Cardiac MRI – Echo’s Friend on Enemy?

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Disclosures

• None relevant
Outline

• Quantification of LVEF

• Assessment of valvular heart disease

• Tissue characterization

Definitions

Friend = someone you can depend on when you need help!

Enemy = someone who is antagonistic, hostile, seeking to overthrow you!
Question 1

CMR differs from 2D echo in the following ways except:

1. CMR has better contrast to noise and signal to noise ratio
2. CMR has superior inter, intra, test-re-test variability
3. CMR Cine images have similar or worse spatial resolution
4. Analysis of LVEF is faster by CMR

Strengths of CMR for LVEF
No acoustic window limitations
No shape assumptions

Better Contrast to Noise and Signal to Noise Ratio
**Accuracy** - phantoms

- Contiguous 10mm short axis slices

Debatin JF et al, Invest Radiol 1992; 27:198-204

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**Reproducibility**

Test re-test – MRI vs Echo

<table>
<thead>
<tr>
<th></th>
<th>MRI (COV)</th>
<th>2D Echo (COV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EDVi</td>
<td>3.7%</td>
<td>8.7%</td>
</tr>
<tr>
<td>ESVi</td>
<td>6.2%</td>
<td>17.3%</td>
</tr>
<tr>
<td>EF</td>
<td>3.7%</td>
<td>11.5%</td>
</tr>
</tbody>
</table>

- 60 subjects (20 normal, 20 HF, 20 LVH)
- Studies 15 minutes apart
- FLASH, SAX
- Echo MRI time difference <60 minutes

Grotheus et al Am J Cardiol 2002; 90:29-34
### Sample Size for Studies of EF change

<table>
<thead>
<tr>
<th></th>
<th>Echo</th>
<th>CMR</th>
<th>Reduction in sample size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SD</td>
<td>SD</td>
<td></td>
</tr>
<tr>
<td>3% absolute ΔLVEF</td>
<td>6.1</td>
<td>2.1</td>
<td>87%</td>
</tr>
</tbody>
</table>

Grotheus et al Am J Cardiol 2002; 90:29-34

3D Echocardiography LVEF

Dorosz et al. JACC, 2012; 15:1799

Thavendiranathan et al, JACC 2013, 8;61(1):77-84.
CMR vs 3D Echocardiography

<table>
<thead>
<tr>
<th></th>
<th>Cardiac MRI</th>
<th>3D Echo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signal to Noise</td>
<td>Excellent</td>
<td>Moderate</td>
</tr>
<tr>
<td>Contrast to Noise</td>
<td>Excellent</td>
<td>Moderate</td>
</tr>
<tr>
<td>Spatial Resolution</td>
<td>1-2mm</td>
<td>1-2mm</td>
</tr>
<tr>
<td>Temporal resolution</td>
<td>25-50ms</td>
<td>20-30ms</td>
</tr>
<tr>
<td>Shape assumptions</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>True 3D datasets?</td>
<td>Selected sequences</td>
<td>Yes</td>
</tr>
</tbody>
</table>

To A et al. iJACC, 2011; 4:788-98

CMR Limitations

- Manual post processing
- Not portable
Practicality

<table>
<thead>
<tr>
<th>Availability</th>
<th>Large institutions / Academic Centers</th>
<th>Widely</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>++++</td>
<td>++</td>
</tr>
<tr>
<td>Rapidity</td>
<td>+</td>
<td>++</td>
</tr>
</tbody>
</table>

LVEF - Summary

- CMR - reference standard for LVEF, mass
- Excellent reproducibility = smaller Ns
- Limitations – availability / portability
- 3D Echo improves reproducibility
- Echo remains primary method for LVEF
Valvular Heart Disease
Regurgitation / NOT STENOSIS

Echo - strengths
Echo - reproducibility

- Severe vs non-severe MR
  - Agreement 28% for VC, 37% for PISA

Echo - accuracy

Uretsky et al JACC, 2015
The use of cardiac MRI techniques

• Direct and Indirect Techniques

Thavendiranathan et al. JACC, 2012

Cardiac MRI techniques - Direct

Thavendiranathan et al. JACC, 2012
The use of cardiac MRI techniques

Diastole

Systole

LV Stroke Volume (LVSV):
LVSV = LVEDV - LVESV
LVSV = 250 mL - 100 mL
LVSV = 150 mL

Mitrail Regurgitant Volume (M RVol):
M RVol = LVSV - Ao Stroke Volume
M RVol = 150 mL - 80 mL
M RVol = 70 mL
Threshold values?

<table>
<thead>
<tr>
<th></th>
<th>RF</th>
</tr>
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<tbody>
<tr>
<td>Mild</td>
<td>≤15%</td>
</tr>
<tr>
<td>Moderate</td>
<td>16-26</td>
</tr>
<tr>
<td>Moderate-severe</td>
<td>26-48</td>
</tr>
<tr>
<td>Severe</td>
<td>&gt;48</td>
</tr>
</tbody>
</table>

Gelfand EV et al JCMR 2006

Myerson SG et al Circulation 2016

Threshold values?

<table>
<thead>
<tr>
<th>Valve disease</th>
<th>Indicator</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aortic stenosis</td>
<td>Peak velocity [m/s]</td>
<td>&lt;3</td>
<td>3-4</td>
<td>&gt;4</td>
</tr>
<tr>
<td></td>
<td>Orifice area [cm²]</td>
<td>&gt;1.5</td>
<td>1.0-1.5</td>
<td>&lt;1.0</td>
</tr>
<tr>
<td></td>
<td>Orifice area /BSA [cm²/m²]</td>
<td></td>
<td>&lt;0.6</td>
<td></td>
</tr>
<tr>
<td>Aortic regurgitation</td>
<td>Regurgitant volume [m³/beat]</td>
<td>&lt;30</td>
<td>30-59</td>
<td>≥80</td>
</tr>
<tr>
<td></td>
<td>Regurgitant fraction [%]</td>
<td>&lt;30</td>
<td>30-49</td>
<td>≥50</td>
</tr>
<tr>
<td></td>
<td>Regurgitant orifice area [cm²]</td>
<td>&lt;0.10</td>
<td>0.10-0.29</td>
<td>≥0.30</td>
</tr>
<tr>
<td>Mitral stenosis</td>
<td>Peak velocity [m/s]</td>
<td>&lt;1.2</td>
<td>1.2-2.2</td>
<td>≥2.2</td>
</tr>
<tr>
<td></td>
<td>Orifice area [cm²]</td>
<td>&gt;1.5</td>
<td>1.0-1.5</td>
<td>≤1.0</td>
</tr>
<tr>
<td>Mitral regurgitation</td>
<td>Regurgitant volume [m³/beat]</td>
<td>&lt;30</td>
<td>30-59</td>
<td>≥80</td>
</tr>
<tr>
<td></td>
<td>Regurgitant fraction [%]</td>
<td>&lt;30</td>
<td>30-49</td>
<td>≥50</td>
</tr>
<tr>
<td></td>
<td>Regurgitant orifice area [cm²]</td>
<td>&lt;0.20</td>
<td>0.20-0.39</td>
<td>≥0.40</td>
</tr>
<tr>
<td>Pulmonary stenosis</td>
<td>Peak velocity [m/s]</td>
<td>&lt;30</td>
<td>30-40</td>
<td>≥40</td>
</tr>
<tr>
<td></td>
<td>Orifice area [cm²]</td>
<td>&lt;1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pulmonary regurgitation</td>
<td>Regurgitant volume [m³/beat]</td>
<td>&lt;30</td>
<td>30-40</td>
<td>≥40</td>
</tr>
<tr>
<td></td>
<td>Regurgitant fraction [%]</td>
<td>&lt;25</td>
<td>20-35</td>
<td>≥35</td>
</tr>
<tr>
<td>Tricuspid stenosis</td>
<td>Orifice area [cm²]</td>
<td>&lt;1.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Kawel-Boehm et al JCMR 2015
When is CMR indicated

• Echo images suboptimal
• Discrepancy between clinical TTE/TEE Discrepancy between quantitative techniques
• To understand mechanism / associations
• Assessment of consequences of regurgitation
  – LV/RV volumes function
  – AO/PA size

Friend

Myocardial Tissue Characterization
Tissue characterization

- The promise of a non-invasive myocardial biopsy!!

**T2* imaging**

*Example in patient with Sickle Cell Disease*

*T2* values can be read directly from generated *T2* map

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**T2 mapping**

Thavendiranathan et al, Circ CV Imaging: 2012;5:102-110
Native T1 mapping

ECV Fraction


Wong T C et al. Circulation 2012;126:1206-1216
Using Tissue Characterization

Messroghli et al, JCMR 2017; 19:75

Tissue characterization

• Opportunity to recognize myocardial changes even in the absence of functional changes
• Use in individual patients?
• Not widely available / multiple sequences

• But not possible with echocardiography

Friend
Conclusions

• CMR has important strengths
  – LVEF, Valvular regurgitation, tissue characterization
• Echocardiography readily available, portable, much more experience, prognostic
• 3D echocardiography can help overcome some of limitations
• CMR remains a good friend!

Thank you