

# **Transcutaneous Oximetry Testing and Interpretation**

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### Blood Pressure

#### Ankle-Brachial Index (ABI)

1.0-1.2/1.4 normal exam  
 0.9-0.99 borderline exam +/- irregularity; "clinically acceptable"  
 0.8-0.9 modest impairment; identify & manage risk factors  
 0.5-0.8 greater impairment (50-80% perfusion); specialist referral  
 < 0.5 severe disease (< 50% perfusion); specialist referral

> 1.2/1.4 abnormal exam c/w incompressible vessels  
 clinically significant calcification may be present prior 1.0

**How to Interpret the ABI?**  
 • For diagnosis of PAD interpret each leg separately (see ABI per leg)  
 • For the CV risk stratification take the lowest ABI between the two legs  
 • Interpretation:

European Society Vascular Surgery 2018

### Blood Pressure

#### Ankle-Brachial Index (ABI)

#### Strengths

- Long-standing most widely recognized/employed screening tool
- Relative ease of testing; not operator dependent
- Standardized interpretation largely c/w MRI/MRA findings

#### Weaknesses

- Only assesses macro-vasculature
- Doesn't localize disease
- Doesn't assess below level of ankle cuff
- No information related to oxygen delivery

### Blood Pressure

#### Toe-Brachial Index (TBI)

0.7 essentially normal exam  
 <0.7 c/w arterial occlusive disease

### Blood Pressure

#### Toe-Brachial Index (TBI)

#### Strengths

- Assesses all-important foot/digits
- Relative ease of testing; not operator dependent

#### Weaknesses

- Poor consensus re threshold values
- Not obtainable with Hallux; Ray; Ray revision; TMA amputations
- Confounded by calcification; no formal elevated index guidance
- No information related to oxygen delivery

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### Blood Pressure

#### Skin Perfusion Pressure (SPP)

Minimum BP required for restoration of microcirculatory & capillary flow  
 Laser light strikes RBCs as flow resumes > Doppler (wavelength shift) effect  
 Interrogates shifted & unshifted light; places arbitrary value on shifted light = RBCs

50-100 mmHg considered normal range  
 30-50 mmHg marginal ischemia +/- PAD symptoms  
 <30 mmHg CLI; wound healing/limb preservation problematic

Vasamed Sensilase

### Blood Pressure

#### Skin Perfusion Pressure

#### Strengths

- Unaffected by calcification
- Unaffected by mild-moderate edema
- Can be used when TBI not possible
- Assesses microcirculation

#### Weaknesses

- Pressure responses & predictive aspects poorly validated
- No information related to oxygen delivery

### Blood Flow

#### Doppler Ultrasound/Ultrasonography

- Pulsed sound waves transmitted to area of interest
- Undergoes Doppler (shift in pitch) effect when bouncing off moving objects
- Returning sound interrogated to determine RBC speed & direction

Lifedop L250

### Blood Flow

#### Doppler Ultrasound/Ultrasonography

**Strengths**

- Widely accepted & ubiquitous screening device
- Accurate & reliable
- Simple to use
- Unaffected by vessel calcification & very low flow rates

**Weaknesses**

- Resolution not great enough for microcirculation
- No information related to oxygen delivery

### Blood Flow

#### Laser Doppler Flowmetry (LDF)

- Another Doppler-based technology; near infrared low power laser light
- Interchangeable probes for shallow & deeper penetration
- Assesses velocity & direction of RBCs
- Filters out reflected unshifted/scattered light ("noise")
- Generates proportional shifted light scale as estimate of flow

### Blood Flow

#### Laser Doppler Flowmetry (LDF)

### Blood Flow

#### Laser Doppler Flowmetry

**Strengths**

- Accurate & reliable; hematocrit WNL
- Simple to use
- Unaffected by vessel calcification & very low flow rates

**Weaknesses**

- Arbitrary perfusion scale (1-10) as flow surrogate
- Susceptible to hematocrit changes
- Signal return may include RBCs flowing below skin
- No information related to oxygen delivery

### Blood Flow

#### Local Tissue Oxygen Saturation

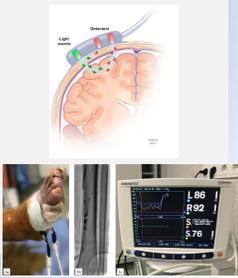
#### Near Infrared Spectroscopy (NIRS)

- Emits light (just outside visible spectrum) to area of interest
- Detects various reflective light spectrum differences
- Selectively measures OxyHb & DeoxyHb reflectance values
- Calculates percent "tissue" oxygen saturation

### Local Tissue Oxygen Saturation

#### Near Infrared Spectroscopy (NIRS)

- Introduced as continuous non-invasive monitoring of brain tissue oxygen saturation (StO<sub>2</sub>)
- Employment increasingly suggested elsewhere
- Longer wavelengths being researched



Somanetics INVOS

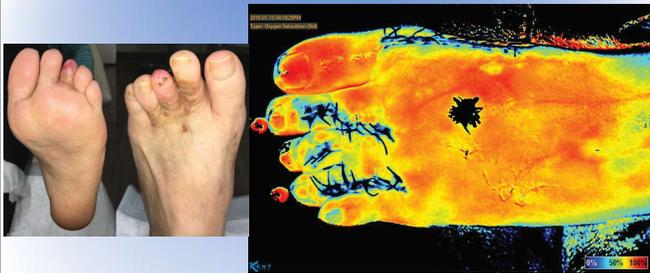
### Local Tissue Oxygen Saturation

#### Near Infrared Imaging (NIR)

- Battery-operated, handheld device
- Single "snapshot" vs. continuous monitoring
- Initially two manufacturers: NIR vs. visible light
- Measures OxyHb, DeOxyHb > calculates StO<sub>2</sub>



Snapshot NIR



With permission: Today's Wound Clinic/Kent Imaging

#### practice

### Comparing near infrared spectroscopy and transcutaneous oxygen measurement in hard-to-heal wounds: a pilot study

**"The gold standard for assessing oxygenation is TCOM."**

TCOM is a serial diastacks  
Tunefactor intensive  
Room temp must be between 68-72F  
Probes cannot be placed in wound bed  
Disposable are expensive

**Advantages of NIRS vs. TCOM**  
Non-invasive  
Does not require skin contact  
Does not require spectrophotics  
Immediate real-time data, avoiding delay in treatment regimen

**NIRS derived mmHg O<sub>2</sub>**: electromagnetic light reflectance from IR wavelengths measured by a patented computer interface algorithm to generate calculated OxyHb level which is mathematically converted to StO<sub>2</sub>, that is then mathematically converted to pO<sub>2</sub> using standard Severinghaus dissociation curve

**TCOM derived mmHg O<sub>2</sub>**: direct measurement free oxygen that diffuses to skin surface

**Conclusion:** Data suggests TCOM overestimates O<sub>2</sub> measurements vs. NIRS

Serena TE, et al. *Journal Wound Care* 2020;29(6)

### Local Tissue Oxygen Saturation

#### Near Infrared Imaging (NIR)

**Strengths**

- Battery-operated handheld; high image storage capacity
- Uniquely assesses regional StO<sub>2</sub>
- Ease of use/interpretation; touch screen display StO<sub>2</sub> values
- Suggested healing response tracker

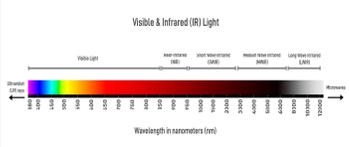
**Weaknesses**

- Does not measure tissue oxygenation  
So, no assessment plasma-borne oxygen delivery (basis for HBO)
- Unable to direct HBO case management as per tcPO<sub>2</sub>
- Presently ill-defined normal/abnormal StO<sub>2</sub> values; some crossover
- Presently unclear as to clinical relevance wound StO<sub>2</sub>

### Wound Thermal Reflectance

#### Long-Wave Infrared Thermography (LWIT)

**Visible & Infrared (IR) Light**






### Is any such hypoxia reversible?

**Normobaric 100% oxygen challenge tcpO<sub>2</sub> ≥ 100 mmHg per NRB mask @ 14-16 lpm**

Strauss MB, et al. Foot Ankle Int. 2002;23(10):933-937  
 Fikri CE, et al. Wound Regen Repair. 2002;10:188-207  
 Middelkoop J. Wound Regen Repair. 2003;11:458-464  
 Fikri CE, et al. Undersea Hyperbaric Med. 2009;36(1):43-53  
 Misson H, et al. Undersea Hyperbaric Med. 2010;43(5):441-448

- > 300 mmHg...<w>normal distal arterial perfusion
- 200-300 mmHg...<w>minimal occlusive disease
- 100-199 mmHg...<w>moderate occlusive disease
- 51-99 mmHg...<w>significant occlusive disease \*\*
- < 50 mmHg...<w>high grade occlusive disease \*\*

\*\* further arterial work-up indicated

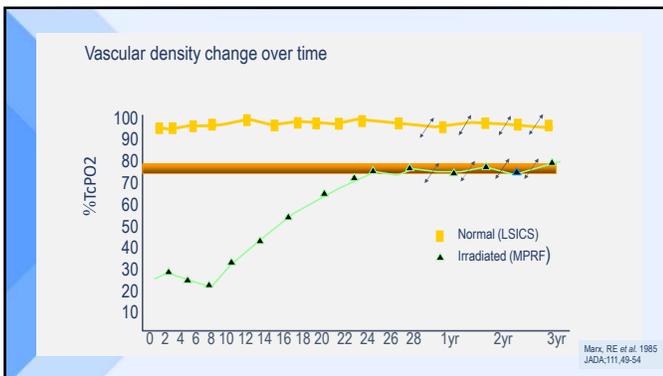
### Is there early evidence of response to HBO?

Repeat normobaric air breathing tcpO<sub>2</sub> test after 15 treatments

*"A lack of improvement in tcpO<sub>2</sub> measurements should discourage further HBO"*  
**Hyperbaric Oxygen Therapy Indications 14<sup>th</sup> Edition 2019**

*"One should see (tcpO<sub>2</sub>) changes by 10-15 HBO treatments to determine response"*  
**Hyperbaric Oxygen Therapy Indications 15<sup>th</sup> Edition 2023**

In responders, five days weekly HBO with weekly f/u tcpO<sub>2</sub> testing



### Has therapeutic endpoint been reached?

Support of tissue viability & wound healing defined as tcpO<sub>2</sub> ≥ 40 mmHg

David GSE, et al. J Bone Joint Surg [Br]. 2002;79-B:2  
 Sherriff CR, et al. Orthop Sports Med Rehabil. 2006;8(2):22-26  
 Ramgopalratnam C, et al. J Wound Care. 2013;23(3):202-206  
 Givoni G, et al. Diabetes Care. 2010;33(2):377-382

### Four-step transcutaneous oximetry screening of hyperbaric referrals

Is wound healing complicated by local hypoxia?  
 < 40 mmHg

Is any such hypoxia reversible?  
 ≥ 100 mmHg

Is there early evidence of response to HBO?  
 after 15 treatments

Has a therapeutic endpoint been reached?  
 peri wound value(s) ≥ 40 mmHg

