Role of ABI in Detecting and Quantifying Peripheral Arterial Disease

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November 4, 2017
Arterial Occlusive Disease

- Atherosclerosis affects ALL arterial beds
- Symptoms/Treatment depend on affected vessels
- Peripheral Arterial Occlusive Disease (PAOD→PAD)
  - Diminished Perfusion
    - Atherosclerosis- common
    - Thrombosis
    - Embolization
Arterial Occlusive Disease

- Peripheral Arterial Disease
  - Slowly progressive atherosclerotic deposition
    - Tobacco/Cigarette Use
    - Diabetes Mellitus
    - Hyperlipidemia
    - Hypertension
    - Hyperhomocyst(e)inemia
Arterial Occlusive Disease

- Peripheral Arterial Disease
  - Asymptomatic
  - Claudication
  - Limb-threatening ischemia (Critical limb ischemia (CLI))
  - Rest pain
  - Non-healing ulceration
  - Gangrene
CLAUDICATION

CRAMPY MUSCULAR DISCOMFORT BROUGHT ON BY EXERCISE AND RELIEVED BY REST
Intermittent Claudication

- Claudicatio - from Latin “to limp”
- Marginal arterial supply
  - Adequate at rest
  - Inadequate to meet demands of exercise
- Skin changes:
  - Dry but intact
  - Limited hair on lower leg or toes
  - Thickened nails
Not all leg pain...

**True claudication versus pseudoclaudication**

<table>
<thead>
<tr>
<th></th>
<th>Claudication</th>
<th>Pseudoclaudication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caliber of pain</td>
<td>Cramping, tightness, and fatigue</td>
<td>Similar, may also describe paresthesias</td>
</tr>
<tr>
<td>Location</td>
<td>Calf, thigh and/or buttocks</td>
<td>Similar</td>
</tr>
<tr>
<td>Exacerbated by walking</td>
<td>Yes</td>
<td>Variable</td>
</tr>
<tr>
<td>Exacerbated by standing</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Sitting required for resolution</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Distance to discomfort</td>
<td>Reproducible</td>
<td>Variable</td>
</tr>
</tbody>
</table>

![Diagram of vertebrae with annotations](image)
REST PAIN

BURNING PAIN IN THE FOREFOOT/TOES, WHICH OCCURS WITH LEG ELEVATION AND IS ALLEVIATED WITH DEPENDENCY
Rest Pain

- Marginal arterial perfusion to foot
- Pain is usually in distal foot particularly over the dorsum of the foot
- No break in skin integrity, all tissues viable
- Pallor on elevation, dependent rubor
SEVERE ARTERIAL INSUFFICIENCY SUCH THAT DISTAL TISSUES BECOME NON-VIABLE INCLUDES NONHEALING ULCERS
Non-healing Ulcer and Gangrene

• **Severe** arterial insufficiency
• Distal tissues become non-viable
• Small wounds do not heal or continue to deteriorate for protracted periods of time
Anatomy of Lower Extremity Vascular Tree

Inflow

Outflow

Run-off
Noninvasive Diagnostics

• Investigators recognized that significant blockages in the limb arteries resulted in reduced blood pressure and volume of blood in the tissues distal to obstruction

• Indirect, physiologic testing remains the primary diagnostic method for assessment of arterial disorders in the vascular laboratory

• Duplex provides site-specific, quantitative diagnostic information
Ankle Brachial Index (ABI) Test to Diagnose PAD
Segmental Pressures

- **Ankle-Brachial Index**
  - Ratio of BP in tibial arteries to the BP in the arm
- **Segmental pressures** are systolic BP measurements using cuffs from thigh to ankle
ABI

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

- Right brachial systolic pressure
- Left brachial systolic pressure
- Right ankle systolic pressure
- Left ankle systolic pressure

**Interpretation of ABI**
- \( >1.30 \): uncompressible
- \( 0.91 \sim 1.29 \): normal
- \( 0.41 \sim 0.90 \): mild-to-moderate peripheral arterial diseases
- \( <0.41 \): severe peripheral arterial diseases
What does the ABI mean clinically?

Ankle-Brachial Index Values and Clinical Classification

<table>
<thead>
<tr>
<th>Clinical Presentation</th>
<th>Ankle-Brachial Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>&gt; 0.90</td>
</tr>
<tr>
<td>Claudication</td>
<td>0.50-0.90</td>
</tr>
<tr>
<td>Rest pain</td>
<td>0.21-0.49</td>
</tr>
<tr>
<td>Tissue loss</td>
<td>&lt; 0.20</td>
</tr>
</tbody>
</table>

Values >1.25 falsely elevated; commonly seen in diabetics

*Am J Cardiol 2001; 87 (suppl): 3D-13D
NEJM 2001; 344: 1608-1621*
Clinical Significance of ABI

Table 5. Systolic ankle/brachial blood pressure (ABI) differential diagnosis

<table>
<thead>
<tr>
<th>Arterial disease severity</th>
<th>Ankle-brachial index (ABI) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No disease: normal arterial perfusion</td>
<td>At least 0.86</td>
</tr>
<tr>
<td>Mild arterial disease</td>
<td>0.75–0.85</td>
</tr>
<tr>
<td>Intermittent claudication (walking capacity limited)</td>
<td>0.50–0.75</td>
</tr>
<tr>
<td>Severe arterial disease</td>
<td>0.20–0.50</td>
</tr>
<tr>
<td>Gangrene</td>
<td>&lt; 0.20</td>
</tr>
</tbody>
</table>

Bolton et al 2014
ABI Correlates with CV Events

ABI – inverse relationship with 5-year risk of cardiovascular events and death

10.2% relative risk increase per 0.1 decrease in ABI
($p = 0.041$)
Pathogenesis of PVD

- Laminar Flow
- Endothelial Cell Mediated Vasodilation
- Distal Pressure and Flow Maintained

NORMAL

- Normal ABI
- Matched O₂ Supply-Demand
- Efficient Oxidation
- Low Oxidative Stress

Collateral Vessel

- Turbulent Flow Pressure Drop across Stenosis
- Impaired Endothelial Function
- Inability to Increase Flow with Exercise

PERIPHERAL ARTERIAL DISEASE

- Reduced ABI
- Mismatched O₂ Supply-Demand
- Inefficient Oxidation
- High Oxidant Stress

80% Stenosis High Resistance
Normal Arterial Circulation

• Normal triphasic flow pattern
  – Rapid systolic acceleration
  – Reverse flow component
  – Forward diastolic flow
Moderate Arterial Insufficiency

- Absence of diastolic flow reversal suggesting forward flow demand
- Vasodilation with flow-reducing arterial disease (>60%)
- Exercise-induced vasodilation
Severe Arterial Insufficiency

- Intrinsic disease—arterial pressure higher proximal to narrowing and lower distally
- Delayed systolic upstroke due to increased time for blood to bypass stenosis through collaterals
- Decreased PVR and waveform has delayed diastolic runoff (bowing to the right) and loss of amplitude
PVR Waveforms

PVR Waveform Interpretation

- Triphasic
  (Minimal ischemia)

- Biphasic
  (Mild ischemia)

- Monophasic
  (Moderate ischemia)

- Stenotic
  (Severe ischemia)
Normal or Abnormal?
Arterial Imaging

- Magnetic resonance angiography-MRA
  - Nephrogenic fibrosis syndrome with gadolinium
- CT angiography
  - Iodinated contrast in diabetic patients
- Digital subtraction angiography
  - Selective catheterization
  - Carbon dioxide “contrast agent”
Diabetic foot deformity

Pressure points at specific bony prominences

- Hammertoes or claw toes
- Metatarsal head mal perforans ulcer
- Midfoot collapse or Charcot’s foot
ABI in Diabetic Patients

Non compressible arteries; Even 250 mmHg are not enough

Measurable Pulse volume recordings
Exercise ABI

- Exercise-related limb pain due to inability of collateral circulation to meet flow demands of exercising muscle
- With moderate exercise, total limb blood flow must increase 5x to meet metabolic demands of working calf muscle
Exercise ABI

- Vasodilation of peripheral collateral resistance vessels and muscular arterioles
- During exercise, a pressure gradient develops across lesion because collateral circulation cannot maintain distal perfusion pressures
Resting vs. Exercise ABI

Exercise Testing

- Exercise
  - ABI at baseline
  - 2 mph at 12% grade, 5 minutes
  - ABI post-exercise, 1 minute, then q 2 minutes
- Post-exercise ankle systolic pressure
  - Falls >20% from baseline
  - Takes longer than 3 minutes to recover
Benefits of Exercise ABI

- Exercise simulates activity that produces symptoms
- Pain can be localized to one or more limb segments
- Determine whether postexercise ankle pressures deteriorate to ischemic levels
- Determine recovery time
- Differentiate true vascular claudication from pseudoclaudication
- Assess disease progression and response to therapy
Interpretation of Exercise ABI

- Decrease in ankle pressure to 60 mm Hg or less is consistent with CLI and vascular claudication
- Document recovery time, symptoms experienced during exercise, and pre- and post-exercise pressures to gauge disease severity and extent of collateral compensatory flow
Case 1

- 65M with 1 block L calf claudication
- Denies rest pain/tissue loss
- 1 ppd x 40 years
CT Angiogram
Case 2

- 72F s/p cardiac catheterization following MI
- Drug eluting stents x 2 placed
- Closure device used to close R femoral artery
Duplex
CT Angiogram
Femoral Endarterectomy
Case 3

- 60F complains of L buttock claudication after walking 2 blocks relieved with rest
- Denies rest pain/tissue loss
- Smokes 1 ppd x 40 years
ABI
Where is the lesion?
Iliac Stenting

- Balloon stent in position across lesion
- Expansion of balloon & stent
- Stent scaffolded artery after removal of balloon
Case 4

- 43M type 1 DM
- Owns glucometer but no strips
- BS 650
ABI and Segmental Pressures

Right femoral artery: biphasic
Right popliteal artery: biphasic
Right posterior tibial artery: biphasic
Right dorsalis pedis artery: stenotic
Left femoral artery: biphasic
Left popliteal artery: stenotic
Left posterior tibial artery: stenotic
Left dorsalis pedis artery: stenotic

Systolic pressures (mm Hg)
Brachial: 150
Right popliteal: 131
Right posterior tibial: 130
Right dorsalis pedis: 83
Left popliteal: 106
Left posterior tibial: 43
Left dorsalis pedis: 45
Tibial Angioplasty
Case 5

- 55M presents to ER with base of 5\textsuperscript{th} metatarsal ulcer
- BS 500
ABI
Toe Pressures

Measure the Toe Pressure Instead

- “Trust ABI when low but not when high.”
- Toe pressures have proven to be an excellent option for the diagnosis of PAD in patients at risk for falsely elevated ABI >1.4 values.
- Toe arteries are smaller and more easy to occlude.
- Accurate toe pressures require sensitive techniques such as laser Doppler.

Toe Pressures

- Digital arteries infrequently calcify
- In absence of flow-limiting proximal atherosclerotic disease, no significant difference in mean TBIs in normal diabetic and nondiabetic patients
- TBI <0.5—moderate proximal arterial disease
- TBI <0.2 or TP <30 mm Hg—critical ischemia with poor healing potential
Case 6

- 58M banker who complains of intermittent claudication while golfing
- Lifestyle severely limited
- Denies rest pain or tissue loss
Exercise ABI
SFA Angioplasty
Case 7

- 53M seen by pain management for spinal stenosis
- Bilateral hip/buttock pain with minimal ambulation
- Smokes 1 ppd x 40 years
Segmental Blood Pressures, Doppler and PVR

R Thigh 4 s PVR
P=67 HR=73 Amp=0.347 RT=284 Sc=x12 G=3

R Ab Knee 4 s PVR
P=66 HR=71 Amp=0.255 RT=326 Sc=x12 G=3

R Bl Knee 4 s PVR
P=69 HR=70 Amp=0.485 RT=310 Sc=x10 G=3

R Ankle 4 s PVR
P=56 HR=36 Amp=0.149 RT=166 Sc=x16 G=3

L Thigh 4 s PVR
P=68 HR=69 Amp=0.199 RT=250 Sc=x12 G=3

L Ab Knee 4 s PVR
P=65 HR=70 Amp=0.126 RT=264 Sc=x12 G=3

L Bl Knee 4 s PVR
P=63 HR=71 Amp=0.130 RT=264 Sc=x10 G=3

L Ankle 4 s PVR
P=57 HR=50 Amp=0.167 RT=126 Sc=x16 G=3

ABI
CT angio
Aortobifemoral Bypass
Postoperative ABI

Segmental Blood Pressures, Doppler and PVR

R Popliteal 4 s

L Popliteal 4 s

R Post Tibial 4 s

L Post Tibial 4 s

R Dors Pedis 4 s

L Dors Pedis 4 s

1.11 156 PT 151 1.07

0.97 137 DP 144 1.02

0.57 80 141 1.00