DETECT-PAD
Computerized and patient specific model to determine pressure gradients in borderline iliac artery stenosis with MRA/CTA

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Disclosures

Speaker name: J.P.P.M. de Vries

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
Problem

- **Equivocal iliac artery stenoses (40-60%)**
  - Hard to predict clinical relevance
  - No non-invasive tools to predict pressure drop

- **Physiology**
  Lumen area reduction versus pressure gradient \([1]\)
  - Pearson Correlation (0.01-0.17)
  Lumen area reduction not sufficient to diagnose patients with equivocal iliac artery stenoses (40-60%)

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Invasive pressure measurements

• **Advantages**
  Gold standard to determine significance of stenosis.

• **Disadvantages**
  Invasive
  Time consuming
  Expensive
Solution

Non-invasive, patient specific, predictive model to determine pressure drop over equivocal stenosis
Physical Model

Patient-specific Physiological data

Physics $^{[1,2]}$

I. Conservation of mass
II. Conservation of momentum
III. Energy loss due to turbulence

Prediction patient-specific pressure drop


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Physical Model framework

Physics \[1,2\]

I. Conservation of mass
II. Conservation of momentum
III. Energy loss due to turbulence

\[
\frac{\partial A}{\partial t} + \frac{\partial q}{\partial z} + \Psi = 0
\]
\[
\frac{\partial q}{\partial t} + \frac{\partial \gamma}{\partial z} + \frac{A}{\rho} \frac{\partial p}{\partial z} = \frac{2\pi a_0}{\rho} \frac{\tau_w}{\rho}
\]
\[
\frac{\partial q}{\partial t} + \frac{I_v}{I_t} q + \frac{I_t}{I_w} |q|q + \frac{I_s}{I_u} \frac{\partial p}{\partial z} + \frac{I_c}{I_w} q = 0
\]
DETECT-PAD

Comparison of the predicted pressure drop (model-based) with in-vivo measurements in rest and during reactive hyperemia (NTG)
Inclusion criteria

• Symptomatic, chronic atherosclerotic lesions of the common iliac artery and/or external iliac artery
• Single or multiple equivocal stenoses (US)
• Rutherford class 1-6
DETECT-PAD Protocol

• **Standard of care**
  – Treadmill test
  – Duplex Ultrasound
  – CE-MRA / CTA
  – Digital Subtraction Angiography

• **Non-invasive additional measurements**
  – MR-Flow

• **Additional during DSA/PTA**
  – Pressure measurements (XT ComboWire, Volcano Inc.)
  – 3D-rotational angiography

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DETECT-PAD Protocol
Typical Example

- Predicted hyperemic pressure gradient: $26.8 \pm 5.0$ mmHg
- In vivo measured hyperemic pressure gradient: $24.5 \pm 1.7$ mmHg

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## Patient characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Study Cohort</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years</td>
<td>67 (44-79)</td>
</tr>
<tr>
<td>Male</td>
<td>15 [71%]</td>
</tr>
<tr>
<td><strong>Cardiovascular risk factors</strong></td>
<td></td>
</tr>
<tr>
<td>Tobacco use</td>
<td>12 [57%]</td>
</tr>
<tr>
<td>Diabetes Mellitus</td>
<td>2 [10%]</td>
</tr>
<tr>
<td>Hyperlipidemia</td>
<td>9 [38%]</td>
</tr>
<tr>
<td>Hypertension</td>
<td>13 [62%]</td>
</tr>
<tr>
<td><strong>Clinical description</strong></td>
<td></td>
</tr>
<tr>
<td>ABI rest (%)</td>
<td>0.73 (0.37-1.17)</td>
</tr>
<tr>
<td>ABI after exercise (%)</td>
<td>0.46 (0.18-0.89)</td>
</tr>
<tr>
<td>Pain free walking distance (m)</td>
<td>140 (40-320)</td>
</tr>
</tbody>
</table>
Results
Bland Altman plot

Bias: -0.9 mmHg
### Contingency table

<table>
<thead>
<tr>
<th>Measured pressure gradient</th>
<th>$\Delta p &lt; 10$ mmHg</th>
<th>$\Delta p \geq 10$ mmHg</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predicted</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta p &lt; 10$ mmHg</td>
<td>3</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>$\Delta p \geq 10$ mmHg</td>
<td>2</td>
<td>19</td>
<td>21</td>
</tr>
<tr>
<td>Total</td>
<td>5</td>
<td>20</td>
<td>25</td>
</tr>
</tbody>
</table>

- Sensitivity: 95% (76%-100%)
- Specificity: 60% (39%-78%)
- Predictive value: 88% (68%-98%)

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Study limitations

• Current approach requires a 3D rotational angiography

• Small number of lesions

• The threshold of 10 mmHg pressure drop may be suboptimal
Future perspectives

• Application of the model to other vascular diseases
  – Femoral artery stenoses
  – Renal artery stenoses

• Model improvement
  – Computational time need to solve equations
  – Incorporate bifurcations and multi-segment disease
Conclusion

• Pressure drop ≠ lumen area reduction

• The current model enables prediction of pressure drop in equivocal artery stenoses at pre-intervention MRA/CTA

• Predictive value for yes/no treatment 22/25 (88%)