The Ever Changing Role of Diagnostic Testing

- Donna M Mendes MD, FACS
Learning objectives

- Understand the reliability and cost effectiveness of:
  - History and physical exam
  - Non-invasive physiologic testing
  - Ultrasound for venous and arterial imaging
  - Contrast utilizing imaging

- When to use:
  - Non-invasive physiologic testing
  - Venous imaging tests
  - Arterial imaging test
  - Lymphatic imaging studies

- Understand the difference between functional testing and imaging

- Understand the role for emerging technologies
The History
The Physical Exam

Initial assessment

- A time to develop mutual trust between you and the person “signing out” to you
- Tailor to flow to the presenting problem, but should be comprehensive enough to understand the complete picture of the patient
- Remember test results (pulse exam) must be correlated with clinical impression
- If there is a discrepancy between the clinical impression and the findings the provider must develop a workable explanation
General Vascular History

- Previous heart attack, angina, coronary intervention
- Previous arterial vascular surgery
- Medication – reconciliation
- Leg swelling, history of DVT, history of venous surgery
The History

Venous History
- How long have the varicose veins been present
- How long has there been swelling
- How long has an ulcer been present
The History

- Arterial history – typical features
  - Pain brought on by exercise, relieved by rest (claudication)
    - Most commonly in the calf
    - *Nocturnal cramps have no known vascular basis
  - Pain in the forefoot at nighttime (rest pain)
  - In the diabetic patient a complete lack of pain is normal
  - *Pain that is intermittently present in the foot or leg and occurs with exercise, BUT is also present at rest is not related to arterial disease
  - Other differentials include: Osteoarthritis, Neurospinal compression, chronic compartment syndrome
The History

- Lymphatic
  - The duration of swelling of the leg
  - When was the onset of symptoms
  - Previous malignancy, previous surgery, previous radiotherapy
CAROTID DUPLEX ULTRASOUND OR CAROTID DOPPLER
Carotid duplex study - extracranial

- **Indications**
  - TIA - transient ischemic attack
  - CVA – cerebrovascular accident
  - Bruit

- **Symptoms**
  - Amourosis Fugax
  - Numbness/Weakness (unilateral)
  - Speech difficulty
  - Dizziness

- **Used as a frontline or screening test**
  - No prep for test and no harm to patient
  - Internal carotid artery supplies 80% of the blood to the brain
  - Vertebral arteries are the other 20%

- **Diagnostic criteria**
  - Laboratory variability
  - Incidence of CVA in the next year with intervention vs. conservative treatment
Transcranial Doppler (TCD)
Intracranial circulation

- This test is a Doppler only
  - Recent advances have added M-mode doppler which increases the accuracy of the test and B-mode imaging with Color doppler: although imaging is not widely used and has serious limitations.

- Indications
  - CVA
  - TIA
  - Sickle cell anemia- as a tool to determine risk of TIA/CVA
  - monitoring for vasospasm and vasculitis
  - assessing initial collateral blood flow and embolization during carotid endarterectomy (shunt placement to reduce the risk of stroke)

- Evaluates the arteries the make up the Circle of Willis
Upper extremity duplex ultrasound

- arteries

- Indications
  - Palmer arch assessment prior to radial artery harvesting for cardiac bypass surgery
  - Suspected digital embolization
  - Evaluation of A-V fistula/Hemodialysis grafts
  - Arm Claudication

- Symptoms
  - Cold hands/fingers (vasospasm/Raynaud's)
  - Non-healing finger wounds
  - Hand or finger pain
  - Problem with hemodialysis pressures/maturation
Upper extremity duplex ultrasound - veins

- Indications
  - Vein mapping prior to vascular or cardiac surgery, hemodialysis
  - DVT (deep vein thrombosis)

- Symptoms
  - Arm pain
  - Acute or chronic swelling
The Examination

- Palpation
  - Temperature
    - Cool suggest poor circulation
  - Pitting edema
    - Test on dorsum of foot, if present on the dorsum of the foot
  - Capillary refill
    - Should be less than 3 seconds
The Examination

- Arterial pulses
  - Dorsalis pedis artery pulse – on the dorsal of the foot, running lateral to the tendon of the first toe – missing in 10% of normals
  - Posterior tibial artery pulse – posterior and inferior to the medial malleolus
  - Popliteal artery pulse – behind the knee, typically done with both hands, examiner facing the patient. The patient needs to relax the leg
  - Femoral artery pulse – in the femoral triangle/halfway between the anterior superior iliac spine and pubic symphysis
Pulse Exam
Lower Extremity

• Femoral
  – Easy to palpate
  – May be obscured in obesity
  – Can examine lymph nodes
  – Femoral hernia
Pulse Exam-LE

• Popliteal
  – More difficult to palpate
  – Femoral condyles/muscle
  – Slightly flex and relax leg
  – One hand – Pop aneurysm

www.jdaross.mcmail.com
Pulse Exam-LE

- **PT**
  - Gentle pressure best
  - Relax & dorsiflex ankle

- **DP**
  - 2 hands to palpate
  - Absent in 10%
  - May have lateral tarsal
Pulse Exam - LE

- May need to press through edema
- Calcified vessels

Regents of the University of California

www.diabetes.usyd.edu.au
The Hand Held Doppler

- **Bedside Ankle Brachial Index**
  - Compare the systolic occlusion pressure of the brachial artery with the systolic occlusion pressure of the posterior tibial artery, and dorsalis pedis artery
- **Artificially elevated in diabetes mellitus, chronic renal disease, old age**
- **Listen to the ultrasound**
  - Normal triphasic ultrasound
  - Proximal disease – biphasic ultrasound
  - Severe – monophasic ultrasound
The Hand Held Doppler

- Inexpensive
- Widely available
- Does not offer detailed description of length, severity, or type of the diseased vessel
- Time and labor consuming
- The PAD screening score using the hand held Doppler has the greatest diagnostic accuracy
The Vascular Laboratory
Arterial

- Plethysmography
- Noninvasive Extremity Pressure Measurements
- Doppler Waveform Analysis
- Transcutaneous Oximetry
Goals of Testing

- Does the Patient Have Disease? --- $P=I$
- How Does the Disease Relate to the Patient’s Presentation? ---- $P$ alone
- Where Is the Disease Located? ---- $I>P$
- What Are the Therapeutic Options? --- $I>>P$
- What Are the Results of Therapy? --- $P$ alone

$P=\text{physiologic} \quad I=\text{imaging (Anatomic)}$

From: Brenenati, JF, 2005
Physiologic Tests

- Ankle-Brachial Index (ABI)
- Pulse Volume Recordings, i.e. Segmental Plethysmography (PVRs)
- Exercise PVRs

- *Does the patient have the disease, is it related to their symptoms, where is the general location of the disease*
Plethysmography

- A plethysmograph is a device that measures or records variations in:
  - The volume of an organ or extremity
  - The blood contained in or passing through

- Most commonly used Segemental air plethysmography
Segmental Air Plethysmography

- The change in volume of an extremity between systole and diastole
- The change in volume is completely dependent upon pulsatile blood flow
- The Pulse Volume Recording (PVR) was developed in the 1970s specifically for arterial diagnosis
- The cuffs are off appropriate diameter to the location on the limb
- They are inflated to 65 mmHg to ensure appropriate contact between the cuff and the extremity
PVRs

- Pneumatic cuffs of specific size placed at thigh, calf, ankle, and transmetatarsal level
- Inflated to 65mm Hg
- Measure volume changes at each level
- Generates pulse waveform
Segmental Air Plethysmography

- Most laboratories report qualitative interpretation
- A normal trace displays a sharp systolic rise and prominent dicrotic notch
- As disease progresses the wave flattens
- Quantitative methods of reporting have been described but are not widely applied
Segmental Air Plethysmography

- Most commonly used in conjunction with segmental pressure measurements
- PVR not affected by vessel wall stiffness
- Not effected significantly by edema
Noninvasive Extremity Pressure Measurements

- Ankle pressure
  - Patient should rest for 15 minutes in the supine position
  - A standard 12 cm cuff is placed above the malleolus
  - A continuous wave (CW) doppler is used to listen to the DP/PT signals
  - The cuff is inflated until the flow stops and then is gently deflated
  - The highest occlusion pressure from the DP/PT is used as the ankle index
  - This is then interpreted in relation to the highest brachial occlusion pressure
  - Primary source of error is calcification of the vessel wall: 5-15% of patients
Noninvasive Extremity Pressure Measurements

- Segmental Pressures
  - These detect the level of significant disease
  - Determine what disease exists at a single level or multiple levels
  - Pressure cuffs are placed high on the thigh, above the knee, below the knee, on the ankle and the forefoot
    - Many do not use the proximal cuff due to leg girth
  - * The recommended cuff width for accurate blood pressure measurement is 1.2 times the diameter of the extremity under the cuff
Doppler Waveform Analysis

- The arterial waveform is determined by:
  - Cardiac pulsations
  - Viscosity of the blood
  - Elasticity of the arterial wall
  - Location and extent of atherosclerotic occlusive disease

- Many vascular laboratories assess Doppler waveform qualitatively and assign it a category

- Proximal stenosis dampens the peak systolic; normal arteries have a reversal of flow in early diastole
Doppler Waveform Analysis

- Pulsatility Index – Quantitative analysis of doppler waveforms
  - The difference between the highest velocity and the lowest velocity divided by mean velocity
ABI

- Ratio of ankle SBP to brachial SBP
- Measure ankle pressure at DP & PT
- Use the higher value for ankle pressure

- Excellent predictor for all CV risk
ABI

- **Interpretation**
  1.1 NL (systolic pressure augmented in periphery)
  0.9-1.09 - Asx
  0.7-0.89 - Mild claudication
  0.5-0.69 - Mod-severe claudication
  0.2-0.49 - Rest pain, tissue loss

- **Falsely Elevated (can be >1.5)**
  ✓ Extensive Calcification (incompressible)
  ✓ Subclavian or other UE stenosis
PVRs

Circulation. 2007;115:e624-e626
PVRs

- Reveals pulse waveform
- Measure volume changes at each level
- Determine level of disease
- Reflects overall flow
PVRs

Shallow upstroke

Delayed, Rounded Peak

Downslope bows away from baseline

Dicrotic wave gone

Decreased Amplitude

Iliac disease

Bilateral Fempop disease

From: Neumyer, M, 2005
Exercise Testing

- Performed in patients with normal pulses and/or normal resting studies
- Useful in those with minimally abnormal studies
- To evaluate whether exercise induced symptoms are reflected by a change in the arterial waveform
- Correlate symptoms & physiology
Exercise Testing

- Pt rests for 15-20 min
- Measure resting pressures
- Exercise x 5 min or sxs
- Treadmill (2 mph, 12 deg grade)
- If sxs - note quality, quantity, duration
- Complete exercise
- Measure serial pressures x 10 min
Exercise Testing

Evaluate

1. Change in waveform

2. Decrease in ABI

3. Time to recovery

Rutherford’s vascular surgery, Cronenwett, Johnston, Eds, 7th ed., 2010, Elsevier
Transcutaneous Oximetry

- Probes contain a heating element to heat the skin to 43°C; this acts to optimize gas exchange and capillary blood flow
- A 20-30 min equilibration period is necessary
- Normal subjects have values in the 40 to 70 mmHg range
- In claudication there is significant overlap with normals
- Main advantage is the use in patients with rest pain and tissue loss
- Has been used to predict healing of wounds and amputation level
- Also predictive of patients that will have a favorable response to hyperbaric therapy
Transcutaneous Oximetry

- **Drawbacks:**
  - Long time required for equilibration
  - On avg 25 minutes per site studied
  - Skin thickening and edema
  - Decreased baseline levels with age
Imaging

Arterial
- Ultrasound
- Computerized Tomography
- Magnetic Resonance
- Invasive – contrast based

Venous
- Ultrasound
- Computerized Tomography
- Magnetic Resonance
- Invasive – contrast based
Arterial Ultrasound

- This is an imaging test/ NOT a physiologic test
- Can help determine the length of a lesion
- Can help determine the severity of a lesion
- Can find suitable distal revascularization targets
- Time consuming
- Technologist dependent
- Inexpensive to payor/expensive to provider
Anatomic Tests

- Duplex Arterial mapping
- Conventional Arteriography
- CT Angiography
- MR Angiography

- What is the anatomy (where is the disease located, lesion characteristics), what are the therapeutic options?
Anatomic Tests

- Real time flow information (collaterals)
- Invasive
  - Needles (Arterial vs venous access)
  - Contrast
  - Radiation
- Calcification
- Visualize previous grafts
- Bony/surface landmarks
Anatomic Tests

- Soft tissue/non-vascular information
- Cost
- Operator dependent
- Ability to perform therapeutic intervention at same setting
- Portable
Principles

- Use anatomic tests that
  - Are less invasive as first line
  - Can guide further invasive testing if required
  - Address specific anatomic issues such as calcification and the presence of previous interventions
- Information gained from anatomic tests should *add to* and not simply *duplicate* information from previous studies
Arterial Duplex

*Advantages*
- Non-invasive, Non-toxic,
- No radiation, No contrast
- Readily available, Easily repeatable
- Inexpensive
- Provides functional information
- Better in larger vessels
- Portable (can be brought to the patient)
Duplex Arterial Mapping

University of Washington Medical Center - Vascular Diagnostic Service

Lower Extremity Arterial Duplex Exam

History: 83 year old female with new area of pain and swelling in the mid anterior tibial region. This is possibly myositis vs. extraneous ischemia.

Date

Name

DOB

Referred By

Address

Phone

Ink Factors

HTN

Diabetic

Smoker

CURRENT MEDICATIONS

Medication

DOSAGE

RIGHT FINDINGS

Abdominal Aortic Aneurysm: (Diameter)

Prox: 1.5 cm

Mid - AAA: 6.3 cm x 6.2 cm x 6.0 cm length

Dist: 2.15 cm

Intramural, Nonocclusive thrombus in AAA.

Right

KCI

Triple

Preliminary Report in Chart:

Dictated

Dr. Signature/Distribution:

Duplex Scanning in Vascular Disorders, 3rd Ed, 2002, Lippincott Williams & Wilkins
LE Arterial Duplex

- Scans selective portions or all (LE arterial mapping) of LE circulation
- Is time consuming
- Operator dependent
- Requires knowledgeable, dedicated technologist
- Information should be used in conjunction with physiologic studies
Duplex Arterial Mapping

**Advantages**
- Non-invasive, Non-toxic, No radiation
- Readily available, Easily repeatable
- Inexpensive
- Provides functional information
- Better in larger vessels
- Portable (can be brought to the patient)
Duplex Arterial Mapping

**Disadvantages**

- Operator dependent
- Requires dedicated, knowledgeable technologist
- Time consuming
- Results depend on criteria chosen
Duplex Arterial Mapping

**Primary Utility**
- Large vessels (pelvis, fempop)
- Surveillance of interventions
  - Open
  - Endovascular
- Procedural guidance
  - Eliminate radiation exposure
  - Easier conversion to an outpatient setting
Venous Ultrasound

- Use to determine the EAP portion of the CEAP...

**Etiologic classification**
- Ec: congenital
- Ep: primary
- Es: secondary (post-thrombotic)
- En: no venous cause identified

**Anatomic classification**
- As: superficial veins
- Ap: perforator veins
- Ad: deep veins
- An: no venous location identified

**Pathophysiologic classification**
- Pr: reflux
- Po: obstruction
- Pr,o: reflux and obstruction
- Pn: no venous pathophysiology identifiable
Venous Ultrasound

- Venous tests performed in the vascular laboratory are done for two primary reasons
  - first done to determine if reflux or obstruction is causing hypertension
  - then to identify the location of the reflux or obstruction
- Doppler ultrasound and color duplex scanners are used to obtain information about the venous system.
Venous Ultrasound

- Capable of characterizing partial and complete anatomic obstruction as well as valvular incompetence in the deep, superficial and perforating veins
- Duplex ultrasonography accurately identifies and localizes segmental venous reflux, the relationship of these findings to global venous hemodynamic does not correlate directly
- Abnormal direct venous pressure measurements are only present in 80% of those with common femoral or popliteal venous reflux detected by duplex
Arterial CT

- With the history and physical exam CTA can evaluate significant occlusive disease
  - Helpful in atypical disease
    - Popliteal entrapment
    - Medial cystic degeneration
- However, not very cost effective
- Large bolus of dye necessary (>100 cc)
- Spiral CT evaluation of vascular disease in the thigh and popliteal area may be more accurate than angiography
- CTA evaluation of the tibial arteries much more difficult
  - Calcium can also confound the CT (Hint: Look at using bone windows)
CT Arteriography

- Are still artifacts
- Is 2-D, can do 3-D reconstructions
- Protocol dependent
- Post-processing is an important component
CT Arteriography

**Advantages**

- Allows precise calculation of stenosis in 3-D
- Assessment of calcification
- Location of previous interventions regardless of status
- Status of previous interventions
- Assessment of other pathology, vascular and non-vascular
- Identifies concomitant aneurismal disease
CT Arteriography

*Disadvantages*

- Radiation exposure
- Requires contrast
  - Nephrotoxicity (different types, amount)
  - Other reactions
- Somewhat Invasive, IV, local complications
- Protocol dependent
- No real time flow information
- Relatively Expensive
CT Arteriography

*Primary Utility*
- Large vessels (Aortoiliac, fempop)
- In setting of previous interventions
- Extensive calcifications
  - Decreased image quality
  - Beneficial for planning intervention
- With concomitant aneurismal disease
CT Arteriography
CT Arteriography
Venous CT

- Very useful for pelvic DVT.
- However, must time the contrast correctly
- Not dynamic enough for most leg pathology
- Best for possible pelvic obstructive disease
  - Intravascular and extravascular compressive disease
Arterial MR

- MRA is concordant with conventional runoff angiography in all cases
- MRA has a sensitivity of 99.6%, a specificity of 100%, a positive predictive value of 100%, and a negative predictive value of 98.5%
- MRA appears superior to conventional angiography for evaluating runoff vessels
  - MRA is significantly more sensitive than conventional angiography in identifying patent runoff vessels
  - This is because MRA only depends on local flow at velocities as low as 2 cm/sec
Arterial MR

- In one study of MRA 80 patients with MRA were noted to have a 100% correlation to intra-operative findings.
- MRA can identify patients that are candidates for bypass procedures that were thought not to be candidates based upon traditional subtraction angiography.
- Therefore it is recommended that prior to deeming a patient non-operative that an MRA be done.
- MRA is more cost effective than traditional angiography as long as it used as the only modality.
- However, now contra-indicated in patients with renal failure of any amount.
MR Arteriography

Radiology, 211, 1999, 59-67

www.healthimaging.com
MR Arteriography

- Is not an X-ray, no radiation
- Subject is magnetized – 3 types of magnetic fields combined to produce a signal, amplified, digitized, Fourier transformation
- 3-D reconstruction
- Images depend on magnet strength 1, 1.5, 3 Tesla
- Can be “closed” or “open”
MR Arteriography

- MRA with or without (time of flight) contrast
- Contrast enhances by effect on water molecules, not direct visualization of contrast – as each contrast molecule has an effect on multiple water molecules - can use less
- Safety issues – implants, metallic objects
- Are still artifacts
- Protocol dependent
- Post-processing is an important component
MR Arteriography

*Advantages (depends on magnet)*
- Allows calculation of stenosis in 3-D
- No radiation exposure
- Status of previous interventions
- Assessment of other pathology, vascular and non-vascular
MR Arteriography

Disadvantages

- Requires contrast
  - Nephrotoxicity, systemic toxicity
- Somewhat Invasive, IV, local complications
- Magnet & Protocol dependent
- Does not differentiate calcium
- Overestimates stenoses
- No real time flow information
- Relatively Expensive
MR Arteriography

*Primary Utility*
- Depends on magnet
- Most uses as in traditional arteriography and CT Arteriography
In one study of 101 lower extremity MRVs were compared with duplex ultrasound and contrast venography and found to have near 100% specificity and sensitivity for DVT.

MRV is very sensitive for pelvic vein and IVC pathology, in addition the internal iliac and deep femoral veins can be imaged.

In addition MRV is very good for identifying compressive venous syndromes such as May Thurner etc.
Arterial – Subtraction angiogram

- Subtraction of the radiodensities surrounding the arterial tree enhances the ability to see surrounding vessels significantly.
- Associated with a minor and major complication rate of up to 8%.
- 29% of patients having peripheral angiograms have some baseline renal dysfunction.
- Low sensitivity for detecting patent runoff vessels secondary to proximal occlusions.
Arterial – Subtraction angiogram

- The not so “Gold” – “Gold Standard”
  - Pitfalls-
    - Motion artifact
    - Overlying vessels
    - 2 D Image
  - Radiation exposure
    - The operator and the patient
Contrast Arteriography

- X-ray with radiopaque contrast injected into vessels
- “Cut-film” → Long leg changer → video radiography → Cineradiography → Digital Subtraction Angiography (DSA)
- Is 2-D
- Post-processing is an important component
Contrast Arteriography
Contrast Arteriography

**Advantages**
- Provides functional information (flow patterns)
- Assess collateral circulation
- Allows precise calculation of stenosis
- Measure pressure gradients
- Fine details in small vessels
- Therapy can be performed
Contrast Arteriography

Disadvantages

- Radiation exposure
- Requires contrast
  - Nephrotoxicity (contrast types, load)
  - Other reactions
- Invasive
  - Bleeding, pseudoaneurysm, dissection
  - Embolization
- Requires Cath Lab setting, Expensive
Contrast Arteriography

Primary Utility

- All vessels
- When therapy is likely
Venography

- A powerful tool in the evaluation of both acute and chronic DVT
- A very high diagnostic accuracy for the presence of deep venous disease
- Ideally the table has a tilt capability and can actually go to the $>40^\circ$ upright position
- A radio-opaque ruler is placed upon the patient to facilitate future recording of location of the lesions
Venography

- **Ascending venography**
  - Demonstrates the location and extent of post-thrombotic disease
    - Identifies: occlusion, venous recanalization, collateral channels, and superficial varicosities

- **Descending venography**
  - Identifies the level of deep vein reflux
  - Morphology of the venous valves
Venographic categories of deep vein reflux

- Grade 0 – Normal valvular function with no reflux
- Grade 1 – Minimal reflux confined to the upper thigh
- Grade 2 – More extensive reflux to the lower thigh, no reflux into calf, due to competent popliteal vein valve
- Grade 3 – Grade 2 but with popliteal vein valve incompetence
- Grade 4 – Virtually no valvular competence, with immediate and dramatic filling of the calf
Lymphatic Evaluations

- Lymphscintiogram
- Lymphangiogram
- CT of lymphatics
- MR of lymphatics
Etiologic Classification of Lymphedema

I Primary Lymphedema
- A Congenital (onset before 1 yo)
  - Nonfamilial
  - Familial (Milroy’s disease)
- B Precox (onset 1 to 35 yo)
  - Non-familial
  - Familial (Meige’s disease)
- C Tarda

II Secondary Lymphedema – Filariasis, LN excision ± radiation, tumor invasion, infection, trauma, other
Lymphoscintigraphy

- Radiolabeled serum albumin or sulfur colloid is injected in the foot
- Gamma camera takes multiple images in one hour (ex 12)
- Normal transit time is between 15 and 60 minutes, less than 15 minutes indicates rapid transport, > 60 minutes delayed transport
- Qualitative interpretation of images is associated with a 92% sensitivity, and a 100% specificity
Lymphatic CT and MR

- **CT**
  - Best used to look for obstructing mass
  - Tubular, nonenhancing structures in the subcutaneous tissue

- **MR**
  - Differentiates – lipedema, chronic venous edema and lymphedema
    - Lipedema – increased subQ fat without increased veins or edema fluid
    - Lymphedema - Honeycomb pattern in subQ, No change in subQ to fascial compartment
    - Venous stasis – Increased veins and increased fluid
  - Also good at delineating LN anatomy
Lymphangiography

Normals
- 5-15 lymph channels on medial aspect of the thigh
- Valves every 5 to 10 mm
- Lateral lymphatics and deep lymphatics not seen
- NI LN have a ground glass appearance

Abnormals
- Primary
  - Obstruction
  - Complete obliteration distally
- Secondary
  - With pelvic obstruction the inguinal and iliac nodes are few or absent
  - Leg lymphatics distended and tortuous
Other technologies

- Laser doppler
- Near infrared spectroscopy
- Hyperspectral imaging
Hyperspectral imaging

- Quantifies cutaneous tissue hemoglobin oxygenation
- Generates anatomically relevant tissue oxygenation maps
- A healing index photograph derived from oxygenation and deoxy values was used to assess the potential for healing
- Sensitivity was 80%, Specificity was 74%, positive predictive value 90%
  - These were better when osteomyelitis cases and heavily callused cases removed
Near Infrared Spectroscopy (NIRS)

- Continuous monitoring of oxygen saturation, oxygenated hemoglobin (Oxy Hb) and deoxygenated hemoglobin (deoxy Hb)
- Seems to have better predictive value in severe disease
- However, some patients have probably adapted to very low peripheral flows and their Oxy Hg was higher and their Deoxy Hb lower than may have been expected
Laser Doppler

- Gives a relative index of cutaneous blood flow
- Output is expressed in millivolts (mV)
- mV is roughly proportional to the avg, blood flow in a 1.5 mm\(^3\) 0.8 to 1.5 mm below the skin surface
- Normal skin
  - Pulse waves that coincide with the cardiac cycle
  - Vasomotor waves that occur four to six times per minute
  - A mean blood flow velocity that is represented by the elevation of a tracing
  - In the foot – highest velocities are under the skin of the big toe
Laser Doppler

- In limbs with PVD
  - Pulse waves are attenuated
  - Mean velocities are decreased
  - Vasomotor waves disappear

- Prediction of healing
  - Mean velocity > 40 mV and pulse wave amplitude > 4mV – 96% healing rate
  - Mean velocity < 40 mV and pulse wave amplitude < 4mV – 79% healing rate

* Not as accurate as TCPO2
Obtain Chief Complaint

History of present illness/ Risk factors

“Prejudiced” physical exam

Swollen limb

With swelling on dorsum of foot → Lymphscintiogram

With skin changes → Venous ultrasound

Ischemic limb

No palpable pulses → NIFs/TCPO2

Functional Test

Planning for Intervention

ICG Lymphography

Ascending/Descending Venogram

Angiography

Intervention

MRA
CEAP Determination

**Etiologic classification**
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