The Many Views of PAD: Imaging Modalities for the Interventionist

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Disclosures

- None
Objectives

- Review the role of non-invasive physiologic evaluation and imaging prior to invasive angiography
  - Physiological
    • Ankle-Brachial Index (ABI)
    • Segmental pressures
    • Pulse-volume recordings (PVR)
  - Imaging
    • Duplex Ultrasound (DUS)
    • Computed Tomographic Angiography (CTA)
    • Magnetic Resonance Angiography (MRA)
## Levels of Evidence

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
<th>Class I</th>
<th>Class IIa</th>
<th>Class IIb</th>
<th>Class III</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Benefit &gt;&gt;&gt; Risk</td>
<td>Benefit &gt;&gt; Risk</td>
<td>Benefit ≥ Risk</td>
<td>Risk ≥ Benefit</td>
</tr>
<tr>
<td></td>
<td>Procedure/Treatment SHOULD be performed/administered</td>
<td>IT IS REASONABLE to perform procedure/administer treatment</td>
<td>Procedure/Treatment MAY BE CONSIDERED</td>
<td>Procedure/Treatment should NOT be performed/administered SINCE IT IS NOT HELPFUL AND MAY BE HARMFUL</td>
<td></td>
</tr>
<tr>
<td>Level A</td>
<td>Multiple (3-5) population risk strata evaluated*</td>
<td>Recommendation that procedure or treatment is useful/effective</td>
<td>Recommendation in favor of treatment or procedure being useful/effective</td>
<td>Recommendation’s usefulness/efficacy less well established</td>
<td>Recommendation that procedure or treatment not useful/effective and may be harmful</td>
</tr>
<tr>
<td>General consistency of direction and magnitude of effect</td>
<td>Sufficient evidence from multiple randomized trials or meta-analyses</td>
<td>Some conflicting evidence from multiple randomized trials or meta-analyses</td>
<td>Greater conflicting evidence from multiple randomized trials or meta-analyses</td>
<td>Sufficient evidence from multiple randomized trials or meta-analyses</td>
<td></td>
</tr>
<tr>
<td>Level B</td>
<td>Limited (2-3) population risk strata evaluated*</td>
<td>Recommendation that procedure or treatment is useful/effective</td>
<td>Recommendation in favor of treatment or procedure being useful/effective</td>
<td>Recommendation’s usefulness/efficacy less well established</td>
<td>Recommendation that procedure or treatment not useful/effective and may be harmful</td>
</tr>
<tr>
<td>General consistency of direction and magnitude of effect</td>
<td>Limited evidence from single randomized trial or non-randomized studies</td>
<td>Some conflicting evidence from single randomized trial or non-randomized studies</td>
<td>Greater conflicting evidence from single randomized trial or non-randomized studies</td>
<td>Limited evidence from single randomized trial or non-randomized studies</td>
<td></td>
</tr>
<tr>
<td>Level C</td>
<td>Very limited (1-2) population risk strata evaluated*</td>
<td>Recommendation that procedure or treatment is useful/effective</td>
<td>Recommendation in favor of treatment or procedure being useful/effective</td>
<td>Recommendation’s usefulness/efficacy less well established</td>
<td>Recommendation that procedure or treatment not useful/effective and may be harmful</td>
</tr>
<tr>
<td>General consistency of direction and magnitude of effect</td>
<td>Only expert opinion, case studies, or standard-of-care</td>
<td>Only diverging expert opinion, case studies, or standard-of-care</td>
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<td></td>
</tr>
</tbody>
</table>
Non-invasive Evaluation - Treatment Planning

- Location and severity of disease
- Access vessels
- Approach
  - Antegrade, retrograde, targets for pedal access, radial access
- Device choice and appropriate sizing
- Stratification into clinical trials
Physiological Evaluation

• Ankle-brachial index (ABI)
  – Compare resting pressures at arm/ankle levels (Highest pressures used)
    • Cannot localize level of disease
    • Affected by noncompressible arteries
  – 2005 ACC/AHA guidelines\(^1\)
    • *Class I, Level C evidence*
      – Establish diagnosis of peripheral arterial disease (PAD)
        » 70 years and older
        » 50 years and older with smoking history/diabetes
    • Baseline and post-intervention follow-up
ABI

• Validated predictor of all cause and cardiovascular mortality\(^1\)
  – Cheap, available, easily performed/reproducible

• Stratification of PAD severity\(^3\)
  – ABI < 0.90 -> 90% sensitivity and specificity in detecting PAD compared with angiography\(^4,5\)

• Screen asymptomatic individuals\(^6\)
  – ABI < 0.9 or >1.4 useful adjunct to Framingham cardiovascular risk score
All-cause and CVD mortality according to ABI group, Strong Heart Study, 1988-99, n=4393

**ABI**

### How to calculate the ankle-brachial index

- **Right arm:**
  - Systolic pressure: 230 mm Hg

- **Left arm:**
  - Systolic pressure: 200 mm Hg

- **Right ankle:**
  - Systolic pressure:
    - Posterior tibial (PT): 168 mm Hg
    - Dorsalis pedis (DP): 64 mm Hg

- **Left ankle:**
  - Systolic pressure:
    - Posterior tibial (PT): 130 mm Hg
    - Dorsalis pedis (DP): 132 mm Hg

**Right ABI equals ratio of:**

\[
\frac{168 \text{ mm Hg}}{230 \text{ mm Hg}} = 0.73
\]

**Left ABI equals ratio of:**

\[
\frac{132 \text{ mm Hg}}{130 \text{ mm Hg}} = 1.01
\]

*The lower of these numbers is the patient’s overall ankle-brachial index. Overall ankle-brachial index = 0.57*

### Normal and Abnormal Values of ABI and TBI

<table>
<thead>
<tr>
<th>TBI</th>
<th>ABI</th>
<th>Clinical significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;0.7</td>
<td>1.0–1.3</td>
<td>Normal</td>
</tr>
<tr>
<td>N/A</td>
<td>0.91–1.0</td>
<td>Borderline</td>
</tr>
<tr>
<td>0.5–0.7</td>
<td>0.7–0.9</td>
<td>Mild</td>
</tr>
<tr>
<td>0.35–0.5 or 30–40 mm Hg</td>
<td>0.4–0.7</td>
<td>Moderate</td>
</tr>
<tr>
<td>&lt;0.35 or &lt;30 mm Hg</td>
<td>&lt;0.4 or &lt;50 mm Hg</td>
<td>Severe</td>
</tr>
<tr>
<td></td>
<td>&gt;1.3</td>
<td>Noncompressible</td>
</tr>
</tbody>
</table>

### Interpretation

- A change of 0.15 from prior exam is significant
- Absolute ankle pressure < 50 mmHg -> critical limb ischemia
Physiological Evaluation

• Segmental Pressure Measurement
  – Compare resting pressures at multiple levels
    • Brachial, thigh, calf, ankle, toe
  – Level of disease
    • All segmental flow at a given level; not specific artery
  – Affected by noncompressible arteries
  – ACC/AHA guidelines\(^1\)
    • Class I, Level B evidence
      – Anatomic localization of lower extremity PAD and in designing therapeutic plan
    • Baseline and post-intervention follow-up
Segmental Pressures

• Interpretation:
  – Vertical or lateral pressure gradient \( \geq 20 \text{ mmHg} \) represents hemodynamically significant arterio-occlusive disease

Physiological Evaluation

• Pulse Volume Recording (PVR)
  – Plethysmographic evaluation of blood flow at multiple levels (like segmental pressures)
  – Level of disease; not specific artery
  – Not affected by noncompressible arteries
  – ACC/AHA guidelines\(^1\)
    • Class IIa, Level B evidence
      – Establish PAD diagnosis, anatomic localization and severity of disease
    • Post-intervention follow-up
Physiological Evaluation

• Example
  – Standard form combining ABI, segmental pressure and PVR information
  – Numerical and graphical representation of PAD level and severity
Imaging Evaluation

• Duplex Ultrasound (DUS)
  – Determine specific level of arterial stenosis
  – ACC/AHA guidelines\(^1\)
    • Class I, Level A evidence
      – Diagnose anatomic location and degree of stenosis in PAD
      – Routine surveillance for surgical bypass
    • Class IIa, Level B evidence
      – Select candidates for endovascular intervention
    • Class IIb, Level B evidence
      – Evaluate long-term patency after angioplasty
DUS

- Gray-scale
  - Anatomic information
  - Qualitative evaluation of atherosclerotic plaque, aneurysm, stenosis, calcification and other luminal abnormalities

Popliteal Artery Aneurysm with mural thrombus
DUS

- Color Doppler
  - Distinguish artery & vein
  - Evaluate “laminar” or turbulent flow
  - Auxiliary info for gray scale findings

- Power Doppler
  - Non-directional info, low flow
DUS

• Spectral Waveform Analysis
  – Flow velocity calculation
    • Stenosis: velocity change b/w contiguous segments
    • 50% stenosis:
      – 80-96% sensitivity, 89-99% specificity
    • Occlusion:
      – 90% sensitivity, 96-100% specificity
  – Vascular compliance
  – Waveform characteristics predict normal, pre-stenotic and post-stenotic regions
Imaging Evaluation

• CT Angiography (CTA)
  – Level of disease and extravascular evaluation
  – Large vessel disease, aortoiliac occlusive and aortic aneurysmal disease
  – ACC/AHA guidelines\(^1\)
    • Class IIb, Level B evidence
      – Diagnose anatomic location/degree of stenosis in PAD
    • Class IIb, Level B evidence
      – Suitable substitute for MRA in patients with contraindications to MRA
CTA

- Obviate diagnostic DSA
- Multidetector-row CT and 3-D workstations permit high-level reconstruction
  - Multiplanar reformations, maximal intensity projection, 3-D Volume-rendering
  - Isotropic, submillimeter imaging of entire vascular tree
  - Data can be viewed from any plane without loss of spatial resolution
CTA

- Aortoiliac occlusive disease
- Important preprocedure information for access
CTA

- Abdominal aortogram with runoff
- Bone removal algorithm improves anatomic information, still with obstructive artifact (A&C)
- Dual-energy acquisition provides improved detail in small vessels (B&D; tibials often more difficult to evaluate by CTA when compared to MRA)
• Right popliteal artery aneurysm before and after surgical repair\textsuperscript{6}
• Same patient with prior surgical repair of a juxtarenal aortic aneurysm
• Special Scenarios - Popliteal entrapment\textsuperscript{6}
  - Exquisite delineation of the gastrocnemius slip occluding popliteal artery during forced plantar flexion
CTA

• Advantages:
  – Readily available
  – Fast
  – Easy to interpret

• Disadvantages:
  – Iodinated contrast
  – Ionizing radiation
  – Calcium can limit luminal evaluation
Imaging Evaluation

• MR Angiography
  – Useful to determine level of disease
  – ACC/AHA guidelines\(^1\)
    • *Class I, Level A evidence*
      – Diagnose anatomic location/degree of stenosis in PAD
      – Selecting candidates for endovascular intervention
    • *Class I, Level B evidence*
      – Use of gadolinium enhancement in MRA
MRA

• Time-Resolved Imaging of Contrast Kinetics (TRICKS)
• Dynamic contrast enhancement simulating DSA
• Excellent resolution of carotid and tibial arteries
MRA

- Non-contrast enhanced series
  - Bipolar-gradient Flow-Sensitive Dephasing module
  - Prepared Balanced SSFP
    (Northwestern University Radiology)
MRA

- Non-contrast enhanced series
  - Subtraction-based NC-MRA technique
    (Northwestern University Radiology)
MRA

• Advantages:
  – No ionizing radiation
  – No iodinated contrast
  – Experimental non-contrast series

• Disadvantages:
  – Slower acquisition times (now trivial)
  – Gadolinium contrast
    • Nephrogenic systemic fibrosis: GFR < 30
  – Metallic susceptibility
MSMC Institutional Protocol

- Initial evaluation with physical examination
- Non-invasive examination including ABI, segmental pressure, PVR and Duplex
- CTA:
  - Typically in patients with suspected aortoiliac or iliofemoral arterio-occlusive disease
- MRA:
  - Typically in non-CKI patient with CLI and suspected multilevel disease, particularly when tibial disease is expected
Questions?
Mount Sinai Interventional Vascular Radiology

• Don’t hesitate to call us with questions at (305) 674-2071
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  – Timothy E. Yates, MD
    • Timothy.Yates@msmc.com

• Students welcome to rotate
Thank you
References


3. Victor Aboyans, MD, PhD, FAHA, Chair et al. Measurement and Interpretation of the Ankle-Brachial Index: A Scientific Statement From the American Heart Association on behalf of the American Heart Association Council on Peripheral Vascular Disease, Council on Epidemiology and Prevention, Council on Clinical Cardiology, Council on Cardiovascular Nursing, Council on Cardiovascular Radiology and Intervention, and Council on Cardiovascular Surgery and Anesthesia


6. Abrams’ Angiography

