

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

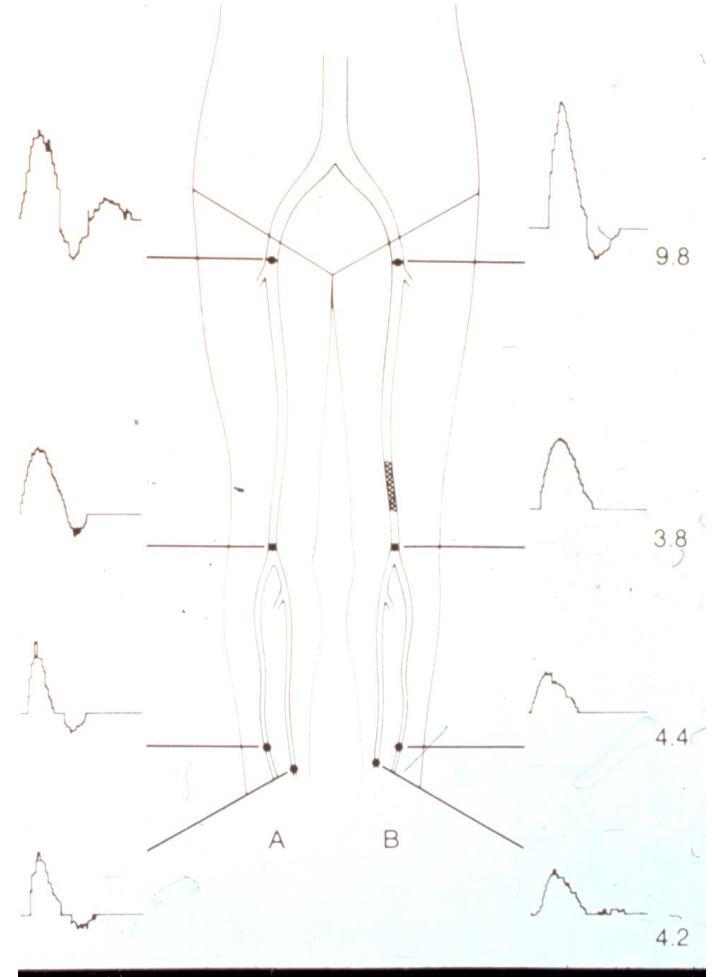
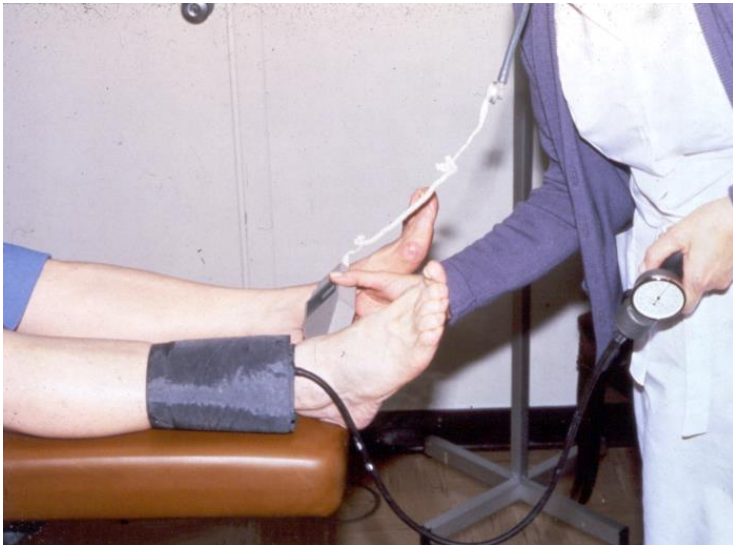




Non Invasive Studies in PVD

- 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

ABI	Interpretation
0.90–1.30	Normal
0.70–0.89	Mild
0.40–0.69	Moderate
≤ 0.40	Severe
> 1.30	Noncompressible vessels

Adapted from Hirsch AT. *Family Practice Recertification*. 2000;22:6-12.

INDIRECT TESTING

IDENTIFICATION WITH INDIRECT TESTING CAPABILITY

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 / Plesthythmography (*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**

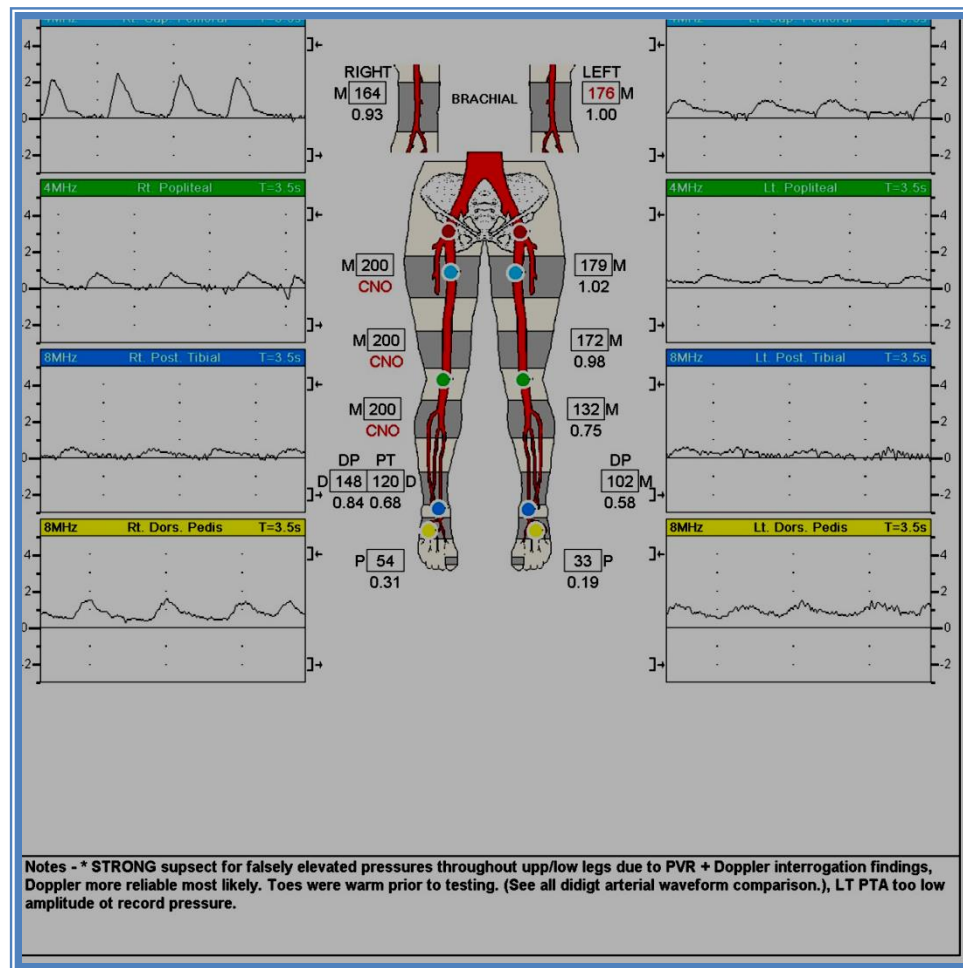
INDIRECT TESTING

IDENTIFICATION WITH INDIRECT TESTING CAPABILITY

INDIRECT TESTING: ABI

FALSE ELEVATION AT

.84



TOE Index Revealing

INDIRECT TESTING

IDENTIFICATION WITH INDIRECT TESTING CAPABILITY

INDIRECT TESTING: ABI

Variable Criteria #1

ABI = .9 → 1.0

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

ABI = .6 → .9

**Suspected Claudication Symptoms
Compare Pre / Post Exercise Values**

ABI = < .5

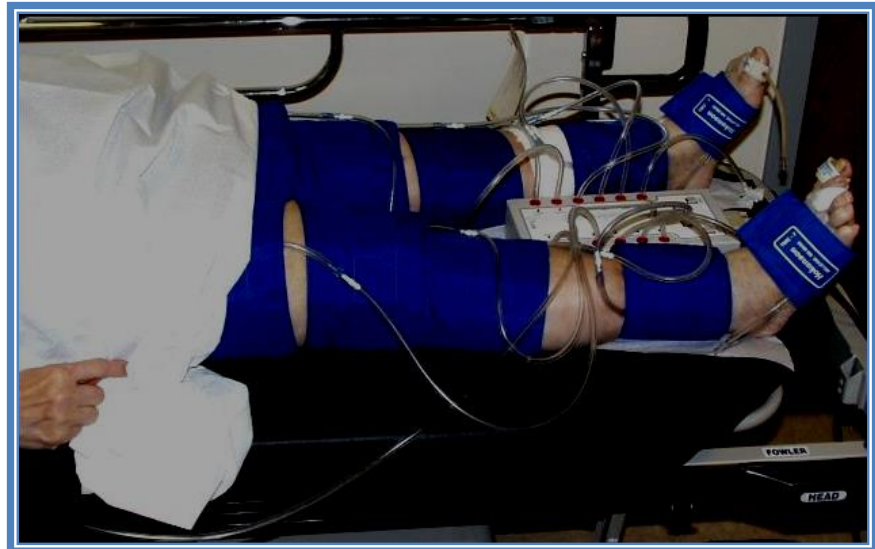
**Exercise Testing Not Necessary
Most Likely Rest Pain**

Always Compliment ABI With Doppler Waveform Morphology

IDENTIFICATION WITH INDIRECT TESTING CAPABILITY

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**

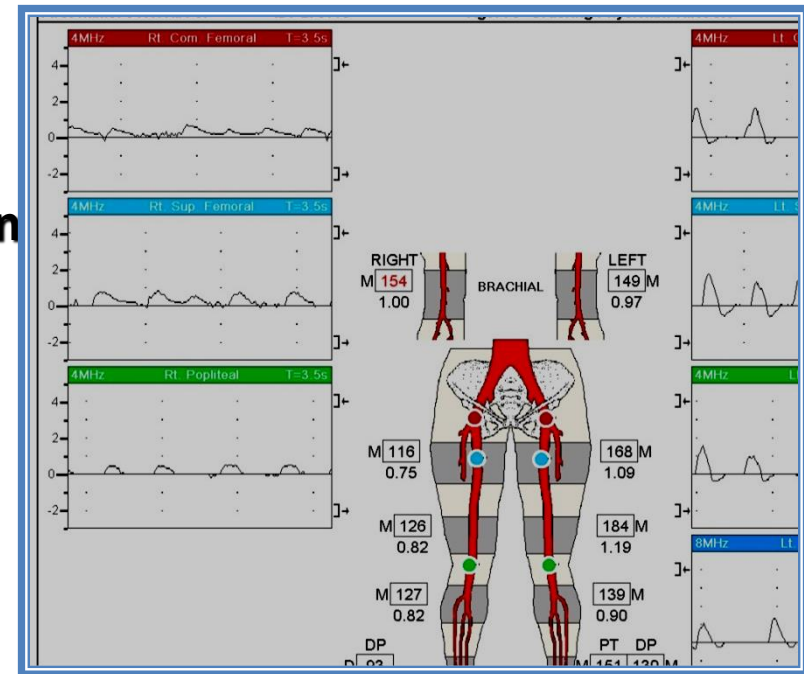


INDIRECT TESTING: SEGMENTAL Pressures**Some Common Values Stratifying Disease : Levels Of Disease****AORTOILIAC:**

- **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

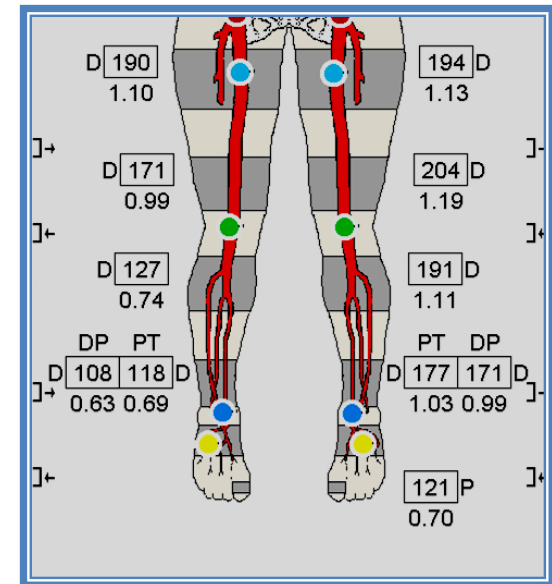


INDIRECT TESTING: SEGMENTAL Pressures

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.

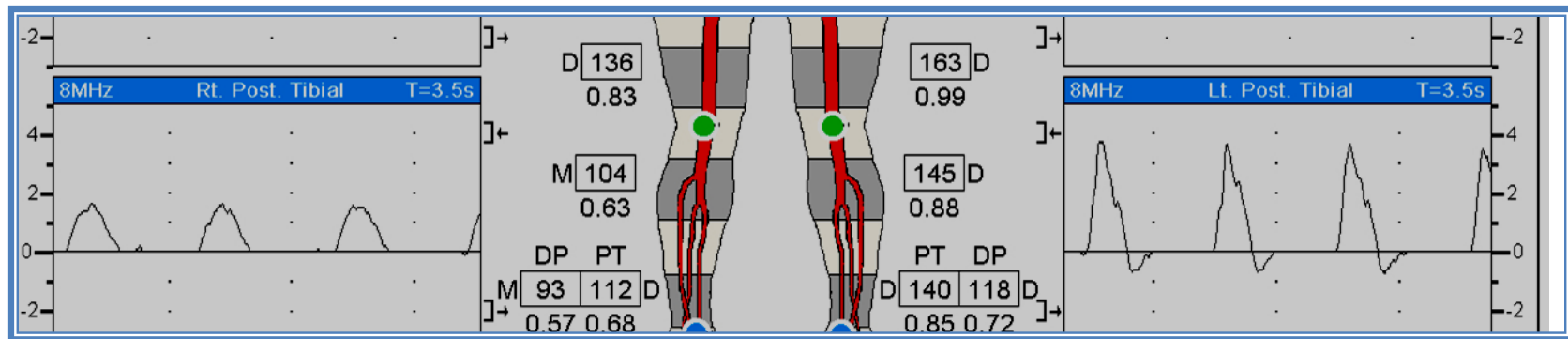


INDIRECT TESTING: SEGMENTAL Pressures

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**

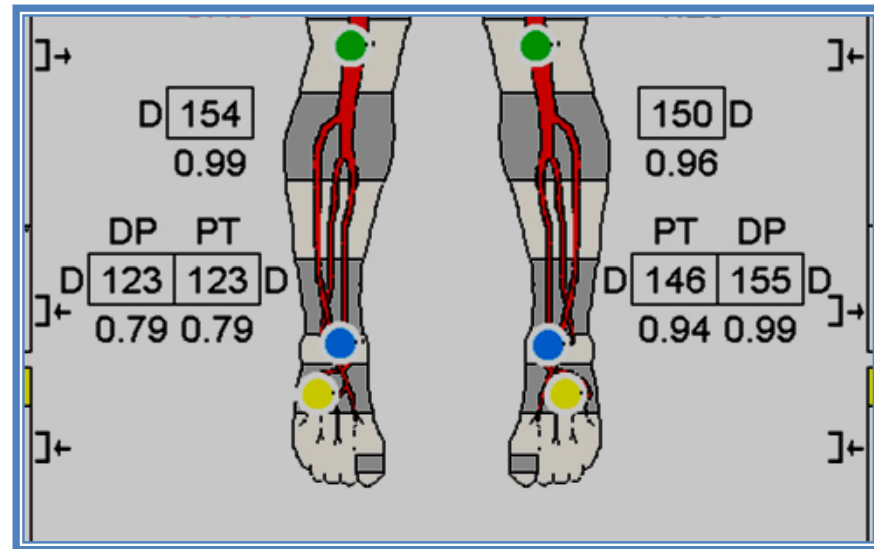


INDIRECT TESTING: SEGMENTAL Pressures

Some Common Values Stratifying Disease : Levels Of Disease

TIBIOPERONEAL DISEASE:

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

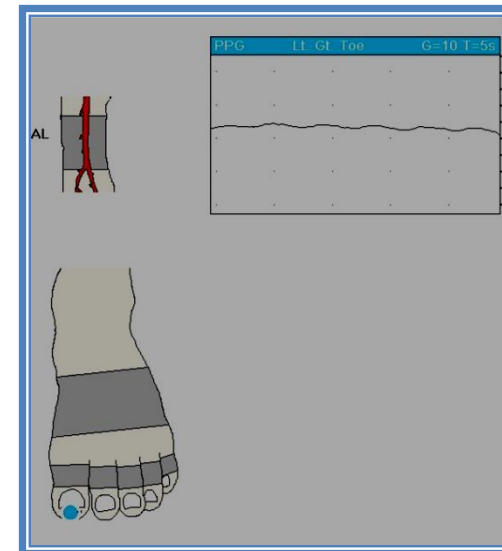
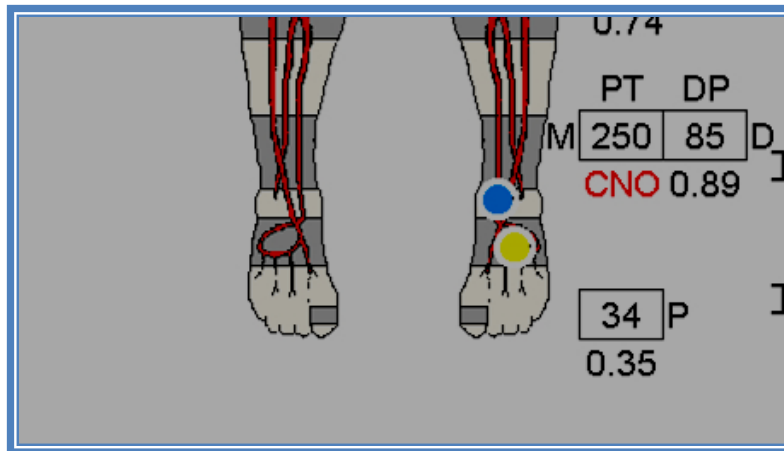


INDIRECT TESTING: SEGMENTAL Pressures

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



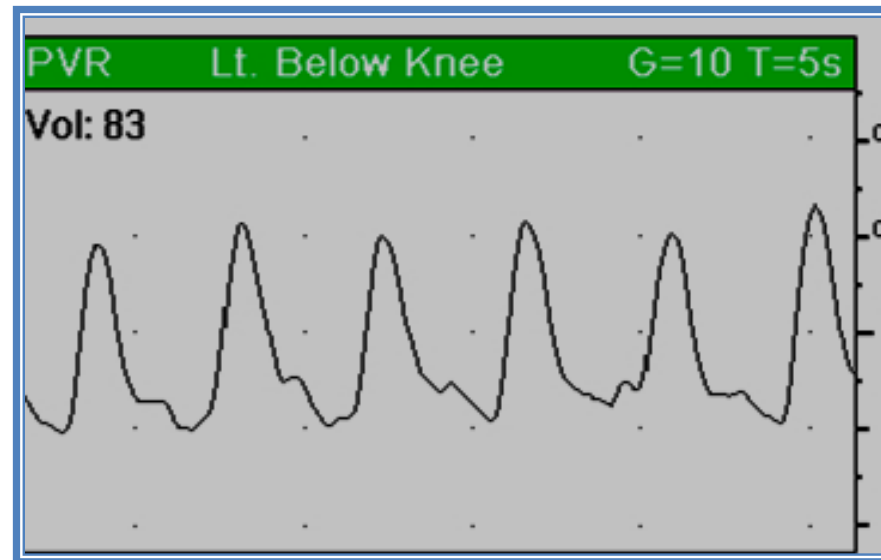
- Applications of Noninvasive Vascular Techniques: Gelock, Guianani, Krebs; Saunders, 1988: Ch. 17, 299-322.
- Segmental Pressures and Doppler Velocity Waveforms in the Evaluation of Peripheral Arterial Occlusive Disease: C. Burnham, BSN, RN, RVT. The Journal of Vascular Technology 18[5] 249-255, 1994.

INDIRECT TESTING

IDENTIFICATION WITH INDIRECT TESTING CAPABILITY

INDIRECT TESTING:

PULSE VOLUME RECORDING / PLETHYSMOGRAPHY



TO RECORD THE CURVE OF FILLING – *Greek Origination*

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**

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

IDENTIFICATION WITH INDIRECT TESTING CAPABILITY

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 :

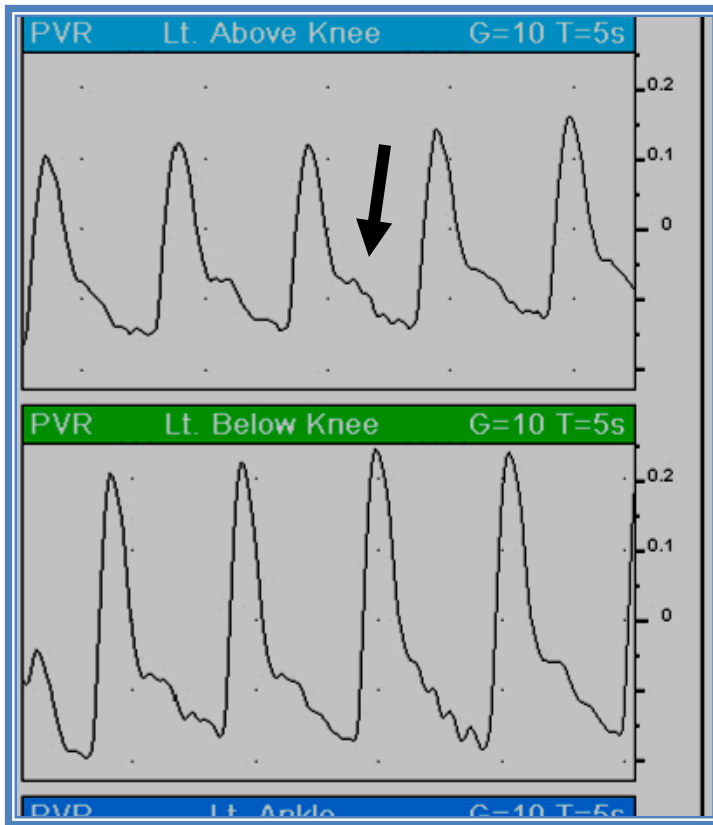
- Pre + Post Exercise Measurements**
- Intra-Op Monitoring**
- Post-Op Evaluations**
- Healing Potential**
- Confirmation Of Rest Pain Symptoms**

INDIRECT TESTING

IDENTIFICATION WITH INDIRECT TESTING CAPABILITY

INDIRECT TESTING: PULSE VOLUME RECORDING / PLETHYSMOGRAPHY

CONTOUR PRESENTATION: **NORMAL**



Dicrotic Notch Present

(*Arterial Pulse Reverse Component*)

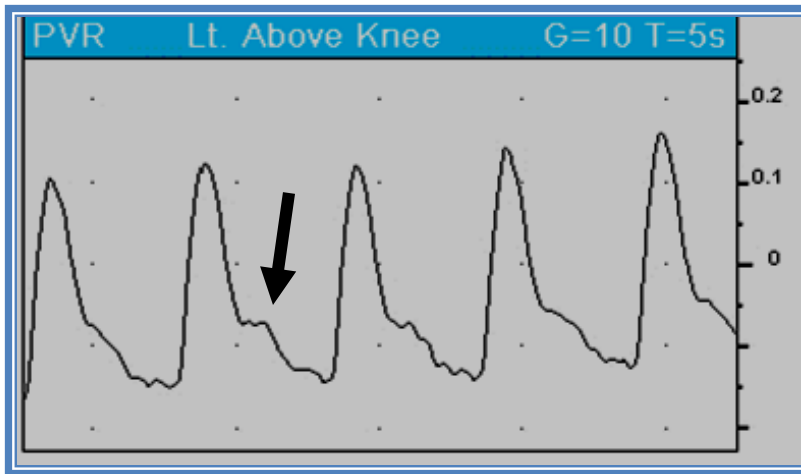
← Higher Amplitude BK

INDIRECT TESTING

IDENTIFICATION WITH INDIRECT TESTING CAPABILITY

INDIRECT TESTING: PULSE VOLUME RECORDING / PLETHYSMOGRAPHY

CONTOUR PRESENTATION: NORMAL



Dicrotic Notch

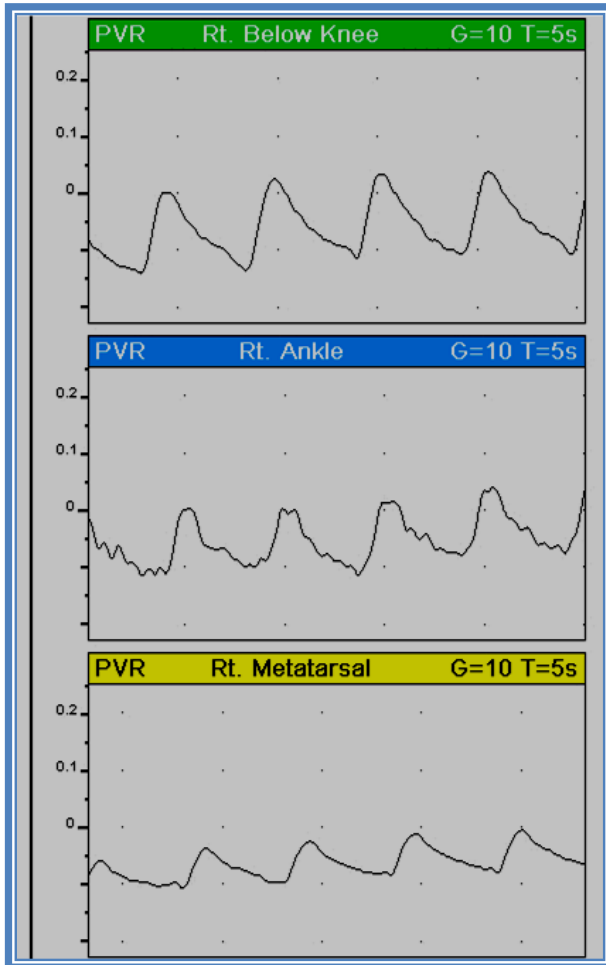
- **More Pronounced W/ Vasoconstriction**
- **Less Pronounced / Disappears**
W/ Vasodilation
W/ Prox. Obstruction

INDIRECT TESTING

IDENTIFICATION WITH INDIRECT TESTING CAPABILITY

INDIRECT TESTING: PULSE VOLUME RECORDING / PLETHYSMOGRAPHY

CONTOUR PRESENTATION: **MILD** (*Criteria Varies*)



Loss Of Dicrotic Notch

Upstroke Is Less Steep

Rounded Peak

Down slope Bowing

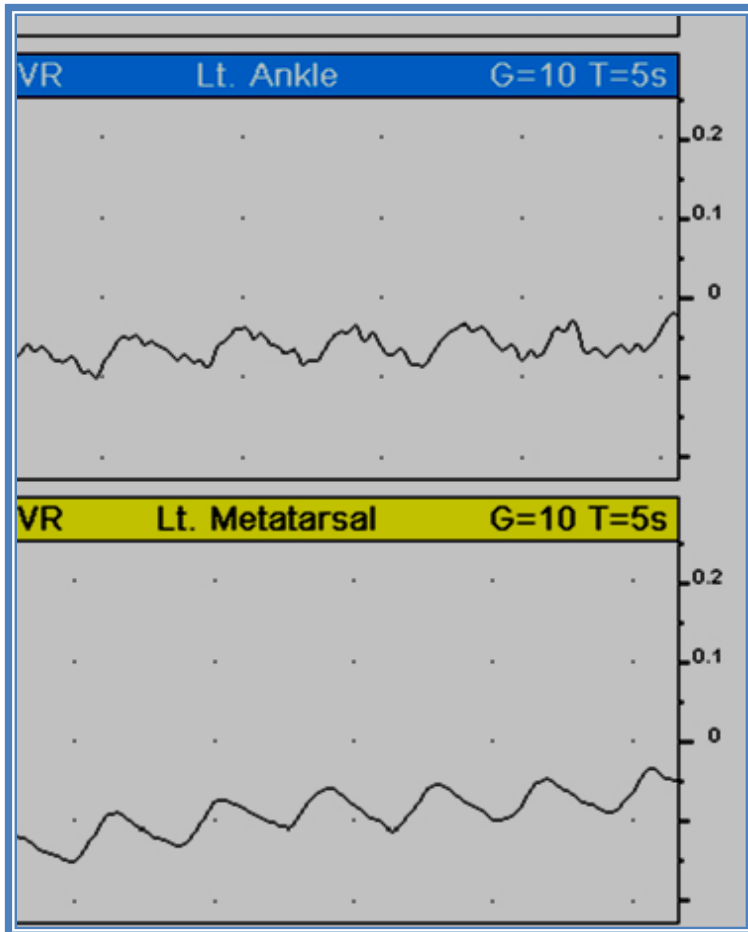
INDIRECT TESTING

IDENTIFICATION WITH INDIRECT TESTING CAPABILITY

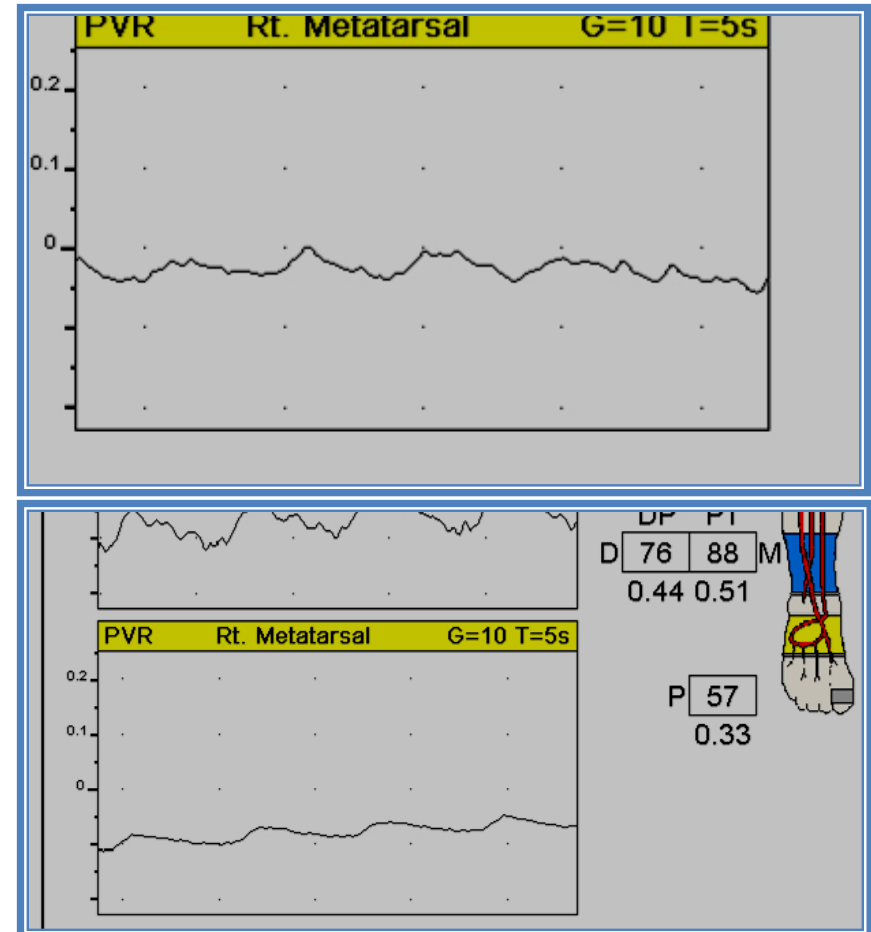
INDIRECT TESTING: PULSE VOLUME RECORDING / PLETHYSMOGRAPHY

CONTOUR PRESENTATION: (*Criteria Varies*)

MODERATE



SEVERE



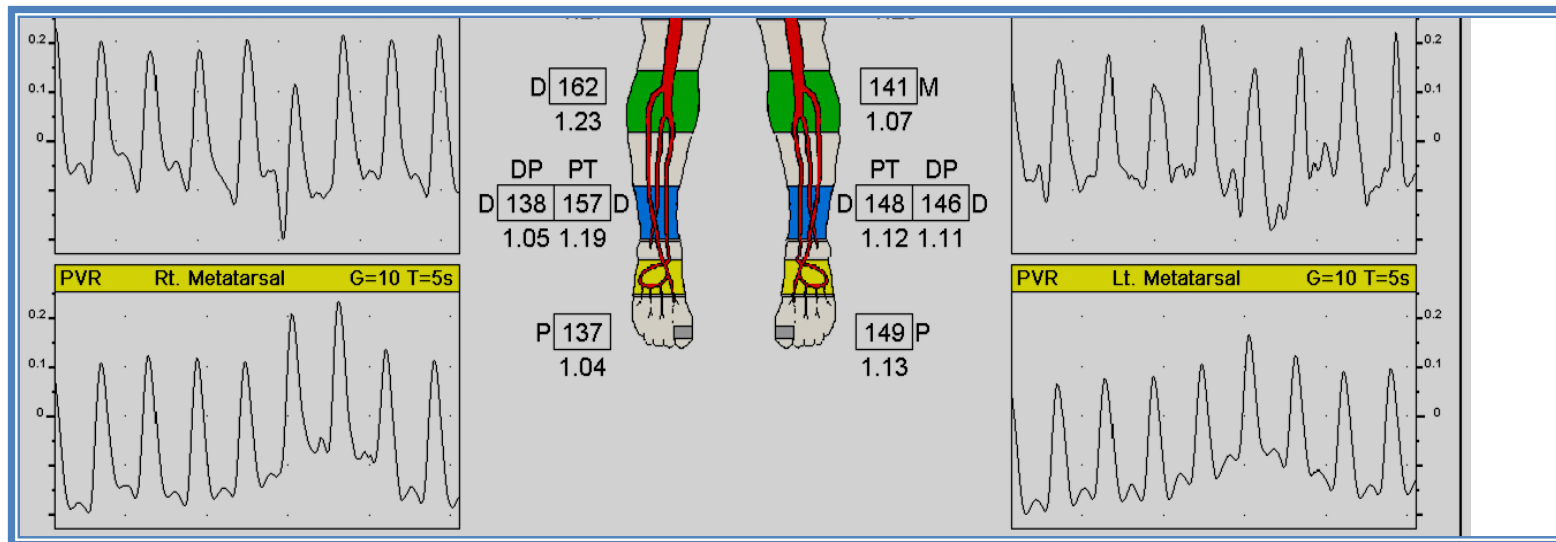
Less Amplitude With Severity

INDIRECT TESTING

IDENTIFICATION WITH INDIRECT TESTING CAPABILITY

INDIRECT TESTING: PULSE VOLUME RECORDING / PLETHYSMOGRAPHY

CONTOUR PRESENTATION: (*Criteria Varies*)



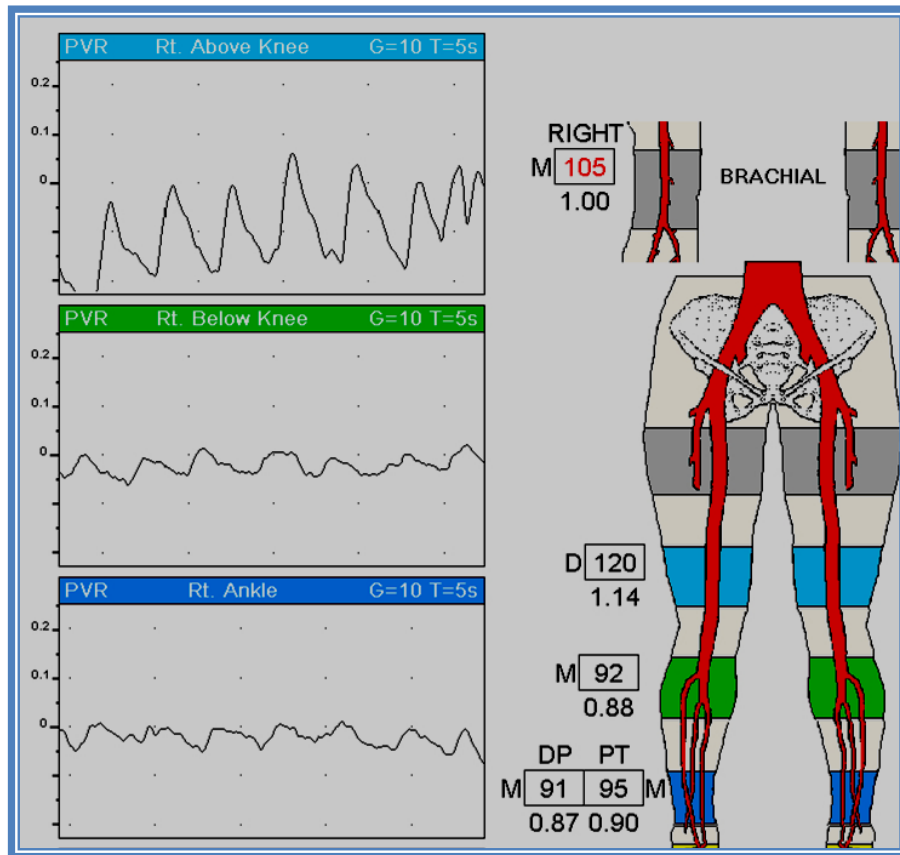
**Tachycardia – Camouflaged Notch
Obviously Normal**

INDIRECT TESTING

IDENTIFICATION WITH INDIRECT TESTING CAPABILITY

INDIRECT TESTING: PULSE VOLUME RECORDING / PLETHYSMOGRAPHY

CONTOUR PRESENTATION: (*Criteria Varies*)



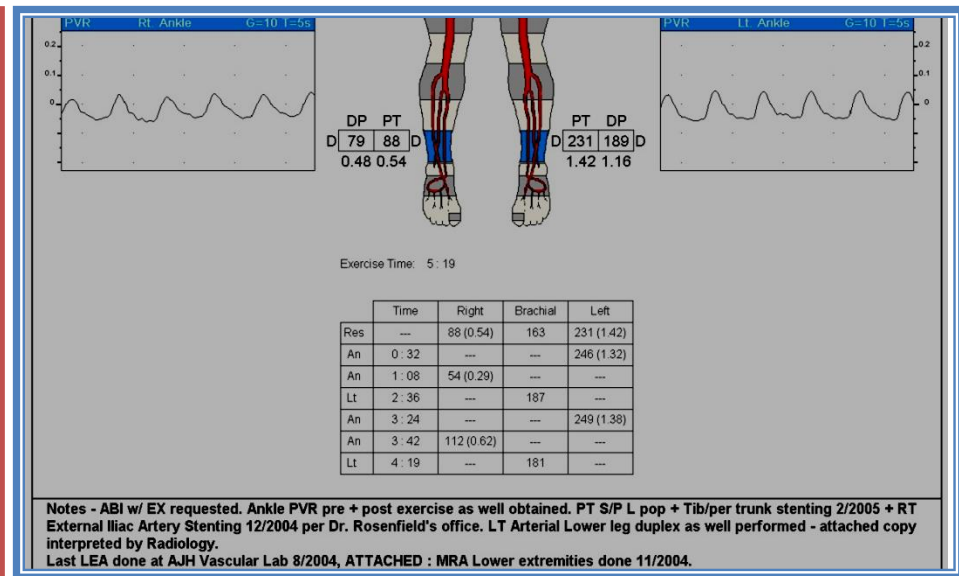
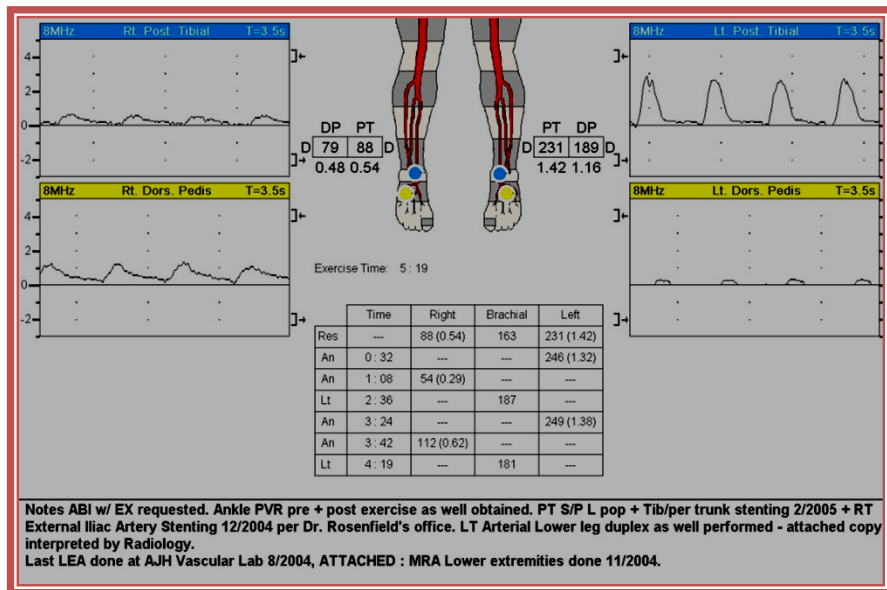
**Popliteal / Tibial Trunk
Disease**

INDIRECT TESTING

IDENTIFICATION WITH INDIRECT TESTING CAPABILITY

INDIRECT TESTING: PULSE VOLUME RECORDING / PLETHYSMOGRAPHY

CONTOUR PRESENTATION: (*Criteria Varies*)



Well Developed Collateralization ?

INDIRECT TESTING

IDENTIFICATION WITH INDIRECT TESTING CAPABILITY

INDIRECT TESTING:

CW DOPPLER

INDIRECT TESTING

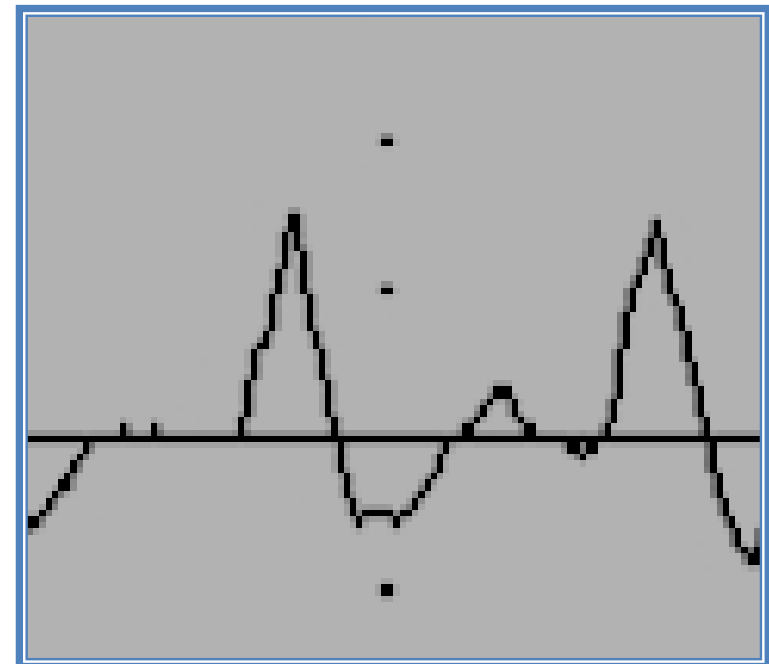
IDENTIFICATION WITH INDIRECT TESTING CAPABILITY

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

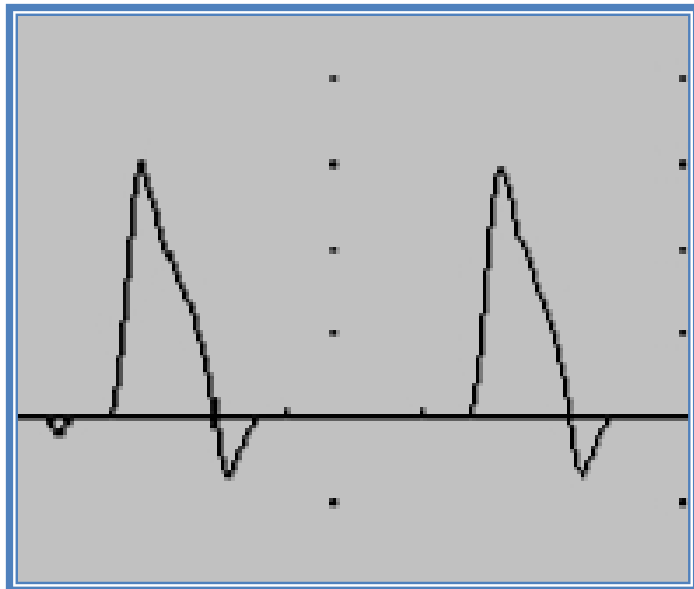
INDIRECT TESTING

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

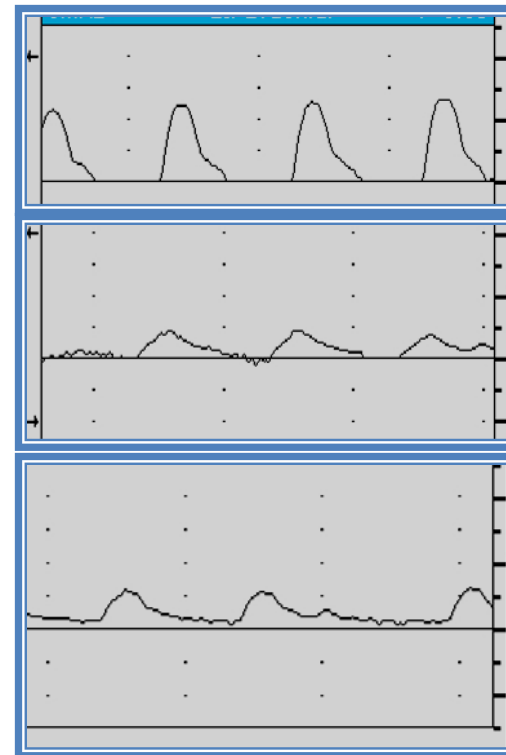
BIPHASIC



Forward In Late Diastole Loss

What's The
Difference? →

MONOPHASIC



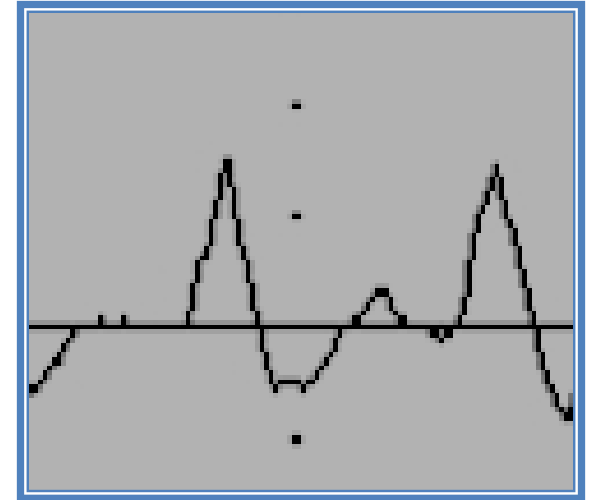
INDIRECT TESTING

IDENTIFICATION WITH INDIRECT TESTING CAPABILITY

INDIRECT TESTING: CW DOPPLER

NOTE :

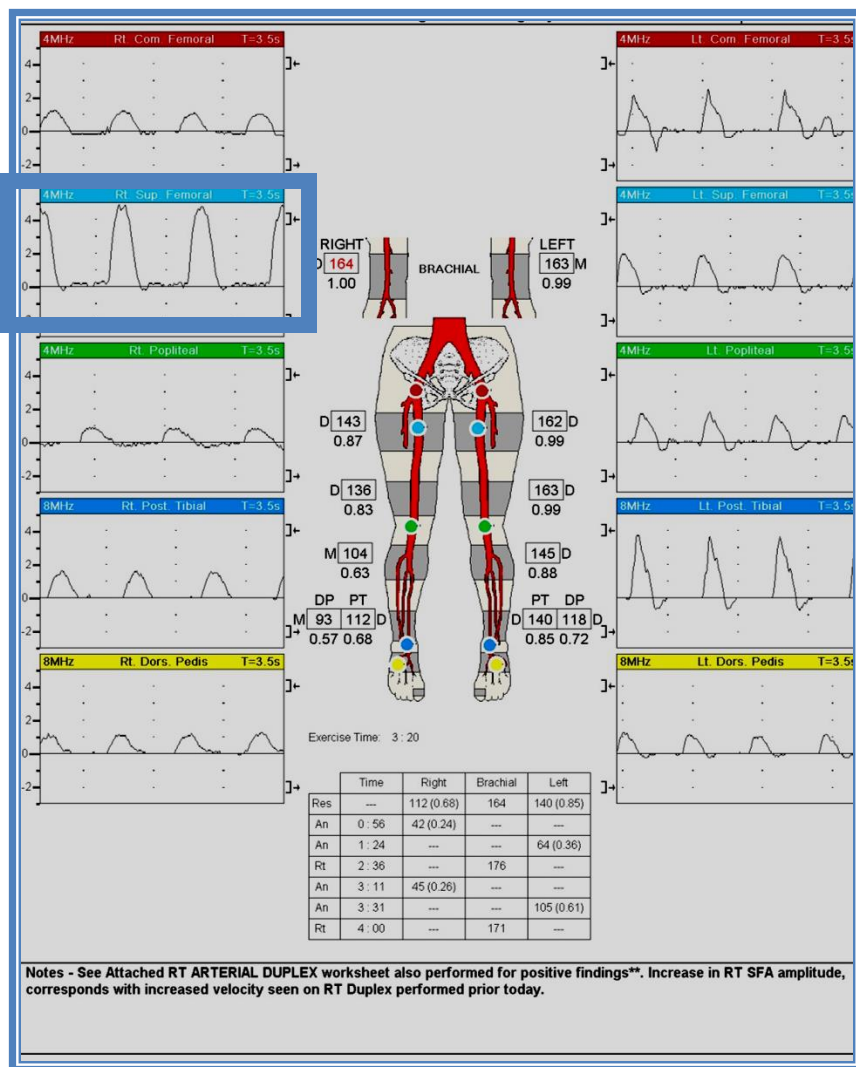
- **CW Is Qualitative**
- **Between Region Changes Indicate Disease**
- **Sensitivity Reduced :**
Obesity
Wrong Freq. Selection
Scarring Of Skin
Calcifications W/In Artery Insonated
- **Artifacts:**
Venous Interference
Movement
- **Correct Filter / Scale Adjustment**
- **Don't Make A Triphasic Signal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



**Requires Expertise In Obtaining True Doppler Insonation Angle &
Clean Signal For True Morphology**

IDENTIFICATION WITH INDIRECT TESTING CAPABILITY

INDIRECT TESTING: CW DOPPLER



CW

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

INDIRECT TESTING

IDENTIFICATION WITH INDIRECT TESTING CAPABILITY

INDIRECT TESTING:

TREADMILL EXERCISE TESTING

INDIRECT TESTING

IDENTIFICATION WITH INDIRECT TESTING CAPABILITY

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

IDENTIFICATION WITH INDIRECT TESTING CAPABILITY

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

IDENTIFICATION WITH INDIRECT TESTING CAPABILITY

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

IDENTIFICATION WITH INDIRECT TESTING CAPABILITY

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:

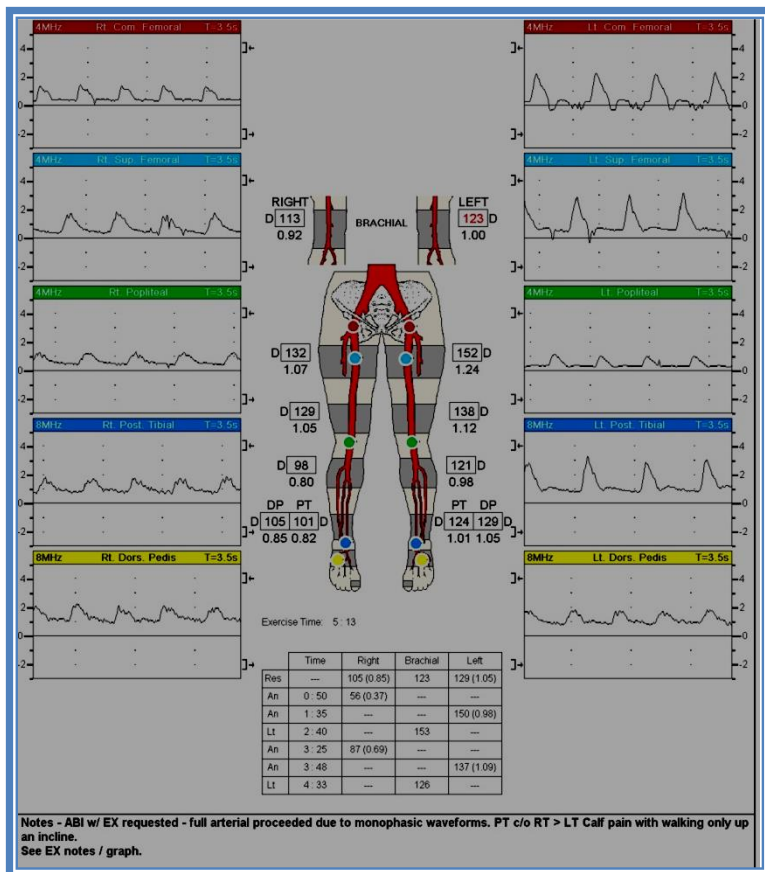
- Immediate Ankle + Brachial Pressure
30 Second Intervals – First 4 Minutes
Immediate Post Ex PVR
Every Minute Until Pressure Returns To Resting State (*< 10 min.*)
- Immediate Ankle + Brachial Pressure
2 Minute Intervals Until Pressure Returns To Resting State
(*<10 min*)
- *All Protocols : Record PT Symptoms While Exercising*

Post Exercise PVR For Non-Occlusive ABI

INDIRECT TESTING

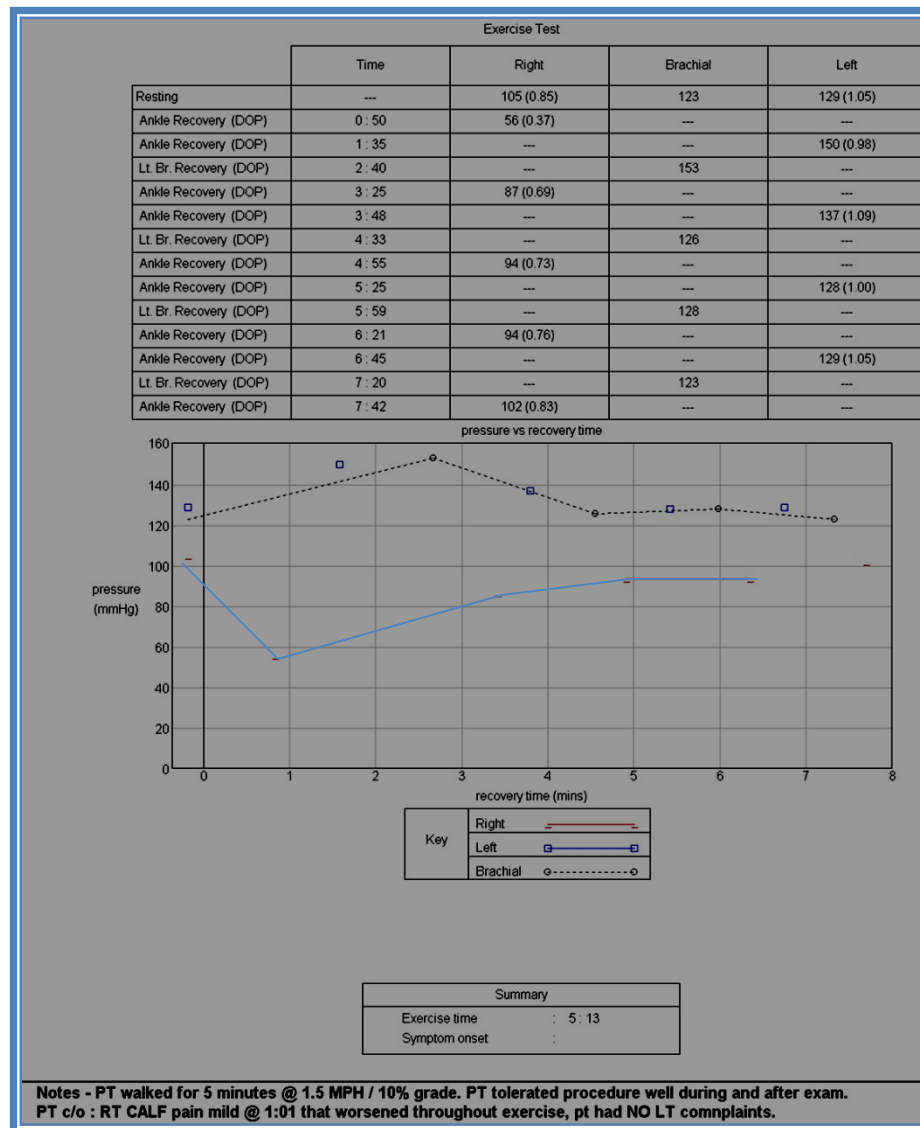
IDENTIFICATION WITH INDIRECT TESTING CAPABILITY

INDIRECT TESTING: TREADMILL EXERCISE TESTING



PRE RT : .85

POST RT: .37



INDIRECT TESTING

IDENTIFICATION WITH INDIRECT TESTING CAPABILITY

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**

INDIRECT TESTING

IDENTIFICATION WITH INDIRECT TESTING CAPABILITY

COLOR DUPLEX

VS.

SEGMENTAL / INDIRECT PHYSIOLOGIC ASSESSEMENT

INDIRECT TESTING

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. Collateralization**

 - False Elevation Of Pressures**

 - Exact Segment Difficult To Quantify**

INDIRECT TESTING

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

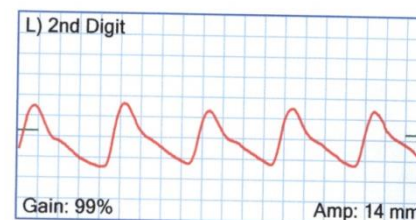
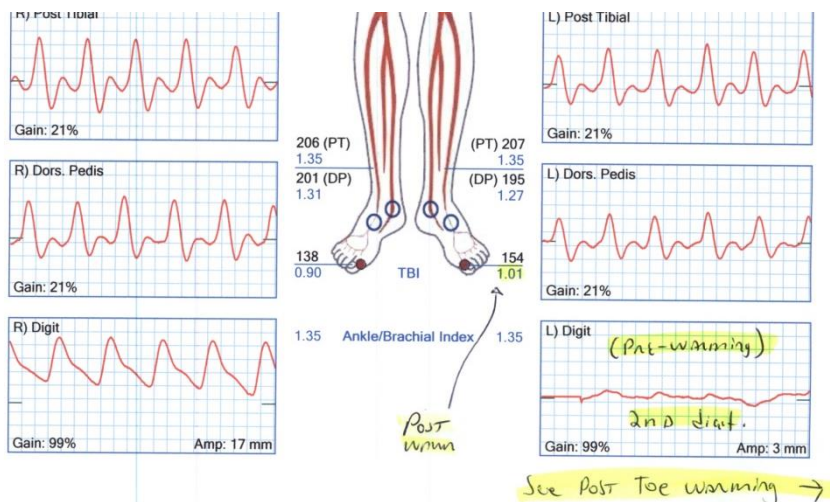
GENERAL ACCEPTED PRACTICES :

**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

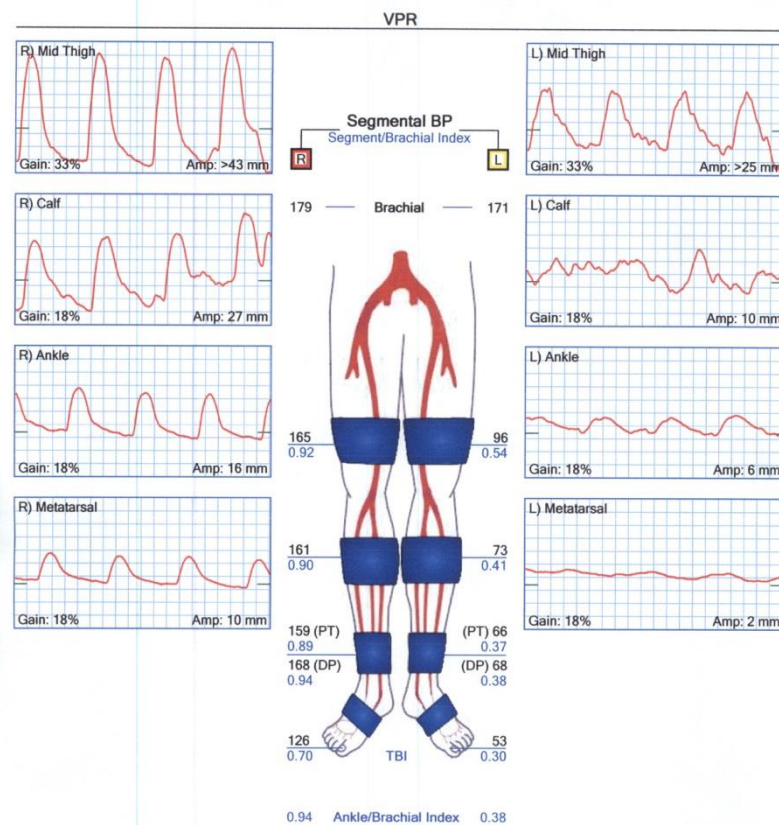
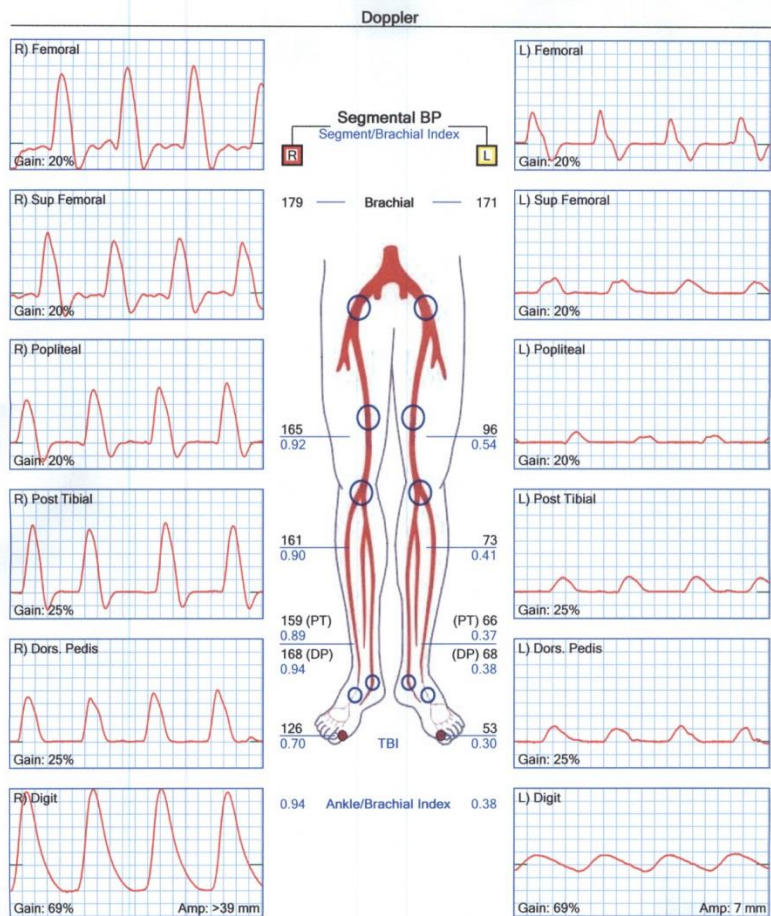


Post warming
5 minutes 2nd digit,
significant increase in
morphology.

Post 5 minutes Toe
Warming

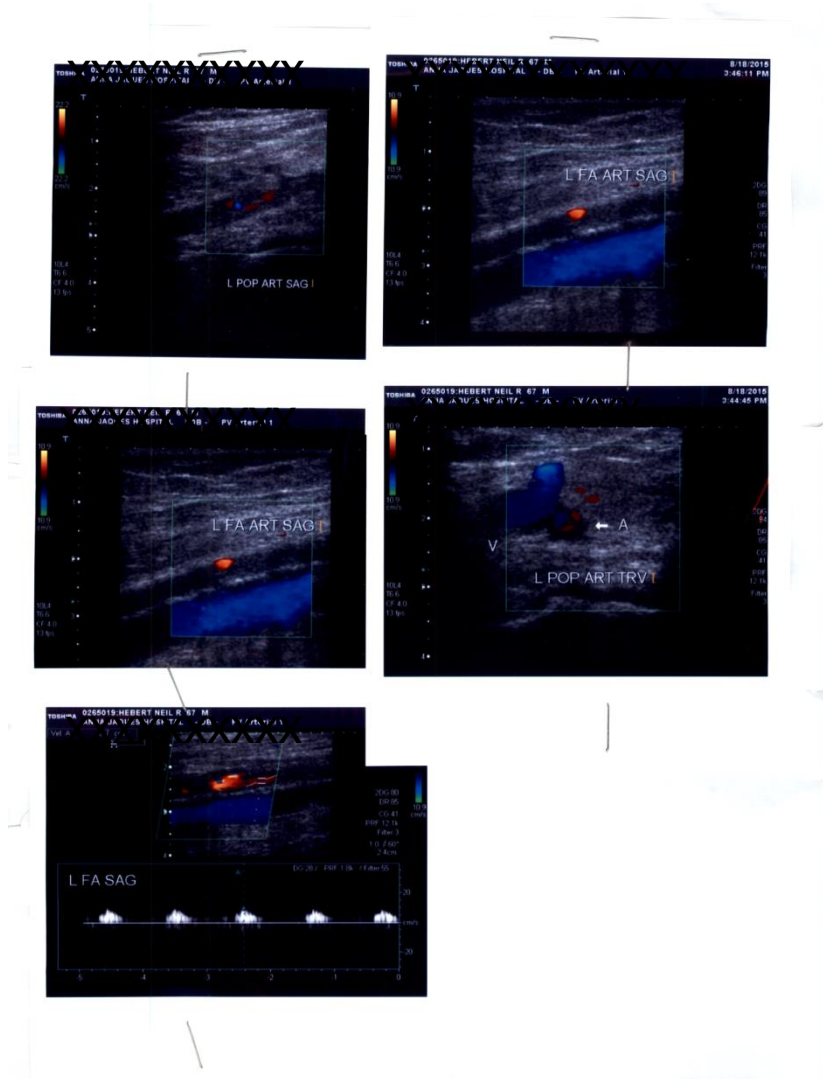
INDIRECT TESTING

TAKE NOTE - EXAMPLE 4 – Image When Suspicious

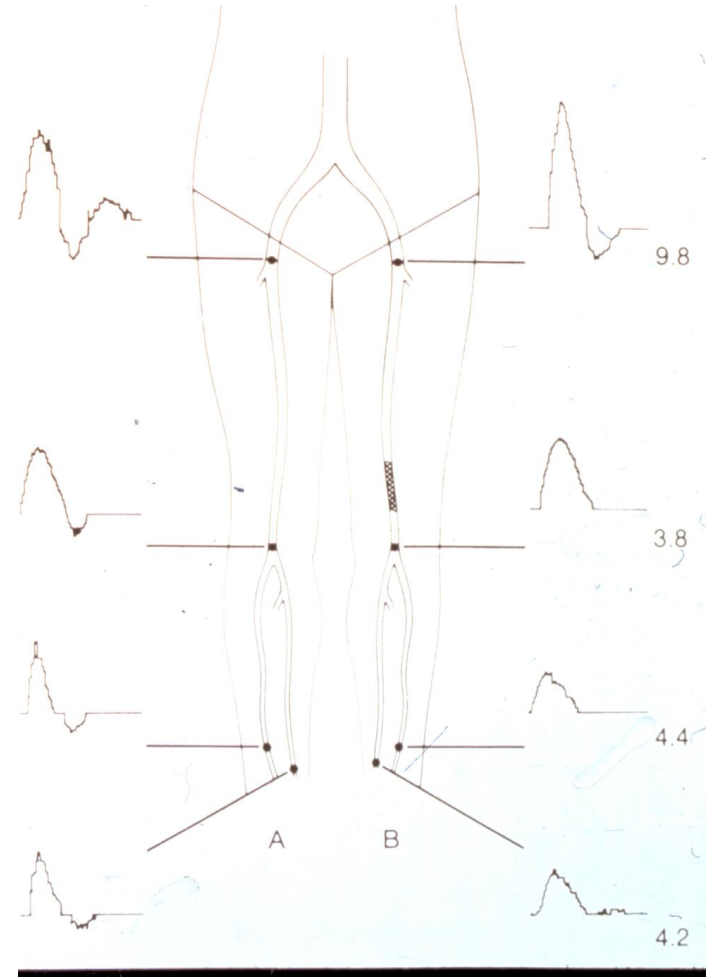
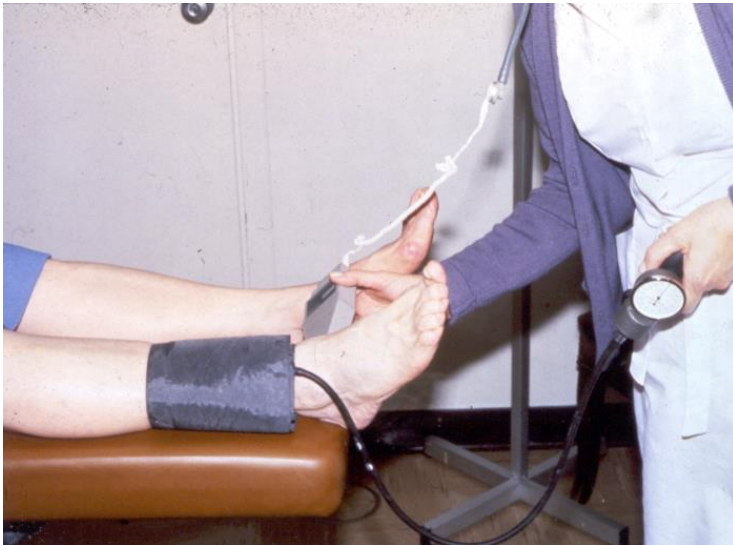


INDIRECT TESTING

TAKE NOTE - EXAMPLE 4 – Image When Suspicious



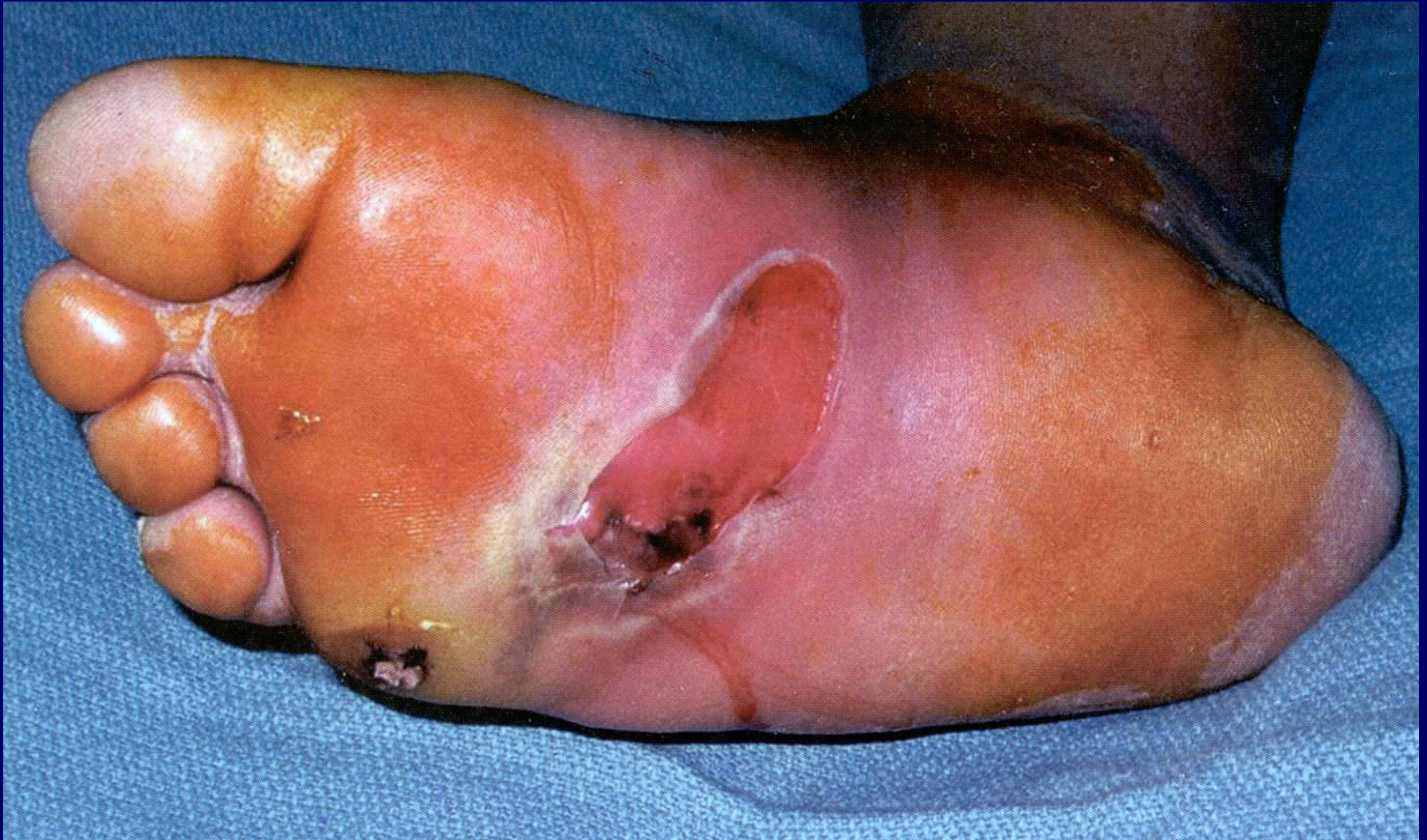
Hand Held Doppler



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