DETECT-PAD
A computerized model to predict the pressure drop in borderline iliac artery stenosis on the basis of MRA

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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%)

Invasive pressure measurements

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

• **Disadvantages**
  Invasive
  Time consuming
  Expensive
Solution

Non-invasive, patient specific, predictive computerized model to determine pressure drop over equivocal iliac artery stenoses
Model

Physics [1,2]

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

Prediction patient-specific pressure drop

Patient-specific Physiological data


Physical Model framework

Patient-specific Physiological data

Physics $^{[1,2]}$

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

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

• **Aim = Validation**
  Comparison of the predicted pressure drop (model-based) with in-vivo measurements in rest and during reactive hyperemia (NTG)

• **N = 30**

• **Angiography**
  PTA if hyperemic pressure gradient > 10 mmHg
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
  – Digital Subtraction Angiography

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

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

![Graph showing the relationship between minimal area of stenosis and flow in mL/s.](image-url)
Case example

- Predicted hyperemic pressure gradient: 26.8 ± 5.0 mmHg
- In vivo measured hyperemic pressure gradient: 24.5 ± 1.7 mmHg
## 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>Cardiovascular risk factors</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>Clinical description</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>Δp &lt; 10 mmHg</th>
<th>Δp ≥ 10 mmHg</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predicted</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Δp &lt; 10 mmHg</td>
<td>3</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Δp ≥ 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%)
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

• DETECT-PAD study II
  – Additional inclusion of N=50 patients
  – Testing the feasibility to use CTA and MRA

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

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

- Pressure drop ≠ lumen area reduction
- The current model first to predict pressure drop in equivocal artery stenoses at pre-intervention MRA
- Predictive value for yes/no treatment 22/25 (88%)