How to Interpret Noninvasive Vascular Testing and Diagnose Peripheral Vascular Disease

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Clinical Diagnosis

- Claudication versus Spinal Stenosis
- Ischemic Rest Pain versus Neuropathic Pain
- Location of foot lesions – ischemic versus neuropathic
- Absence of symptoms does not rule out significant ischemia
Signs of PVD

- Pulse examination. Frequently inaccurate due to calcified vessels.
- Inflow versus outflow disease
- Autonomic neuropathy
- Dependent Rubor
Non Invasive Studies in PVD

• Many sophisticated tests available eg Ankle Brachial Indices, Segmental pulse volume recordings, Duplex ultrasound, Transcutaneous oxygen, Xenon flow studies.

• Most useful and cost effective is a hand held Doppler to assess wave form
Hand Held Doppler
## Interpreting the Ankle–Brachial Index

<table>
<thead>
<tr>
<th>ABI</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.90–1.30</td>
<td>Normal</td>
</tr>
<tr>
<td>0.70–0.89</td>
<td>Mild</td>
</tr>
<tr>
<td>0.40–0.69</td>
<td>Moderate</td>
</tr>
<tr>
<td>≤0.40</td>
<td>Severe</td>
</tr>
<tr>
<td>&gt;1.30</td>
<td>Noncompressible vessels</td>
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</tbody>
</table>

INDIRECT TESTING COMPONENTS: Reliable & Inexpensive

ABI (Ankle–Brachial Index)

Multiple Level Segmental Pressures Using Doppler / Pneumatic Cuffs

Multiple / Single Level Pulse Volume Plethysmography (PVR)

Digital Pressures / Plethysmography (PPG)

TBI (Toe–Brachial Index) or DBI (Digital–Brachial Index)

Maneuver Measurements

Transthoracic Outlet Examination
Cold Immersion Testing
INDIRECT TESTING

IDENTIFICATION WITH INDIRECT TESTING CAPABILITY

INDIRECT TESTING: ABI

Some Considerations: False Elevation Of Values / ABI:

Arterial Wall (Medial) Calcification:

Common In Diabetics / Renal Failure Pt’s, Chronic Anticoagulation

Index 1.4 Usually / Greater Than 250-300 mmHg

Use Toe Pressure(s) → More True Vascular Status If False Elevation Suspected

Does Not Affect Doppler / PVR Measurements
INDIRECT TESTING: ABI

FALSE ELEVATION AT

.84

TOE Index Revealing
INDIRECT TESTING

IDENTIFICATION WITH INDIRECT TESTING CAPABILITY

INDIRECT TESTING: ABI

Variable Criteria #1

\[ \text{ABI} = 0.9 \rightarrow 1.0 \]

Symptomatic Patients With Borderline Or Normal Resting Values
Compare Pre / Post Exercise Values

\[ \text{ABI} = 0.6 \rightarrow 0.9 \]

Suspected Claudication Symptoms
Compare Pre / Post Exercise Values

\[ \text{ABI} < 0.5 \]

Exercise Testing Not Necessary
Most Likely Rest Pain

*Always Compliment ABI With Doppler Waveform Morphology*

INDIRECT TESTING: SEGMENTAL PRESSURES

• Can Localize Segment / Location Of Disease
• Vertical Pressure Comparisons
• Horizontal Pressure Comparisons
• Artifacts To Consider
• 4 Cuff Or 2 Cuff Method
INDIRECT TESTING
IDENTIFICATION WITH INDIRECT TESTING CAPABILITY

INDIRECT TESTING: SEGMENTAL Pressures

Some Common Values Stratifying Disease: Levels Of Disease

AORTOILIAC:

- Thigh / Brachial index .8 – 1.2 – Stenosis
- Thigh / Brachial index < 0.8 – Iliac occlusion

Reduced high thigh pressure may also result from combination of:

- CFA Occlusion / Stenosis
- SFA occlusion / Stenosis
- PFA Occlusion / Stenosis

• Applications of Noninvasive Vascular Techniques: Gelock, Guianani, Krebs; Saunders, 1988: Ch. 17, 299-322.
INDIRECT TESTING: SEGMENTAL Pressures

Some Common Values Stratifying Disease: 

Levels Of Disease

SFA DISEASE:

> 30 mmHg gradient between high thigh pressure and above knee pressure.

> 25 mmHg gradient between above knee pressure and contra lateral above knee pressure.

Applications of Noninvasive Vascular Techniques: Gelock, Guianani, Krebs; Saunders, 1988: Ch. 17, 299-322.

INDIRECT TESTING: SEGMENTAL Pressures

Some Common Values Stratifying Disease: Levels Of Disease

POPLITEAL DISEASE:

- > 30 mmHg gradient between above knee & below knee
- > 15 mmHg gradient between below knee & contra lateral below knee

Applications of Noninvasive Vascular Techniques: Gelock, Guianani, Krebs; Saunders, 1988: Ch. 17, 299-322.
INDIRECT TESTING: SEGMENTAL Pressures

TIBIOPERONEAL DISEASE:

- > 30mmHg gradient between below knee & ankle
- > 15 mmHg gradient between ankle pressure & contra lateral ankle

Applications of Noninvasive Vascular Techniques: Gelock, Guianani, Krebs; Saunders, 1988: Ch. 17, 299-322.
INDIRECT TESTING: SEGMENTAL Pressures

Some Common Values Stratifying Disease: Levels Of Disease

DIGITAL ARTERY DISEASE:

- Digital pressure < 60% of ankle pressure
- Toe / Brachial index < 0.7
- Toe systolic pressure < 30 mmHg Indicates a probable non-healing lesion
- Digit pressures < 80% of the brachial pressure indicate proximal disease

Applications of Noninvasive Vascular Techniques: Gelock, Guianani, Krebs; Saunders, 1988: Ch. 17, 299-322.
INDIRECT TESTING:

PULSE VOLUME RECORDING / PLETHYSMOGRAPHY

TO RECORD THE CURVE OF FILLING – Greek Origination
INDIRECT TESTING

IDENTIFICATION WITH INDIRECT TESTING CAPABILITY

INDIRECT TESTING: PULSE VOLUME RECORDING / PLETHYSMOGRAPHY

What Does It Do?

- Measures Changes In Pressure Within The Cuff

  Pressure Changes In The Volume Of The Cuff Or Bladder

  Relates To

  ↓

  Pressure Changes Within Limb Volume Detected

- Cuffs At Various Levels Compare Volume Changes Between Horizontal + Vertical Levels

- Typically Inflated To 65 mmHg (*Protocols Vary*) Enough To Provide Contact To Skin And To Reflect Pulsatility

- Amplitude Changes On The Graph
INDIRECT TESTING

IDENTIFICATION WITH INDIRECT TESTING CAPABILITY

INDIRECT TESTING: PULSE VOLUME RECORDING / PLETHYSMOGRAPHY

PVR Influenced By:

- Blood Pressure
- Volume Of Blood (Infection? Cellulitis?)
- Position Of Extremity
- Overall Size Of Extremity
- Cardiac Stroke Volume
- May Even Be Different On Same Patient B/W Visits
- Large Habitus + Edema Will Attenuate PVR Presentation / Wave
- Excessive or Not Enough Cuff Inflation
INDIRECT TESTING: PULSE VOLUME RECORDING / PLETHYSMOGRAPHY

USEFUL FOR:

**Determining Level Of Disease:**
- Aorto-Iliac + Outflow
- Proximal SFA / DFA Involvement
- Mid SFA / Abductor Canal
- Popliteal / Tibial

**Other Uses:**
- Pre + Post Exercise Measurements
- Intra-Op Monitoring
- Post-Op Evaluations
- Healing Potential
- Confirmation Of Rest Pain Symptoms
INDIRECT TESTING: PULSE VOLUME RECORDING / PLETHYSMOGRAPHY

CONTOUR PRESENTATION: NORMAL

Dicrotic Notch Present

(Arterial Pulse Reverse Component)

Higher Amplitude BK
INDIRECT TESTING: PULSE VOLUME RECORDING / PLETHYSMOGRAPHY

CONTOUR PRESENTATION: NORMAL

Dicrotic Notch
- More Pronounced W/ Vasoconstriction
- Less Pronounced / Disappears W/ Vasodilation
- W/ Prox. Obstruction
INDIRECT TESTING: PULSE VOLUME RECORDING / PLETHYSMOGRAPHY

CONTOUR PRESENTATION: MILD  (Criteria Varies)

- Loss Of Dicrotic Notch
- Upstroke Is Less Steep
- Rounded Peak
- Down slope Bowing
INDIRECT TESTING: PULSE VOLUME RECORDING / PLETHYSMOGRAPHY

CONTOUR PRESENTATION: (Criteria Varies)

MODERATE

SEVERE

Less Amplitude With Severity
INDIRECT TESTING: PULSE VOLUME RECORDING / PLETHYSMOGRAPHY

CONTOUR PRESENTATION:  *(Criteria Varies)*

Tachycardia – Camouflaged Notch  Obviously Normal
INDIRECT TESTING: PULSE VOLUME RECORDING / PLETHYSMOGRAPHY

CONTOUR PRESENTATION: (Criteria Varies)

Popliteal / Tibial Trunk Disease
INDIRECT TESTING
IDENTIFICATION WITH INDIRECT TESTING CAPABILITY

INDIRECT TESTING: PULSE VOLUME RECORDING / PLETHYSMOGRAPHY

CONTOUR PRESENTATION: (Criteria Varies)

Well Developed Collaterization?
INDIRECT TESTING
IDENTIFICATION WITH INDIRECT TESTING CAPABILITY

INDIRECT TESTING:

CW DOPPLER
INDIRECT TESTING
IDENTIFICATION WITH INDIRECT TESTING CAPABILITY

INDIRECT TESTING: CW DOPPLER

- Reflects The Compliance and Elasticity Of The Artery
- Triphasic Morphology Normal
- Loss Of Phasicity Due To Decreased Elasticity / Compliance Of The Artery As Disease Progresses

Reversal In Early Diastole
Forward In Late Diastole

NORMAL
INDIRECT TESTING
IDENTIFICATION WITH INDIRECT TESTING CAPABILITY

INDIRECT TESTING: CW DOPPLER

• Reflects the compliance and elasticity of the artery
• Loss of phasicity due to decreased elasticity/compliance of the artery as disease progresses

BIPHASIC

MONOPHASIC

What's the Difference? →

Forward in Late Diastole Loss
INDIRECT TESTING
IDENTIFICATION WITH INDIRECT TESTING CAPABILITY

INDIRECT TESTING: CW DOPPLER

NOTE:

- CW Is Qualitative
- Between Region Changes Indicate Disease
- Sensitivity Reduced:
  - Obesity
  - Wrong Freq. Selection
  - Scarring Of Skin
  - Calcifications W/In Artery Insonated
- Artifacts:
  - Venous Interference
  - Movement
- Correct Filter / Scale Adjustment
- Don’t Make A Triphasic Signal Look Biphasic

Requires Expertise In Obtaining True Doppler Insonation Angle &
Clean Signal For True Morphology
INDIRECT TESTING
IDENTIFICATION WITH INDIRECT TESTING CAPABILITY

INDIRECT TESTING: CW DOPPLER

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CW

– Morphology At And Distal To Stenosis Confirmed By Arterial Duplex Same Day

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Notes - See Attached RT ARTERIAL DUPLEX worksheet also performed for positive findings. Increase in RT SFA amplitude, corresponds with increased velocity seen on RT Duplex performed prior today.
INDIRECT TESTING
IDENTIFICATION WITH INDIRECT TESTING CAPABILITY

INDIRECT TESTING:

TREADMILL EXERCISE TESTING
INDIRECT TESTING: TREADMILL EXERCISE TESTING

MAIN INDICATIONS:

- Important for differentiating true vascular claudication from pseudo-claudication
- Performed on all patients that complain of pain while walking
- Evaluate S/P Revascularization (Iliac Stents, etc.)

ABI’s MAY BE NORMAL AT REST:
- Collateral Development Adequate For Resting Vascular State
- Not Adequate With Increased Demand For Blood Supply

WITH EXERCISE:
- Obstruction Present Will Not Be Able To Meet Perfusion Needs
- Need Will Exceed Collateral Capability
- Significant Pressure Drop As Result
INDIRECT TESTING: TREADMILL EXERCISE TESTING

MAIN CONTRA-INDICATIONS:

- ABI less than .5 (Varies)
- Recent onset of chest pain
- Severe Pulmonary Disease
- ? Cardiac status, known cardio-vasc. dis., prev. MI or CABG
- Severe pulmonary disease / Shortness of Breath
- Inability to ambulate at treadmill speed
- Ischemic rest pain
- Ischemic limb ulceration

*If the Patient’s symptoms occur at rest (non-claudication symptoms) and the resting examination is negative, there is no need to exercise the patient (?)
INDIRECT TESTING: TREADMILL EXERCISE TESTING

OPTIONS OTHER THAN TREADMILL:

• Toe Ups / Toe Raises
  Simple & Effective

• Reactive Hyperemia
  Can Be Painful
  Occlusion Of Cuff / Post Release Measurements

Lab Dependant, Personal Physician Preference, Supporting Data Exists For All Methods Of Post Maneuver Measurements
INDIRECT TESTING: TREADMILL EXERCISE TESTING

Discussion: Method

Patient Walks For Specified Time At Specified Grade Or Until Symptoms Halt Exercise

Protocols Vary:

- 5 Minutes, 10% (7°) Grade At 1.5 MPH
- 5 Minutes, 12% Grade At 2 MPH
- More..
INDIRECT TESTING
IDENTIFICATION WITH INDIRECT TESTING CAPABILITY

INDIRECT TESTING: TREADMILL EXERCISE TESTING

METHOD Discussion: Post Exercise Measurements

Protocols Vary:

• **Immediate Ankle + Brachial Pressure**
  30 Second Intervals – First 4 Minutes
  Immediate Post Ex PVR
  Every Minute Until Pressure Returns To Resting State (< 10 min.)

• **Immediate Ankle + Brachial Pressure**
  2 Minute Intervals Until Pressure Returns To Resting State
  (<10 min)

• **All Protocols**: Record PT Symptoms While Exercising

Post Exercise PVR For Non-Occlusive ABI
IDENTIFICATION WITH INDIRECT TESTING CAPABILITY

INDIRECT TESTING: TREADMILL EXERCISE TESTING

PRE RT: .85
POST RT: .37
INDIRECT TESTING: EXERCISE TESTING

METHOD Discussion: Toe Raises

PT Standing – Raises On Toes – Returns To Flat
Performed Until PT Cannot Continue Or Set Rate (50)
Symptom Onset / Toe Raising #’s Recorded

Has Been Considered As Criteria For Positive (Varies)

> 20 mmHg Drop In Pressure
↓ of 20% Of Resting ABI

Some Considerations:

Can Be Alternative To Treadmill Exercise
Cardiac Risk Factors / Exertional Limitations
Calf Pain May Be Due To General Fatigue
Treadmill Exercise More Accurate For Claudicate Patients
INDIRECT TESTING

IDENTIFICATION WITH INDIRECT TESTING CAPABILITY

INDIRECT TESTING: EXERCISE TESTING

METHOD Discussion: Reactive Hyperemia

- Inflate Thigh Cuff > 20 mmHg Beyond Thigh Pressure
- Maintain Inflation B/W 3-5 Minutes
- Release And Obtain Ankle Pressures

General Criteria:

↓ In 20 mmHg (+)

Limitations:

- Difficult Differentiating True vs. Pseudoclaudication
- Extremely Painful For Most Patients

Some Considerations:

- Apply Calf Cuff Instead Of Thigh In Suspected Below CFA Disease
COLOR DUPLEX

VS.

SEGMENTAL / INDIRECT PHYIOLOGIC ASSESSEMENT
SEGMENTAL BP / PVR Suggested For Primary Diagnosis:

• Reimbursement Conditions & Requirements
• Used For 1st Time Diagnosis/ Initial Screen
  * * Localize + Characterize Arterial Disease
• Follow Up Exams
  Revascularization
  Functional Status Of Stents/ Grafts
  Treadmill Exercise
• General Limitations:
  Cannot Differentiate From Tight Stenosis Vs. Collaterization
  False Elevation Of Pressures
  Exact Segment Difficult To Quantify
COLOR DUPLEX - Suggested In Known Disease States:

- Localizes Stenosis + Severity Of Stenosis
- Collateral Development Visualization
- F/U Revascularization Patentcy
  Stent + Graft + Angioplasty

General Limitations:

Regions Difficult To Assess:
- Tibial Vessels + Tibio – Peroneal Trunk
- Calcification / Dense Plaque
- Iliac Involvement
INDIRECT TESTING

SEG BP / PVR VS DUPLEX SUMMATION

Best Used In Conjunction
Each Have Specific Indications
Follow Recommendations By ICAVL / Other Associations

GENERAL ACCEPTED PRACTICES:

General Concept Is To Use Physiological Assessment For PT Management / Decision Making Initially
Color Duplex Utilization For Further Quantification
INDIRECT TESTING

TAKE NOTE - EXAMPLE: Warm the Digits

Post 5 minutes Toe Warming
INDIRECT TESTING

TAKE NOTE - EXAMPLE 4 – Image When Suspicious

Doppler

Segmental BP

Gain: 20%

Gain: 52%

Gain: 20%

Gain: 20%

Gain: 20%

Gain: 52%

Gain: 25%

Gain: 18%

Gain: 18%

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INDIRECT TESTING

TAKE NOTE - EXAMPLE 4 - Image When Suspicious
Hand Held Doppler
When to Operate on Foot

• In patient with abscess systemic sepsis and an ischemic foot - I+D of the foot as an emergent procedure. Limit procedure to drainage of all pus and dead tissue

• Over extensive debridement may convert ischemic tissue to frank gangrene and thereby reduce options for closure of the foot
Severe infection secondary to MRSA
Chronic infection

• Generally can perform podiatric procedure 48 hours after revascularisation.

• Inflow procedures and revascularisation of peroneal artery may take 48 hours to obtain maximal perfusion of foot
Osteomyelitis
Beware!

- Revascularisation may convert dry gangrene to wet gangrene.
- Need to closely monitor and be prepared to perform urgent debridement.
Diabetic Foot
Thank you