Role of ABI in Detecting and Quantifying Peripheral Arterial Disease

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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
Foam Cells  Fatty Streak  Intermediate Lesion  Atheroma  Fibrous Plaque  Complicated Lesion/Rupture

Endothelial Dysfunction

From First Decade  From Third Decade  From Fourth Decade
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>
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
GANGRENE / TISSUE LOSS

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
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

**Formula:**

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

**Interpretation of ABI:**
- >1.30: uncompressed
- 0.91~1.29: normal
- 0.41~0.90: 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*
### 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>
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
\( p = 0.041 \)

European Society of Cardiology Vol 4 2014
Pathogenesis of PVD
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

Thresholds:
- R) Ankle: Gain 20%, Amp 18 mm
- L) Ankle: Gain 20%, CV 14259 ml, Amp 22 mm
- R) Metatarsal: Gain 40%, Amp >31 mm
- L) Metatarsal: Gain 40%, CV 14253 ml, Amp >25 mm
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

Segmental BP
Segment/Brachial Index

R) High Thigh:
Gain %: 20
Amp: 20 mm

R) Low Thigh:
Gain %: 15
Amp: 30 mm

R) Calc:
Gain %: 15
Amp: 24 mm

R) Ankle:
Gain %: 15
Amp: 15 mm

R) Metatarsal:
Gain %: 30
Amp: 15 mm

L) High Thigh:
Gain %: 20
Amp: 12 mm

L) Low Thigh:
Gain %: 15
Amp: 8 mm

L) Calc:
Gain %: 15
Amp: 12 mm

L) Ankle:
Gain %: 15
Amp: 11 mm

L) Metatarsal:
Gain %: 30
Amp: 8 mm

0.75 Ankle/Bigeminal Index — 0.43
Where is the lesion?
Iliac Stenting

- Stents
  - Balloon stent in position across lesion
- Expansion of balloon & stent
- Sheath retracted
- Stent scaffolds artery after removal of balloon
Case 4

- 43M type 1 DM
- Owns glucometer but no strips
- BS 650
ABI and Segmental Pressures
Tibial Angioplasty
Case 5

- 55M presents to ER with base of 5th metatarsal ulcer
- BS 500
ABI
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

Segmental blood pressure

Right leg
- Thigh
  - Gain 10%
  - Amp: 16 mm
- Calf
  - Gain 10%
  - Amp: 16 mm
- Ankle
  - Gain 10%
  - Amp: 18 mm
- Metatarsal
  - Gain 10%
  - Amp: 5 mm
- Digit
  - Gain 10%
  - Amp: 14 mm

Left leg
- Thigh
  - Gain 10%
  - Amp: 16 mm
- Calf
  - Gain 10%
  - Amp: 40 mm
- Ankle
  - Gain 10%
  - Amp: 25 mm
- Metatarsal
  - Gain 10%
  - Amp: 10 mm
- Digit
  - Gain 10%
  - Amp: 24 mm

Segment/Brachial index

122 Brachial blood pressure

117

ABI (at rest)

1.14

1.28

1.22

1.16

1.11

0.88

0.80

0.80

0.76

65 (PT)

108 (PT)

98 (PT)

98 (DP)

141 (PT)

136 (DP)

138

156

Exercise ABI

Right leg
- Thigh
  - Gain 10%
  - Amp: 16 mm
- Calf
  - Gain 10%
  - Amp: 16 mm
- Ankle
  - Gain 10%
  - Amp: 18 mm
- Metatarsal
  - Gain 10%
  - Amp: 5 mm
- Digit
  - Gain 10%
  - Amp: 14 mm

Left leg
- Thigh
  - Gain 10%
  - Amp: 16 mm
- Calf
  - Gain 10%
  - Amp: 40 mm
- Ankle
  - Gain 10%
  - Amp: 25 mm
- Metatarsal
  - Gain 10%
  - Amp: 10 mm
- Digit
  - Gain 10%
  - Amp: 24 mm

Segment/Brachial index

122 Brachial blood pressure

117

ABI (at rest)

1.14

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1.16

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0.88

0.80

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0.76

65 (PT)

108 (PT)

98 (PT)

98 (DP)

141 (PT)

136 (DP)

138

156
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
ABI

Segmental Blood Pressures, Doppler and PVR

R Thigh 4 s

P=87 HR=73 Amp=0.347 RT=284 Sc=x12 G=3

R Ab Knee 4 s

P=66 HR=71 Amp=0.255 RT=326 Sc=x12 G=3

R Bl Kneee 4 s

P=59 HR=70 Amp=0.485 RT=310 Sc=x10 G=3

R Ankle 4 s

P=50 HR=36 Amp=0.149 RT=166 Sc=x16 G=3

L Thigh 4 s

P=88 HR=79 Amp=0.199 RT=250 Sc=x12 G=3

L Ab Knee 4 s

P=65 HR=70 Amp=0.126 RT=264 Sc=x12 G=3

L Bl Knee 4 s

P=63 HR=71 Amp=0.130 RT=264 Sc=x10 G=3

L Ankle 4 s

P=57 HR=50 Amp=0.167 RT=126 Sc=x16 G=3
Aortobifemoral Bypass

Abdominal aorta

Femoral artery

Blockage

Graft
Postoperative ABI

Segmental Blood Pressures, Doppler and PVR