Use of hyperspectral imaging to determine tissue perfusion with CLI and the effect of revascularization.

LINC, Leipzig, January 2019

Jean-Paul de Vries, Head Department of Surgery
University Medical Centre Groningen
The Netherlands
Disclosures

- Cofounder of Endovascular Diagnostics B.V.
- Consultant for Bentley Innomed
- Advisory board member Getinghe
- Research Grants Cardionovum, Lijf & Leven
Introduction

• 15% of PAOD will progress to chronic limb threatening ischemia

• 22% of CLTI patients will undergo major amputation

• 15% of amputees will need 2\textsuperscript{nd} amputation

• Treatment options
  – Bypass surgery
  – Endovascular treatment (PTA/stent)

• Both with substantial comorbidity, expenses and need for reinterventions
Introduction

• Current diagnostics
  – eg. ABI, doppler ultrasound, CTA, MRA, DSA

• Determination of macrovasculature

• Focus on stenosis or occlusion of arteries
Introduction

• What do we also (really) want to know:
  – Determination of tissue perfusion (TP)/oxygenation
  – Real time monitoring TP during interventions
  – TP values to predict (un)successful outcomes
  – TP monitoring during complete care process
  – Even at home during follow-up

• At every location of the lower limb / foot
Current tissue perfusion measurements

A systematic review of diagnostic techniques to determine tissue perfusion in patients with peripheral arterial disease

Kirsten F. Ma, Simone F. Kleiss, Richte C.L. Schuurman, Reinoud P.H. Bokkers, Çagdas Ünlü & Jean-Paul P.M. De Vries

https://doi.org/10.1080/17434440.2019.1644166
Current tissue perfusion measurements

**Identification**
- 3129 records identified from the search strategy
- 859 Duplicates removed

**Screening**
- 2270 titles and abstracts to screen
- 2065 Records excluded
  - 771 Did not include PAD patients
  - 482 Involved treatments other than standard
  - 306 No tissue perfusion of the legs/feet
  - 259 Study design; review or case report etc.
  - 234 Animal studies
  - 13 Other

**Eligibility**
- 205 full text to review
  - 185 Records excluded
    - 89 No comparison between PAD and healthy
    - 58 Only a published abstract
    - 20 Used hyperemia or exercise testing
    - 18 Other

**Inclusion**
- 20 studies included
Current tissue perfusion measurements

Graphical display is bias and quality assessment according to QUADAS-2.
Current tissue perfusion measurements

- Transcutaneous oxygen measurement (tcPO₂)
- NIRS
- Hyperspectral imaging
- Laser speckle contrast imaging
- Laser Doppler perfusion monitoring
Current tissue perfusion measurements

- Transcutaneous oxygen measurement (tcPO$_2$)
- Considered as a gold standard
- Time consuming, operator dependent
- Not ‘idiot prove’ and ‘real-time’
- No measurements at home
Hyperspectral imaging

• With the HyperView™ system

• Visible light spectroscopy
  – Oxyhemoglobin, deoxyhemoglobin and oxygen saturation

• Non-invasive and transcatheter measurements

• Easy to use, hand-held camera

• Applicable in hospital and in home setting
• 9 manuscripts (3 on PAOD, 4 on DM)

• In 5 of 7 patient studies HSI was associated with
  – Wound healing
  – Severity of peripheral ischemia

• No robust validation of technique
Validation study

- 43 healthy volunteers
- Plantar side of both feet
- Lateral side of the calves

- Standardized conditions
- 90° angulation Hyperview with skin
- Skin temperature
Validation study

- Repeated measurements (3 at each location)
## Results

<table>
<thead>
<tr>
<th></th>
<th>Oxyhemoglobin</th>
<th>Deoxyhemoglobin</th>
<th>Saturation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Right leg</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plantar</td>
<td>0.86 (0.78-0.92)</td>
<td>0.87 (0.79-0.92)</td>
<td>0.86 (0.78-0.92)</td>
</tr>
<tr>
<td>Lateral calf</td>
<td>0.83 (0.70-0.91)</td>
<td>0.87 (0.78-0.93)</td>
<td>0.81 (0.69-0.89)</td>
</tr>
<tr>
<td><strong>Left leg</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plantar</td>
<td>0.84 (0.76-0.91)</td>
<td>0.89 (0.83-0.93)</td>
<td>0.85 (0.77-0.91)</td>
</tr>
<tr>
<td>Lateral calf</td>
<td>0.87 (0.79-0.93)</td>
<td>0.89 (0.82-0.94)</td>
<td>0.82 (0.71-0.90)</td>
</tr>
</tbody>
</table>
## Results

### Intra Class Correlation (95% CI) of 3 repeated measurements

<table>
<thead>
<tr>
<th></th>
<th>Oxyhemoglobin</th>
<th>Deoxyhemoglobin</th>
<th>Saturation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Right leg</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plantar</td>
<td>0.86 (0.78-0.92)</td>
<td>0.87 (0.79-0.92)</td>
<td>0.86 (0.78-0.92)</td>
</tr>
<tr>
<td>Lateral calf</td>
<td>0.83 (0.70-0.91)</td>
<td>0.87 (0.78-0.93)</td>
<td>0.81 (0.69-0.89)</td>
</tr>
<tr>
<td><strong>Left leg</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plantar</td>
<td>0.84 (0.76-0.91)</td>
<td>0.89 (0.83-0.93)</td>
<td>0.85 (0.77-0.91)</td>
</tr>
<tr>
<td>Lateral calf</td>
<td>0.87 (0.79-0.93)</td>
<td>0.89 (0.82-0.94)</td>
<td>0.82 (0.71-0.90)</td>
</tr>
</tbody>
</table>

**ICC > 0.81**
## Results

<table>
<thead>
<tr>
<th>Location</th>
<th>N.</th>
<th>OxyHb (a.u.)</th>
<th>DeoxyHb (a.u.)</th>
<th>Saturation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Right leg</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plantar</td>
<td>43</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lateral calf</td>
<td>32</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Left leg</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plantar</td>
<td>43</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lateral calf</td>
<td>32</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Results

<table>
<thead>
<tr>
<th>Location</th>
<th>N.</th>
<th>OxyHb (a.u.)</th>
<th>DeoxyHb (a.u.)</th>
<th>Saturation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Right leg</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plantar</td>
<td>43</td>
<td>85.2 ± 24.9</td>
<td>54.1 ± 15.4</td>
<td>60.5 ± 11.7</td>
</tr>
<tr>
<td>Lateral calf</td>
<td>32</td>
<td>41.9 ± 11.4</td>
<td>37.8 ± 9.9</td>
<td>52.4 ± 10.6</td>
</tr>
<tr>
<td><strong>Left leg</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plantar</td>
<td>43</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lateral calf</td>
<td>32</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*P < 0.001*
## Results

<table>
<thead>
<tr>
<th>Location</th>
<th>N.</th>
<th>OxyHb (a.u.)</th>
<th>DeoxyHb (a.u.)</th>
<th>Saturation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right leg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plantar</td>
<td>43</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lateral calf</td>
<td>32</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left leg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plantar</td>
<td>43</td>
<td>80,4 ± 23,1</td>
<td>57,3 ± 15,9</td>
<td>57,9 ± 11,7</td>
</tr>
<tr>
<td>Lateral calf</td>
<td>32</td>
<td>39,8 ± 10,5</td>
<td>38,3 ± 9,8</td>
<td>50,9 ± 10,3</td>
</tr>
</tbody>
</table>

P < 0.001
## Results

<table>
<thead>
<tr>
<th>Location</th>
<th>N.</th>
<th>OxyHb (a.u.)</th>
<th>DeoxyHb (a.u.)</th>
<th>Saturation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Right leg</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plantar</td>
<td>43</td>
<td>85.2 ± 24.9</td>
<td>54.1 ± 15.4</td>
<td>60.5 ± 11.7</td>
</tr>
<tr>
<td>Lateral calf</td>
<td>32</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Left leg</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plantar</td>
<td>43</td>
<td>80.4 ± 23.1</td>
<td>57.3 ± 15.9</td>
<td>57.9 ± 11.7</td>
</tr>
<tr>
<td>Lateral calf</td>
<td>32</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

P < 0.05
# Results

<table>
<thead>
<tr>
<th>Location</th>
<th>N.</th>
<th>OxyHb (a.u.)</th>
<th>DeoxyHb (a.u.)</th>
<th>Saturation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Right leg</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plantar</td>
<td>43</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lateral calf</td>
<td>32</td>
<td>41.9 ± 11.4</td>
<td>37.8 ± 9.9</td>
<td>52.4 ± 10.6</td>
</tr>
<tr>
<td><strong>Left leg</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plantar</td>
<td>43</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lateral calf</td>
<td>32</td>
<td>39.8 ± 10.5</td>
<td>38.3 ± 9.8</td>
<td>50.9 ± 10.3</td>
</tr>
</tbody>
</table>

P < 0.05
Conclusions

• Tissue perfusion measurements in its infancy

• Hyperspectral imaging might be an option

• ICC of repeated HSI measurements good

• However, each measurement location should be used as its own reference
The SPECTACULAR study

- Validation of the Hyperview™ system in:
  - Clinical setting
  - Home monitoring

- Collecting values of tissue oxygenation during all phases of treatment

- Predictive value of hyperspectral imaging for clinical outcome
  - Wound healing
Design – Prospective cohort study

- Pre- and post-interventional diagnostics per current protocol
  - Collecting data of standard diagnostics

- Standard treatment according to guideline
  - PTA/Bypass surgery

- Additional diagnostics throughout the complete process (also at home)
Methods – patient inclusion

- Chronic limb threatening ischemia
  - Rutherford 4, 5 and 6
- Standard diagnostics
- PTA/bypass surgery
- Hyperspectral imaging
- tcPO$_2$ measurements
- Local skin temperature
- Wound measurements

Start inclusion Nov 29th 2019
Example
Measurements at home
Use of hyperspectral imaging to determine tissue perfusion with CLI and the effect of revascularization.

LINC, Leipzig, January 2019

Jean-Paul de Vries, Head Department of Surgery
University Medical Centre Groningen
The Netherlands