Infrared thermal imaging for distal ischaemia

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Disclosure

Speaker name: ........N Inston..........................................

☐ I have the following potential conflicts of interest to report:
   ☐ Consulting
   ☐ Employment in industry
   ☐ Shareholder in a healthcare company
   ☐ Owner of a healthcare company
   ☐ Other(s)

☒ I do not have any potential conflict of interest
Arteriovenous Access Induced Ischaemia

Diagnosis is clinical
But not always simple

| Grade 1 | No clear symptoms but discrete signs of mild ischaemia may be observed (slight cyanosis of nail beds, mild coldness of skin of hand, reduced arterial pulsations at wrist, reduced systolic finger pressures). (only relevant for upper limb access) |
| Grade 2a | Complains during dialysis sessions or intense use of the hand: tolerable pain cramps, paraesthesia, numbness or disturbing coldness in fingers or hand |
| Grade 2b | Complains during dialysis sessions or use of the hand. Intolerable pain, cramps, paraesthesia, numbness or disturbing coldness in fingers or hand |
| Grade 3 | Rest pain or motor dysfunction of fingers or hand. Upper limb relevant only |
| Grade 4a | Limited tissue loss (ulceration, necrosis). Clinically significant hand function (upper limb) is probably maintained if ischaemia is reversed |
| Grade 4b | Irreversible tissue loss of the hand (upper limb) impossible to preserve clinically significant hand function. Requires amputation |

Classification by Scheltinga et al (23).
Clinical symptoms

- Incidence 2-8%

- The clinical presentation
  - Acute (<24 hours)
  - Subacute (<1mo)
  - Chronic (>1mo)

- Clinical symptoms determine management options.
Investigation

• No definitive test

• Angiography and blood flow measurement
  – May not assist diagnosis but may identify the etiology
    and choice for treatment.

• Digital pressures, BDP, DBPI, transcutaneous oxygen measurement
  – If the differential diagnosis is difficult digital pressure measurements may assist.
  – may be a useful adjunct in monitoring response to treatment.
<table>
<thead>
<tr>
<th>Stage</th>
<th>Symptoms</th>
<th>Signs</th>
<th>Investigations</th>
<th>Suggested treatment options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade 1</td>
<td>Mild symptoms or signs alone</td>
<td>Pale or blueish nail beds, mild coldness of skin of hand, reduced arterial pulsations at wrist</td>
<td>Reduced finger pressures &lt; contralateral side but DBPI &gt; 0.4; DUS shows high or normal access flow.</td>
<td>Observation and review</td>
</tr>
<tr>
<td>Grade 2a</td>
<td>Symptoms (tolerable pain cramps, paraesthesia, numbness or coldness)</td>
<td>Pale or blueish nail beds, coldness of skin of hand, reduced arterial pulsations at wrist</td>
<td>Reduced finger pressures (DBPI &lt; 0.4); DUS shows high or normal access flows. Angiography may demonstrate arterial stenosis proximal to the anastomosis ± collateral and ± run-off disease.</td>
<td>If high flow, treat by banding/DRIL/RUDI and treat underlying arterial disease where possible. If low flow, PAI or tie off may be required.</td>
</tr>
<tr>
<td>Grade 2b</td>
<td>Symptoms (intolerable pain cramps, paraesthesia, numbness or coldness)</td>
<td>Pale or blueish nail beds, coldness of skin of hand, reduced arterial pulsations at wrist</td>
<td>Reduced finger pressures (DBPI &lt; 0.4); DUS shows high or normal access flows. Angiography may demonstrate arterial stenosis proximal to the anastomosis ± collateral and ± run-off disease.</td>
<td>If high flow, treat by banding/DRIL/RUDI and treat underlying arterial disease where possible. If low flow, treat any underlying arterial disease and PAI or tie off may be required.</td>
</tr>
<tr>
<td>Grade 3</td>
<td>Rest pain or motor dysfunction of fingers or hand.</td>
<td>Pale, white or blueish nail beds and skin, coldness of hand, reduced arterial pulsations at wrist</td>
<td>Reduced finger pressures (DBPI &lt; 0.4); DUS shows high or normal access flows. Angiography may demonstrate arterial stenosis proximal to the anastomosis ± collateral and ± run-off disease.</td>
<td>Definitive treatment is required and should be tailored to all causative factors (Tie off/DRIL/PAI angioplasty)</td>
</tr>
<tr>
<td>Grade 4</td>
<td>Rest pain and or paraesthesia. Loss of sensation (numbness).</td>
<td>Tissue loss (ulceration, necrosis). Motor and sensory loss.</td>
<td>Reduced finger pressures (DBPI &lt; 0.4); DUS shows high or normal access flows. Angiography may demonstrate arterial stenosis proximal to the anastomosis ± collateral and ± run off disease.</td>
<td>Definitive treatment is required and should be tailored to all causative factors (Tie off/DRIL/PAI angioplasty) and debriement/amputation may be required.</td>
</tr>
<tr>
<td>Grade 5</td>
<td>Irreversible tissue loss of the hand.</td>
<td>Extensive tissue loss</td>
<td>Reduced systolic finger pressures (DBPI &lt; 0.4); DUS shows high or normal access flows. Angiography may demonstrate arterial stenosis proximal to the anastomosis ± collateral and ± run off disease. X ray may show bone loss/osteomyelitis.</td>
<td>Treatment should be attempted but amputation/debridement of necrotic areas required and abandonment of access may be necessary although underlying arterial disease amenable to treatment should be attempted.</td>
</tr>
</tbody>
</table>

Finger pressures DBPI > 0.4
Finger pressures DBPI < 0.4
Differential diagnosis

- Diabetes
- PVD
- Reynauds and vasculitis
- Arthropathy
- Neuropathy
Treatment options

Banding
Directed vs non directed

<table>
<thead>
<tr>
<th>Study (ref)</th>
<th>Number</th>
<th>Pre-operative classification</th>
<th>Technique</th>
<th>Symptomatic response (%)</th>
<th>Early thrombosis (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wang 2016 (59)</td>
<td>30</td>
<td>Yes (SVS mean = 2.8)</td>
<td>Banding</td>
<td>79.1</td>
<td>4.1</td>
</tr>
<tr>
<td>Leake 2014 (53)</td>
<td>37</td>
<td>Yes</td>
<td>Banding</td>
<td>75</td>
<td>11</td>
</tr>
<tr>
<td>Wang 2013 (55)</td>
<td>7</td>
<td>No</td>
<td>Banding</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>Smith 2013 (54)</td>
<td>6</td>
<td>No</td>
<td>Banding</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>Gupta 2011 (46)</td>
<td>21</td>
<td>No</td>
<td>Banding</td>
<td>52.4</td>
<td>19</td>
</tr>
<tr>
<td>Shemesh 2010 (56)</td>
<td>7</td>
<td>No</td>
<td>Banding</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>Miller 2010 (52)</td>
<td>114</td>
<td>Non standard</td>
<td>Banding</td>
<td>88.6</td>
<td>4.4</td>
</tr>
<tr>
<td>Van Hoek 2009 (57)</td>
<td>9</td>
<td>Steal questionnaire</td>
<td>Banding</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>Thermann 2007 (58)</td>
<td>15</td>
<td>SVS classification I-III (75% mild steal)</td>
<td>Banding</td>
<td>66.7</td>
<td>0</td>
</tr>
<tr>
<td>Schneider 2006 (60)</td>
<td>6</td>
<td>No</td>
<td>Banding</td>
<td>83.3</td>
<td>0</td>
</tr>
<tr>
<td>Goel 2006 (61)</td>
<td>16</td>
<td>No</td>
<td>Banding</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>Morsy 1998 (62)</td>
<td>6</td>
<td>Yes</td>
<td>Banding</td>
<td>100</td>
<td>66.7</td>
</tr>
<tr>
<td>DeCaprio 1997 (63)</td>
<td>11</td>
<td>No</td>
<td>Banding</td>
<td>90.9</td>
<td>81.8</td>
</tr>
</tbody>
</table>
Treatment options

Distal Revascularisation and interval ligation (DRiL)
Treatment options

Proximalisation Arterial Inflow (PAI)
AVAIS

- Diagnosis is poorly defined
- Management is varied and difficult to compare
- Are there any other tools?

Coldness of hand is the main clinical feature
Prototype Pyroscan used in Bath in 1959.

Can we use infrared thermography?

E. F. J. Ring Rheumatology 2004; 43:800-802

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- [http://www.thermology.com/medical_thermal_imaging_research.html](http://www.thermology.com/medical_thermal_imaging_research.html)

Fig 1. Infrared thermograms before and after 6-minute walk test in lower extremity peripheral arterial disease (PAD) (A, B) and non-PAD patients (C, D).
Diabetic hand

Dorsal view of feet. The left forefoot is inflamed (red) and toes are cold.
Normal Thermography

Figure 4.2: Illustration showing the setting for the vascular occlusion test
Normal Thermography

- Pre occlusion
- Occlusion
- Post Occlusion reperfusion

Figure 4.4: Typical thermal changes seen during the three different periods of the vascular occlusion test.
Post AV fistula formation

“Physiological steal occurs in 85% of AV access”
Shanzer H

Immediate reduction in distal temperature is predictive of maturation
In Ischaemic Steal

- 76 F  ESRD: ANCA positive microscopic polyangitis
- Right BC AVF with no complications.

- 3 weeks following the surgery and the arteriovenous fistula had matured and dilated well.

- BUT:
  - intermittent coldness of the hand and non-specific numbness.
  - She denied any pain.
  - On examination, there was no tissue loss but the radial pulse was absent but returned on compression of the AVF.

- On assessment with IRTI (fig 1a) skin perfusion was reduced in all digits compared to the other hand.

- Based on clinical parameters a banding procedure was planned and immediate post-operative IRTI performed which showed improvement in temperature.

- At two weeks follow up she was clinically improved and was asymptomatic. On examination, she had a strong radial pulse and the brachiocephalic fistula was patent and used for dialysis.

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• 45 F ESRD secondary to diabetic nephropathy

• Lt BCAVF which was aneurysmal.

• Pain over her left index finger with tissue loss at the tip of her finger.

• Refused treatment as prior line sepsis

• A CT angiogram did not demonstrate significant arterial disease.

• Finger tip necrosis worsened and increased pain including night pain.

• As this was rapidly deteriorating she consented to fistula ligation.

• Pre-operative IRTI demonstrated poor flow in the digits) which improved on ligation

• Symptoms were relieved and deterioration halted.

• The necrotic distal phalanx required limited debridement with primary healing.

C. Thermogram of the hand before the ligation procedure

D. Thermogram of the hand after the ligation procedure
• 65M ESRD secondary to diabetic nephropathy
• Progressive painless necrosis of his right index finger.
• Right B/C AVF

• He had a significant history of comorbidities:
  – peripheral vascular disease with previous bilateral carotid endarterectomies,
  – previous left femoral-popliteal bypass and amputations of two toes,
  – hypertension, diabetes and ischaemic heart disease.

• Weak palpable radial pulse
• Necrotic distal right index finger.

• On compression of the fistula, there was minimal change to the strength of pulse

• IRTI demonstrated perfusion in the digits including the affected index finger and no change in temperature following compression of the fistula

• Previous fistulogram and duplex examination heavily calcified vessels aetiology was felt to be microvascular disease rather than HAIDI.

• The patient was referred to the hand surgeon for amputation of the distal phalanx and his fistula was preserved.
Conclusions

• Infrared thermography is
  – Affordable
  – Available
  – User friendly for near patient study

• May be predictor of AVF outcome
• May be used to aid diagnosis in AVAIS

• Further studies are required:
  – Monitoring AVAIS
  – Predicting and guiding banding procedures
  – Guiding surgical intervention
Thank you

Acknowledgments to Mr J Alshakarchi

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