient of 20 mmHg or greater suggests subclavian artery disease on the lower side.



Brachial systolic pressures:  
Abnormal on Left

Do not take a pressure in an arm with a shunt or dialysis access graft.

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## Next, obtain ankle pressures

- Use a continuous wave Doppler and acquire pressures from the posterior tibial artery (PTA) and the dorsalis pedis artery (DPA), bilaterally

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## 4. Obtain leg pressures

- Dorsalis Pedis (DPA)
  - easily compressed, beware!
  - harder to locate



Note fingers and hand are resting on the foot to support the probe and prevent probe slipping.

- Posterior Tibial (PTA)
  - harder to compress
  - easier to locate



*Essential not to drift off vessel !*

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## CW Doppler on posterior tibial artery



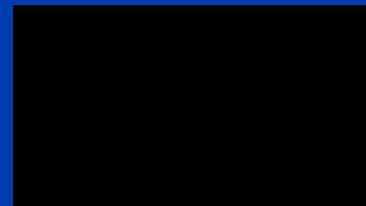
Image #1: the Doppler probe is positioned over the artery at a 90° angle; this is not good!

Image #2: The Doppler probe is positioned too far distal to the medial malleolus (notice the dot on the ankle marking the center of the MM). The probe is over the smaller plantar arteries. Try to keep the probe forward of the line on the image to be over the actual PTA.

Image #3: Probe is in a good position over the PTA with a good angle (45-60°) and pointed parallel to the long axis of the artery. Good!

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## CW Doppler Transducer Position Demo



If the movie does not play, Click on Link (in Powerpoint Show) To play Youtube video

<http://youtu.be/zPDcyMyW8X8>

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## Most common errors in pressure acquisition

- The Doppler probe drifts off the artery during supra-systolic phase (No audio signal)
- The artery being evaluated is occluded by excessive probe pressure during the "bleed-down" phase.

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## Traditional Pressure Sequence

- Rt brachial
- Lt. brachial
- Rt. DPA
- Rt. PTA
  - From this vessel, Rt. calf and thigh pressures are obtained if "segmentals" are performed.
- Lt. DPA
- Lt. PTA —used from calf and thigh

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## AHA Recommended Sequence for ABIs (2012)

- Rt. arm
- Rt. PTA
- Rt. DPA
- Lt. PTA
- Lt. PTA
- Lt. arm
- Rt. arm -repeat

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## AHA Logic

- Systemic systolic pressures may decrease during the ABI exam causing an artifactual pressure gradient between arm and ankle.
- Obtaining Rt. arm then Rt. PTA (usually the "strongest" and easiest to locate) reduces the chance that this artifact will occur.

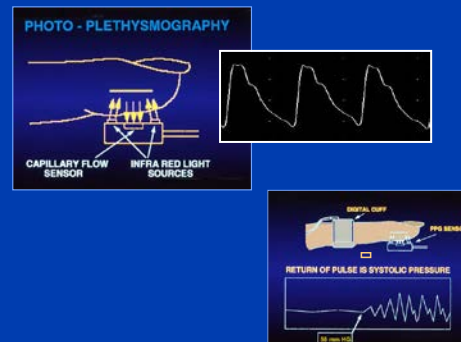
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## Alternative Methods for Pressures

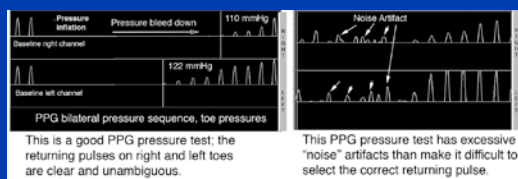
- Photoplethysmography (PPG)
  - Infrared emitting and receiving diode attached to the skin to detect cutaneous blood flow
- Oscillometric

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## Digit Pressure Acquisition with PPG



## Toe Pressures with PPG



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## PPG Segmental Pressures-Advantages

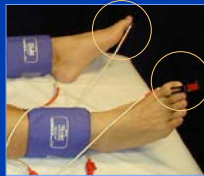
- Less operator dependence
- Simultaneous, bilateral capability
- Convenient



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## PPG Segmental Pressures- DISadvantages

- No audible signal
- Doesn't work in severe disease (a good waveform is necessary)
- Motion and ambient light artifact can cause false readings



Currently (2014) not compliant with Medicare CPT guidelines

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## Oscillometric Pressures

- Convenient, but prone to errors
- Tendency to overestimate pressures
- Problem with irregular heart rate
- Not defined as a method in vascular CPT codes.

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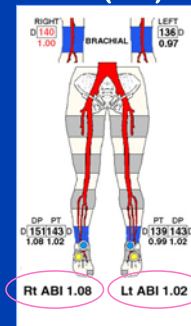
## Segmental Pressures Doppler versus PPG Bottom line

- Doppler is a bit more time consuming, but it's more reliable, especially for patients with disease.

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## 5. The Ankle/Brachial Index (ABI)

- Bilateral ankle pressures divided by the higher brachial pressure
- Highest ankle pressure value is used for reported ABI
- Lowest ABI reported as a "marker" for PAD



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## 6. Segmental Pressures

- Instruct the patient that this pressure measurement may be uncomfortable and caution him/her not to move their leg during the test.
- Cuffs should be snug, (don't allow the patient to lift their leg to "help").
- If thigh pressures must be obtained, do it quickly and precisely. Get it right the first time!



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## Segmental Pressures

- Inflate cuffs to at least 20 mmHg above systolic pressure, pause for a moment, then bleed pressure down and record returning systolic pressures. The narrow high-thigh cuff (12 cm size) usually must be inflated to 40 mmHg above the arm pressure.



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## Segmental Pressures

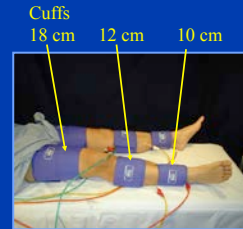
- The four-cuff method is useful in differentiating inflow disease from SFA disease. Because the high thigh cuff is narrow compared to limb girth, a pressure artifact usually exists that elevates the pressure value 20 - 30 mmHg above systemic pressure.



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## 3-Cuff Pressure Method

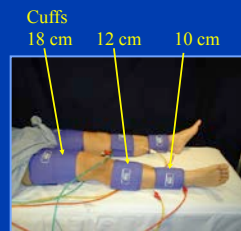
- One large (18 cm width) thigh cuff
- Normal thigh pressure is = brachial pressure
- Abnormal pressure is 20-30 mmHg less than brachial



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## 3-Cuff Pressure Method

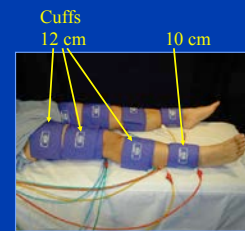
- If thigh pressure is abnormal, the disease location could be:
  - Aortoiliac disease?
  - Femoral disease?
- Must use thigh PVR or Dop. waveform to differentiate



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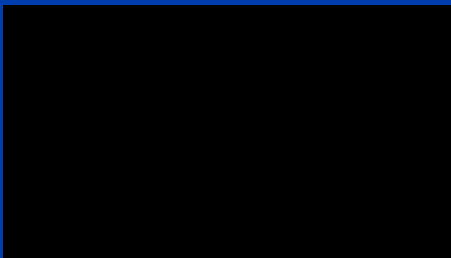
## 4-Cuff Pressure Method

- 2 thigh cuffs
- "Normal" High-thigh pressure is 30 mmHg > brachial pressure
- High-thigh cuff artifact may occur; artificially elevated thigh pressure
- Able to differentiate AI from SFA disease if high thigh pressure is low.



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## Cuff Wrap Demo



Movie-Segmental cuffs

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## 7. Toe Pressures

- Useful in evaluating small vessel disease and in diabetic patients with calcified, incompressible large vessels.
- Pressures are with a small (1.9 or 2.5 cm) digital cuff on the great toe and PPG transducer positioned distally on the toe.



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## Toe Pressures

- Inflate the cuff and bleed pressure back down slowly until the PPG pulsatile trace returns. This is the toe systolic pressure.



Toe Pressures obtained with PPG

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## Toe / Brachial Index (TBI)

- **Normal** > 0.75
- **Abnormal** < 0.66



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## Resting (ABI) Values

- > 1.35 = probable calcified arteries
- 0.90-1.34 = normal
- < 0.90 = abnormal, stress testing may be appropriate
- < 0.8 = probable claudication
- < 0.5 = multi-level disease or long segment occlusion
- < 0.3 = ischemic rest pain-severe disease

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## ABI Value Exception for Normals

- **Brachial systolic pressure below 100 mmHg or above 200 mmHg:**
  - ankle pressure may be 25% lower than brachial p.

Belcaro et al. *Non-invasive Diagnostic Techniques in Vascular Disease*, 3rd edition p 507 E. Bernstein editor

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## Segmental Limb Pressure Interpretation

- **Arm pressures:**
  - A gradient of 20 mmHg or more between brachial pressures indicates subclavian stenosis/occlusion on the side of the lower pressure. This finding should be confirmed with pulse volume recording, Doppler waveform analysis, or duplex imaging.

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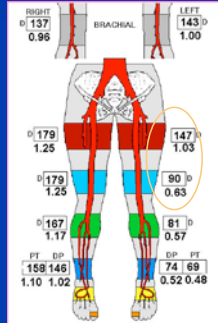
## Segmental Limb Pressure Interpretation

- Compare to contralateral limb
- Compare to adjacent segments
- Compare to brachial pressure
- **A 30 mmHg or greater pressure gradient (drop) is significant in the presence of an abnormal ABI**

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### Segmental Limb Pressures Sites

- Useful in identifying region(s) of disease
- Metatarsal and toe pressures often useful
- This study indicates probable inflow disease and femoro-popliteal disease in the left leg



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### 3-cuff versus 4-cuff

- **3 cuff method (17cm thigh cuff)**
  - if abnormal, cannot differentiate AI from SFA disease
- **4 cuff method (12 cm thigh cuffs)**
  - upper thigh cuff pressure artifact ( $\geq 20$  mmHg)
  - suppose to differentiate AI from SFA

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### High-thigh pressure for detection of A-I disease

4 cuff technique

- **normal thigh pressure  $\geq 20$  mmHg above brachial pressure**
  - negative predictive value: 100%
  - positive predictive value: 42%

C Kupper, Detection of iliac artery lesions. Bruit 8: 157-63, June 1984

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### Interpretation Tip 1.

- If thigh pressure (3 & 4 cuff) is normal = no significant inflow disease
- If upper thigh Pressure (4 cuff) or large thigh cuff Pressure (3 cuff) is abnormal, other methods are needed to differentiate AI from Femoral disease

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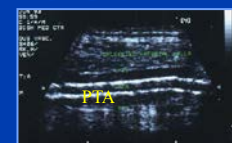
### Interpretation Tip 2.

- Cuff pressures vary from intra-arterial pressures due to variations in limb girth
- Expect a "fudge factor" up to 20 mmHg.

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### Pressure Limitation: calcified arteries

- Diabetics
- Chronic steroid therapy
- Renal dialysis patients
- Segmental pressures unobtainable or excessively high (ABI  $> 1.35$ )



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## Calcified Arteries



- You can rely on a low pressure recording, but not a high one. In the presence of calcific medial sclerosis and incompressible vessels, limb perfusion must be assessed with other methods, e.g., PVR, Doppler waveform analysis, or toe pressures.

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## Calcification Clues:

- **Incompressible artery- pressures unobtainable**
- **or, excessively high ABI (>1.35)**
- **High pressures in limb distally, compared to proximal pressures**

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## Pressure Advantages

- **Quantitative information on limb perfusion**
- **Easy to perform**
- **Substantial clinical validation**

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## Pulse Volume Recording

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## Arterial Plethysmography

### Volume Plethysmography

“The measurement of a volume change in a limb or organ.”

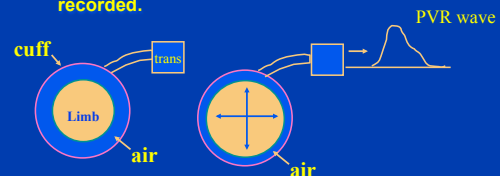
### Pulse Volume Recording (PVR)

- aka volume pulse recording (VPR)
- aka pulse cuff recording (PCR)

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## Pulse Volume Recording (PVR)

- Limb volume changes w /systole
- Air is displaced within a cuff
- Instantaneous pressure change is recorded.



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## PVR

- Cuffs are sequentially connected to the plethysmograph and inflated to a specific air pressure (60 +/- 5 mmHg).
- Instruct the patient to be still and not to talk during the test to minimize motion artifact in the tracing.



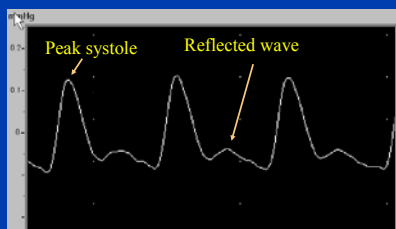
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## PVRs

- PVR waveforms are then recorded for each limb segment.
- Set the PVR gain or scale to optimize the waveform amplitude.
- You can inadvertently make a normal waveform abnormal with a low gain setting.
- You cannot make an abnormal waveform normal

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## Normal PVR



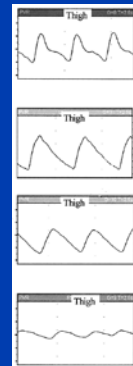
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A normal PVR waveform has a sharp upstroke and a prominent reflected wave, also called the dicrotic notch, in late systole and early diastole.

Mild disease will cause the waveform to broaden and the reflected wave will not be present. There is also a slight loss of amplitude.

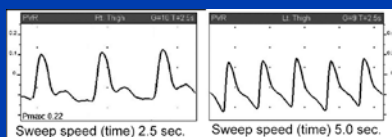
A moderately abnormal PVR has a rounded peak, no reflected wave and a pronounced decrease in amplitude.

A severely abnormal PVR is of low amplitude, or even "flatline".



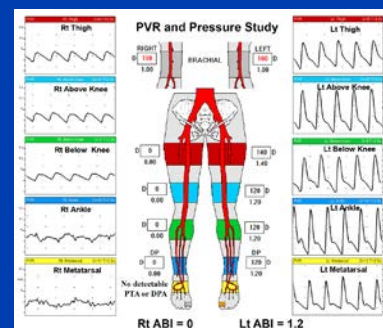
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## Sweep speed can affect the waveform appearance



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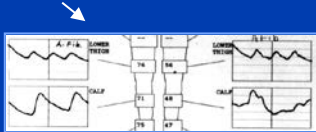
## Pt. with thrombosed aorto-iliac bypass graft



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## PVR Limitations

- Tremor - motion
- Distal disease with prox. occlusion
- Subjective interpretation
- Atrial Fib.



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## PVR Advantages

- Easy to learn and to perform
- Assessment of global limb perfusion
- Metatarsal and toe evaluation
- Fast method
- Not affected by calcified arteries

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## Continuous-wave Doppler Waveform Analysis:

- Waveforms are obtained from
  - CFA
  - SFA
  - Popliteal artery
  - PTA
  - DPA

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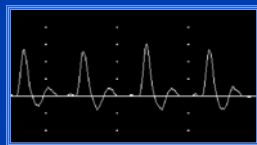
## Doppler Waveform Analysis: Technique

- Patient in basal state - warm room
- 4 or 8 MHz CW Doppler
- 45 - 60 degree angle to skin
- Obtain clean waveforms

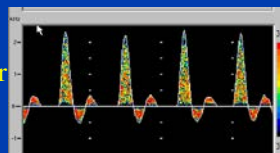
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## Doppler Waveform Analysis:

Analog, low-cost  
zero-crossing  
detector



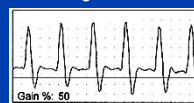
FFT color  
spectrum analyzer



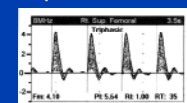
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## Doppler Waveforms

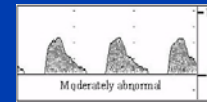
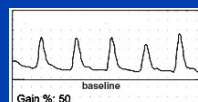
Analog waveforms



Spectral waveforms



Normal -multiphasic

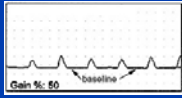


Abnormal-moderate

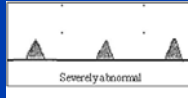
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## Doppler Waveforms

Analog waveforms



Spectral waveforms

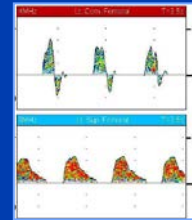


Severe disease-monophasic

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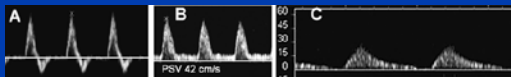
## Doppler Waveform Analysis: Interpretation

- Subjective assessment
- Loss of triphasic waveform
- Dampening of amplitude
- Slow upstroke



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## Doppler Waveform Definition Problems



The term "biphasic" is problematic, as it can be applied to waveforms representing very different flow patterns. Some would call waveform "A" biphasic, others would call "B" biphasic. "C" is monophasic.

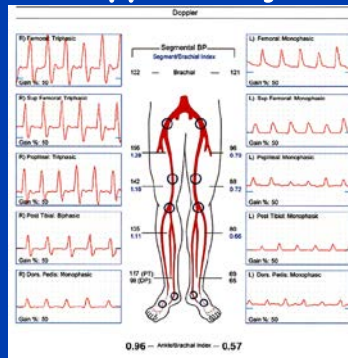
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## Doppler Waveform Analysis: Limitations

- Junk signals
  - Obesity, scar tissue, occluded artery
- Venous interference (averaged signal)
- Requires SKILL, ( a lot )
- Medicare guidelines (2011) indicate waveforms must be obtained with CW-Doppler, not duplex ultrasound systems.

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## Doppler Study



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## Exercise Stress Testing, Purpose:

1. Differentiate true vascular claudication from "pseudo-claudication".
2. Differentiate borderline normal from abnormal.
3. In patients with combined neuropathy and vascular disease, determine which condition is limiting walking.

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### Exercise Stress Testing, Purpose:

- Resting blood flow over a stenotic lesion may be sufficient to maintain normal or near normal distal pressure.
- When flow is augmented over the stenosis, as in exercise or reactive hyperemia, distal pressure may drop revealing the presence of disease.
- It is appropriate to exercise those with claudication symptoms despite a normal resting exam.

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### Exercise Stress Test:

- treadmill speed = 1.5 or 2 mph
- 5-10 percent grade
- 5 minutes = standard walking time
- Post exercise ankle pressures- ASAP



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### Exercise Candidates

1. Intermittent claudicators
2. ABI 0.85 - 0.5
3. If symptoms occur only at rest and resting study is normal, don't exercise.
4. If resting study is normal, but patient has claudication, exercise.

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### Contraindications for Treadmill Exercise

- Questionable cardiac status
- Resting ischemia (ABI < 0.3)
- Ischemic ulceration or rest pain
- Severe pulmonary disease
- Poor ambulators

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### Arterial Stress Testing: Goals

Stress perfusion to  
define extent of disease

USE

Treadmill  
Toe raises  
Reactive hyperemia

True vascular claudication  
or pseudo-claudication ?

USE

Treadmill

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### Post-exercise Methods

#### Method # 1

- one bilateral ABI from both ankles and one arm.
- Efficient method

#### Method # 2

- serial ABI's for post exercise until ankle pressures have reached pre-exercise levels

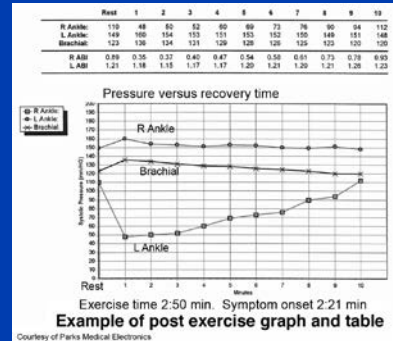
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## Claudication Criteria

- Post exercise ankle pressure of 60 mmHg or less confirms a vascular etiology

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## Post-exercise Serial Pressures



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## Stress Testing Caveats

- Record time of onset of symptoms and nature of symptoms
- Record total walking time
- Following exercise, if ankle pressures (or ABIs) remain normal, no need to continue taking pressures.

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## PORH

Post Occlusive Reactive Hyperemia

- Occlude distal thigh - 3 minutes
- Occlude Pressure is 20 mm Hg above limb pressure
- Record post occl. ankle pressure
- Painful exam, poor patient acceptance
- Learn it but don't do it!



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## Toe Raises

- Substitute for treadmill
- Toes raises for 1 minute
- Obtain post exercise ankle pressures



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## Physiologic Testing Limitations

- Detects only hemodynamically significant disease (> 60 % stenosis)
- Usually cannot distinguish stenosis from occlusion
- Region, but not site of disease

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## Physiologic Case Studies

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## Remember the goals of physiologic testing as you review the cases

- Is the objective evidence for PAD?
- Is the disease, if present, causing the patients symptoms?
- How severe is the disease?
- What is the region: aorto-iliac, femoro-popliteal, popliteal-tibial ?

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## Interpretation Tips

- Step #1: Look at the ABIs first.
- Step #2: Confirm that ankle waveforms correlate with ankle pressures. If the ankle pressures are normal, the ankle waveforms should also be normal. If pressures are low, waveforms should be abnormal.

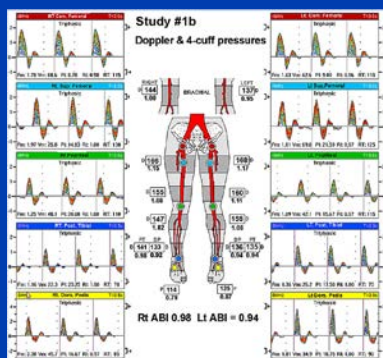
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## Interpretation Tips (cont.)

- Step #3: Determine the disease location (inflow versus infrainguinal), by assessing thigh PVRs (or CFA waveforms), and thigh pressures.
- Step #4: Determine multi-level versus single level disease.
- Step #5: Determine severity, and if disease is related to the patient's condition.

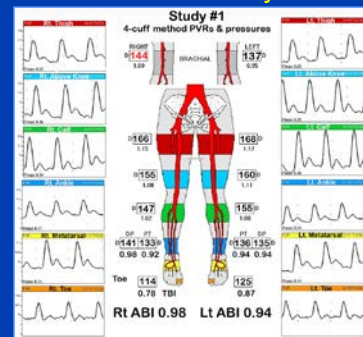
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Doppler study from same person.



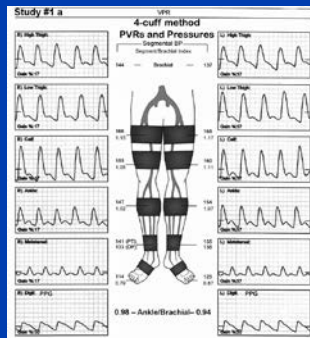
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## Normal study



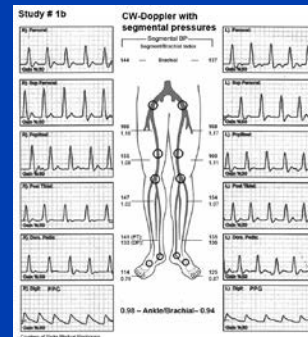
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## Study #1a &amp; 1b. - Normal 52-year-old volunteer



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## Normal Doppler Exam from the same patient

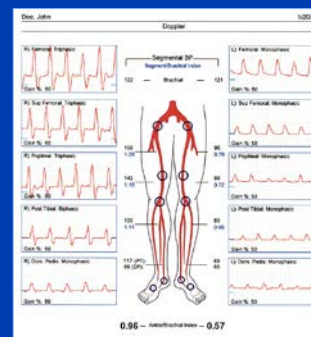


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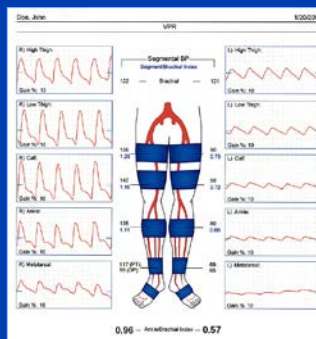
## Study #2-Patient; John Doe

- 53 year old male presents with Hx of left buttock, thigh, calf claudication limiting walking to 2 blks.
- HX smoking 1-2 ppd
- Hx of Hypertension, angina
- Hx of coronary angioplasty with stent

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Study #2a. Patient: John Doe  
Analog Doppler study with 4-cuff pressures.

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Study #2b Patient John Doe  
PVR (VPR) study with 4-cuff pressures

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## Study #2-J.Doe- Discussion

- Rt leg normal
- Severe aorto-iliac disease on left.

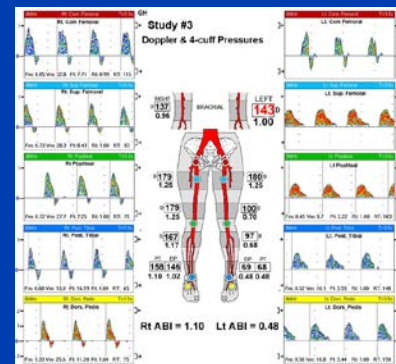
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### Study #3 Patient GH

- 82-year-old female
- Presents with ulcer on left lateral ankle.
- No Hx MI, DM or smoking
- Hx of hypertension

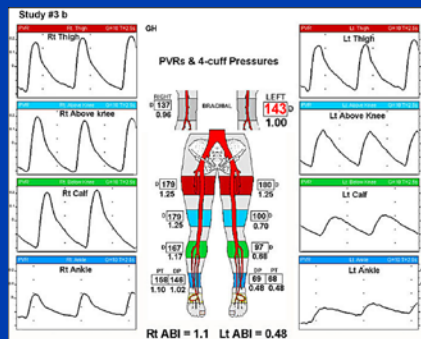
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### Study #3a



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### Study #3b



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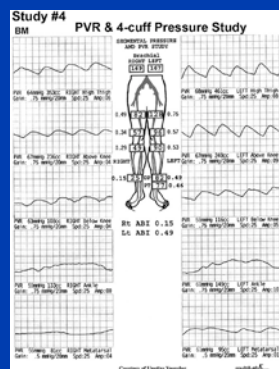
### Study #3 -GH- Discussion

- No significant inflow disease
- Moderate to severe left femoro-popliteal disease, "???" of tibial involvement.
- Resting study in right leg is normal

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### Study #4 -BM

- 90 yr. old female with gangrenous toes right foot.



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### Study #4-BM- Discussion

- ABIs abnormal bilaterally, severe on right.
- Severe aorto-iliac and femoro-popliteal disease on right.
- Moderate AI and femoro-popliteal disease on left.
- Severe ischemia right foot

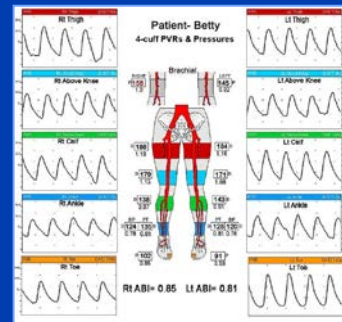
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## Study #5- Betty

- 78 yr. old female presented with recent onset Rt. hip and leg pain soon after walking.
- Walking limited to 1 blk.
- No Hx of CVA, HT, DM, or vascular surgeries
- Hx of bilateral SFA disease
- She has been an active walker.

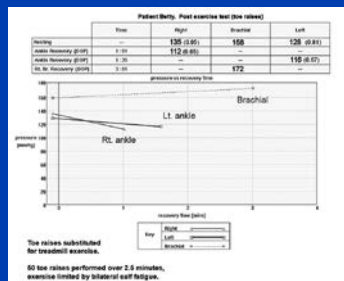
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## Study #5-Betty



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## Study #5- Betty- exercise test



- Toes raises substituted for treadmill

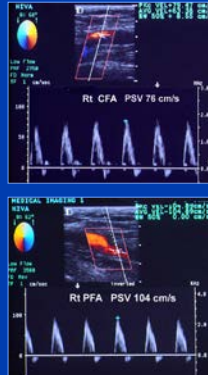
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## Study #5- Discussion

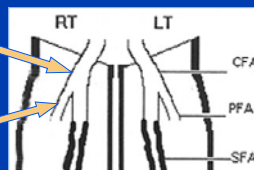
- Although patient experienced a mild decrease in ankle pressures post ex, it was not of a magnitude to explain leg pain on a vascular basis.
- Color duplex exam revealed bilateral, long SFA stenoses.
- Patient subsequently found to have spinal stenosis at L-5 level by CT scan.

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Pt. Betty

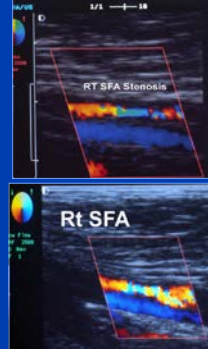


Right Leg

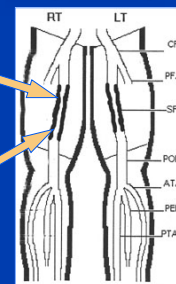


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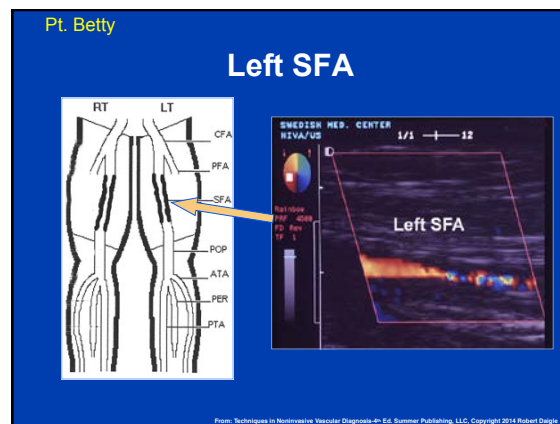
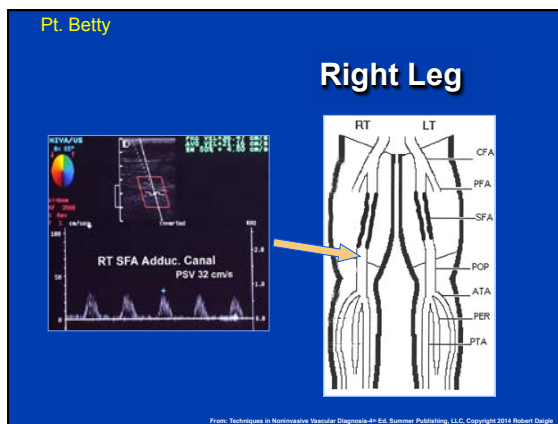
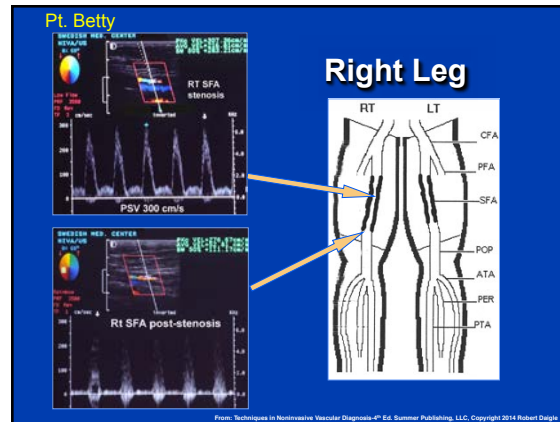
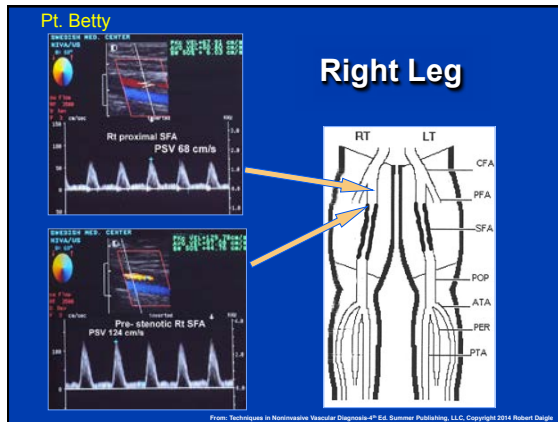
Pt. Betty



Right Leg



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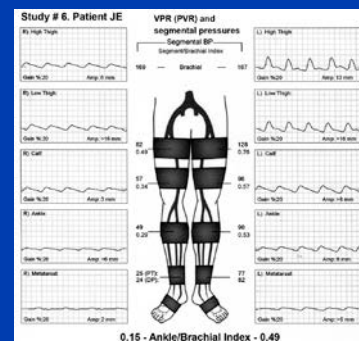


## Study # 6- JE

- This 68-year-old male presented with Hx of rest pain and non-healing ulcer on right lower leg.
- History of hypertension, hyperlipidemia, MI, and smoking (quit 5 years ago).

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## Study #6. Patient JE



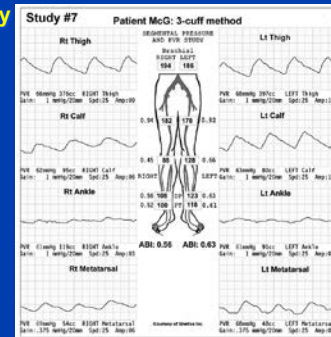
## Case #6. JE- Discussion

- Impression:** Severe aorto-iliac and femoro-popliteal disease on right with severe distal ischemia. Moderate to severe femoral-popliteal disease on left.

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## Study #7- McG

- No history available**



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## Study #7- McG; Discussion

- Bilateral femoro-popliteal disease**
- Note:** there are a few technical glitches in the study.
  - Ankle PVRs are almost flatline, but ankle pressures are >100 mmHg! Ankle pressures and PVRs should have been repeated.

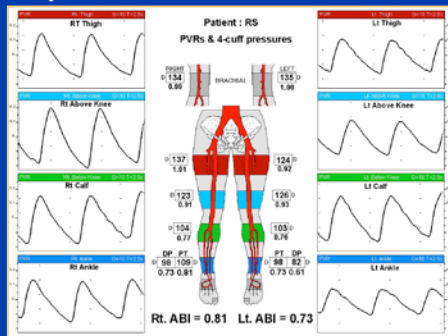
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## Study #8-RS.

- 53 year old male**
- Hx of stable, bilateral intermittent hip, thigh and buttock claudication limiting walking to 3 blks.**
- Hx of angina, hypertension, smoking 1-2 ppd**
- CABG 3/23/00**
- Pulses: CFA 1, Pop 0, PTA 1, DPA 1 bilat.**

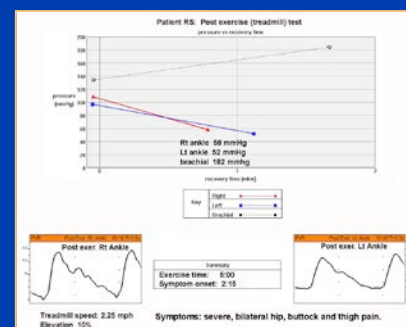
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## Study #8-RS



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## Study #8-RS Post treadmill exercise study



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### Study #8-RS; Discussion

- Moderate aorto-iliac disease bilaterally resulting in vascular claudication
- Question of mild femoro-popliteal disease bilaterally
- Color Duplex Imaging revealed bilaterally severe common iliac artery stenoses.

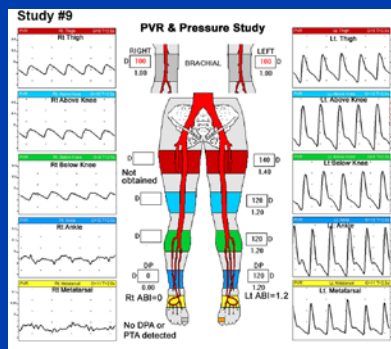
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### Study #9-JF

- 34 -year-old male
- Acute onset Rt. calf claudication
- Hx of Aorto-Rt. femoral bypass graft 9 months prior
- Rt. pulses CFA, POP, DP, PT all 0
- Lt pulses all 2+

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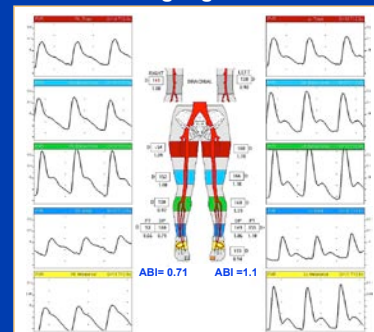
### Study #9



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### Study #9

Pt. JF: post thrombectomy of right graft.



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### Study #9-JF- Discussion:

- Normal PVRs and ABI on left side.
- Unable to obtain pressures in right leg (no flow detectable by Doppler in either pedal arteries).
- Abnormal PVR at left upper thigh indicates severe inflow disease. The fact that he has a graft on the right side suggests graft occlusion.
- Angiography revealed a thrombosed aorto-femoral graft.

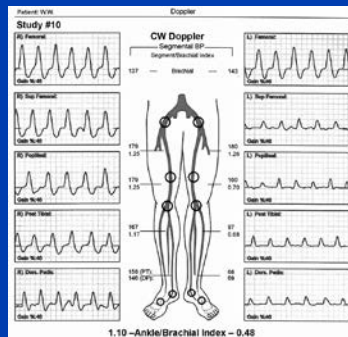
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### Study #10-W.W.

- This 82-year-old female presented with an ulcer on her left lateral ankle.
- Pulses: right CFA 2+, right Pop 2+, right DPA 1+, right PTA 2+; left CFA 2+, pulses below were absent.
- No history of smoking, MI or DM. History of hypertension.

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## Study #10



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## Study #10. WW-Discussion

- Patient was unable to exercise.
- **Impression:**
  - No significant inflow disease.
  - Moderate to severe left femoro-popliteal disease, with question of tibial involvement.

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## Abbreviated, Efficient Arterial Protocols for Physiologic Testing

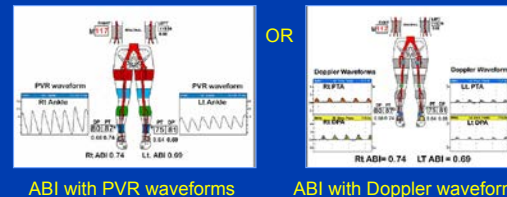
- Is there evidence for PAD? To answer...
- Perform limited, bilateral physiologic study (CPT 93923)
- Perform exercise in appropriate (claudicating) patients, or borderline normals

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## Abbreviated, efficient arterial protocols.

## Limited, physiologic study- ABIs with ankle waveforms

CPT code 93923



ABI with PVR waveforms

ABI with Doppler waveforms

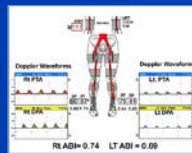
Acquire both PVRs and Doppler waveforms from the ankle level. If PVRs are non-diagnostic due to motion artifact, rely on the waveforms obtained with Doppler.

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## Abbreviated, efficient arterial protocols.

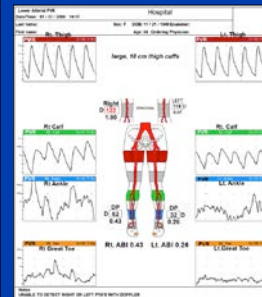
## Questions answered in a 15 minute exam

- Patient has peripheral arterial disease bilaterally, slightly greater on left
- It's of moderate severity
- Exercise stress testing at this point would confirm that PAD is causing claudication



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## Patient with severe disease bilaterally. PVRs were "non-diagnostic" at the ankle level, but Doppler waveforms correlated with low ankle pressures.



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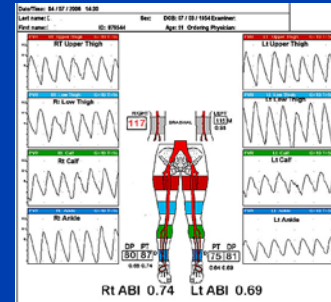
## Questions NOT answered in this exam

1. Disease Level- Inflow or infrainguinal?
  2. Single level or multilevel disease (is this relevant or important?)
  3. Is the disease causing the claudication ? (probably)
- To answer Question #1, we expand to a "complete" (multi-level) segmental exam.

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## Segmental PVRs (with ABIs)



Inflow disease- Aortoiliac disease bilaterally

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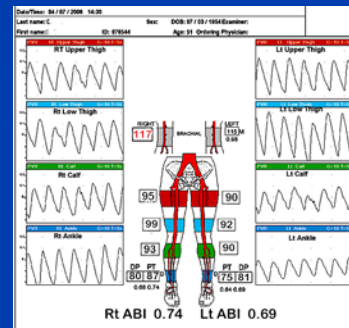
## Questions answered in an additional 5-10 minute exam

- Abnormal PVR waveforms at upper thigh
- No significant further drop in PVRs
- Aortoiliac disease (Inflow disease)
- PVRs easy to perform and faster than "blind" CW-Doppler.

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## Would full segmental pressures help in this case?



No, not here!

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## Questions NOT answered in this exam

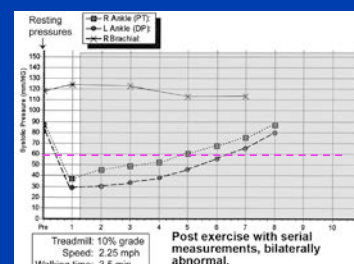
3. Is the vascular disease causing the claudication ?
- How do we answer #3
  - Assumption (low resting ankle pressures)
  - Exercise stress test

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CPT Code 93924

## Post exercise test



Post exercise ankle pressure  $\leq 60$  mmHg confirms a vascular etiology for claudication bilaterally

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Abbreviated, efficient arterial protocols.

## Exam Efficiency

- **ABI with ankle waveforms**
  - Total time 10-15 mins
- **ABI with addition of segmental PVRs**
  - Total time 20-25
- **ABI, segmental PVRs, and stress test**
  - Total time 35-45 minutes

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