Invasive Assessment of Microvascular Integrity Indexes in AMI Following Primary PCI

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Myocardial Blush Scores

- Cumulative survival (1 yr) after PCI in 173 pts with AMI and in 163 patients in whom TIMI-3 flow was achieved.

Final Blush Score (patients with final TIMI-3 flow)

- Cumulative survival (%)

- Months

Final Blush Score (all patients)

Blush 1 year mortality
3 6.8%
2 13.0%  p=0.002
0/1 22.0%

Blush 1 year mortality
3 6.8%
2 13.2%  p=0.004
0/1 18.3%

### Myocardial Blush Scores

- **Inter- and intraobserver variability of myocardial blush grades**

<table>
<thead>
<tr>
<th></th>
<th>Differences</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
</tr>
<tr>
<td>Intraobserver variability</td>
<td>40</td>
</tr>
<tr>
<td>Interobserver variability</td>
<td>40</td>
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</tbody>
</table>

Coronary Flow Reserve (CFR)

- CFR is defined as the ratio of maximal coronary blood flow at hyperemia and coronary blood flow at resting which means the reservoir capacity of microvascular circulation according to demand.

- CFR doppler
  \[ \text{CFR doppler} = \frac{hAPV \times CSA}{bAPV \times CSA} = \frac{hAPV}{bAPV} \]

- CFR thermo
  \[ \text{CFR thermo} = \frac{\text{mean } bTMN}{\text{mean } hTMN} \]
## Invasive Measurement of CFR in MI

<table>
<thead>
<tr>
<th>Author (Year)</th>
<th>Pts no.</th>
<th>PCI time</th>
<th>Measuring CFR</th>
<th>Infarct location</th>
<th>Comparison</th>
<th>F/U</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lepper W. (Circulation 2000;101:2368)</td>
<td>25</td>
<td>Within 6 hours</td>
<td>Just after PCI and after 24 hours</td>
<td>LAD : 11</td>
<td>MCE</td>
<td>1 month echo</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>RCA : 14</td>
<td></td>
<td></td>
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<tr>
<td>Mazur W. (Am H J 1998;136:335)</td>
<td>29</td>
<td>6.9±3.4 D</td>
<td>Just after PCI</td>
<td>LAD : 15</td>
<td>Venticulograms (LV RWMA)</td>
<td>6-8 weeks echo</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>LCX : 4</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>RCA : 10</td>
<td></td>
<td></td>
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<tr>
<td>Teiger E. (Eur H J 1999;20:285)</td>
<td>22</td>
<td>16 ±4 D</td>
<td>Just after PCI</td>
<td>LAD : 10</td>
<td>Thallium 201 SPECT</td>
<td>4 months ventriculogram</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>RCA : 12</td>
<td></td>
<td></td>
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<tr>
<td>Beygui F. (J Am Coll Cardiol 2002;40:877)</td>
<td>41</td>
<td>Within 6 hours</td>
<td>Pre-discharge</td>
<td>LAD : 16</td>
<td>Thallium 201 SPECT</td>
<td>6 months Thallium 201 SPECT</td>
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<td></td>
<td></td>
<td>RCA : 25</td>
<td></td>
<td></td>
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<tr>
<td>Feldman LJ (Circulation 2003;107:2684)</td>
<td>50</td>
<td>Within 12 hours</td>
<td>Just after PCI</td>
<td>LAD : 32</td>
<td>ST resolution</td>
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<td></td>
<td></td>
<td></td>
<td>Thallium 201 SPECT</td>
<td>3 wks, 6 months ventriculogram</td>
</tr>
<tr>
<td>Shimada Y. (Circ J 2004;68:208)</td>
<td>37</td>
<td>Within 12 hours</td>
<td>3 weeks after PCI (pre-discharge)</td>
<td>LAD : 37</td>
<td>Venticulograms (LVEDV)</td>
<td>3 wks, 6 months ventriculogram</td>
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<tr>
<td>Sezer M (Heart 2006;29)</td>
<td>41</td>
<td>Primary</td>
<td>Within 48 hours after PCI</td>
<td>LAD : 41</td>
<td>Hematologic indexes</td>
<td>.</td>
</tr>
</tbody>
</table>
Physiologic Impact of Distal Embolization

- Open chest dogs embolized with microspheres 15, 100, 300 micron, up to $10^5$/g of myocardium.
- Initial increase in resting flow (adenosine) but with blunting of hyperemia, and then reduction in resting flow as particulate burden increased.


* $p < 0.05$ vs control

** $p < 0.01$ vs control
# CFR and LV Function Changes

<table>
<thead>
<tr>
<th></th>
<th>Reperfusion Group (n=13)</th>
<th>Nonreperfusion Group (n=12)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFR after PCI</td>
<td>1.67 ± 0.47</td>
<td>1.48 ± 0.31</td>
<td>0.289</td>
</tr>
<tr>
<td>CFR at 24 hr follow-up</td>
<td>2.15 ± 0.53</td>
<td>1.58 ± 0.30</td>
<td>0.003</td>
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</table>

<table>
<thead>
<tr>
<th></th>
<th>Recovery Group (n=17)</th>
<th>Nonrecovery Group (n=8)</th>
<th>p</th>
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</thead>
<tbody>
<tr>
<td>CFR after PCI</td>
<td>1.64 ± 0.42</td>
<td>1.51 ± 0.40</td>
<td>0.451</td>
</tr>
<tr>
<td>CFR at 24 hr follow-up</td>
<td>2.15 ± 0.47</td>
<td>1.37 ± 0.11</td>
<td>&lt;0.001</td>
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</tbody>
</table>

Microvascular Integrity and Coronary Blood Flow Patterns

Mild myocardial damage  Severe myocardial damage

Iwakura. et al. Circulation 1996;94:1269-75
Microvascular Integrity and Coronary Blood Flow Patterns

Mild myocardial damage  Severe myocardial damage

## Coronary Flow Velocity Patterns

<table>
<thead>
<tr>
<th>Study</th>
<th>Pts no.</th>
<th>Reperfusion time</th>
<th>Measuring flow patterns</th>
<th>Infarct location</th>
<th>Comparison</th>
<th>F/U</th>
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</thead>
<tbody>
<tr>
<td>Yamamoto K.</td>
<td>105</td>
<td>About 9 hours</td>
<td>Just after PCI</td>
<td>LAD : 57</td>
<td>MCE TIMI grade</td>
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<tr>
<td>(J Am Coll Cardiol 2002;40:877)</td>
<td></td>
<td></td>
<td></td>
<td>LCX : 9</td>
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<td></td>
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<tr>
<td>(Circulation. 1996;94:1269)</td>
<td></td>
<td></td>
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<td>LCX : 4</td>
<td></td>
<td></td>
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<tr>
<td>Akasaka T</td>
<td>23</td>
<td>Within 12 hours</td>
<td>Just after PCI</td>
<td>LAD : 23</td>
<td>RWMAs by Echo</td>
<td>1 month Echo</td>
</tr>
<tr>
<td>(Circulation 1999;100:339)</td>
<td></td>
<td></td>
<td></td>
<td>RCA : 10</td>
<td></td>
<td></td>
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<tr>
<td>Lepper W</td>
<td>25</td>
<td>Within 6 hours</td>
<td>Just after PCI</td>
<td>MCE</td>
<td></td>
<td>1 month MCE</td>
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<tr>
<td>(J Am Coll Cardiol 2002;39:1283)</td>
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<tr>
<td>Okamura A</td>
<td>72</td>
<td>Within 24 hours</td>
<td>Just after PCI</td>
<td>LAD : 72</td>
<td>Cardiac enzyme TIMI flow</td>
<td>.</td>
</tr>
<tr>
<td>(Am J Cardiol 2005;96:927)</td>
<td></td>
<td></td>
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<td>RCA : 10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hoffmann R</td>
<td>35</td>
<td>Within 6 hours</td>
<td>Just after PCI</td>
<td>LAD: 15</td>
<td>TMPG</td>
<td>.</td>
</tr>
<tr>
<td>(Heart 2003;89:1147)</td>
<td></td>
<td></td>
<td></td>
<td>RCA: 20</td>
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<tr>
<td>Furber AP</td>
<td>68</td>
<td>7.6 ± 7.0 h</td>
<td>Just after PCI</td>
<td>LAD : 36</td>
<td>MACE 3.8 yrs</td>
<td></td>
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<tr>
<td>(Circulation 2004;110:3527)</td>
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<td>LCX : 6</td>
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<td></td>
<td></td>
<td>RCA : 30</td>
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</tr>
</tbody>
</table>
Coronary Wedge Pressure (Pcw)
- The distal coronary artery wedge pressure during balloon occlusion

Pressure derived Collateral Flow Index (CFI\(p\))
- \((Pcw - Pv) / (Pa - Pv)\)
- simplified by \(Pcw / Pa\)
Coronary Wedge Pressure and Collateral Flow in AMI

- Cell necrosis
- Cell edema
- WBC, thrombotic materials and platelets packing
- Spasm ......
Comparison of pressure-derived collateral flow index (CFI_p) among angiographically collateral grades in AMI with PCI within 12 hours.

Coronary Wedge Pressure

- Relationship between Pcw and % FDG uptake, wall motion chandes

\[ r = -0.696 \]
\[ p < 0.001 \]

Derivation of Index of Microcirculatory Resistance (IMR)

- Resistance = \( \Delta \) Pressure / Flow
- IMR = \( \frac{P_d - P_v}{1/T_{mn}} \)
- IMR = \( P_d \times T_{mn} \)

at maximal hyperemia

IMR : 12.1 U

Pd: coronary distal Pressure
Tmn: mean transit time
IMR and Microvascular Damages

- Twenty-seven patients with STEMI treated with primary stenting.

### IMR

<table>
<thead>
<tr>
<th></th>
<th>IMR</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak CK</td>
<td>0.54</td>
<td>0.004</td>
</tr>
<tr>
<td>Neutrophil %</td>
<td>0.52</td>
<td>0.01</td>
</tr>
<tr>
<td>TMPG</td>
<td>-0.42</td>
<td>0.03</td>
</tr>
<tr>
<td>TFG</td>
<td>-0.44</td>
<td>0.03</td>
</tr>
<tr>
<td>CFR</td>
<td>-0.43</td>
<td>0.03</td>
</tr>
<tr>
<td>cTFC</td>
<td>0.54</td>
<td>0.004</td>
</tr>
</tbody>
</table>

- IMR above the median level of 35 had greater peak CK (3387±1531 vs. 1209±966 IU, p=0.03)

Fearon W et al. Abstracts, Circulation 2006;II-586
IMR and Cardiac PET

- Correlation between IMR and FDG uptake rate by Cardiac PET
- Twenty-four patients with STEMI treated with primary PCI was studied.

\[ r = -0.696 \quad p < 0.001 \]

\[ r = -0.480 \quad p = 0.018 \]

\[ r = 0.454 \quad p = 0.026 \]

SJ Tahk, HS Lim, et al. Korean Circulation 2006;36(suppl II)
IMR and Cardiac PET

- Accuracy of IMR for predicting viability (50%>FDG uptake rate)

- IMR
  - Sensitivity: 81.8%
  - Specificity: 84.6%
  - AUC: 0.846
  - BCV: 22

- Pcw / Pa
  - Sensitivity: 63.6%
  - Specificity: 76.9%
  - AUC: 0.738
  - BCV: 0.26

- Thermodilution CFR
  - Sensitivity: 72.7%
  - Specificity: 76.9%
  - AUC: 0.727
  - BCV: 1.8

AUC: Area under the Curve
BCV: Best Cutoff Value

SJ Tahk, HS Lim, et al. *Korean Circulation* 2006;36(suppl II)
Correlation of Microvascular Integrity Indexes with FDG PET

Forty-six patients with STEMI treated with primary PCI and follow up echocardiography at 6 months was studied.

Comparison Between TMPG and the FDG Uptake, LV Wall Motion

**FDG uptake rate**

- **p<0.001**
- **p=0.003**

**LV wall motion**

- **p<0.001**
- **p=0.003**

Comparison of the Accuracy Each Indices and PET for Predicting LV Wall Motion

All Patients (n=46)  Ant. Wall MI Patients (n=34)

- CFR
- DDT
- Pcw
- MVR
- TMPG
- FDG uptake

Pcw: AUC = 0.610
PET: AUC = 0.853
P = 0.020
Limitations

- Although, the TMPG is a subjective index, it might be a simple and useful index for predicting microvascular integrity and LV functional changes.

- Although, there are little studies about the IMR, it might be an excellent index for predicting microvascular integrity in AMI regardless of the patient’s hemodynamic status.

- The CFR might be a good index for predicting microvascular integrity, however, it was affected by patient’s hemodynamics and baseline flows after primary PCI in acute stage of AMI.

- The Pcw might represent the microvascular tone and function, However, further study will be required about the effect of collateral flows on the Pcw in acute stage of AMI.
Conclusion

- **Indexes of microvascular integrity**, such as CFR, Coronary flow patterns (DDT), MVR index, Pcw/Pa, and TMPG, which are measured during primary PCI in AMI, **are useful and comparable with FDG PET for predicting the LV functional changes.**