In-vivo validation of a non-invasive MR-based patient specific pressure model to determine the severity of equivocal iliac artery obstructions and the need for revascularization

The DETECT-PAD study

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Disclosure

Speaker name: S.G.H. Heinen

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 (50-75%)**
  – 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 (50-75%)

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


Physical Model

Physics $^{[1,2]}$

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

\[
\begin{align*}
\frac{\partial A}{\partial t} + \frac{\partial q}{\partial z} + \Psi &= 0 \\
\frac{\partial q}{\partial t} + \frac{\partial \gamma}{\partial z} + \frac{A}{\rho} \frac{\partial \rho}{\partial z} &= \frac{2\pi a_0}{\rho} R_w \\
\frac{\partial q}{\partial t} + \frac{I_w}{I_u} q + \frac{I_r}{I_u} q |q| + \frac{I_s}{I_u} \frac{\partial \rho}{\partial z} + \frac{I_w}{I_u} q &= 0
\end{align*}
\]
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 atheroslerotic lesions of the common iliac artery and/or external iliac artery
- Single or multiple equivocal (50-75%) stenoses (US)
- Rutherford class 1-6
DETECT-PAD Protocol

• Standard of care
  – Treadmill test
  – Duplex Ultrasound
  – CE-MRA
  – Blood pressure

• Non-invasive additional measurements
  – MR-Flow

• Additional during DSA/PTA
  – Pressure measurements (XT ComboWire, Volcano Inc.)
Patient #1: Model validation (predicted pressure)

**Rest**
- Proximal (P1): 97.4 mmHg
- Distal (P2): 96.4 mmHg
- Gradient (P1-P2): 1.0 mmHg

**Hyperemia**
- Proximal (P1): 95.7 mmHg
- Distal (P2): 92.5 mmHg
- Gradient (P1-P2): 3.2 mmHg
Patient #1: Angiography (in-vivo pressure)

Rest
- Proximal (1) : 92.4 mmHg
- Distal (5) : 91.2 mmHg
- Gradient (1-5) : 1.2 mmHg

Hyperemia
- Proximal (1) : 89.4 mmHg
- Distal (5) : 81.6 mmHg
- Gradient (1-5) : 7.8 mmHg
Results (rest)
Results (hyperemia)

* Rest measurement
Conclusion

• Pressure drop $\neq$ lumen area reduction
• The current model first to predict pressure drop in PAD
• Predictive value for yes/no treatment 14/15 (93%)
• Improvements:
  – Inflow and outflow conditions
  – Refinement of clinical input data
• Inclusion patients 16-30 (Q1-2 2016)
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