Imaging techniques to determine tissue perfusion in critical limb ischemia

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Disclosure

Speaker name:

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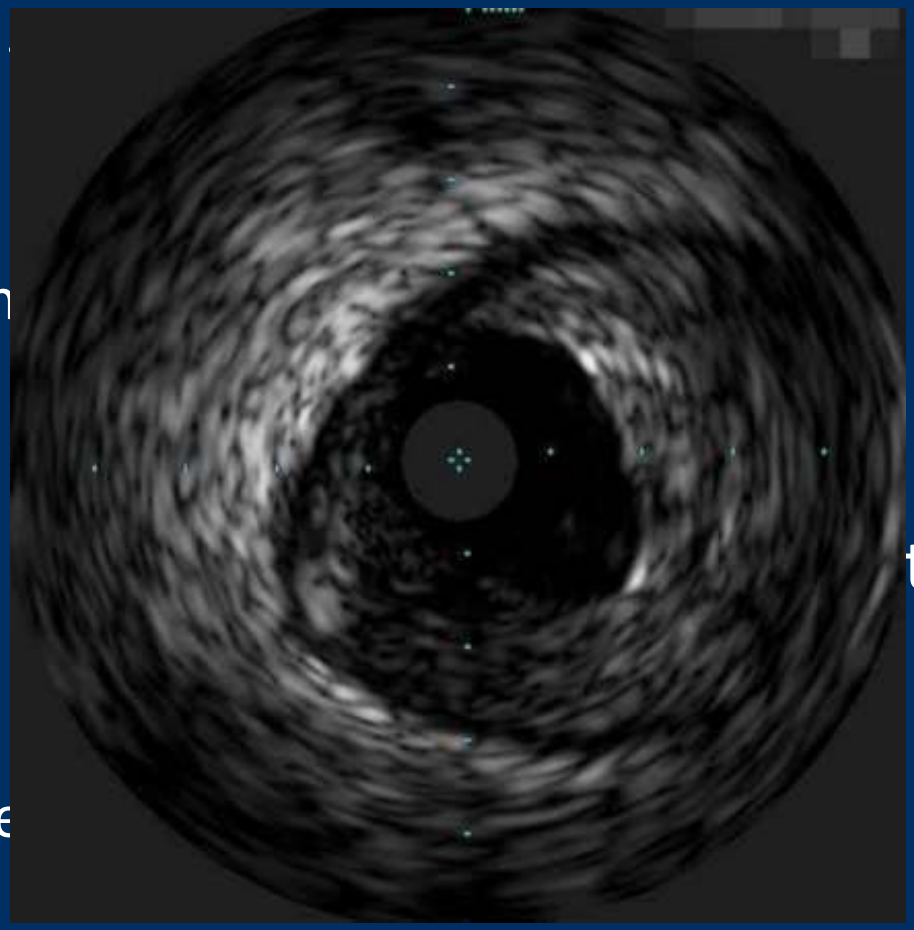
I have the following potential conflicts of interest to report:

- ☒ Consulting
- ☐ Employment in industry
- ☐ Stockholder of a healthcare company
- ☐ Owner of a healthcare company
- ☐ Other(s)

- ☐ I do not have any potential conflict of interest

Tissue perfusion in CLI

- Diagnosis ar cal
  - When doe sion ich is critical for tissue l
  - Currently a odyn this
- Revasculariz key tissue perfusion in
  - But how to this
  - Angiogram iable



Tissue perfusion in CLI

- Ideal test for foot perfusion:
  - inexpensive
  - readily available
  - reproducible
  - improve the clinician's ability to predict outcomes
  - provide perfusion data specific to the area of the foot with a wound
- Improving the ability to evaluate foot perfusion would benefit patients with CLI by
  - assisting with the etiology of a non-healing wound
  - identifying patients with poor perfusion in the angiosome of interest who might benefit from revascularization
  - identifying patients with seemingly adequate perfusion who may not require revascularization
  - selecting a target vessel for revascularization
  - providing insight when revascularization is sufficient
  - facilitating surveillance for patency

Misra S, Shishehbor MH, Takahashi EA, et al. Perfusion assessment in critical limb ischemia: Principles for under- standing and the development of evidence and evaluation of devices: A scientific statement from the American Heart Association. *Circulation* 2019; 140: e657–e672.

Tissue perfusion in CLI

- Current modalities of foot perfusion have limitations
  - Arterial non compressibility makes the ankle–brachial index (ABI) non-meaningful in many patients with CLI
  - Transcutaneous oximetry has a high coefficient of variation
  - Intra- procedural measures of foot perfusion are attractive to the interventionalist to direct the target and extent of revascularization

… but there are limitations!

- ✓ ‘Angiographic blush’ have been reported to correlate with wound healing but is somewhat subjective and dependent on technique
- ✓ Two-dimensional (2D) angiographic perfusion imaging is an intra-procedural method that attempts to provide objective angiographic data of perfusion but is also technique-dependent and is yet to be validated
- ✓ ……..

Tissue perfusion in CLI_Imaging techniques

Transcutaneous oximetry (TcPO2)

measures oxygen diffusion from the capillary beds to the epidermal layer of the skin

Sensor-containing electrode placed on the skin, warms the surrounding skin leading to local hyperthermia, measures the partial pressure of oxygen in the underlying tissue

Benefit

- Can be predictive of wound healing
- Identify individuals with nonhealing ischemic wounds who may benefit from hyperbaric oxygen therapy (HBOT)
- Noninvasive, bedside tool with no radiation exposure

Limitation

- Mechanism of action (skin perfusion): barriers to diffusion can lead to falsely low TcPO2 values

Tissue perfusion in CLI_Imaging techniques

Laser Doppler flowmetry and imaging

Limitations due to their mode of action, no broader use

Skin perfusion pressure (SPP)

SPP obtained with laser Doppler is noninvasive and time-efficient

Measure hemodynamics at a wound edge

Some data on the ability of SPP to predict wound healing that suggest it is superior to ABI and TcPO [1]

Lo T, Sample R, Moore P, et al. Prediction of wound healing outcome using skin perfusion pressure and transcutaneous oximetry: A single-center experience in 100 patients. Wounds 2009; 21: 310–316.

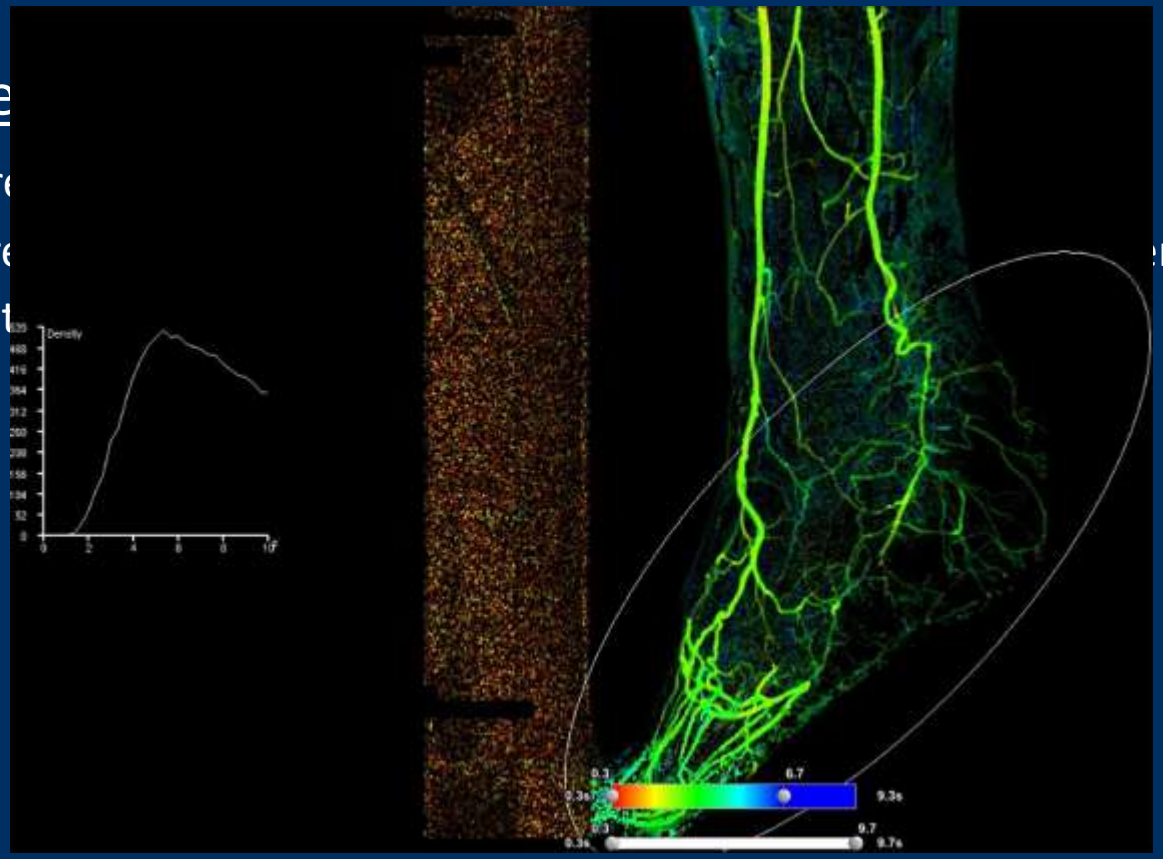
Tissue perfusion in CLI_Imaging techniques

Two-dime

softwar

measur erest in the foot

no addit



Two-dimensional angiographic perfusion. Right: Color map of the foot generated from a standard catheter-based angiogram. Left: Time density curve representing the time to peak contrast density in the foot. The average time to peak contrast density for this patient was 4.0 seconds.

Tissue perfusion in CLI_Imaging techniques

Two-dimensional angiographic perfusion imaging

Available evidence/3 studies

- Majority of patients increase in perfusion was observed after revascularization
- ABI correlated well to time-to-peak and peak density ratios
- Improvement in 2D angiographic perfusion parameters was observed following revascularization

Benefit

- Practical, as it can be incorporated into a standard angiogram
- 'Angiosome specific', providing information of regional foot perfusion
- Theoretically could guide revascularization decisions in real time

Limitation

- No evidence on longitudinal outcomes associated with 2D perfusion parameters
- Modality not standardized
  - Technique would need to be the same across operators and institutions so that the data generated would be generalizable to patient care.

Miguel Montero-Baker et al; Vascular Medicine2020, Vol. 25(3) 235–245

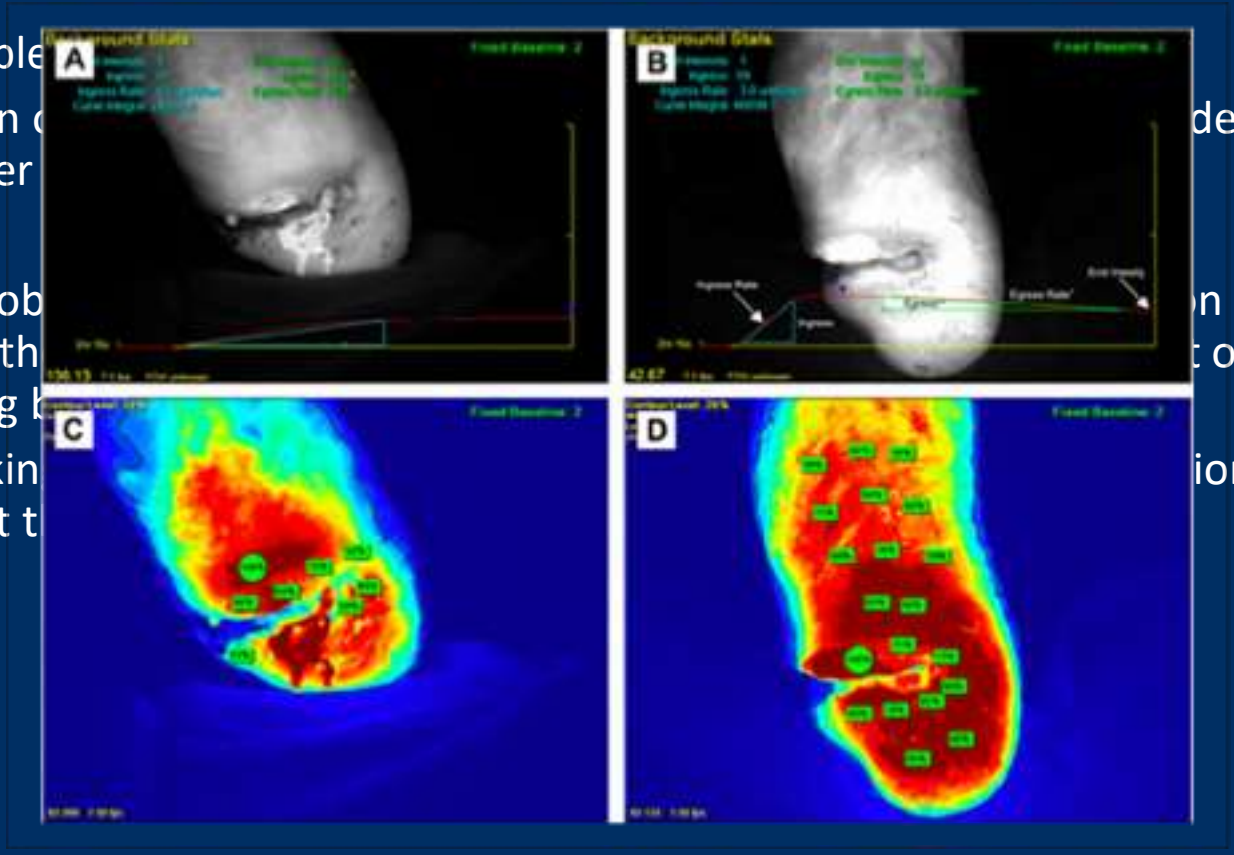
Tissue perfusion in CLI_Imaging techniques

Indocyanine green angiography

- Water-soluble
- Visualization detect the fluorescence emitted after

To obtain the ob n in the patient with CLI, a single area of th of either the foot or camera once recording

However, lookin ional perfusion variations in the entire foot t



Tissue perfusion in CLI_Imaging techniques

Indocyanine green angiography

Available evidence/3 studies

- Ingress (the increase in fluorescence intensity from baseline) and Ingress rate (the increase in intensity over the time to maximum intensity) have shown some correlation with ABI and toe pressure[1]
- Able to detect severe ischemia, based on the Wound-Ischemia-foot-Infection (WIfI) classification, with reasonable accuracy [2]
- Parameter of time to half-maximal intensity to detect response to revascularization [3]

Benefit

- appear to show promise for providing incremental information

Limitation

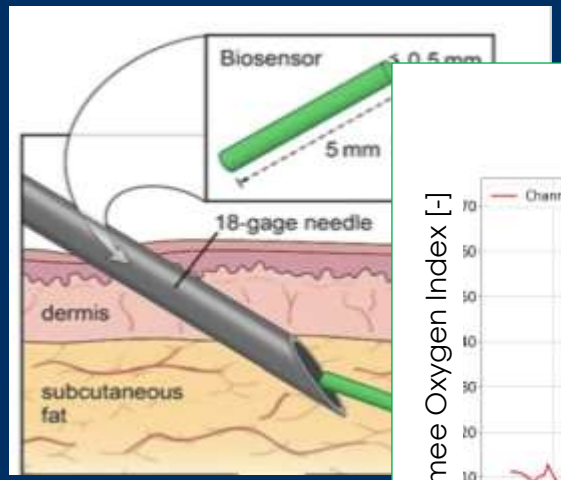
- Need for intravenous access
- Contraindication in previously documented iodinated contrast allergies
- Specialized equipment
- Inability to assess perfusion deeper than 5 mm

1 Braun JD, Trinidad-Hernandez M, Perry D, et al. J Vasc Surg 2013; 57: 1213–1218.
2 Braun JD. J Vasc Surg 2014; 60: 538.
3 Colvard B, Itoga NK, Hitchner E, et al. SPY technology as . J Vasc Surg 2016; 64: 195–201.

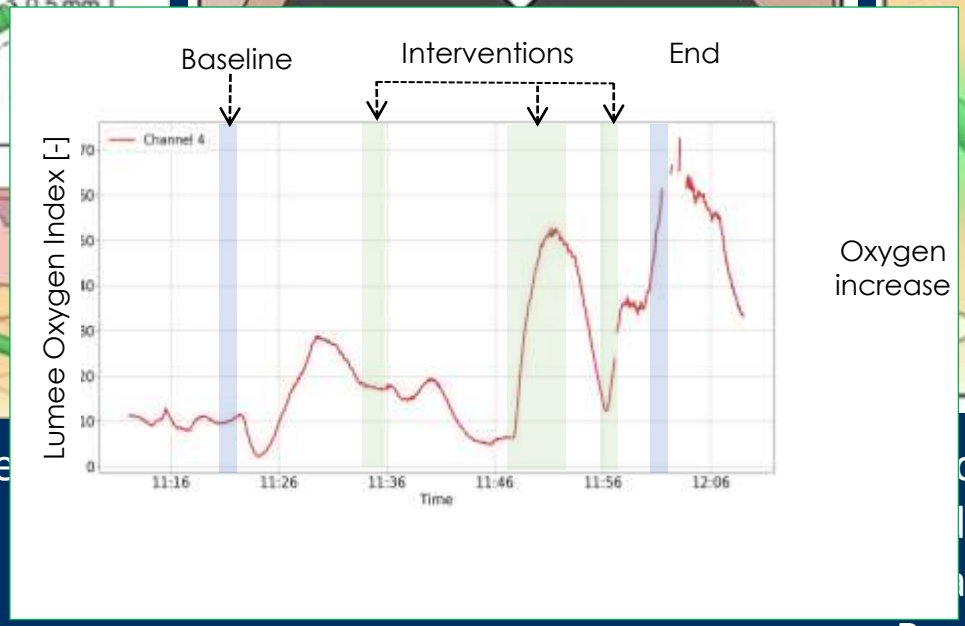
Tissue perfusion in CLI_Imaging techniques

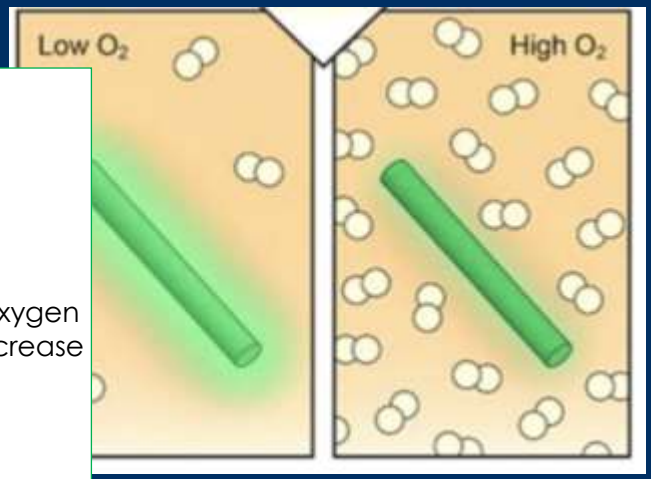
Oxygen Microsensors

- injectable oxygen microsensors to directly monitor oxygen in the subcutaneous tissue in vivo



Soft biocompatible hydrogel sensor injected into subcutaneous space





orescence chemistry on
lrogel responds based on
lyte concentration
Reader collects emissions and data sent to cloud

Tissue perfusion in CLI_Imaging techniques

Oxygen Microsensors

Available evidence/3 studies

- Healthy volunteer study provided validation of the ability of oxygen microsensors to reliably detect changes in tissue oxygen confirmed by TcPO2, with data over 3 months after sensor injection [1]
- FIH/ 10 CLI: patients average tissue oxygen in the affected foot increased after EVR [2]
- Post-market Registry study (OMNIA): Increases in oxygen levels assessed during endovascular revascularization procedures were associated with wound healing 3 months following the procedure [3, 4]

Benefit

- Sensitivity to both arterial insufficiency and microvascular impairment (eg diabetics)
- Treatment planning and long-term monitoring
- Prediction of wound healing

Limitation

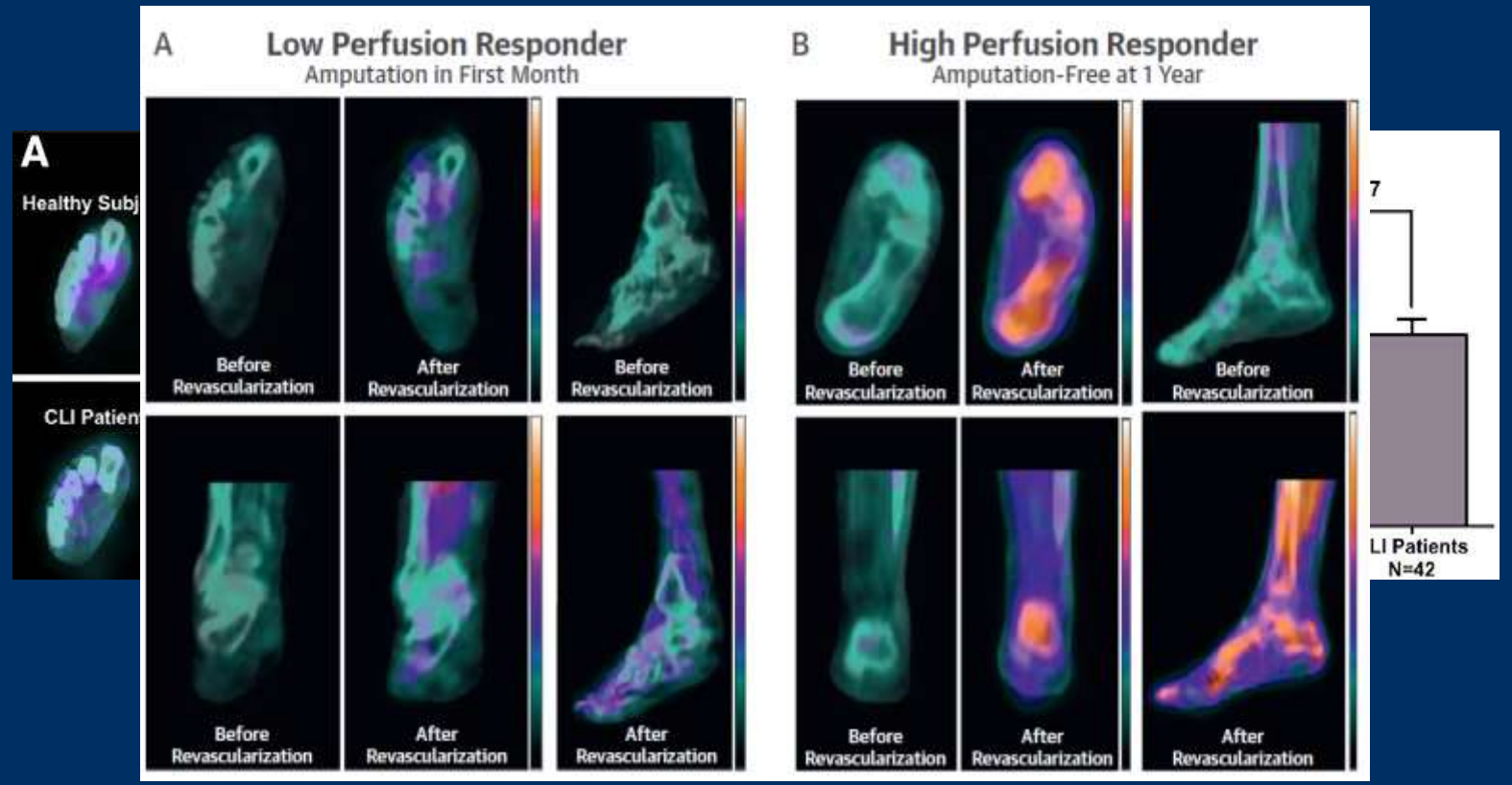
- Limited data available

1 Kanick SC, Schneider PA, Klitzman B, et al. Microvasc Res 2019; 124: 6–18. 2 Montero-Baker MF, Au-Yeung KY, Wisniewski NA, et al. J Vasc Surg 2015; 61: 1501–1509.e1. 3 Brodmann M. Interventional course (LINC), Leipzig, Germany, 2019

Tissue perfusion in CLI_Imaging techniques

Single photon emission computed tomography (SPECT)

Assessment of skeletal muscle microvascular perfusion



Mitchel R. Stacy, et al Circ Cardiovasc Imaging. 2018;11:e006932. DOI: 10.1161/CIRCIMAGING.117.006932

Tissue perfusion in CLI_Imaging techniques

Impact in CLI patients

Proper diagnosis
Identification of differences related to sex and ethnicity
Reduction of major amputation
Identification of procedural failures or incomplete revascularization
Potential for telemedicine to reduce disparities in CLI
Potential cost savings in the care of patients with CLI