Value of Index of Microvascular Resistance (IMR) in Microvascular Integrity

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To date, a simple and invasive method for assessing the integrity of coronary microcirculation and myocardial viability in patients with AMI immediately after primary angioplasty is lacking.
Assessment of Microvasculature

1. Noninvasive imaging
   ; Contrast Echo, MRI, RI scan, PET…
2. ECG; ST segment resolution
3. Coronary Angiography
   ; TIMI myocardial perfusion grade
4. Physiologic Studies
   1) Coronary flow reserve,
   2) other Doppler parameters
   3) Index of Microcirculatory Resistance (IMR)
Microvascular Integrity

- Microvascular resistance
  - Cell necrosis
  - Cell edema
  - WBC, thrombotic materials and platelets packing
  - Spasm

- Microvascular circulation

Collateral flow and pressure

Pa

Tmn

Pd

R

Pv
Methods

Intracoronary Pressure Wire
(Radi Medical System, Uppsala, Sweden)

- $P_a$ (mean Ao pr.), $P_d$ (mean distal coronary pr.)
- $T_{mn}$ (mean transit time)
- $P_{cw}$ (coronary wedge pressure), $P_{cw}/P_a$ ratio
- Thermodilution CFR = hyperemic $T_{mn}$ / basal $T_{mn}$
- $FFR$ = hyperemic $P_d$ / hyperemic $P_a$
- $IMR$ = $P_d \times$ hyperemic $T_{mn}$
Intracoronary Doppler Measurements

Measurement of CFR

ACC: 6.7

CFR APV
BAPV: 24
PAPV: 52
RATIO: 2.2
Intracoronary Doppler Measurements

Measurement of DDT

- ECG
- Ao
- SPV

- 2 sec
- 240 cm/s
- 120 cm/s
- 0 cm/s
Intracoronary Pressure Measurements

Equalization:
G/C pressure with the sensor

\[ \frac{bPd}{hPa} = \frac{hPd}{hPa} = \text{FFR} \]

\[ \frac{bTmn}{hTmn} = \text{CFR}_{thermo} \]

\[ \text{Pd} \times hT_{mn} = hT \]

\[ hT_{mn} = \text{IMR} \]

Adenosine
Saline

Thrombus
IMR

Derivation of Index of Microcirculatory Resistance (IMR)

★ Resistance = Δ Pressure / Flow

★ 1 / Tmn ≅ Flow

★ IMR = (Pd − Pv) / (1 / Tmn)

★ IMR = Pd × Tmn

at maximal hyperemia...
• Clearly defined normal value
• Not affected by resting hemodynamics
• Easy to perform

Adapted from: Pijls and De Bruyne, Coronary Pressure
Index of Microcirculatory Resistance (IMR)
Measurement of IMR

IMR = 15 U
Derivation of Index of Microcirculatory Resistance (IMR)

The graph shows a linear relationship between the reciprocal of the microvascular transit time ($1/T_{mn}$) and absolute flow (ml/min). The data points are plotted on a scatter plot, and a straight line fits the data, indicating a direct proportionality between these two variables.
Correlation between IMR and TMR at 24 different combinations of myocardial resistance and epicardial stenosis severity

Reproducibility of IMR

Mean correlation coefficients of IMR, CFR, FFR values comparing baseline measurements with each hemodynamic intervention.

Repeat baseline / RV pacing at 110 bpm, nitroprusside infusion / dobutamine infusion.

Martin et al. Circulation 2006;113;2054-2061
Microvascular Integrity in AMI

- The preservation of the microvascular functions (microvascular integrity) is an important determinant of improvement of the left ventricular function and clinical outcomes after PCI in AMI.

- The indices of microvascular integrity were related with clinical outcomes of AMI patients.
  - Coronary flow reserve,
  - Phasic coronary flow velocity pattern,
  - Microvascular resistance index
    - Index of microvascular resistance (IMR)
  - Coronary capillary wedge pressure
Microvascular Integrity

Relationship of both TIMI grade and TMP grade to 30-day mortality

- Epicardial TIMI 3 flow:
  - TMPG 3: 3.5%, n = 455
  - TMPG 0/1/2: 4.7%
  - p = 0.04

- Epicardial TIMI 2/1/0 flow:
  - TMPG 3: 6.8%, n = 294
  - TMPG 0/1/2: 7.4%
  - 4 way p = 0.008

Gibson et al. Circulation 2000;101;125-130
Microvascular Integrity

After successful primary PCI for AMI, CFR performed before discharge was correlated with $^{201}$TI SPECT redistribution patterns and late LV contractility recovery.

F. Beygui et al., J Am Coll Cardiol 2002;40:877

Phasic Coronary flow velocity parameters or patterns is useful in predicting recovery of regional LV function.

- Deceleration time of diastolic flow velocity (DDT) > 600ms
- Systolic average peak velocity (SAPV) > 6.5 cm/sec

Akasaka et al. Circulation 1999;100:339
**Microvascular Integrity**

- The parameter that correlates best with residual myocardial viability is coronary wedge pressure ($P_{cw}$) and this may be a useful index for predicting patient prognosis.

  *Shimada et al. Heart 2003;89:71–76*

- In AMI, collateral flow index ($CFI_p$) seems to increase with the severity of microvascular dysfunction. Because higher $CFI_p$ was associated with poorer functional recovery, it provides a simple and useful estimate of clinical outcomes in AMI.

  *Yamamoto et al. J Am Coll Cardiol 2001;38:1383-9*
Correlation between IMR and Peak CK

R = 0.54
P < 0.001*

<table>
<thead>
<tr>
<th>Feature</th>
<th>R</th>
<th>p</th>
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<tbody>
<tr>
<td>CFR</td>
<td>.26</td>
<td>0.22</td>
</tr>
<tr>
<td>TFG</td>
<td>.13</td>
<td>0.50</td>
</tr>
<tr>
<td>cTFC</td>
<td>.09</td>
<td>0.65</td>
</tr>
<tr>
<td>TMPG</td>
<td>.027</td>
<td>0.89</td>
</tr>
<tr>
<td>ST res</td>
<td>.16</td>
<td>0.42</td>
</tr>
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Shah et al.  AHA 2006
Peak CK and IMR

Shah et al. AHA 2006
Follow-Up Ejection Fraction and IMR

Ejection Fraction (%)

IMR < 35: 57.5 ±12
IMR > 35: 46.1 ±8

P = 0.01

Shah et al. AHA 2006
Follow-Up Echo Wall Motion Score and IMR

Shah et al. AHA 2006
Twenty-nine patients with STEMI treated with primary stenting.

<table>
<thead>
<tr>
<th>IMR</th>
<th>r</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>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 32 had greater peak CK (3128±1634 vs. 1201±911 IU, p=0.002)

Fearon W et al. J Am Coll Cardiol 2008;51:560–5
Three-Month Wall Motion Score With Low Versus High IMR

Fearon W et al. J Am Coll Cardiol 2008;51:560–5
Relation Between Change in WMS and IMR

Fearon W et al. J Am Coll Cardiol 2008;51:560–5
Correlation between the IMR & percent change in A-WMS

\[ r = -0.464 \]
\[ p = 0.003 \]

- Recovery of LV wall motion (−)
- Recovery of LV wall motion (+)
Cut-off value of the IMR for predicting LV wall motion recovery

Sensitivity 73%
Specificity 100%
Accuracy 89%

IMR = 33 U
Comparison of percent change in A-WMS in patients presenting with an IMR ≤ 33 U and those presenting with an IMR > 33 U.

- IMR ≤ 33: 32 ± 12%
- IMR > 33: 12 ± 18%

P < 0.001
Correlation between the IMR and Regional FDG uptake imaged by PET

Correlation plot showing a negative correlation between IMR (in units) and regional FDG uptake (in percentage). The correlation coefficient is $r = -0.738$, and the p-value is $p < 0.001$. The symbols indicate recovery of LV wall motion: • recovery of LV wall motion (−) and ○ recovery of LV wall motion (+).
FDG uptake with an IMR $\leq 33$ U and those presenting with an IMR $> 33$ U

![Graph showing regional FDG uptake with IMR ≤33 and IMR > 33]

- IMR ≤33: 59 ± 11
- IMR > 33: 40 ± 10

P < 0.001
Case 1: CAG

M/64 STEMI (ant.), onset to balloon time - 120 min

Pre PCI

Post PCI
Case 1: IMR

M/64 STEMI (ant.) IMR: 11.7 U, CFR\textsubscript{thermo}: 2.0
Case 1: FDG PET

Myocardial Viability: FDG PET

FDG Uptake = 70.7%
Case 1: Echocardiogram

After primary PCI

Percent change in A-WMS: 42.1%

6-mo follow-up
Case 2: CAG

M/60 STEMI (ant.), onset to balloon time - 600 min

Pre PCI

Post PCI
Case 2: IMR

M/60 STEMI (ant.)  IMR : 72.3 U, CFR_{thermo} : 1.7
Case 2: FDG PET

Myocardial Viability: FDG PET

FDG Uptake = 37.4%
Case 2: Echocardiogram

After primary PCI

Percent change in A-WMS: -8.3%

6-mo follow-up
Advantage of IMR

- Highly reproducible index which is not affected hemodynamic conditions
- IMR has good correlation with absolute coronary blood flow and true microvascular resistance
Limitations of IMR

- Lack of optimal cutoff value about microvascular dysfunction
- Additional procedure for inducing hyperemia
- No large randomized clinical data
Conclusions

IMR, a novel index representing the microvascular integrity, is a reliable parameter for the invasive, on-site assessment of myocardial viability after primary PCI in AMI.

What do Interventionists need in clinical practice?

1) Epicardial Vessel ➔ FFR
2) Microvasculature ➔ IMR!!
Research Fellow 2009

Dr Ramasamy, Dr Poddar from India

RN, Seo Young Park
Korean Research Fellow, Ji Young Park
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Thank you for your attention!