Separate assessment of hyperemic epicardial and microvascular conductance using coronary pressure and flow velocity

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Potential conflicts of interest

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✓ I do not have any potential conflict of interest to report.
Why this study?

Ischemic Heart Disease (IHD)

Epicardial disease

Microvascular disease
Diagnosis of IHD
Epicardial vessels
Microvascular vessels

Why this study?

Epicardial pressure ratios
Microvascular resistance
What was the study aim?

To develop a new method to simultaneously interrogate the **epicardial-** & **microvascular** coronary domains using vascular conductance
How did we perform our study?
\[ C_{EPI} = \frac{(C_{MICRO} \times C_{OVERALL})}{(C_{MICRO} - C_{OVERALL})} \]

\[ C_{EPI} = \frac{1}{R_1} \]

\[ C_{MICRO} = \frac{1}{R_2} \]

\[ C_{OVERALL} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2}} \]

\[ R_T = R_1 + R_2 \]
How can we translate this to our cathlab?

\[ C^{\text{EPI}} = \frac{C^{\text{MICRO}} \times C^{\text{OVERALL}}}{C^{\text{MICRO}} - C^{\text{OVERALL}}} \]

\[ C^{\text{EPI}} = \frac{3.22 \times 0.77}{3.22 - 0.77} \]

\[ C^{\text{EPI}} = 1.01 \]
What are the main findings?

Median: 4.56 (IQR 2.18 – 8.64) cm/s/mmHg

Median: 1.28 (IQR 0.95-1.73) cm/s/mmHg
What are the main findings?

Diagnostic efficiency of epicardial conductance

- Cut-off value: 1.69
- AUC: 0.93
- Sensitivity: 82%
- Specificity: 93%

Robust method: 283 with concordant FFR and HSR values
The essentials to remember

- **Why?**
  - To obtain an integral approach to assess the entire circulation

- **What?**
  - Separate epicardial- and microvascular conductance

- **How?**
  - Pressure and flow in 403 vessels
  - Complex mathematical derivation

- **What are the main results?**
  - $C_{EPI}$ has a great diagnostic efficiency to detect stenoses
  - $C_{MICRO}$ is independent of stenosis severity

- **Why is this important?**
  - Promising new method to separately investigate the contribution of epicardial- and microvascular disease to the impairment of myocardial blood flow.
Thank you for your attention!

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An example from clinical practice

FFR: 0.54
Epicardial conductance: 1.01
Microvascular conductance 3.22

CFR: 1.89

mid LAD lesion 65%

Cut-off epicardial conductance: 1.69
Cut-off microvascular conductance: 1.28
Cut-off CFR: 2.00
Back-up slides
Analogy from the electric circuit

\[ R_T = \frac{1}{G_T} = R_1 + R_2 = \frac{1}{G_1} + \frac{1}{G_2} \]

\[ G_T = \frac{G_1 G_2}{G_1 + G_2} \]

\[ \frac{1}{G_1} = \frac{1}{G_T} - \frac{1}{G_2} \]

\[ G_1 = -\frac{G_T G_2}{G_T - G_2} = \frac{G_2 G_T}{G_2 - G_T} \]
Why are these microvessels so important?

Significant more events in patients with MVD

<table>
<thead>
<tr>
<th>Group</th>
<th>CFR</th>
<th>IMR</th>
<th>Hazard Ratio (95% CI)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>High</td>
<td>Low</td>
<td>1.000 (Reference)</td>
<td>NA</td>
</tr>
<tr>
<td>B</td>
<td>High</td>
<td>High</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>C</td>
<td>Low</td>
<td>Low</td>
<td>2.116 (0.386-11.589)</td>
<td>0.388</td>
</tr>
<tr>
<td>D</td>
<td>Low</td>
<td>High</td>
<td>5.623 (1.234-25.620)</td>
<td>0.026</td>
</tr>
</tbody>
</table>

Breslow P for overall comparison = 0.002
How did we calculate conductance?

1. Pressure
   - Wave free period (iFR)

2. Flow

3. Flow velocity cm/s
   - $y = 1.16x - 48.47$
   - $r^2 = 0.91$
   - $Y = 81.351 - 0.227 \times X; R^2 = 0.084$
   - $Y = -48.47 + 1.165 \times X; R^2 = 0.909$
What do we know about conductance?

**Overall conductance**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Conductance (mm Hg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No stenosis</td>
<td>6.01±1.93*</td>
</tr>
<tr>
<td>Stenosis 1</td>
<td>3.64±1.47</td>
</tr>
<tr>
<td>Stenosis 2</td>
<td>2.81±1.63</td>
</tr>
</tbody>
</table>

**Microvascular conductance**

Conductance in assessment of stenosis severity

Conductance in assessment of microcirculation
The coronary circulation

- $G_T \leftrightarrow \text{IHDVPS}_{Pa}$
- $G_2 \leftrightarrow \text{IHDVPS}_{Pd}$
- $G_1 \leftrightarrow \text{EC}$

$$EC = -\frac{\text{IHDVPS}_{Pa} \cdot \text{IHDVPS}_{Pd}}{\text{IHDVPS}_{Pa} - \text{IHDVPS}_{Pd}}$$

- Equivalently:

$$EC = \frac{\text{IHDVPS}_{Pd} \cdot \text{IHDVPS}_{Pa}}{\text{IHDVPS}_{Pd} - \text{IHDVPS}_{Pa}}$$
Why is this important?

- Selective diastolic interrogation
- Same units in epicardial and microvascular domains: cm/s/mmHg
- $C^{EPI}$ remarkable power to detect stenoses
- $C^{MICRO}$ independent of epicardial stenosis
- Future: head to head comparison between FFR, iFR, HSR and $C^{EPI}$ and PET
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