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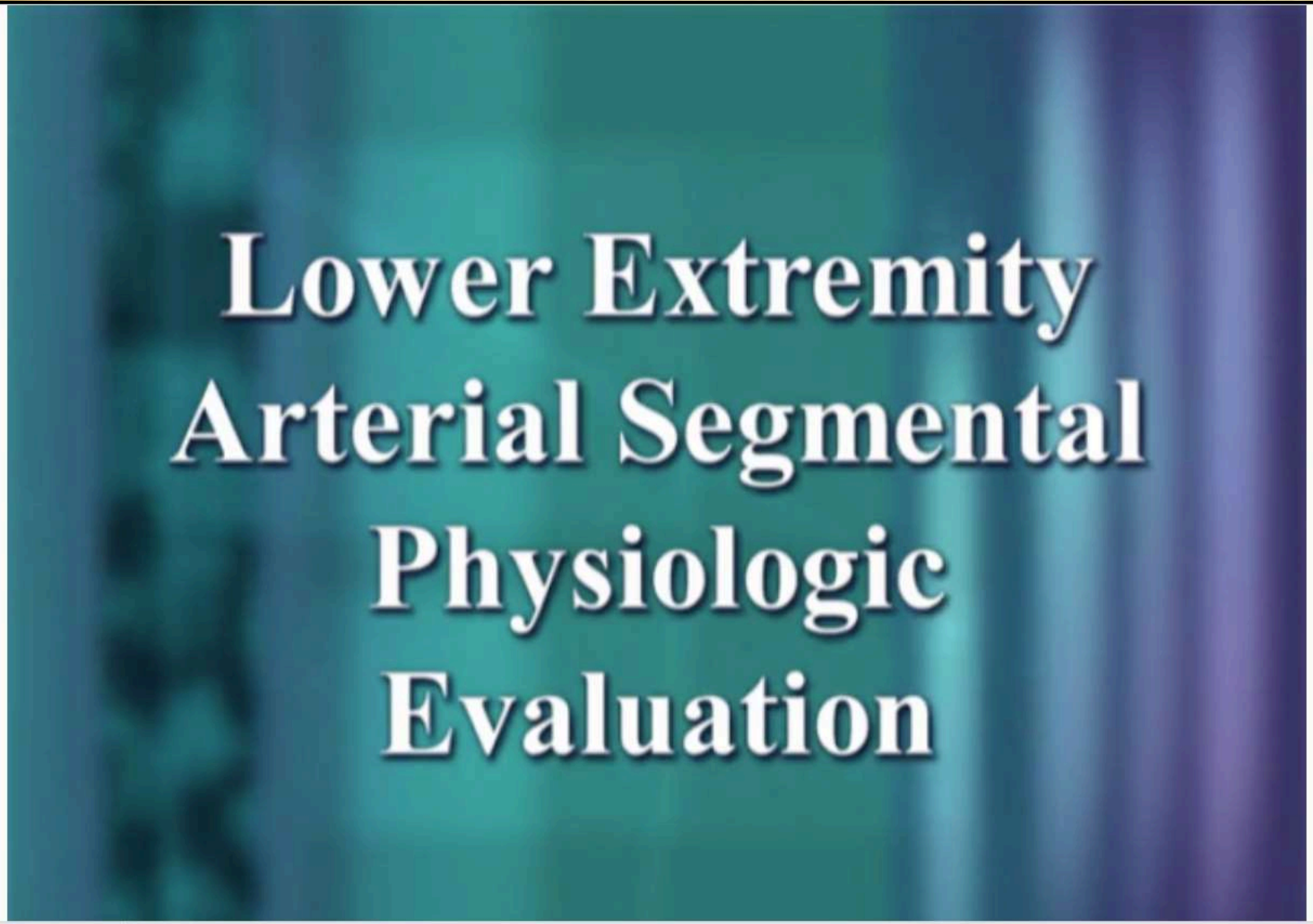
No Disclosures or Conflicts

Lower Extremity Arterial Segmental Physiologic Evaluation


Lower Extremity
Arterial Segmental
Physiologic
Evaluation

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Objectives

- Discuss lower extremity arterial, physiology and pathophysiology
- Explain the common signs, symptoms and etiology of lower extremity arterial disease
- Identify various spectral waveforms and pulse volume recordings encounterded in a lower extremity arterial segmental pressure examination

Objectives

- Recognize the common pitfalls encountered during a lower extremity arterial physiologic segmental examination
- Describe the standard protocol for a lower extremity arterial segmental physiologic evaluation as defined in the Society for Vascular Ultrasound Professional Performance Guidelines

Lower Extremity Arterial Segmental Physiologic Professional Performance Guidelines


SVU

Lower Extremity Arterial Segmental Physiologic Evaluation

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Lower Extremity Arterial Segmental Physiologic Professional Performance Guidelines

- **Purpose**

  - Lower extremity arterial physiologic studies are performed to provide an overview of the location, extent and severity of vascular disease in order to facilitate clinical management decisions.

- **Common Indications**

  - Claudication
  - Ischemic rest pain
  - Arterial ulceration

- **Contraindications and Limitations**

  - Presence of ulcers
  - Casts
  - Bandages

AHA/ACC Guideline 2016 on the Management of Patients With Lower Extremity Peripheral Artery Disease

Patients at Increased Risk of PAD (Table 3)

- Age ≥65 y
- Age 50–64 y, with risk factors for atherosclerosis (e.g., diabetes mellitus, history of smoking, hyperlipidemia, hypertension) or family history of PAD
- Age <50 y, with diabetes mellitus and 1 additional risk factor for atherosclerosis
- Individuals with known atherosclerotic disease in another vascular bed (e.g., coronary, carotid, subclavian, renal, mesenteric artery stenosis, or AAA)

History and/or Physical Examination Findings Suggestive of PAD (Table 4)

History

- Claudication
- Other non–joint-related exertional lower extremity symptoms (not typical of claudication)
- Impaired walking function
- Ischemic rest pain

Physical Examination

- Abnormal lower extremity pulse examination
- Vascular bruit
- Nonhealing lower extremity wound
- Lower extremity gangrene
- Other suggestive lower extremity physical findings (e.g., elevation pallor/dependent rubor)

Guidelines

- Patient Communication and Positioning
  - Introduction
  - Explain and Educate
  - Supine
- Patient Assessment
  - History and physical
  - Risk factors, F/H etc..
- Examination Guidelines
  - Segmental Physiologic Evaluation for Single and Multi-Level studies…ABI, Toe pressures, PVR's etc….
- Review of Findings
  - Review all clinical and technical data
  - Document exceptions to the protocol

Introduction to Lower Extremity Physiologic Testing

Non-imaging tests

- AKA "physiologic testing"
- 1960's, 1970's, and 1980's
- Volume / pressure measurements
- Information on global perfusion
- Some segmental information
- No information about the nature of the disease

Physiologic Testing of the Lower Extremity Arterial System

- Anatomy
- Physiology
- Patient history
- Focused physical exam
- "Physiologic" (non-imaging) evaluation

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VASCULAR TECHNOLOGY
PROFESSIONAL PERFORMANCE GUIDELINES

Lower Extremity Arterial Segmental Physiologic Evaluation

Atherosclerosis

affecting the lower extremity arterial tree

- ≈ 10% of the Western population >65 yrs
- Exertional leg pain is by far the most common symptom
- Symptomatic *peripheral arterial disease* (PAD)
  - commonly affects men > 50 years
  - ≈2% of the population age 40 to 60 years
  - ≈ 6% of those >70 years
- No racial predilection

Peripheral Arterial Disease (PAD)

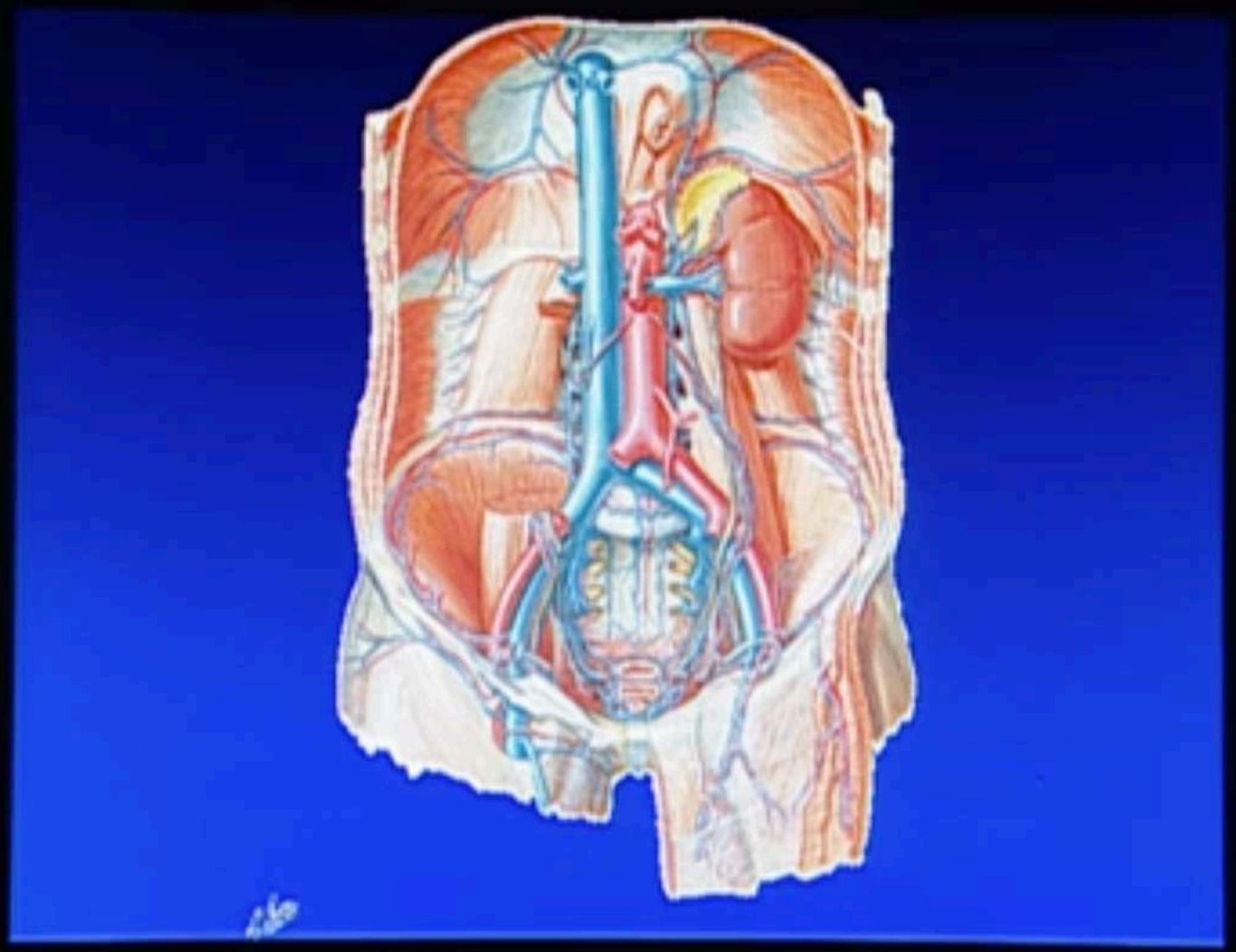
- Severe limb threatening ischemia and possible amputation is the most feared consequence
- Amputation is actually fairly uncommon ranging 2 - 12% with 10 yr follow-up
- Exertional leg pain is by far the most common symptom

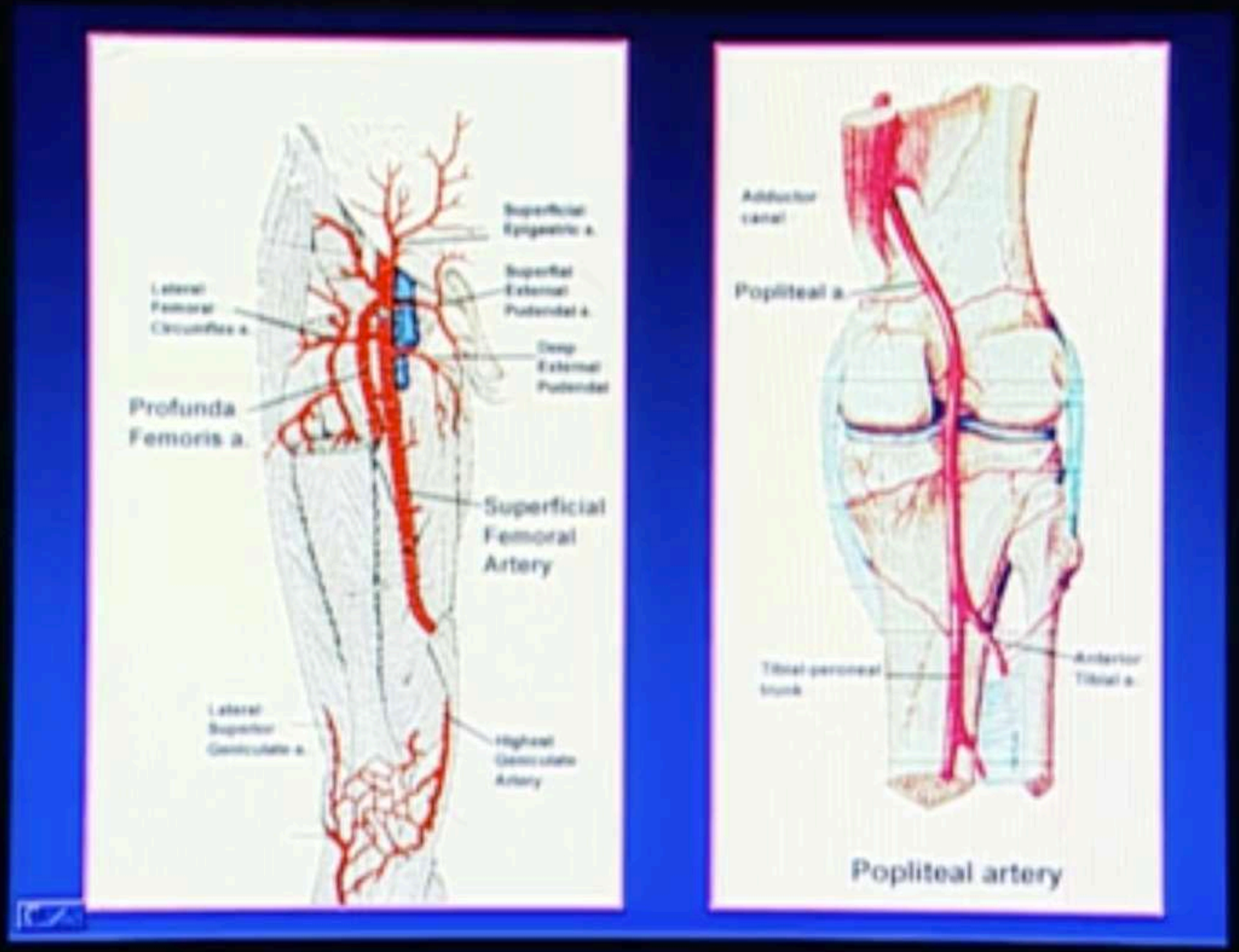
Atherosclerosis

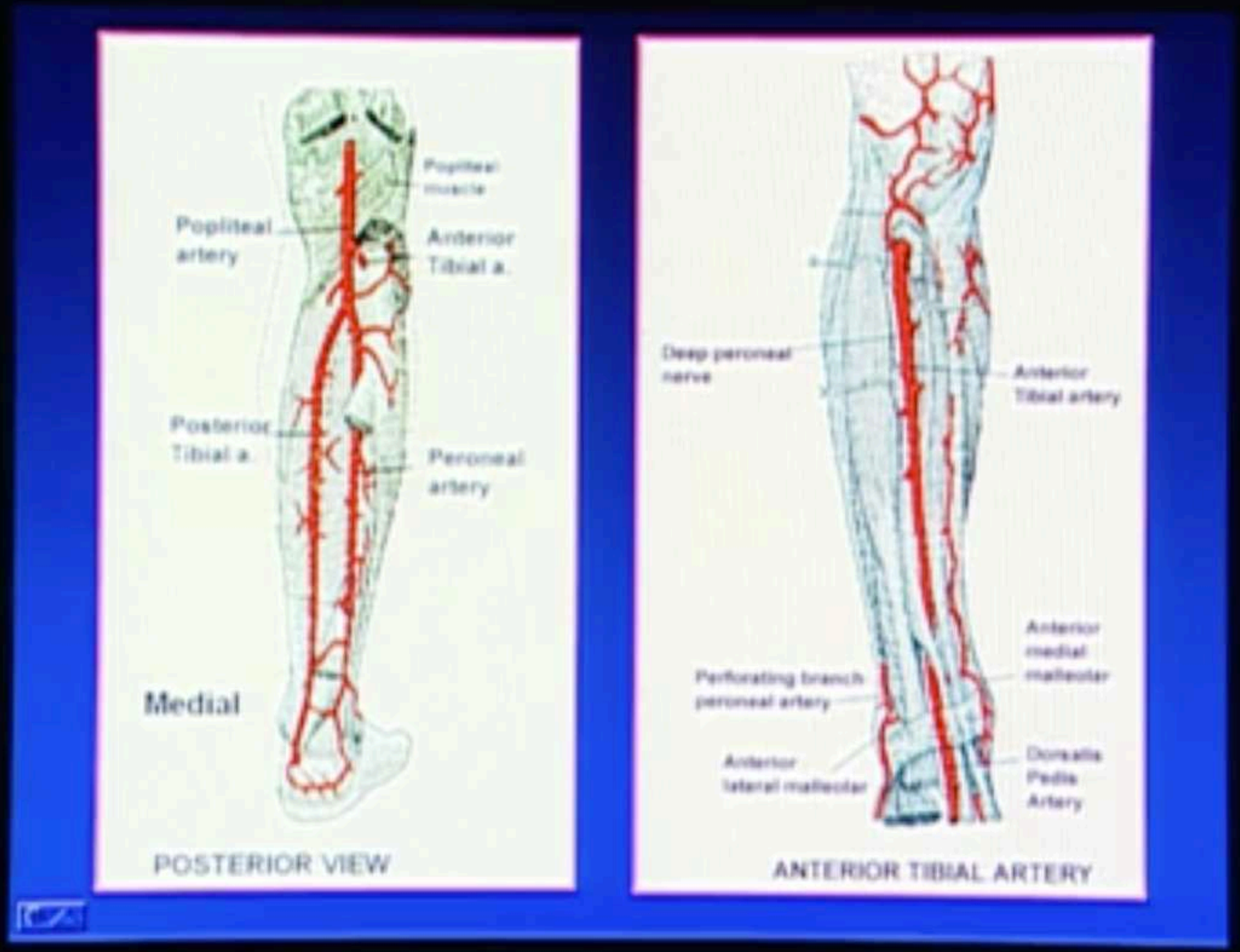
- Atherosclerosis is a systemic disease process
- Patients with symptomatic PAD will likely have disease elsewhere
- Survival is significantly less than other age matched control groups
- Predicted mortality for patients with symptomatic PAD are approximately:
  - 30% at 5 years
  - 50% at 10 years
  - 70% at 15 years
- Myocardial infarction is the major contributor to outcome

The noninvasive vascular laboratory is well-suited to determine the presence and severity of peripheral arterial disease in the lower extremities as well as functional impairment

Lower Extremity Arterial Anatomy




Profunda
Femoris a.
Superficial
Femoral
Artery
Popliteal a.
Popliteal artery


Popliteal artery
Popliteal muscle
Anterior Tibial a.
Posterior Tibial a.
Peroneal artery
Medial
POSTERIOR VIEW
Deep peroneal nerve
Anterior Tibial artery
Anterior medial malleolar
Perforating branch peroneal artery
Anterior lateral malleolar
Dorsalis Pedis Artery
ANTERIOR TIBIAL ARTERY

Assessing the Patient

Why YOU need to perform a history and physical exam!

- Order reads "Doppler of the legs"
- Indication – "Leg pain"
- Is a "clinician" available?
- What is causing the patient's symptoms?

Care for the patient!

Peripheral Arterial Disease Questionnaire –

Patient Name: _____ Date of Birth:_____/_____/_____ Age _____ Today's Date:_____/_____/_____

Have you ever had the blood pressure tested in your ankle before? No Yes Approximately when _____/_____
(This is called an Ankle Brachial Index – ABI) month/ year

(Please complete and discuss with the Doctor, Physician Assistant, or Nurse Practitioner)

What is your present age range?	49 or less **0**	50-64 **5**	65 or older **10**
1. Do you currently smoke or have you quit smoking in the past?	Never **0**	Quit at age _____ **5**	Yes Current **10**
Please answer and circle Yes or No to the following questions			
2. Do you have diabetes?	No **0**		Yes **10**
3. Do you have high blood pressure or take medication for your blood pressure?	No **0**		Yes **3**
4. Do you have high cholesterol or are you taking cholesterol medication?	No **0**		Yes **3**
5. Have you ever had a __heart attack or a __stroke?	No **0**		Yes **5**
6. Have you ever had surgery, angioplasty, or stenting on an artery of the __neck, __abdomen (aorta), __kidney, __heart or __leg?	No **0**		Yes **5**
7. When walking, do your legs ache, feel fatigued, tingle, cramp up, feel heavy or painful? ___#	No **0**		Yes **5**
8. Do you experience any pain at rest in your lower __leg(s) or __feet? ___^	No **0**		Yes **1**
9. Do you experience foot or toe pain that often disturbs your sleep? ___^	No **0**		Yes **1**
Add up the points from each circled answer in the second and third column	___ **0** ___	_____	_____
Total Score: Add up the total for the second and third columns		_____	

Scoring:

0 – 9	Unlikely problems with peripheral arterial disease
10 – 15	Questionable: Your physician can help determine if this may be of concern
15 or more	Likely benefit from a painless, non-invasive test for peripheral arterial disease

10. Do you have chronic kidney disease (CKD)? No Yes
11. Do you have end stage renal disease (ESRD) or on Dialysis? No Yes

The American Diabetes Association (ADA), Kidney Disease Improving Global Outcomes (KDIGO), American Heart Association (AHA), American College of Cardiology (ACC), and American College of Physicians (ACP) recommend PAD evaluations.
If you score 15 or more on the questions above you should consider having a test for circulation in your legs known as the Ankle Brachial Index – ABI.

Patient Signature _____ Reviewed by Doctor / PA / NP _____

PLEASE TAKE EXTRA QUESTIONNAIRES HOME TO SHARE WITH FAMILY AND FRIENDS

ADULT GENERAL/PAD EXAM

DATE:_____/_____/_____

Chief complaint:_____

_____

_____PAD RISK SCORE:_____

RISK FACTORS FOR PAD

_____ Diabetes (___Good ___ Fair ___ Poor control) _____
_____ Smoking Hgb A1C
_____Quit _____Still Smoking
_____ High Blood Pressure
_____ High Cholesterol
_____ History of Heart Attack
_____ History of a Stroke

SYMPTOMS OF PAD

_____ Numbness _____Hands _____Feet
_____ Loss of Hair on legs _____ Cold Feet
_____ Leg Cramps when walking or at rest
_____ Leg Pain that goes away with rest
_____ Pain in legs when legs are elevated
_____ Wound / Ulcer on Leg, foot or toes
_____ Swelling of legs and/or feet

ROS

CONST.
Fever
Subjective / to _____F
Chills_____

ENT
Sore throat_____
Nasal drainage / congestion

CHEST / CVS
Cough_____
Trouble breathing
Chest pain

GI
Abdominal pain
Nausea / vomiting
Diarrhea
URINARY
Problems urinating
Frequent urination

SKIN / Musculoskeletal
skin rash _____
back pain_____
Leg pain_____
foot swelling_____
NEURO/EYES
headache_____
blackout_____
lost feeling / power
in arm leg face R / L
difficulty walking
difficulty with speech
double vision
confusion
_____
_____
#† all systems neg. except as marked

PAST HISTORY___negative
Neurological problems_____
CVA seizure
_____
Cardiac disease_____
Heart attack (MI) angina
Heart failure CABG
_____
High blood pressure_____
_____

Lung disease
asthma emphysema
_____
Diabetes_____
Insulin-dependent diet-controlled
Oral medication Hypoglycemia
_____
High cholesterol_____
_____

Other problems_____
_____

Medications____none____listed in chart
___ASA___Plavix
Allergies____NKDA
___listed in chart

Social Hx ___Smoker ___Quit ___Still smoking

Family HX Mother___L___D (DM/CVA/HTN/MI) Father___L___D (DM/CVA/HTN/MI)
_____Brother___L___D (DM/CVA/HTN/MI) _____Sister___L___D (DM/CVA/HTN/MI)

BP Lt. _____/_____ Rt. _____/_____ HR _____ RR _____

PHYSICAL EXAM _____Alert / General Appearance _____NAD

NECK
____nml inspection
____no carotid bruit
____thyroid nml
thyromegaly_____
lymphadenopathy (R / L)_____
carotid bruit ____Rt ____Lt
_____

RESPIRATORY
____no resp. distress
____breath sounds nml
____chest non-tender
wheezing_____
rales_____
ronchi_____

CVS
____regular rate, rhythm
____no murmur
____no gallop
irregularly irregular rhythm_____
extrasystoles (occasional / frequent)
Murmur grade _____ / 6 sys / dias
gallop (S3 / S4) ____friction rub
tachycardia / bradycardia_____
JVD present_____

Pulses (0-4) Right ____carotid____fem____pop____PT____DP
Left ____carotid____fem____pop____PT____DP

ABDOMEN
____non-tender
____no organomegaly
____nml bowel sounds
____no aortic bruit
____no pulsatile mass
tenderness_____
guarding_____
rebound_____
abnormal bowel sounds_____
increased / decreased / absent
aortic bruit_____
prominent aortic pulsations_____
hepatomegaly / spleenomegaly / mass

SKIN
____color nml, no rash
____warm
____no nail thickening
cyanosis / pallor / rubor_____
skin rash_____
cool_____
trophic nails_____

EXTREMITIES
____non-tender
____no pedal edema
pedal edema_____
tenderness post exercise_____/10
_____

NEURO / PSYCH
____oriented x 3
____mood / affect nml
____CNs nml as tested
____no motor sensory deficit
disoriented to: person / place / time
depressed affect_____
facial droop / EOM palsy / anisocoria
weakness / sensory loss_____
abnormal diabetic monofilament foot exsam
(see diagram below)

Repeat PAD evaluation _____Months _____Year(s)

*_____/_____/_____
PA / NP SIGNATURE **DATE**

*_____/_____/_____
PHYSICIAN SIGNATURE / REVIEW **DATE**

If you want to be recognized as a professional, then you must perform as one!

The Scope of Practice for Diagnostic Ultrasound

Scope of Practice

- Perform patient assessments
- Acquire and analyze data obtained using ultrasound and related diagnostic technologies
- Provide a summary of findings to the physician to aid in patient diagnosis and management
- Use independent judgment and systematic problem solving methods to produce high quality diagnostic information and optimize patient care.

Requirements

At present, there is no licensure requirement to perform these examinations. However, in most states, in order to submit a claim for reimbursement under the Medicare system, the person performing the examination is required to be credentialed in Vascular Technology or practice in an accredited facility.

FOR EXAMPLE:

Credentialing organizations

- ARDMS RVT
- CCI RVS

Accreditation organizations

- ICAVL
- ACR

PATIENT COMMUNICATION

- Introduce yourself
- Explain the procedure to the patient
- Assess patient understanding of each aspect of the procedure(s)
- Address any questions and concerns about any aspect of the evaluation.
- Take the opportunity to provide patient education about risk factors for and symptoms of peripheral arterial disease
- Refer specific diagnostic, treatment or prognosis questions to the patient's physician.

Patient communication

- Allow the patient to talk – "Why are you here?"
- Then ask more specific questions
- Vascular operations ? (operation notes)
- Observation to determine patient ability to understand and tolerate the procedure
- Prepare to "customize" the exam if deemed necessary

Risk Factors for PAD

What to ask and record

- Family history of CAD, PAD, CVA?
- Personal history of CAD, MI?
- Known arterial disease
- Stroke?
- Diabetes?
- Hypertension?
- Hyperlipidemia
- Tobacco abuse?
- Medication list – important!

Mild Disease

- Probably asymptomatic
- Normal / slightly decreased pulses
- ? Bruit
- Decrease in ankle pressure with exercise may be experienced

Moderate disease

- Asymptomatic at rest
- Leg pain with exercise (claudication)

Claudication

"to limp"

- Progressive muscle pain with exertion
- Typically the calf, but may be thigh, or buttock
- Location dependent upon the site of the lesion (s)
- Not typically joint pain
- Relieved by rest
- Consistent onset and severity

Medical Rule

There will always be a pressure drop when a person experiences the pain of true VASCULOGENIC claudication!

Severe Disease

- Ischemic rest pain
- Ulceration
- Tissue necrosis
- Gangrene

Patient History

Symptoms

- Claudication
  - where does it hurt?
  - when does it hurt?
  - walking distance (feet, blocks, miles)?
  - initial onset of SX?
  - progressive SX?
  - "Do you have good days and bad days?"

Physical Exam

- Inspect
- Auscultate
- Palpate

Physical Exam

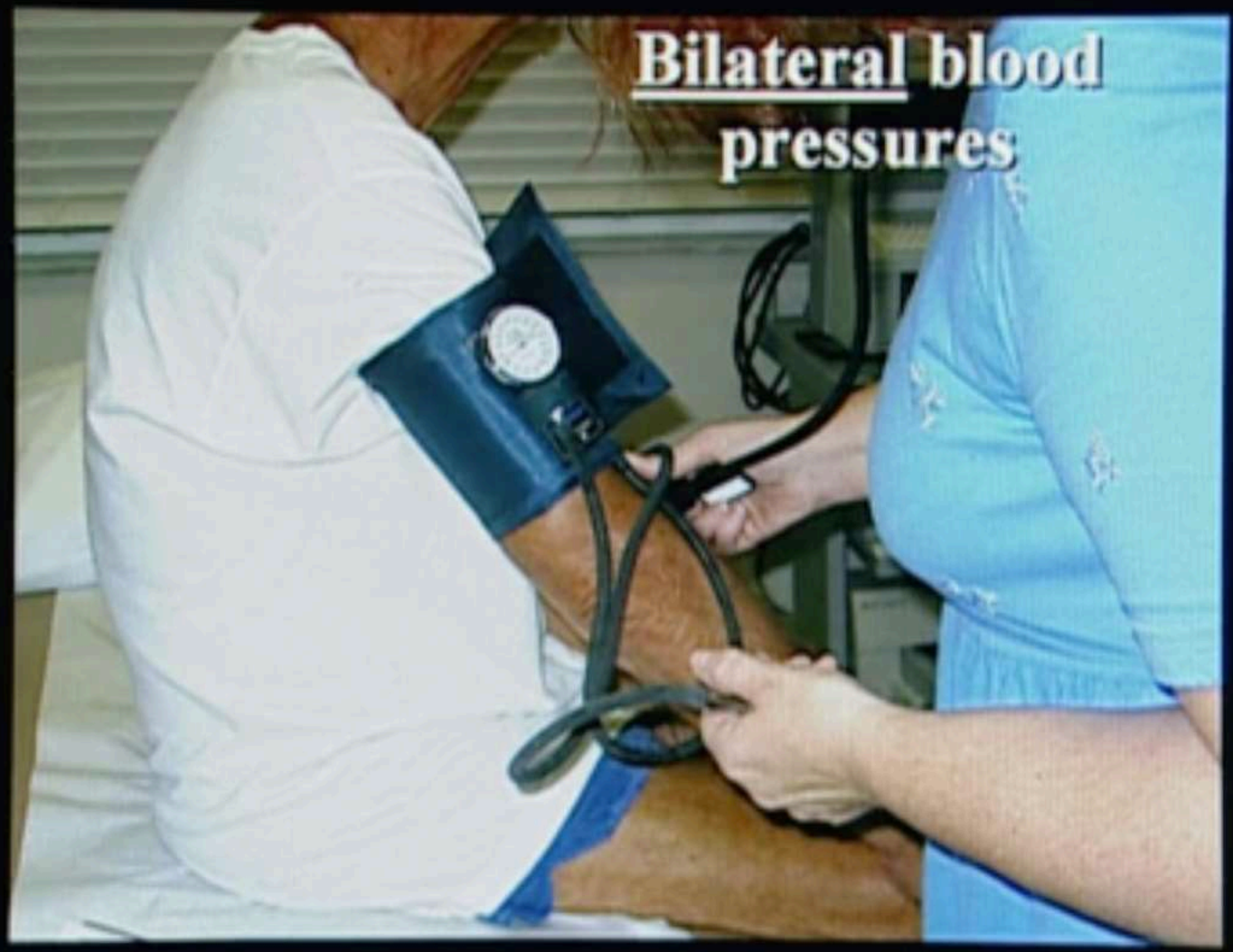
- Inspect
- Auscultate
- Palpate

Look! Listen! Feel!

Physical Exam

What to look for & palpate

- Hair
- Toe nails
- Dependent rubor
- Ulceration, tissue necrosis, gangrene
- Blue toe - trash foot (history)
- Capillary refill times
- Cold foot
- Bruits (abdominal, femoral, carotid)
- Reduced pulses
  - CFA, POP, PTA, DPA
  - Rating 0-3


Bilateral blood pressures

Arterial Pathology

- Atherosclerosis (ASO)
- Thrombosis
  - preceded by ASO
  - sudden onset or increase in symptoms


Notice :
•No Hair on feet or toes
•Thickened toe nails
•Rubor


Popliteal palpation


Anterior tibial / Dorsalis pedis
palpation


Posterior tibial palpation


Checking
capillary refill

Arterial Pathology

- Thrombo-emboli

The 5 P's ??

- Pain
- Pallor
- Pulselessness
- Parasthesia
- Paralysis
- Poikilothermia

Questions to ask the patient with a leg ulcer

- What started the ulcer?
- How quickly did the ulcer develop?
- What did the ulcer first look like?
- What is the family history?
- How painful is the ulcer?
- What drugs has the patient taken?
- Is there a history of other systemic disorders?

Other Arterial Pathology

- Buerger's disease – small vessel thrombosis
- Raynaud's syndrome -small vessel vasospasm
- Arterial –venous fistulas (AVF)
- Arteritis -
- Popliteal entrapment
  - extrinsic compression of popliteal a. in young athletes

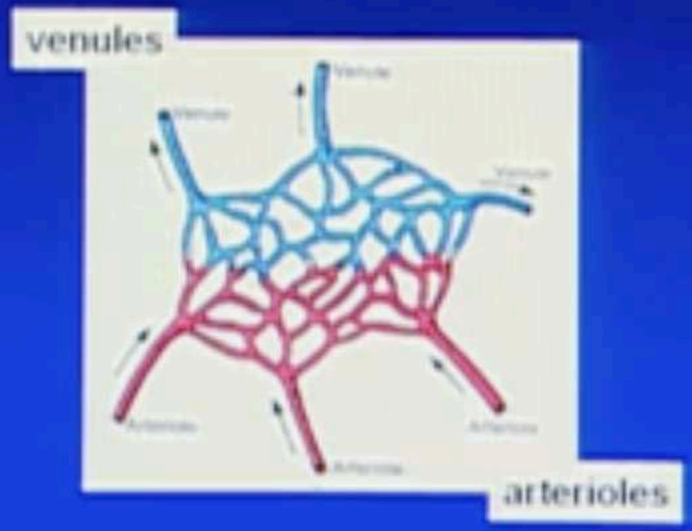
The importance of a careful history and physical examination CANNOT be overstated!

By both the ordering physician and the vascular technologist!

Basis of Physiologic Testing

Peripheral Arterial Flow

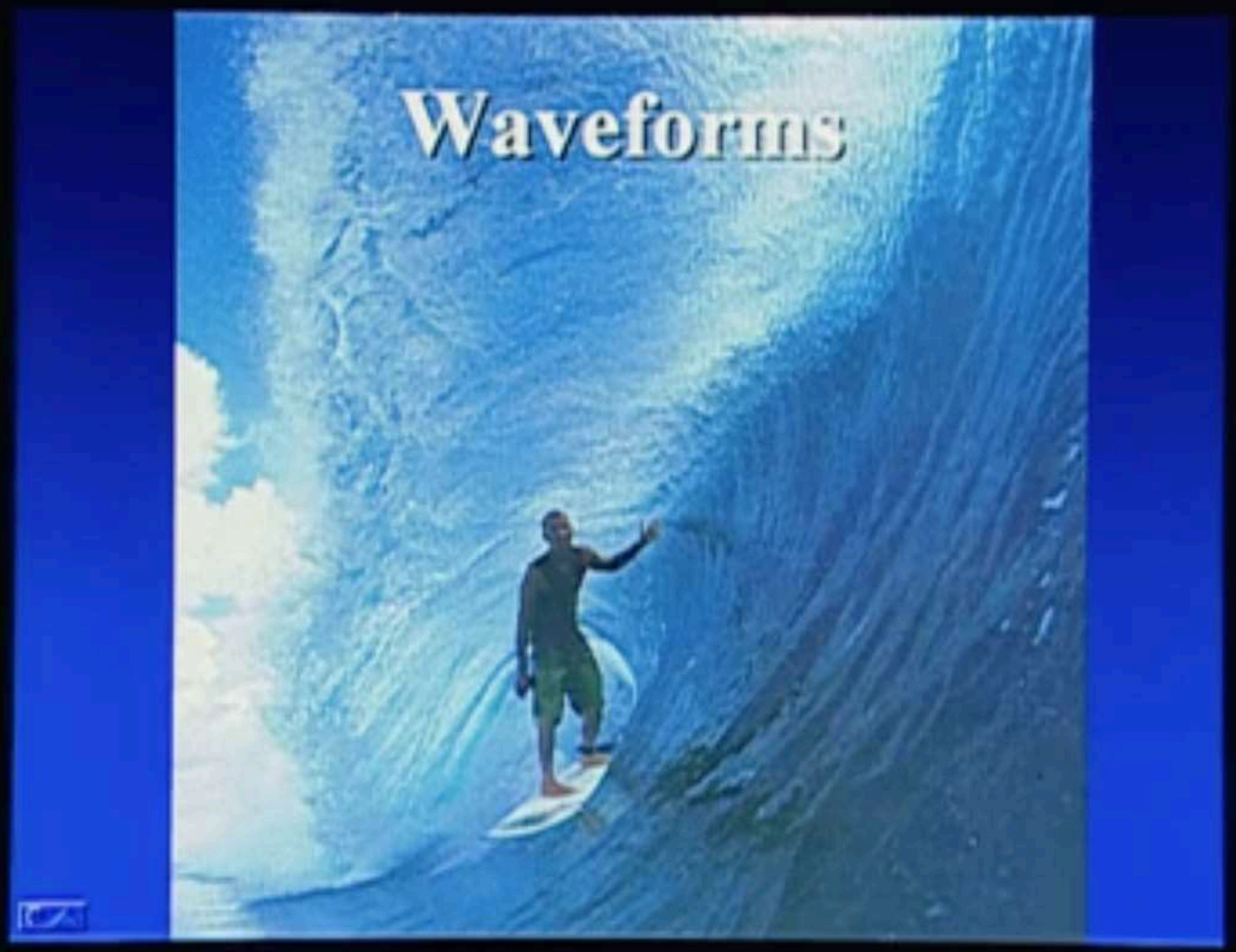
Flow in peripheral arteries is largely regulated by vasoconstriction or dilation in the arterioles.



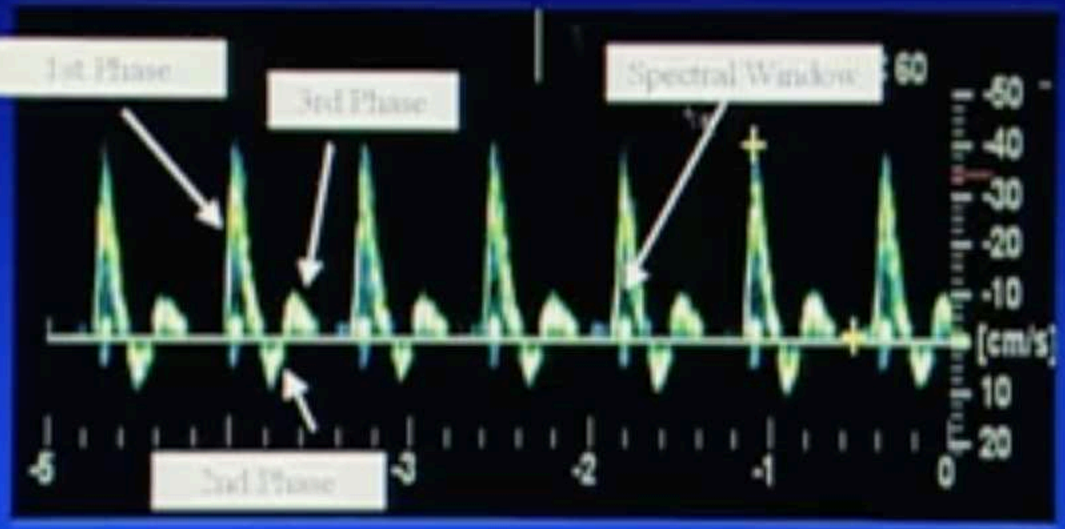
Arterioles and flow

Vasoconstriction
at rest

Vasodilatation
with exercise

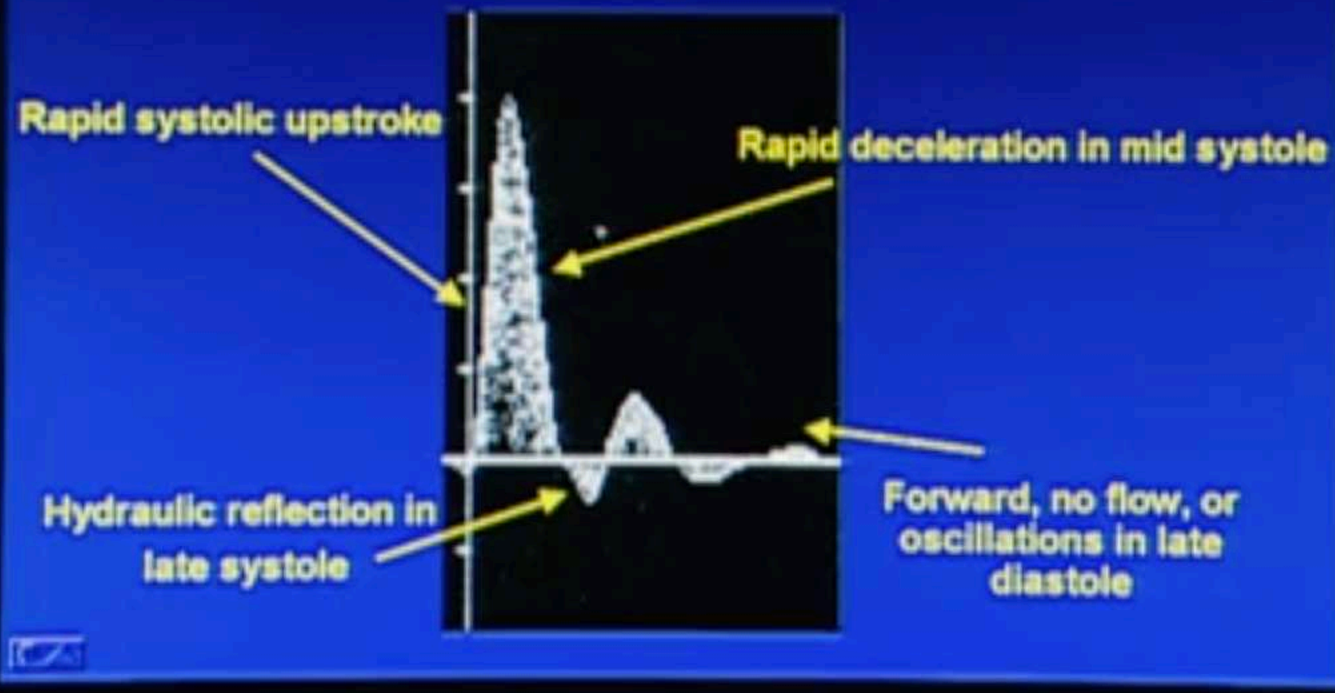

Waveforms

Normal triphasic waveform



Normal Lower Extremity Artery Flow

High resistance, Bi- or Tri-phasic waveform



Stenosis

$$Q = V \times A$$

Flow = Velocity x Area

Uniform flow

Flow is redirected and accelerates

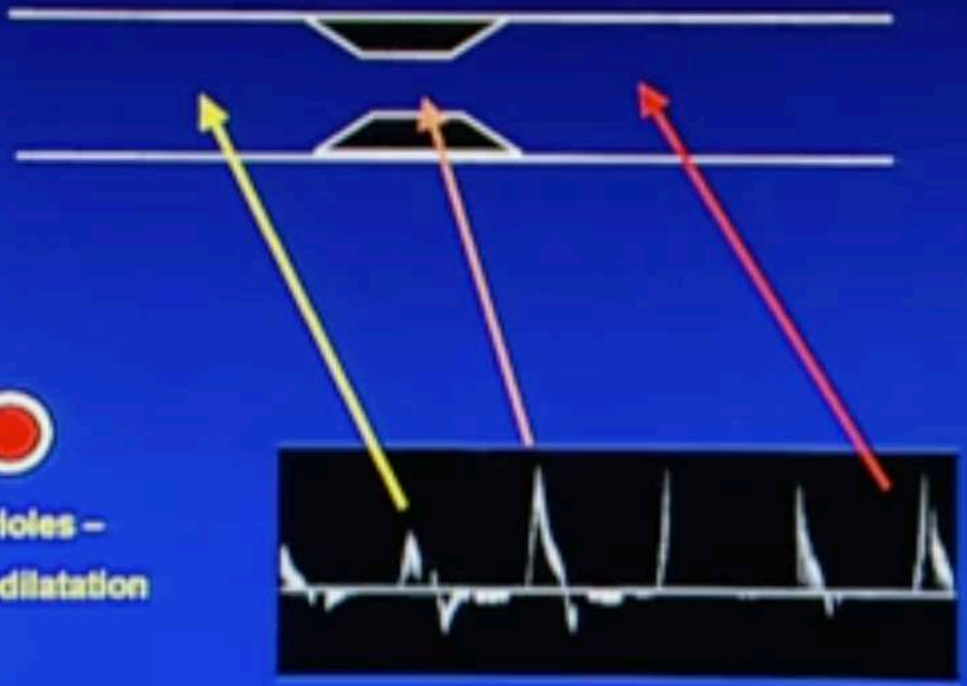
Turbulent flow

When area ↓, velocity ↑

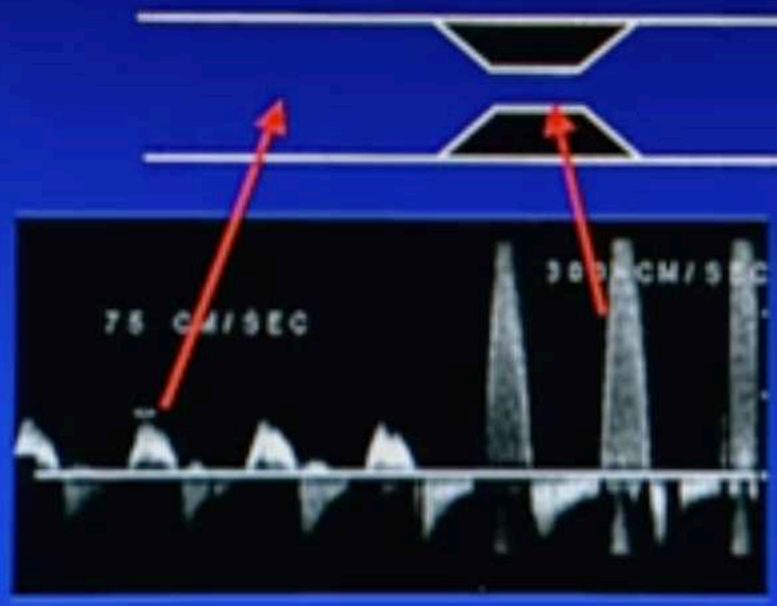
60% or greater diameter stenosis is "hemodynamically significant"

Variables:
- Peripheral resistance
- Flow volume
- Length of stenosis
- Geometry of the lesion

Borderline "hemodynamically significant"



"Hemodynamically Significant" (greater than 60%)

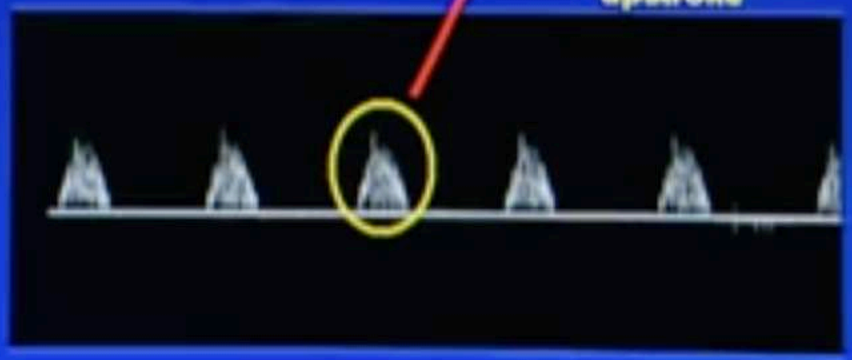


Arterioles –
no vasodilatation
AT REST

"Hemodynamically Significant" (greater than 60%)

Arterioles –
no vasodilatation
AT REST

Note systolic upstroke



Severe Disease

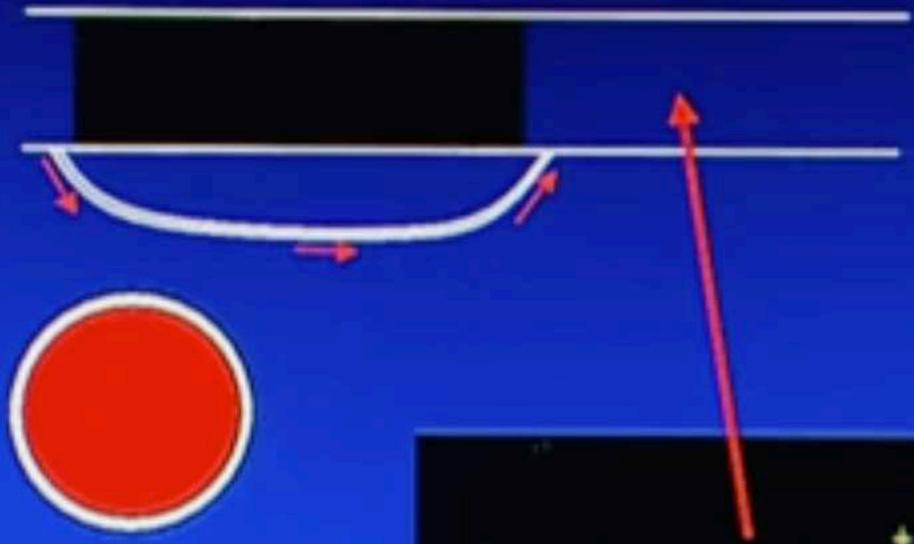
distal to occlusion

Arterioles -
Vasodilatation

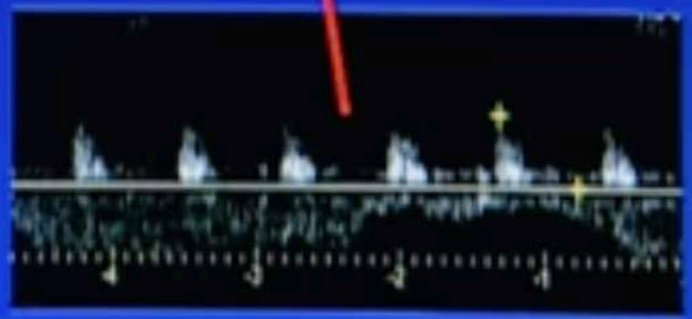
Note dampened
systolic upstroke

Very Severe Disease

poorly collateralized occlusion



Arterioles - Vasodilatation
BUT insufficient diastolic
pressure to maintain flow



Physiologic Testing

Physiologic Testing
Perspectives

- Well documented
- Reproducible
- Short learning curve
- Lower equipment cost
- Quick to interpret

Noninvasive Vascular Laboratory

Segmental Pressures and Pulse Volume Recordings

Right Brachial 150

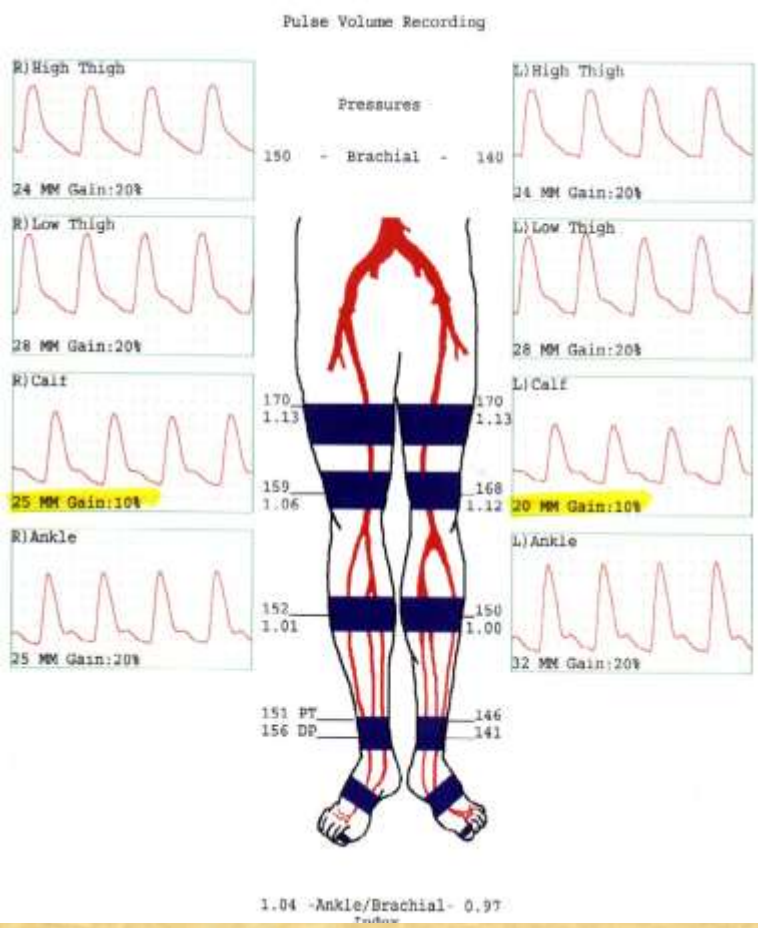
Right Thigh 170

Right Calf 152

Right DP 151

Right PT 156

Right ABI 1.04



Left Brachial 140

Right Thigh 170

Right Calf 150

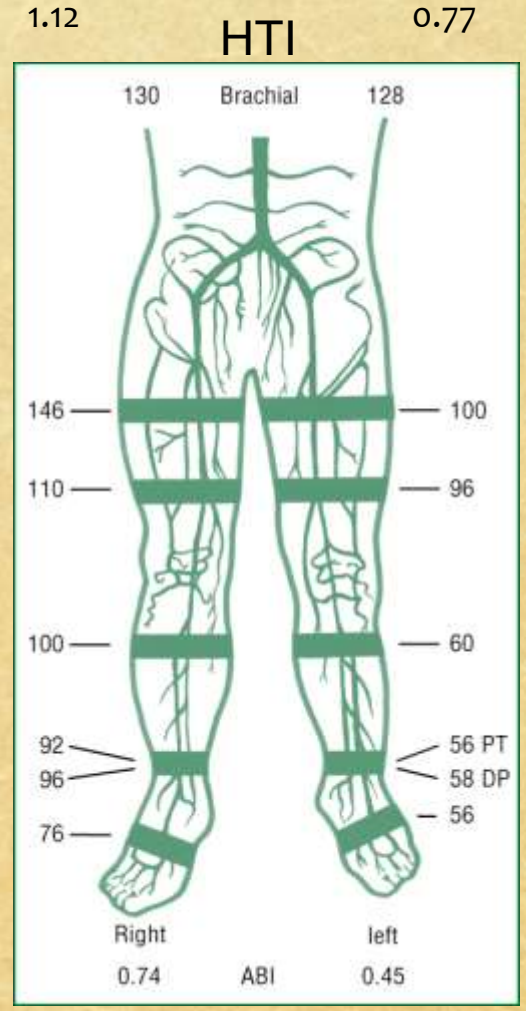
Left DP 146

Left PT 141

Left ABI 0.97

Criteria for Interpretation of Segmental Pressures

- Aortoiliac disease- High thigh/brachial index (HTI) <1.2 bilaterally
- Iliac disease- High thigh/brachial index <1.2 unilaterally
- SFA disease- Pressure gradient (>20 mmHg) between high and low thigh cuffs
- Distal SFA/popliteal- Pressure gradient (>20 mmHg) between wide thigh or distal thigh cuff and calf cuff
- Infrapopliteal- Pressure gradient (>20 mmHg) between calf and ankle cuffs



Physiologic Testing
Perspectives

- Presence of disease
- Severity of disease
- FUNCTIONAL IMPAIRMENT
  - what is causing the symptoms?
- Very useful in diabetics
- Medial calcinosis
- Digit measurements
- Healing potential

Physiologic Tests

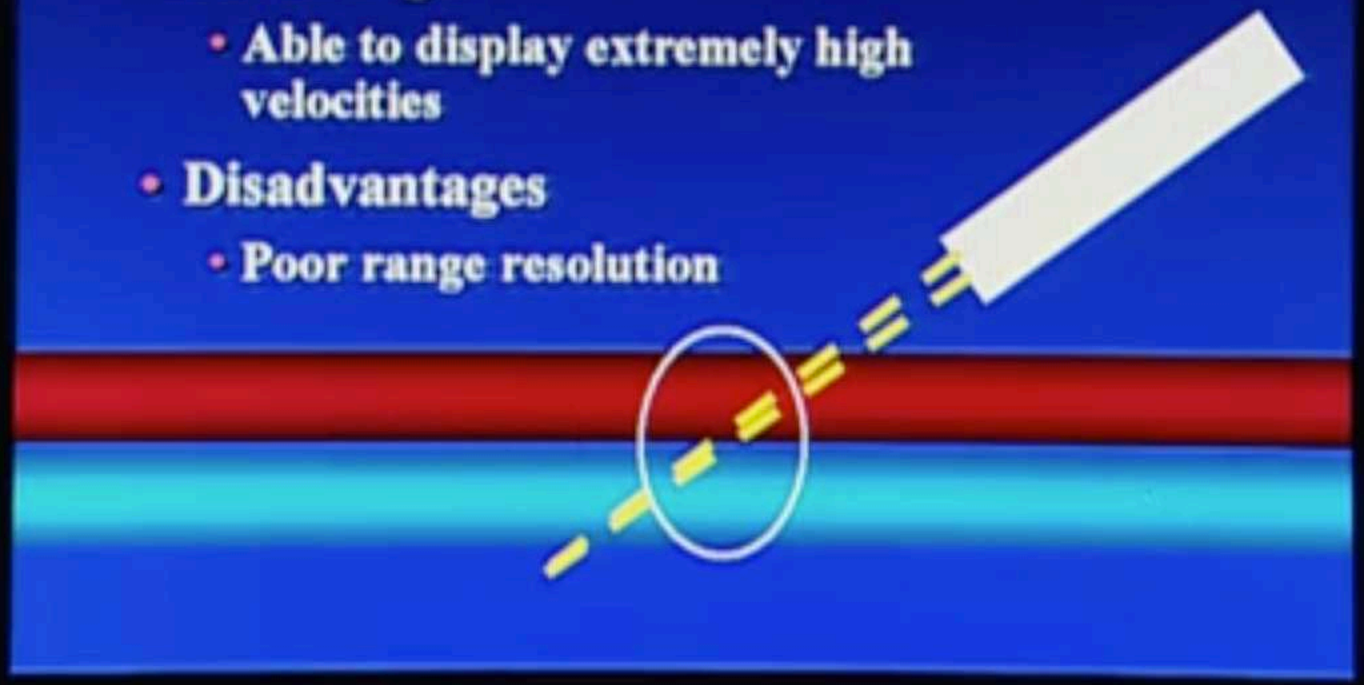
- Doppler waveform analysis
- Plethysmography
  - Pulse volume recording (PVR)
  - Photoplethysmography (PPG)
- Pressure assessment
  - ABI and/or segmental pressures
- Exercise testing

Single Level or Multiple Levels

- Single - generally the ankle
  - A quick method to determine presence and relative severity of disease
- Multiple – two or more levels
  - Can determine presence and severity of disease
  - Region of disease

Continuous Wave (CW) Doppler Analysis

- Advantages
  - Able to display extremely high velocities
- Disadvantages
  - Poor range resolution



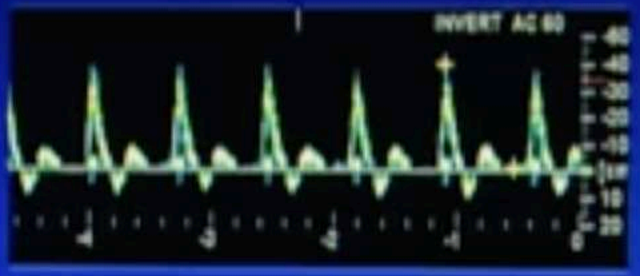
Doppler Waveform Analysis: Technique

- Patient resting in basal state
- Warm room
- 4 - 8 MHz CW Doppler
- 45 - 60 degree angle of insonation
- obtain waveforms from CFA, SFA, Popliteal, DPA, PTA

Doppler Waveform Analysis

Normal - Tri- or Bi-phasic

- Rapid systolic upstroke
- Late systolic flow reversal



Abnormal – mono phasic

- loss of triphasic waveform
- decrease in amplitude
- dampened upstroke

Proximal Occlusion

1. ANKLE BRACHIAL INDEX (ABI) (Cont.)

Take the systolic pressure at the ankle

1. Place a blood pressure cuff snugly above the ankle and connect a sphyg to the cuff.
2. Place ultrasound gel on the skin and apply the Doppler probe to the artery.

   [Pencil Style Probe]
   If using the pencil style probe, hold the probe on the posterior tibial or dorsalis pedis artery at a 45 to 60 degree angle against flow (see figure C). Adjust the probe angle until best sounds are heard and a steady waveform appears on the LCD.

   [Flat Vascular Probe (Model BF8)]
   If using the flat vascular probe, place the probe on the posterior tibial artery, adjust to locate best sounds, and affix in place with the velcro strap provided (see figure D). To produce forward waveforms, make sure the probe cord runs from the probe up the leg toward the groin.
3. Take the systolic pressure by inflating the cuff to 20 mmHg over pressure cessation. Then, slowly deflate the cuff at a rate of 2-3 mmHg per second until the first Doppler sound is heard and waveform motion on the LCD returns.
4. Record the systolic pressure at that point, then repeat the test on the other leg.

Figure C

Figure D

Calculating the ABI

To calculate the Ankle Brachial Index ratio, divide the ankle pressure by the highest arm pressure or refer to the charts on the Pressure Index Guide provided with your Doppler.

$$ABI = \frac{\text{Ankle systolic pressure}}{\text{Arm systolic pressure}}$$

Interpreting the Results

Waveform Examples

Normal

Moderate Obstruction

Severe Obstruction

> 1.40	= Noncompressible
1.00 - 1.40	= Normal
0.91 - 0.99	= Borderline
0.00 - 0.90	= Abnormal

Creager MA, et al. (2011). 2012 ACCF/AHA/ACR/SCAI/SIR/STS/SVM/SVN/SVS Key Data Elements and Definitions for Peripheral Atherosclerotic Vascular Disease: A Report of the American College of Cardiology Foundation/American Heart Association Task Force on Clinical Data Standards (Writing Committee to Develop Clinical Data Standards for Peripheral Atherosclerotic Vascular Disease). Circulation 2012, 125:395-467. Retrieved December 5, 2011 from http://circ.ahajournals.org/content/125/2/395.

ES100V3 Bidop® Testing Instructions

2. SEGMENTAL BLOOD PRESSURES

Segmental pressure studies are performed with the same method as an Ankle Brachial Index, but incorporate additional cuffs wrapped at the high thigh and above and below the knee, in addition to the ankle. Significant pressure differences between adjacent cuff sites indicate narrowing of the artery or blockage in that portion of the leg. Segmental pressures are useful to precisely identify the location of blockages in the arteries of the leg.

PLEASE NOTE: We do not recommend the use of the flat vascular probe (model BF8) when performing Segmental Blood Pressures with the Bidop® 3.

Begin by taking a blood pressure reading at the arm

1. Follow the steps for taking a blood pressure reading at the arm as described in the instructions for performing an Ankle Brachial Index on pages 32-33.

Take the systolic pressures at the leg

1. Place the patient in a supine position. Wrap appropriately sized blood pressure cuffs around each leg at the ankle, above and below the knee, and at the high thigh.
2. Begin by taking the systolic pressure at the ankle. Connect a sphyg to the ankle cuff and apply ultrasound gel to the skin at the posterior tibial or dorsalis pedis artery and apply the Doppler probe at a 45 to 60 degree angle against flow. Adjust the probe angle until best sounds are heard.
3. Inflate the cuff to 20 mmHg over pressure cessation. Then, slowly deflate the cuff at a rate of 2-3 mmHg per second until the first Doppler sound is heard and waveform motion on the LCD returns. Record the systolic pressure.
4. Repeat at the posterior tibial artery for the cuffs below the knee, at the popliteal artery for the cuffs above the knee and at the femoral artery for the cuffs at the thigh.

Interpreting the Results

Observe pressure differences between adjacent cuff sites on the same leg. Pressure differences between cuff sites are used to localize the disease.

Pressure difference between two adjacent levels of less than 20 mmHg is considered normal within limits. [1]

Segmental pressure tests should be combined with treadmill or reactive hyperemia studies to determine pressure recovery times.

PLEASE NOTE:
Lower extremity & ankle systolic pressures may be falsely elevated in patients with calcified/non-compressible arteries (i.e. diabetes mellitus) and should be compared with Doppler waveform analysis.

[1] Weiss RA. Vascular Studies of the Legs for Venous or Arterial Disease. Dermatologic Clinics, Volume 12, Number 1, January 1994

Doppler Waveform Analysis
Limitations

- Poor quality signals
  - limb edema
  - obesity
  - scar tissue
  - occluded artery
  - poor technique
- Venous interference (averaged signal)
- Requires a lot of SKILL

Doppler Waveform
Advantages

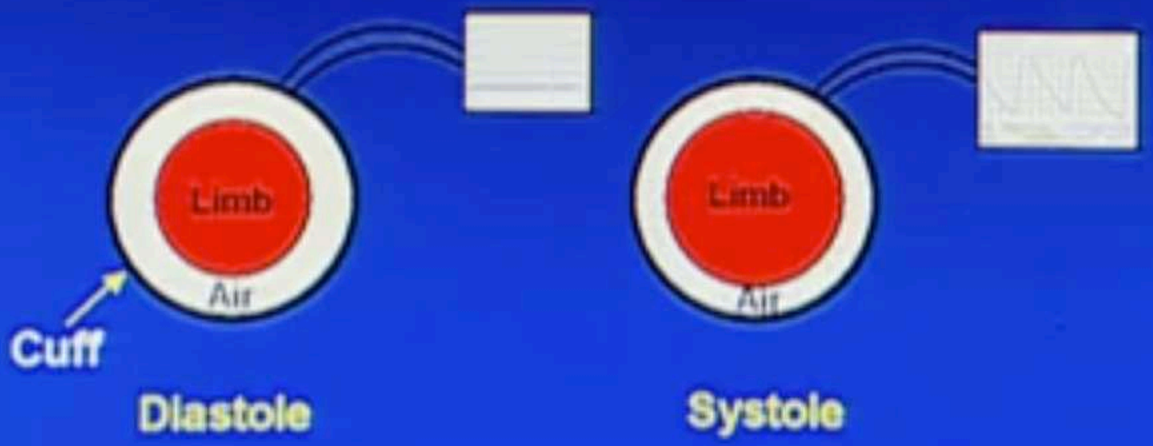
- Provides information about flow in specific arteries
- Demonstrates flow changes caused by disease

Arterial Plethysmography:
The measurement of a volume changes in a limb or organ

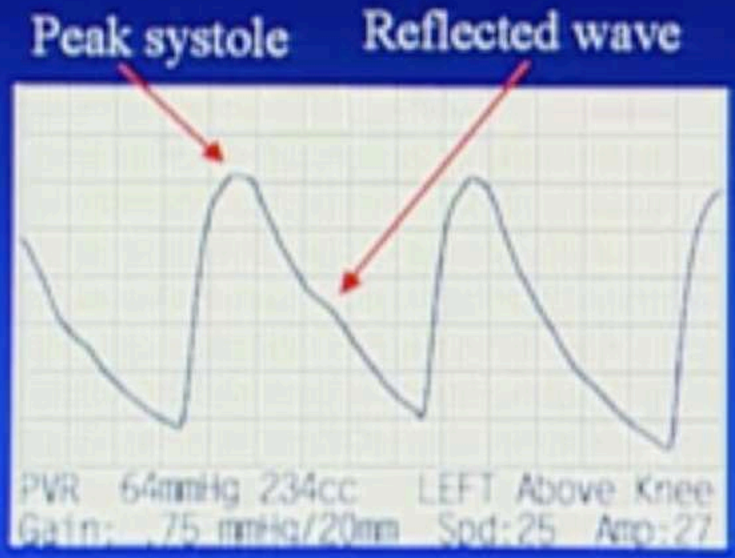
- Pulse volume recording (PVRs)
- Photo-plethysmography (PPG)
  - Assessment of digit perfusion

Pulse Volume Recording (PVR)

- Measures volume changes in limb during systole
- Air is displaced within a cuff
- Volume of displaced air is displayed as waveform



Normal PVR Waveform



Pulse Volume caveats

- Thigh PVR is primarily related to profunda femoris artery perfusion, and to a much lesser extent, the superficial femoral artery
- Calf waveforms reflect blood flow in the SFA-Popliteal segment

PVR advantages

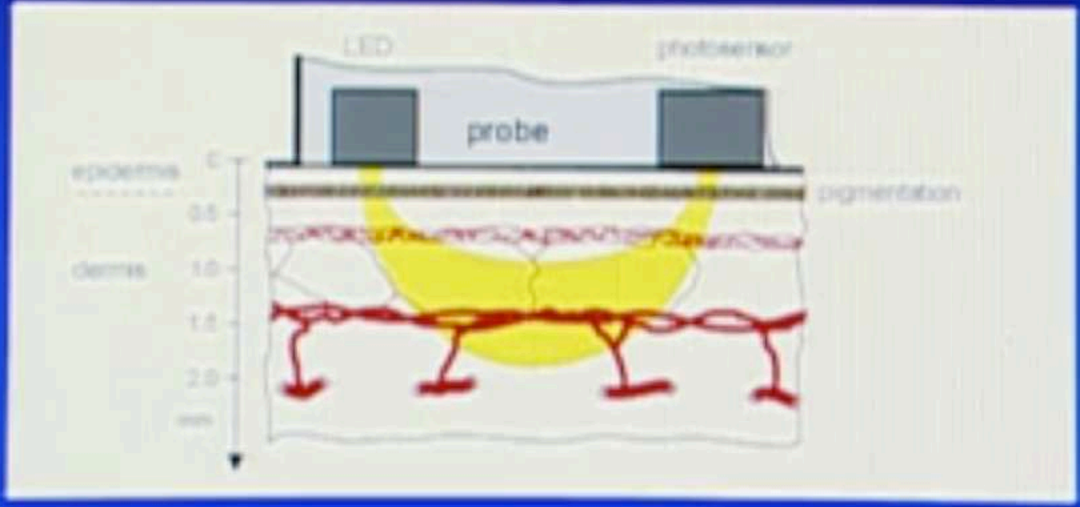
- Relatively easy to learn and perform
- Global perfusion assessment
- Metatarsal and digit information
- Not affected by artery calcification
- Quick to interpret

PVR Limitations

- Subjective - not quantitative
- Disease difficult to discern in presence of proximal occlusion
- Tremor or movement may distort waveforms

Photoplethysmography (PPG) Assessment

- Light transmission into tissue
- Reflection dependent upon absorption which varies with perfusion



Photoplethysmography (PPG)

- Beat-to beat variation of reflected light
- Provides a waveform of digit perfusion

PPG waveforms

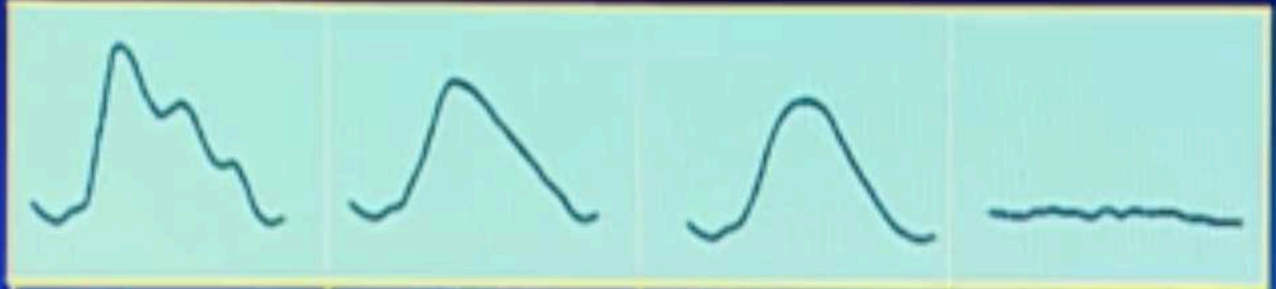
Photoplethysmography (PPG)

- Used to detect return of flow for pressure determination
- Can also provide information about flow state

PPG pressure assessment

- Digits or segmental pressures

Photoplethysmography waveform interpretation



Normal	Mild	Moderate	Severe
Rapid upstroke	Dampened upstroke	Dampened upstroke	Flattened
Reflected wave	Loss of reflected wave	Rounded crest	
		No reflected wave	

Physiologic Tests

- Doppler waveform analysis
- Plethysmography
  - Pulse volume recording (PVR)
  - Photoplethysmography (PPG)
- **Pressure assessment**
  - **ABI and/or segmental pressures**
- Exercise testing

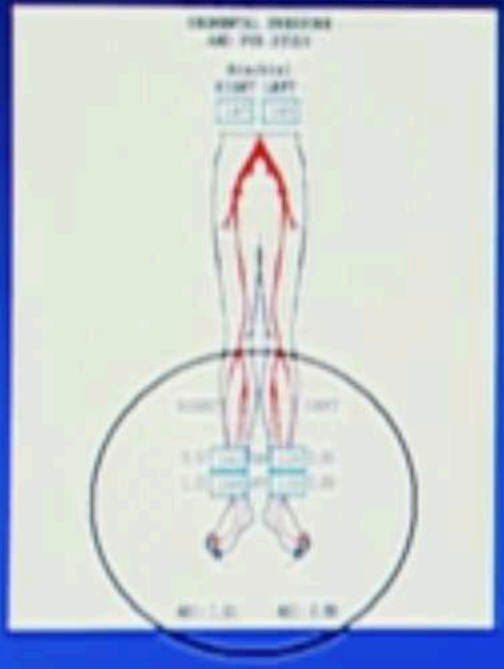
Principles of pressure analysis

- Normal individual in a supine position, ankle systolic pressure is ≥ brachial
- Patient must be in a resting, basal state

Principles of pressure analysis

- Normal individual in a supine position, ankle systolic pressure is ≥ brachial
- Patient must be in a resting, basal state

The Ankle/Brachial Index (ABI)



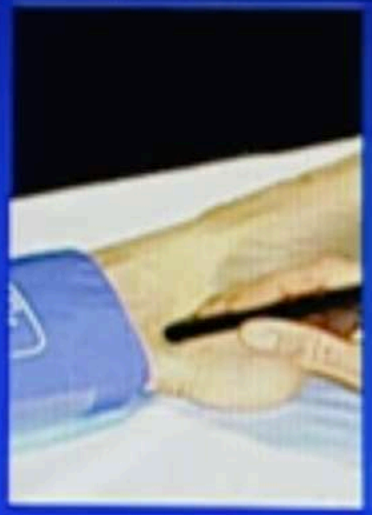
- Ankle pressure divided by the higher brachial pressure
- Report either both or the highest ankle pressure for reported ABI

Dorsalis Pedis

Doppler Sites

for ABI

Posterior Tibial



Resting ABI values

- > 1.0 = normal (usually)
- < 0.96 = abnormal,
  - exercise patient if borderline
- < 0.8 = probable claudication
- < 0.5 = multi-level disease or long segment occlusion
- < 0.3 = ischemic rest pain

Carter SA: Clinical measurement of systolic pressures in limbs with arterial occlusive disease, JAMA 207:1869,1969

ABI values: exception for normals

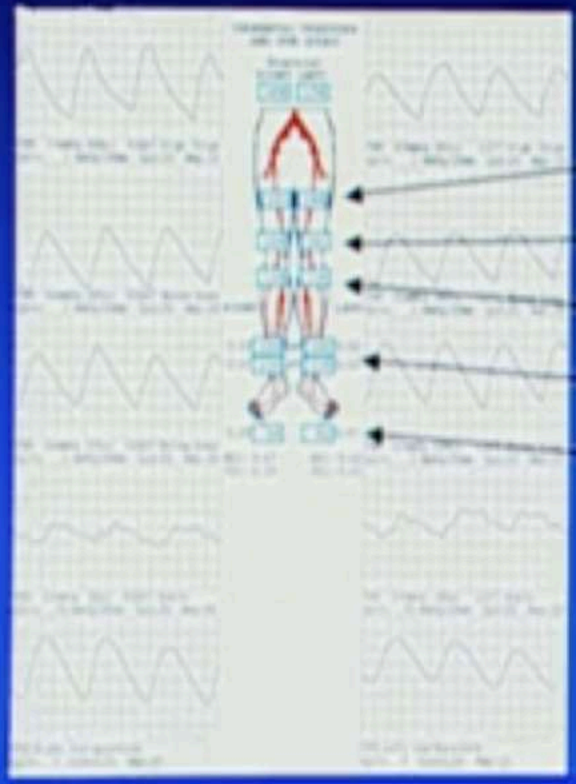
- Brachial systolic pressure below 100 mmHg or above 200 mmHg:
  - ankle pressure may be 25% lower than brachial p

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

Segmental Pressures

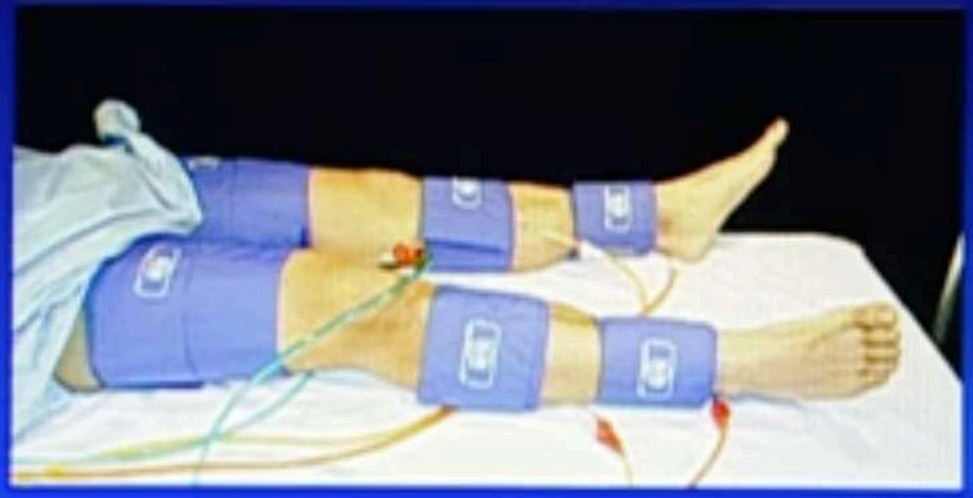
- compare to contralateral limb same level
- compare to adjacent segments
- ≥ 20 mmHg pressure gradient (drop) is significant *if the ABI is abnormal*
- can determine region of disease

Segmental Pressure Sites



- High thigh
- Low thigh (for 4-cuff)
- Upper calf
- Ankle
- Great Toe
- Metatarsals
- All digits

3- cuff method
(17 cm thigh cuff)



If abnormal, cannot differentiate aorta or iliac disease from femoral artery disease

4-cuff method
(12 cm thigh cuffs)

- Upper thigh cuff pressure artifact (≥ 20 mmHg)
- Can often differentiate iliac from femoral disease

Diagnostic ABI Interpretation

- –Normal if 1.00–1.39

- _Equivocal 0.91-0.99*
- –Mild obstruction if 0.70–0.90*
- –Moderate obstruction if 0.40–0.69**
- –Severe obstruction if <0.40***
- –Poorly compressible if ≥1.40#

What does an ABI of 0.90 mean?

- 90/100 = 0.90
- 99/110 = 0.90
- 108/120 = 0.90
- 117/130 = 0.90
- 126/140 = 0.90

If you have a blood pressure in the arm of 140 and the blood pressure in the foot is 126 in a patient with PAD,

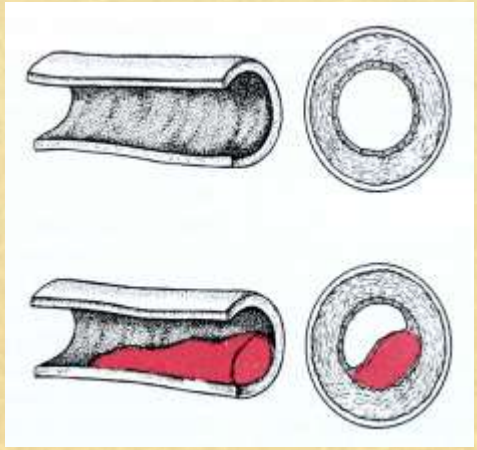
then stop taking blood pressure in the arm and start taking it in the foot.

Because the blood pressure in the foot is controlled!!!!!!

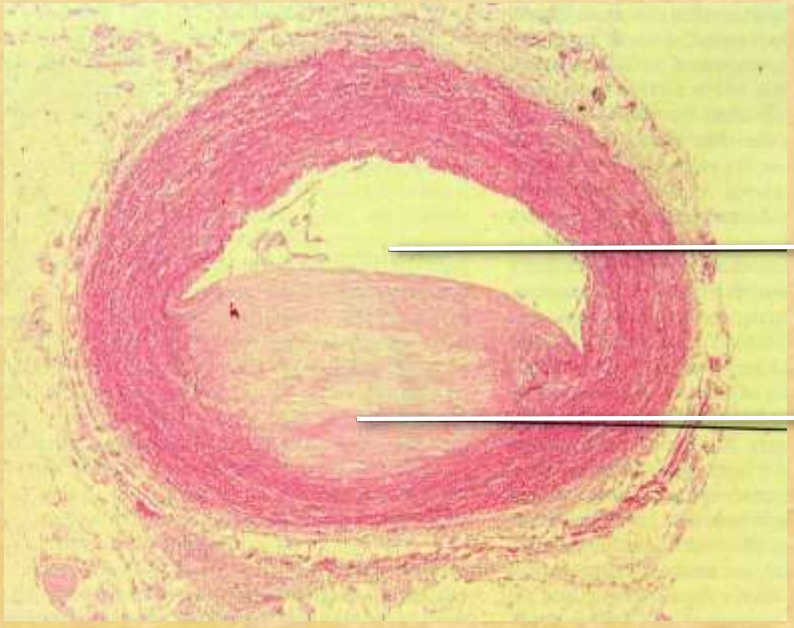
Atherosclerotic Artery

Normal Artery

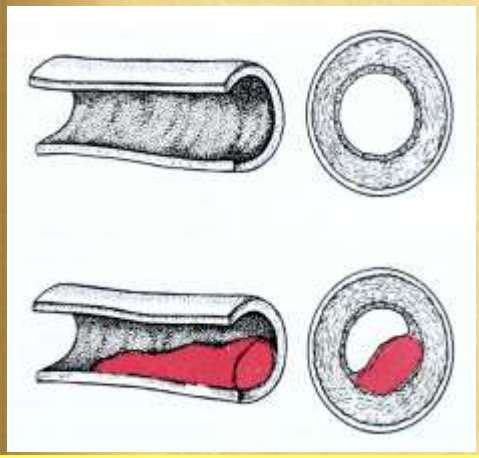
Beginning of Plaque Formation



An ABI of .90 is equal to a 50% Obstructed Arterial Lumen



Clinical Presentation of PAD Patients



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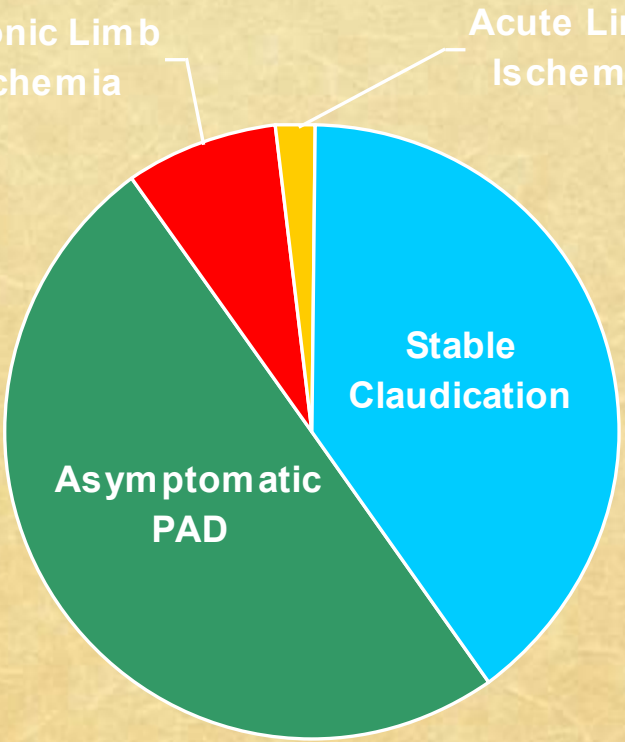

Adapted from Hirsch AT. *Fam Pract Recertification*. 2000;15(suppl):6-12.

Cuff placement

especially for Pulse Volume Waveforms

- Properly sized cuffs
- Evenly spaced
- Uniformly snug
- Tapered legs
- Cuff pressure is ≈ 60 mm/Hg
- Note cuff volume
- ≤15% difference between cuff volumes

Extra time spent in good cuff placement pays dividends in clean artifact free waveforms

Pressure advantages

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

Pressure Limitations

- Calcified arteries
  - diabetics
  - ESRD patients
  - chronic steroid therapy

- Segmental pressures unobtainable or excessively high (ABI > 1.2)

Toe Brachial Index (TBI)

- Normal > 0.75
- Abnormal < 0.66

- <30 mm/Hg – poor healing potential *

*Wutschert R, Bounameaux H, et.al. Predicting healing of arterial leg ulcers by means of segmental systolic pressure measurements. Vasa 1998 Nov;27(4):224-8

Exercise stress testing Purpose:

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

Who should be exercised?

- Intermittent claudicators
- ABI 0.85 - ≈0.5
- If resting study is normal, but patient is symptomatic, exercise
- Borderline normal ABI

Treadmill exercise testing

- Treadmill speed = 1.5 or 2 mph
- 10 percent grade
- 5 minutes = standard walking time or until patient unable to continue
- Post exercise ankle pressures – ASAP and monitor per protocol

PRE-EXERCISE PRESSURE (A) Date of exam ____/____/____

Brachial Pressure	_____		
Posterior Tibial Pressure	_____	RATIO	_____
Dorsalis Pedis Pressure	_____	RATIO	_____

Brachial Pressure	_____		
Posterior Tibial Pressure	_____	RATIO	_____
Dorsalis Pedis Pressure	_____	RATIO	_____

POST-EXERCISE PRESSURE (B) Date of exam ____/____/____

Pressures taken immediately / time	2-6*	6-12**	12-18***	>18***
Brachial Pressure _____	_____	_____	_____	_____
Posterior Tibial Pressure _____	_____	_____	_____	_____
RATIO _____	_____	_____	_____	_____
Dorsalis Pedis Pressure _____	_____	_____	_____	_____
RATIO _____	_____	_____	_____	_____

Take both PT/DP immediately Use lowest pressure at 2 min – 18 min

Pressures taken immediately / time	2-6*	6-12**	12-18***	>18***
Brachial Pressure _____	_____	_____	_____	_____
Posterior Tibial Pressure _____	_____	_____	_____	_____
RATIO _____	_____	_____	_____	_____
Dorsalis Pedis Pressure _____	_____	_____	_____	_____
RATIO _____	_____	_____	_____	_____

Take both PT/DP immediately Use lowest pressure at 2 min – 18 min

2 - 6 min Single level disease* / 6 – 12 min Multiple level disease / > 12-30 min Severe*** occlusive state**
(Any drop in pressure is an indicator of significant disease, and the degree of impairment will be reflected in the time it takes for the pressure to return to normal.)

Contraindications for treadmill exercise

- Questionable cardiac status
- Resting ischemia (ABI < 0.3)
- Ischemic ulceration
- Poor ambulators
- If symptoms occur only at rest and resting study is normal

Vasculogenic Claudication Criteria

- Drop in ankle pressure >20 mm/Hg confirms vascular etiology for claudication
- Larger the drop / longer return to baseline corresponds to lesion severity

Post Occlusive Reactive Hyperemia

- Occlude distal thigh - 3 minutes
- Occlusion pressure = 20 mm/Hg above limb pressure
- Record post occlusion ankle pressure
- Painful exam
- Poor patient acceptance

Toe raises

- Toes raises for 1 minute
- Note patient symptoms
- Post exercise pressures

Ambulation

- Simulates "real world" symptoms
- Observe patient ("neurogenic shuffle")
- Record distance/time and effort
- Post exercise pressures

Physiologic testing limitations

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

Indirect test advantages

- Comparably "easy" to perform
- Technically reproducible
- Quantifiable data on the "effect of disease"
- Extensively validated

Physiologic Testing
Conclusions

- Cost effective, efficient method to assess lower extremity arterial system
- Determine presence of PAD
- Determines severity of disease
- Determines whether patient's symptoms are due to arterial disease or other cause