Diagnostic Tools and Screening

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Disclosures:

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Topics

• Continuous wave Doppler
• Plethysmography
• Ankle-Brachial Index
• Peripheral Arterial Evaluation
Continuous Wave Doppler

- **Doppler effect**: change in the frequency of a detected wave when a source or the detector is moving.

- Objects moving toward the detector have a higher frequency than those moving away from the detector.
Continuous Wave Doppler

- Doppler shift occurs when reflectors move relative to the transducer.

- The frequency \( f_r \) of echo signals from moving reflectors (blood cells) is higher or lower than the frequency transmitted by the transducer \( f_t \), depending on whether the blood cells are moving toward or away from the transducer.

- The Doppler shift frequency is the difference between the received and transmitted frequencies:

\[
fd = f_r - f_t = \frac{2f_t Ve \cos \theta}{c}
\]
Continuous Wave Doppler

- Simplest application of CW Doppler is the handheld Doppler
  - Doppler shift is converted into audible sounds, processed, and emitted from speakers on the device
  - Sum of all signals from moving objects; summation waves may occur (vein signal dampening an arterial signal)
Continuous Wave Doppler

Venous applications
- Determine presence of reflux
- Determine sites of reflux
- Assess severity of reflux
- Determine origin of a varicosity
- Diagnose obstruction
  - (not reliable enough to diagnose or exclude DVT)
Bedside screening for valvular incompetence using CW Doppler

Normal
- No flow with proximal compression or Valsalva
- Antegrade flow with release of proximal compression or Valsalva
- Antegrade flow with distal compression
- No flow with release of distal compression

Handbook of Venous Disorders, 2nd ed.
**A Comparison of Duplex Scanning and Continuous Wave Doppler in the Assessment of Primary and Uncomplicated Varicose Veins**

S. G. Darke*, S. Vetrivel, D. M. A. Foy, S. Smith and S. Baker

- 100 limbs in 73 patients with primary and uncomplicated vv. CWD then DUS all limbs in blinded manner

- **CWD**
  - 95% sens, 100% spec for GSV incompetence
  - 90% sens, 93% spec for SSV incompetence (all false positives at the SPJ)

Eur J Vasc Endovasc Surg 14, 457-461 (1997)
Continuous Wave Doppler

• Advantages
  • Excellent sensitivity and acceptable specificity for venous incompetence
  • Portable, in office tool

• Limitations
  • Operator dependent
  • No info re: anatomy; only that there is flow present
  • Ambiguity (no depth information)—
    • Difficult to differentiate reflux in the deep vein vs in a superficial vein or major tributary at the SFJ or SPJ
    • Reflux in deep vs perforator vein
  • Summation of all signals
    • Vein can dampen arterial signal
  • Inability to standardize testing protocol – ex: tourniquet pressure
Plethysmography

- A **plethysmograph** is an instrument for measuring changes in volume within an organ or whole body (usually resulting from fluctuations in the amount of blood or air it contains).

- Types (not all measure volume directly):
  - Air (pneumato plethysmography)
  - Photoplethysmography
  - Strain gauge plethysmography
  - Impedance plethysmography
Photoplethysmography (PPG)

- Changes in blood volume in the skin is determined by measurement of backscatter of light emitted from a diode with a photosensor
- Not a true volume sensor but correlates well with intravenous and intra-arterial pressure studies
- Arterial application ➔ TBI
- Venous application ➔ incompetence or obstruction

http://www.thewhiteleyclinic.co.uk/
Photoplethysmography (PPG)

- Can be used with maneuvers (calf muscle exercise) to determine venous refill time of the affected limb
- Use of tourniquet or cuff or manual compression of the superficial veins helps determine deep versus superficial venous disease
Photoplethysmography (PPG)

Venous refill time: time required for PPG tracing to return to 90% of baseline after completion of calf exercises

- VFT90 <18-20 sec ➔ CVI
- VFT90 >20 sec ➔ normal
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### Photoplethysmography (PPG)

**Advantages**
- Technically simple
- Equipment inexpensive and portable
- In office screening tool

**Limitations**
- Subjective and nonquantitative
- Not able to localize site of incompetence anatomically
- Variability in sensor placement and tourniquet pressure
- Results can be influenced by body temp, vasodilation, vasoconstriction
Air Plethysmography

- Assesses limb blood volume changes
- Changes in limb volume measured by displacement of air in a cuff surrounding the calf during maneuvers to empty and fill the venous system
- Cuff is inflated to a low pressure and volume changes in the limb are recorded (mL)
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Air Plethysmography

1. Assesses for obstruction to outflow
2. Assess for valvular reflux
3. Effectiveness of calf muscle pump
4. Assess venous hypertension

JVS 1987;5:148-59
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Obstruction

1 Second Outflow Fraction = \( \frac{V_1}{V_C} \times 100\% \)

- > 40% - Normal
- 30-39% - Mild Obstruction
- < 30% - Severe Obstruction

Reflex

Venous Filling Index

- VFI (ml/sec)
- \( \leq 2 \) - Normal
- > 2 - Reflux

Venous Pressure

Residual Volume Fraction

\( RVF = \frac{RV}{V} \times 100\% \)

- < 35% - Normal
- RVF ≈ AVP

Calf Muscle Function

Ejection Fraction

\( EF = \frac{EV}{V} \times 100\% \)

- \( \geq 60\% \) - Normal
- < 40% - Poor Muscle Calf Function
Air Plethysmography

APG tracings of a patient 3 years after femoropopliteal DVT.
- A: unaffected extremity
- B: extremity with venous obstruction has decreased venous capacitance (VC) and decreased maximum venous outflow (MVO)

Lurie and Rooke in Handbook of Venous Disorders, 3rd ed. 2009 (P Gloviczki, ed.)
Air Plethysmography

• Advantages
  • Assesses global lower limb hemodynamics
  • Can be used to select patients who would benefit from intervention
  • Can be used to evaluate effect of noninvasive therapeutic measures such as limb compression

• Limitations
  • Not able to identify specific incompetent valve sites
  • May be difficult for patients to perform rapid maneuvers
Venous disease can coexist with arterial disease

- Up to 1/3 of patients with chronic venous ulceration may have concomitant arterial insufficiency (Br J Surgery 1986;73:693-6)

- There are case reports of compression therapy causing serious limb outcomes

- Patients with venous disease should have screening for arterial disease

Hazard of compression treatment of the leg: an estimate from Scottish surgeons

Compression has been used for centuries to manage many venous, the post-thrombotic syndrome, and leg ulcers, and more recently for the management of venous stasis ulcers. Compression therapy has been recommended to be used in the management of chronic venous disease in order to improve venous return and improve outcomes.

Methods and results

All 134 surgeons in general surgery in Scotland were asked if they used compression in the management of chronic venous disease and whether they had any experience with compression therapy. The response rate was 100%.

- Compression was used in 124 surgeons (92%)
- 105 surgeons (80%) had experience with compression therapy
- 102 surgeons (77%) had experience with compression therapy for more than 1 year
- 98 surgeons (73%) had experience with compression therapy for more than 5 years

The hazards of compression treatment of the leg: an estimate from Scottish surgeons

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- Compression therapy has been recommended to be used in the management of chronic venous disease in order to improve venous return and improve outcomes.
Venous disease can coexist with arterial disease

<table>
<thead>
<tr>
<th>TEST</th>
<th>SENSITIVITY</th>
<th>SPECIFICITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>PULSE EXAM (DP)</td>
<td>50%</td>
<td>73%</td>
</tr>
<tr>
<td>PULSE EXAM (PT)</td>
<td>71%</td>
<td>91%</td>
</tr>
<tr>
<td>Rose Questionnaire</td>
<td>20%</td>
<td>96%</td>
</tr>
<tr>
<td>ABI</td>
<td>79-97%</td>
<td>96-100%</td>
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Ankle-Brachial Index

\[ ABI = \frac{\text{Ankle systolic pressure}}{\text{Brachial systolic pressure}} \]

- PAD screening exam
- Ankle and brachial systolic pressures taken using a Doppler sensor
  - Can be done bedside with a hand-held Doppler device
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ABI Calculation

Right Arm:
- Systolic Pressure: **120 mmHg**

Left Arm:
- Systolic Pressure: **100 mmHg**

Right Ankle:
- Systolic Pressure:
  - Posterior Tibial (PT): **68 mmHg**
  - Dorsalis Pedis (DP): **64 mmHg**

Left Ankle:
- Systolic Pressure:
  - Posterior Tibial (PT): **136 mmHg**
  - Dorsalis Pedis (DP): **132 mmHg**

**Right ABI equals Ratio of:**
- Higher of the Right Ankle Pressure (PT or DP) / Higher Arm Pressure (right or left arm)

**Left ABI equals Ratio of:**
- Higher of the Left Ankle Pressure (PT or DP) / Higher Arm Pressure (right or left arm)

Normal: 1.00-1.40
Borderline: 0.91-0.99
PAD:
- Moderate PAD: < 0.70
- Severe PAD: < 0.40
Non-compressible: >1.40

*The lower of these numbers is the patient's overall ABI. Overall ABI (lower ABI) = 0.57
Ankle Brachial Index

• Advantages
  • Simple, in office procedure
  • High sensitivity and specificity
  • Screening tool not just for PAD but also for CVD and CAD

• Limitations
  • Does not localize disease within the limb
  • Falsely elevated ABI for patients with calcified vessels, obese
  • Decreased sensitivity for mild disease
    • ½ or more of patients with borderline ABI at rest will have fall in ABI with exercise
Non-Compressible Vessels (ABI >1.4)

- Ankle pressure of 255 mm Hg artifact, not severe hypertension; arteries cannot be compressed
  - Partial non-compressibility with ABI < 1.4 possible
- Occurs in 5-8.5% of patients referred for ABI\(^1,2,3\)
- Associated with vascular calcification or obesity
  - Diabetes mellitus
  - Renal failure
  - Hyperparathyroidism
- ABI number is NOT interpretable in this setting
  - Use alternate test to establish the diagnosis of PAD (Toe-brachial index, Pulse volume recordings, imaging (duplex, CTA, MRA))

\(^1\text{Allision MA, et al. JACC. 2008;51:1292}\)
\(^2\text{Suominen V, Eur J Vasc Endovasc Surg. 2008;35:709.}\)
\(^3\text{Sutton-Tyrrell, K. et al. Stroke 2008;39:863-869}\)
Peripheral Arterial Evaluation

• History:
  • Rose questionnaire (96% specificity)

• Physical exam:
  • Pulse palpation (femoral, popliteal, DP, PT)
  • CW Doppler
  • Auscultation for bruits bilateral groins

• ABI:
  • What if the ABI does not match the exam or the patient’s symptoms?

Right ABI = 0.83
Left ABI = 0.89
Normal
Pulse volume recordings

- Normal
- Mild
- Moderate
- Severe

CW Doppler

- Triphasic
- Biphasic
- Monophasic
Toe-Brachial Index (TBI) – ABI does not match exam

- Use when ABI > 1.4 or partial non-compressible vessels as digit pressures are almost always compressible
- Measure great toe pressure using small digit cuff and a flow sensor (PPG)
- Vasoconstriction can be a confounder → warm room or toe warming
- Normal TBI > 0.7
  - Some labs may use a 0.8 cutpoint for TBI

\[
\text{TBI} = \frac{\text{Toe Pressure}}{\text{Brachial Pressure}}
\]
Non-Compressible Vessels

- R ABI 1.10, L ABI 1.08
- Waveforms do not match ABIs
- R TBI 0.43, L TBI 0.69
- ➔ R moderate disease
- ➔ L mild disease
Exercise ABI – ABI does not match symptoms

• Lower extremity “stress test”
• PAD suspected but ABI is normal or borderline at rest
• Obtain ABI and ankle PVR tracings before and immediately post exercise
• Interpretation
  • **Normal**: No significant drop in ankle pressure or ABI with exercise
  • **Abnormal**: Fall in ankle pressure or ABI with change in PVR waveform
57 sec - onset of bilateral calf tightness
2 min 31 sec - tightness radiating to left thigh
I’ve diagnosed PAD, now what?

• Further imaging if revascularization is planned
  • Arterial duplex ultrasound
  • CTA
  • MRA
  • Catheter-based angiography

• Medical Management
  • Treatment of claudication symptoms (cilostazol, PAD rehab)
  • PAD is a CAD risk equivalent (antiplatelet, statin, antihypertensives, etc)
  • Referral to a cardiovascular specialist for ongoing care