MCE for Perfusion Myocardial Viability

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Echocardiographic Methods to Assess Myocardial Viability

Viability

Inotropic reserve (Dobutamine)
Intact microvascular circulation (Microbubble contrast)

Echo from Blood and Myocardial Tissue
-Not ideal for Imaging of Perfusion-

Ideal Method to enhance echo from blood in the microvasculature

Echo from blood in the microvasculature
Echo from Myocardial Tissue

Contrast Echo

LV myocardium
Bubbles behave like RBC
Echo- genic contrast effect

Myocardial Perfusion Imaging

Coronary angiogram
Contrast Echo, CT, MRI
Isotope Imaging
Methods to Enhance Echo from Blood in the Microvasculature

1. Contrast Agents

2. Imaging Technologies and Techniques

Newer Microbubbles

- Fluorocarbon or hexafluoride
- Polymer coated

- High density
- Low diffusivity
- Low saturation constant

Micbubbles: Stimulated Acoustic Emission

Real-Time (Non-Destructive) Imaging

Real-Time (Non-Destructive) Imaging

Power Modulation Real-time MCE

Real-Time (Non-Destructive) Imaging

Single-Pulse Transmission

Transmit

Linear Tissue

Receive

Half

Full
Power Modulation Real-time MCE

Linear Tissue

\[ \text{Subtract} = \]

Non-Linear Contrast

\[ \text{Subtract} = \]

Tissue (Linear Reflector)

\[ \text{Subtract} = \]

Contrast (Non-linear Reflector)

\[ \text{Subtract} = \]

Microbubbles-Summary

- Behaves like RBC
- Reflects high signals
- Susceptible to being destroyed

Hi MI > 1.0 destructive imaging

Low MI < 0.3 non-destructive imaging
**High MI Bubble-Destructive Imaging**

**Pitfalls**
1. Respiratory variation - lose regional comparability
2. Inability to evaluate wall motion abnormality
3. Tissue motion artifacts
4. Blooming artifacts

**Low MI Non-destructive Imaging**

*Simultaneous Assessment*

- Microvascular perfusion
- LV wall motion

- Power modulation
- Power pulse inversion
- Coherent imaging

**Flash Empty d1 d2 d3 d4 d5 t1 t2 t3 t4 t5**

**Normal coronary artery**

**LAD Lesion**
\[ y = A (1 - e^{-\beta t}) \]

\( A \) represents plateau VI or MBV, \( \beta \) is the rate constant reflecting velocity of RBC.

Modified from Wei K et al. Circulation 1998;97:473-483

**Time-Refilling Curve during Hyperemia**

- Normal
- Mild Stenosis
- Severe Stenosis

![Time-Refilling Curve during Hyperemia](image)

Modified from Wei K et al. Circulation 1998;97:473-483

**MCE in myocardial viability**

![MCE in myocardial viability](image)

**Microvascular Integrity** = **Myocardial Viability**

Intact Microcirculation

Microvascular No-reflow

Camilleri JP, et al., Virchow Arch, 1976

**No perfusion**

At 10 cycle

At 20 cycle

![No perfusion](image)
Case 1: A 47-year-old male presented with chest pain for 1 hour.

Wall motion improvement

At acute stage:
- Akinesia of mid LV to apex
- F/U 2 D Echo Mild focal hypokinesia at apical septum

MCE (subendocardial perfusion defect)

MRI at acute stage

Case 2: A 60-year-old male presented with chest pain for 40 min.

MCE (No perfusion)
No functional recovery after revascularization

MRI (100% hyperenhancement)

Acute stage F/U 2 D Echo


CeMRI-derived extent of delayed enhancement (DE) accurately represent transmural extent of infarction (TEI)

YUMC data

Study 1

Quantitative MCE and contrast enhanced MRI in prediction of myocardial viability after primary PCI in AMI : comparative study

Methods (1)

- 20 patients with AMI who were successfully revascularized by primary PCI (age: 59±10 years, 16 males)
- Real time MCE and MRI within 7 days after revascularization (LAD:12, LCx:3, RCA:5)

Methods (2)

- Myocardial perfusion by MCE
  Quantitative analysis of rate of microbubble velocity \( y = A (1 - e^{- \beta t}) \)
- Quantitative measurement of transmural delayed hyperenhancement on MRI
- Improvement in contractile function
  : 2D Echo initial & 12 weeks later
Quantitative assessment of myocardial perfusion by MCE
Rate of microbubble velocity(\(\beta\)) ≥ 0.4

<table>
<thead>
<tr>
<th>Beta</th>
<th>Beta &lt; 0.4</th>
<th>Beta ≥ 0.4</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall motion no improve</td>
<td>21</td>
<td>9</td>
<td>30</td>
</tr>
<tr>
<td>Wall motion improve</td>
<td>4</td>
<td>33</td>
<td>34</td>
</tr>
<tr>
<td>Total</td>
<td>25</td>
<td>33</td>
<td>64</td>
</tr>
</tbody>
</table>

- Sensitivity: 88.2%
- Specificity: 70.0%
- Positive predictive value: 84%
- Negative predictive value: 76.9%

Transmural extent of delayed hyperenhancement( ≤ 50% on MRI)

<table>
<thead>
<tr>
<th>MRI</th>
<th>Hypereenhancement ≥ 50%</th>
<th>Hypereenhancement &lt; 50%</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall motion improvement (-)</td>
<td>63</td>
<td>10</td>
<td>73</td>
</tr>
<tr>
<td>Wall motion improvement (+)</td>
<td>53</td>
<td>10</td>
<td>63</td>
</tr>
<tr>
<td>Total</td>
<td>69</td>
<td>20</td>
<td>89</td>
</tr>
</tbody>
</table>

- Sensitivity: 69.8%
- Specificity: 84.1%
- Positive predictive value: 78.7%
- Negative predictive value: 76.8%

Conclusion

- MRI showed better specificity (sensitivity 69.8%, specificity 84.1%) while MCE showed better sensitivity (sensitivity 88.2%, specificity 70%).

- Combining of quantitative MCE and MRI provided the best diagnostic characteristics, with a sensitivity of 88.2%, a specificity of 84.1% in the prediction of myocardial viability following AMI.

Study 2

Prediction of Transmural Extent of Infarction and Wall Motion Recovery With MCE-Derived MBVF and Index of MBF: Comparison With Contrast-Enhanced MRI

E Choi, N Chung et al JASE 2006

Methods

1. Low MI (<0.2) MCE
- Real time power modulation mode (DR: 20 dB)
- MBF assessment using replenishment curve which fit \(y=A(1-e^{-\beta t})\)
- Analysis with Q-LabTM (Philips, Bothel, USA)

2. High MI (>1.0) MCE
- Ultraharmonic mode (DR: 60 dB)
- 1:5 triggered image (end-systole, peak T wave gated)
- MBV (mL/100g) = 100x10calibrated CI/10
- Analysis with VoluMap-445TM (YD Ltd, Ikom, Japan)

Case, M/53, Ant. AMI

Pre PCI

After PCI
**Fundamental 2DE**

(seven days after PCI)

Akinesia of apical segments

**MCE**

(seven days after PCI)

Low MI (0.1), real-time power modulation mode

High MI (1.5) ultraharmonic mode

**Measurement of MBF index (Axβ, dB/sec) using Q-Lab program**

\[ A = 3.67 \text{ dB} \]

\[ \beta = 0.17 \text{ s}^{-1} \]

\[ Ax\beta = 0.624 \text{ dB/sec} \]

**Measurement of relative CI and MBVF (ml/100g myocardium) using Volu-Map program**

Septal apex relative CI = -26.3

Calculated MBVF = 0.234 ml

**Calibrated transmural MBV (mL/100g) was significantly correlated with MBF (Axβ)**

\[ r = 0.650, p < 0.001 \]
Segments: subdivided into three groups

- Group I: normokinetic without DE (n=80)
- Group II: 0-50% DE (n=94)
- Group III: 51-100% DE (n=30).

Comparison between groups

<table>
<thead>
<tr>
<th></th>
<th>Group I (n=80)</th>
<th>Group II (n=94)</th>
<th>Group III (n=30)</th>
</tr>
</thead>
<tbody>
<tr>
<td>% MR-DE</td>
<td>0</td>
<td>18.83±15.68**</td>
<td>70.83±10.51***</td>
</tr>
<tr>
<td>CCI (dB)</td>
<td>-13.9±1.3</td>
<td>-10.6±2.0 **</td>
<td>-18.9±3.0 **</td>
</tr>
<tr>
<td>MBV (mg/100g)</td>
<td>4.30±1.11</td>
<td>3.05±1.24 **</td>
<td>1.54±0.80 **</td>
</tr>
<tr>
<td>A</td>
<td>9.73±1.01</td>
<td>8.87±2.32 **</td>
<td>5.87±2.02 **</td>
</tr>
<tr>
<td>β</td>
<td>0.37±0.07</td>
<td>0.28±0.92 **</td>
<td>0.13±0.04 **</td>
</tr>
<tr>
<td>Aβ</td>
<td>3.63±0.79</td>
<td>2.54±1.07 **</td>
<td>0.86±0.50 **</td>
</tr>
</tbody>
</table>

DE: delayed hyperenhancement
CCI: calibrated contrast intensity

Mean transmural MBF and MBV were negatively correlated with %DE

Optimal cutoff values for predicting 50% MR-DE

- MBV: 1.64 ml (sensitivity 63%, specificity 91%)
- MBF: 1.26 (sensitivity 83%, specificity 97%)

Future wall motion recovery and parameters of ceMRI and MCE

<table>
<thead>
<tr>
<th></th>
<th>Persistent Dysfunctional (n=15)</th>
<th>Recovered (n=33)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>% DE</td>
<td>69.2±21.6</td>
<td>25.9±23.7</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Relative CI (dB)</td>
<td>-18.9±3.8</td>
<td>-16.6±3.9</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>MBVF (ml/100g)</td>
<td>1.41±1.53</td>
<td>2.67±1.68</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Avg (dB/sec)</td>
<td>1.15±0.84</td>
<td>2.41±1.25</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>
**Conclusion**

- MCE-derived transmural MBVF can be an effective predictor of transmural extent of infarct and future contractile improvement in the reperfused myocardial infarction.

**Thanks for Your Attention**