Perfusion Assessment in Chronic Wounds

American Society of Podiatric Surgeons
Surgical Conference
September 22, 2018

Michael Maier, DPM, FACCWS
Cardiovascular Medicine
Cleveland Clinic
Disclosures

Speaker, Smith & Nephew
Speaker, KCI
Consultant, WNDM Medical
Consultant, Medtronic
OBJECTIVES

• Describe traditional vascular laboratory studies to assess arterial circulation

• Discuss limitations of non-anatomic perfusion assessment

• Compare and contrast non-invasive perfusion assessment strategies
PAD Clinical Presentations

- Asymptomatic: 20 – 50%
- Classic Claudication: 10 – 35%
- Atypical Leg Pain: 40 – 50%
- Critical Limb Ischemia (CLI): 1 – 3%

McDermott et al. JAMA 2001;286:1599.
Critical Limb Ischemia (CLI) Definition

- Critical limb ischemia (CLI) A condition characterized by chronic (≥2 weeks) ischemic rest pain, nonhealing wound/ulcers, or gangrene in 1 or both legs attributable to objectively proven arterial occlusive disease.

Critical Limb Ischemia (CLI) Definition

- The diagnosis of CLI is a constellation of both symptoms and signs. Arterial disease can be proved objectively with ABI, TBI, TcPO2, or skin perfusion pressure. Supplementary parameters, such as absolute ankle and toe pressures and pulse volume recordings, may also be used to assess for significant arterial occlusive disease. However, a very low ABI or TBI does not necessarily mean the patient has CLI.

CLI – Clinical Definition

Fontaine Classification

Stage I
- Asymptomatic

Stage II
- IIa – Claudication > 200m
- IIb – Claudication < 200m

Stage III
- Rest pain

Stage IV
- Ischemic ulcers or gangrene

Rutherford Classification

Stage 0
- Asymptomatic

Stages 1, 2, 3
- Mild, moderate, severe claudication

Stage 4
- Rest pain

Stage 5
- Digital ischemic ulcers

Stage 6
- Severe ischemic ulcers or gangrene

CLI – Hemodynamic Definition

- Ankle pressure < 50 – 70 mmHg
- ABI < 0.4
- Toe pressure < 30 – 50 mmHg
- TcPO2 < 30 – 50 mmHg

Critical Limb Ischemia

Dependent rubor

Tissue loss

Gangrene
Arterial Evaluation

Hand held Doppler/ABI

Segmental Pressures +/- PVR’s

Arterial Duplex Ultrasound

TcPO$_2$/Laser Doppler

“Advanced Imaging”

ABI = ankle-brachial index; PVR = pulse volume recording; TcPO$_2$ = transcutaneous oximetry

Continuous Wave Doppler

- Hand held Doppler
- Measures high-velocity blood flow
- Uses separate crystals to send and receive ultrasound signals of a single frequency
- Lacks depth precision (pulsed wave Doppler is more “location sensitive”)
- Triphasic, biphasic, monophasic
Ankle Brachial Index (ABI)

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

- Measure ankle and brachial (arm) systolic pressures with handheld Doppler device
- Use highest arm and each ankle pressure

**ABI**

- 0.91 - 1.40  Normal
- 0.70 - 0.90  Mild disease
- 0.40 - 0.69  Moderate disease
- 0.00 - 0.39  Severe disease

- ABI >1.4 is abnormal and consistent with calcified vessels – unreliable
- ABI < 0.4 = Critical Limb Ischemia (ankle pressure < 50 – 70 mmHg)
- ABI alone is inadequate to assess distal perfusion

ABI Limitations

- ABI may be elevated in patients with non-compressible arteries (diabetes, ESRD)
- Resting ABI is insensitive to mild aorto-iliac occlusive disease
- Normal resting values in symptomatic patients may become abnormal after exercise
- ABI correlates poorly with functional status
ABI Limitations

- 89 consecutive patients with CLI had non-invasive testing for indications of rest pain ($n=23, 26\%$), as well as minor ($n=29, 33\%$) and major ($n=37, 42\%$) ischemic tissue loss.

- All patients subsequently underwent ABI testing and lower extremity angiography with visualization of the infragenicular arteries.

- Toe–brachial index (TBI) testing was available among 31 of these patients.

ABI Limitations

- Nearly **one-third** of patients with any ischemic tissue loss/CLI had a normal or mildly reduced ABI.

- Assessment of TBI may augment the diagnostic accuracy of ABI in the evaluation of CLI.

TBI = Toe Brachial Index

- Useful in individuals with non-compressible pedal pulses
- Helps to assess distal perfusion, especially for patients with foot ulceration
- TBI ≥ 0.7 is normal
- Critical Limb Ischemia = Toe pressure < 30 – 50 mmHg

Segmental Pressures/PVR

- Segmental pressures and plethysmographic waveforms used for analysis
- Compares blood pressure measurements at multiple sites
- Segmental pressure drop of >20 mmHg between segments is consistent with obstruction
- Metatarsal and toe or digital PPG can help evaluate small vessel perfusion
Segmental Blood Pressures

- Localizes level of disease
  - Aortoiliac
  - Common femoral/profunda
  - Superficial femoral/popliteal
  - Tibial vessel/infra-popliteal
  - Small vessel

- Waveforms are also used to interpret disease in the setting of calcified vessels (diabetes/ESRD)

ESRD = end-stage renal disease

Transcutaneous Oximetry/TcPO$_2$

- Measures oxygen tension 1-2 mm deep in the skin from the local capillary (nutritive) perfusion
- Useful for wound healing prediction in extremities
- Can be used to assess response to HBOT

HBOT = hyperbaric oxygen therapy

Transcutaneous Oximetry/TcPO$_2$

- TcPO$_2$ > 70 mm Hg = Normal Value
- TcPO$_2$ < 40 mm Hg = Impaired Wound Healing
- TcPO$_2$ < 30 mm Hg = Critical Limb Ischemia
- Low values of TcPO$_2$ (< 40 mmHg)
  - Peripheral artery disease
  - High altitude
  - Pulmonary disease
  - Heart failure
  - Edema
  - Inflammation
  - Callous, skin diseases (scleroderma)

Transcutaneous Oximetry/TcPO$_2$

### Assessing:

#### Wound Healing

- **tcpO$_2$**
  - $> 40$ mmHg: Spontaneous healing likely
  - $< 40$ mmHg: Oxygen Challenge
    - $< 30$ mmHg: Severe Arterial Disease
    - $> 100$ mmHg: No Significant Vascular Disease

#### Amputation Level

- **tcpO$_2$**
  - $> 40$ mmHg: Spontaneous healing likely
  - $< 40$ mmHg: Amputation failure likely
    - $< 10$ mmHg increase: Oxygen Challenge
      - $> 10$ mmHg increase: Amputation healing likely

An increase in tcpO$_2$ $> 40$ mmHg after revascularization is also associated with improved wound healing. Note that tcpO$_2$ should not be performed $< 3$ days after surgery.

Regional Perfusion Assessment
Skin Perfusion Pressure (SPP)

- Measurement (mmHg) of the capillary opening pressure after occlusion
- Uses blood pressure cuffs to occlude blood flow, followed by controlled pressure release allowing gradual return of blood flow
- During cuff deflation, laser Doppler is used to determine return of blood flow (reactive hyperemia)
- The pressure at which movement is detected is the skin perfusion pressure

Lo T, et al. Wounds 2009; 21(11);310-316.
The laser Doppler probe emits and detects light scattered in the tissue.

Light hitting moving blood cells will cause a change in frequency = Doppler shift.

An algorithm converts the optical information into SPP by:
- Capturing the onset of capillary flow return
- Determining pressure (mmHg) at which return flow onset occurs

Lo T, et al. Wounds 2009; 21(11);310-316.
SPP Interpretation Guideline (mmHg)

50 or >  = Normal skin perfusion
40 – 50 = Mild ischemia
40 +   = Wound healing probable/mild to moderate ischemia
30 – 40 = Gray zone for healing/moderate ischemia
30 or < = Wound healing unlikely/Critical Limb Ischemia

Lo T, et al. Wounds 2009; 21(11);310-316.
SPP vs. TcPO$_2$

• SPP measures *pressure* (mmHg)
• TcPO$_2$ measures *oxygen molecules* (mmHg)

**SPP Advantages**

- **Not** affected by vessel calcification, callous or thickened skin, or edema and can be used on plantar foot and digits
- Generally more sensitive in its ability to predict wound healing relative to TcPO$_2$

**SPP Disadvantages**

- Not useful for predicting response to HBOT
- Blood flow occlusion of the cuff may be painful
- Patients must lie supine with legs extended

*Lo T, et al. Wounds 2009; 21(11);310-316.*
Arterial Duplex Ultrasound

- Measures velocity of blood flow and visualizes arterial structure
- Provides anatomic information with no contrast
- May help in determining interventional strategies

Arterial Duplex Ultrasound

- Accurate and well-accepted method for assessing peripheral arterial system pre- and post-operatively
- Sensitivity, 97%; specificity, 96%; positive predictive value, 95%; negative predictive value, 98%; overall accuracy, 96% relative to contrast angiography

• 62 year old man
• Brittle diabetes, HTN, HL, borderline CKD (CR 1.4)
• Non-traumatic right BKA
• Calcaneal osteomyelitis
• Treated with IV antibiotics
• Aggressive wound treatment
  – HBOT
TcPO$_2$
Angiosome Approach to Perfusion

- Anterior Tibial
- Medial Plantar
- Lateral Plantar
- Calcaneal Branch of PTA
- Peroneal
- Calcaneal Branch of PA
- ATA Angiosome
- PTA Angiosome
- PA Angiosome
Clinical Course

3 weeks

7 weeks

10 weeks
2 Weeks Post-intervention

- Sharp debridement
- Initiate enzymatic debridement

6 Weeks Post-intervention
10 Weeks Post-intervention
Continue enzymatic debridement
Initiate NPWT 125mmHg (continuous)

14 Weeks Post-intervention
19 Weeks Post-intervention
Hold enzymatic debridement
Initiate sequential tissue grafts

22 Weeks Post-intervention
35 Weeks Post-intervention
• 82 year diabetic lady with bilateral midfoot collapse due to Charcot arthropathy and partial 1\textsuperscript{st} ray amputations
• Presents with left midfoot ulceration x 1 month
Left popliteal artery intervention
- Post-intervention sharp and enzymatic debridement
- Non-weight bearing
3 weeks later…
7 Weeks Post-Intervention

12 Weeks Post-Intervention
Angiosome Approach to Perfusion
4 Weeks Post-Repeat Intervention

8 Weeks Post-Repeat Intervention
16 Weeks Post-Repeat Intervention

21 Weeks Post-Repeat Intervention
1 Year Follow Up
Conclusions

• Utilize screening ABI’s, but recognize limitations for detecting PAD/CLI

• Include TBI’s to augment the diagnostic accuracy of ABI’s

• Consider TcPO2 and SPP as adjunct perfusion assessment tools

• Recognize CLI is a medical urgency that requires a team approach
Thank You
Perfusion Assessment in Chronic Wounds

American Society of Podiatric Surgeons
Surgical Conference
September 22, 2018

Michael Maier, DPM, FACCWS
Cardiovascular Medicine
Cleveland Clinic