Current Indications for Cardiac MRI: What You See is What You Get?

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No disclosures

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The Ideal Diagnostic Technique

- Easy to apply
- Accurate and reproducible
- Widely available
- Harmless
- High spatial resolution
- Morphological and functional data
Cardiac MRI, the Advantages

- Non-invasive
- No radiation
- Excellent signal to noise
- High spatial resolution
- Allows tissue characterization
- Allows visualization of the entire thorax
- Comprehensive evaluation (function, volumes, perfusion, viability, flows, morphology)
- Guidance of interventions?
MRI, the Disadvantages

- Complex to perform
- Expensive
- Not widely available
- No bedside technique
- Lower spatial resolution than CT (coronary arteries?)
- In general, not real time
The Cardiac MR Exam

MRI is not real time imaging
ECG gating and image reconstruction are needed

Requirements
Breatholding
Regular R-R intervals

k-space

Contraindications
Pacemakers, AICDs, Neurostimulators, Cochlear implants

Intracerebral clips, Intraocular foreign bodies, Claustrophobia
The Cardiac MR Exam

Cine MR

T1 fast spin echo

Perfusion imaging

Velocity-encoded (flow quantification)

Post contrast imaging (delayed enhancement)

MR angiography
Ventricular Function

Global:  EDV and ESV

- $\text{EDV} - \text{ESV} = \text{SV}$
- $\frac{\text{SV}}{\text{EDV}} = \text{EF}$
- $\text{SV} \times \text{HR} = \text{CO}$
- LV mass

Cine MRI

Regional:  Wall thickening
- Myocardial deformation
Reproducibility

**TABLE 1.** Accuracy of CMR-Determined LV Mass in Human and Animal Studies

<table>
<thead>
<tr>
<th>Study</th>
<th>No.</th>
<th>SDD</th>
<th>95% CI</th>
<th>Mean Difference</th>
<th>Mean % Difference</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bottini et al[48]</td>
<td>6</td>
<td>8.9 g</td>
<td>±17.5 g</td>
<td>0.7 g</td>
<td>4.0%</td>
<td>Human</td>
</tr>
<tr>
<td>Katz et al[49]</td>
<td>10</td>
<td>7.4 g</td>
<td>±14.5 g</td>
<td>10.2 g</td>
<td>5.3%</td>
<td>Human</td>
</tr>
<tr>
<td>Human studies (mean values)</td>
<td>16</td>
<td>8.0 g</td>
<td>±15.7 g</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>McDonald et al[50]</td>
<td>10</td>
<td>1.8 g</td>
<td>±3.5 g</td>
<td>4.4 g</td>
<td>5.2%</td>
<td>Canine</td>
</tr>
<tr>
<td>Shapiro et al[52]</td>
<td>10</td>
<td>6.7 g*</td>
<td>±13.1 g</td>
<td></td>
<td></td>
<td>Canine normal</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>8.7 g*</td>
<td>±17.1 g</td>
<td></td>
<td></td>
<td>Canine post-MI</td>
</tr>
<tr>
<td>Caputo et al[53]</td>
<td>13</td>
<td>13.7 g*</td>
<td>±26.9 g</td>
<td></td>
<td>10.0%</td>
<td>Canine normal + LVH</td>
</tr>
<tr>
<td>Keller et al[64]</td>
<td>10</td>
<td>3.5 g</td>
<td>±6.9 g</td>
<td>6.8 g</td>
<td>13.3%</td>
<td>Canine</td>
</tr>
<tr>
<td>Maddahi et al[65]</td>
<td>8</td>
<td>4.9 g*</td>
<td>±9.6 g</td>
<td></td>
<td></td>
<td>Canine; in vivo</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>3.4 g*</td>
<td>±6.7 g</td>
<td></td>
<td></td>
<td>Canine; dead (in-situ)</td>
</tr>
<tr>
<td>Florentine et al[66]</td>
<td>11</td>
<td>13.1 g*</td>
<td>±25.7 g</td>
<td></td>
<td></td>
<td>Canine + feline</td>
</tr>
<tr>
<td>Canine studies (mean values)</td>
<td>79</td>
<td>7.0 g</td>
<td>±13.7 g</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**FIGURE 2.** Interstudy SD of the mean differences of repeated measures by 2-dimensional echocardiography in the present study compared with published data.

**Good for follow-up**

**Applicable in clinical trials**

Grouthes F et al, Am J Cardiol, 2002
Severe PR in repaired TOF. RVEDV > 170 ml/m²: Indication for PVR

RVEDV > 110 ml/m², RVEF < 40%. Major diagnostic criteria for ARVC
Great Vessels

- Follow-up of aortic aneurysms
- Follow-up of coarctation repair
- Follow-up of chronic aortic dissection
- Diagnosis of aortic arch anomalies
- Detection of renal arteries stenoses
- Diagnosis of anomalous drainage of the pulmonary veins
MRI in Congenital Heart Disease

- Determine anatomy
- Flow measurements (PR regurgitant volume)
- Measurement of Qp/Qs (VSD, ASD, PDA)
- Great vessels (coarctation, PA stenoses)
- Ventricular function (Subaortic RV, repaired Fallot, Fontan)
- Coronary anomalies
MR Coronary Imaging

Class I indication when an anomalous origin of coronary arteries is suspected

Coro anomalies in 0.5-1% of autopsies

Young with CP/syncope on exertion of unexplained cause

Kawasaki disease

Preop for redo valvular/CHD surgery
Cardiac Masses

- Determine whether the patient has a true cardiac mass
- Determine whether the mass has tumoral or nontumoral characteristics
- Determine whether the tumor is benign or malignant
- Determine the location, extent, complications, and associated features of the cardiac mass
- Use clinical information and knowledge about typical location and appearance of cardiac masses for the analysis
Pericardial Disease

Constriction or restriction?

Assessment of ventricular coupling with real-time cine MRI and its value to differentiate constrictive pericarditis from restrictive cardiomyopathy

Marco Francone
Steven Dymarkowski
Maria Kalantzi
Frank E. Rademakers
Jan Bogaert

DOI 10.1007/s00330-005-0009-0
CAD: Questions to Answer

**Diagnosis**
- Presence and extension of ischemia (stress MRI or other techniques)
- Detection of infarcted myocardium
- Acute or chronic?
- Complications: thrombus, VSD, mitral regurgitation
- Coronary stenoses

**Prognosis**
- Global and regional LV and RV function, LV mass

**Guiding therapy**
- LV remodeling, hibernation, viability
Myocardial Infarction

Delayed enhancement
Patterns of MI/DE

Patterns
- Reflect severity
- Correlate with enzyme rise
- Lead to different degree of LV dysfunction
- 3 and 4 = worse prognosis > LV remodeling
MI Acute or Chronic

Table 3. Comparison of Diagnostic Accuracy Between Standard CMR Protocol (Cine + Perfusion + DE-MRI) and a New CMR Protocol (T2W, Cine, LVWT, Perfusion, and DE-MRI) for Detection of Patients With ACS

<table>
<thead>
<tr>
<th></th>
<th>Cine + Perfusion + DE-MRI</th>
<th>Cine + Perfusion + DE-MRI + T2W + LVWT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>85% (11/13)</td>
<td>85% (11/13)</td>
</tr>
<tr>
<td>Specificity</td>
<td>84% (41/49)</td>
<td>96% (47/49)</td>
</tr>
<tr>
<td>PPV</td>
<td>58% (11/19)</td>
<td>85% (11/13)</td>
</tr>
<tr>
<td>NPV</td>
<td>95% (41/43)</td>
<td>96% (47/49)</td>
</tr>
<tr>
<td>Accuracy</td>
<td>84% (52/62)</td>
<td>93% (58/62)</td>
</tr>
</tbody>
</table>

Cury R et al, Circ 2008
MR-viability Approach

Contrast-enhanced MRI

- Minimal scar tissue (< 25% transmurality)
- Recovery of dysfunctional myocardium is likely to occur

- Scar tissue > 50-75%
  - Recovery is not likely

- Scar tissue 25-50% transmurality
  - Intermediate likelihood of recovery
  - Additional dobutamine stress or PET imaging
Detection of thrombi

DE MRI detects a substantial number of LV apical thrombi that are not seen by echo.

Table III. Sensitivity and specificity for subgroup with all 3 imaging modalities

<table>
<thead>
<tr>
<th></th>
<th>Total (n)</th>
<th>MRI</th>
<th>TTE</th>
<th>TEE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>48</td>
<td>88%</td>
<td>23%</td>
<td>40%</td>
</tr>
<tr>
<td></td>
<td>(79%-97%)</td>
<td>(11%-35%)</td>
<td>(26%-54%)</td>
<td></td>
</tr>
<tr>
<td>Specificity</td>
<td>112</td>
<td>99%</td>
<td>96%</td>
<td>96%</td>
</tr>
<tr>
<td></td>
<td>(97%-100%)</td>
<td>(92%-99.6%)</td>
<td>(92%-99.6%)</td>
<td></td>
</tr>
</tbody>
</table>

White R, AHJ, 2005; Mollet N, Circ 2002
87/120 avoided angiography
£ 945 vs 1245

Assomull RG et al, Circ, 2011
The role of cardiovascular magnetic resonance in patients presenting with chest pain, raised troponin and unobstructed coronary arteries

Table 2  Cardiovascular magnetic resonance findings

<table>
<thead>
<tr>
<th>CMR findings</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Myocarditis</td>
<td>30 (50.0)</td>
</tr>
<tr>
<td>Acute</td>
<td>19 (31.7)</td>
</tr>
<tr>
<td>Non-acute</td>
<td>11 (18.3)</td>
</tr>
<tr>
<td>Myocardial infarction</td>
<td>7 (11.6)</td>
</tr>
<tr>
<td>Takotsubo cardiomyopathy</td>
<td>1 (1.7)</td>
</tr>
<tr>
<td>Dilated cardiomyopathy</td>
<td>1 (1.7)</td>
</tr>
<tr>
<td>Normal CMR findings</td>
<td>21 (35)</td>
</tr>
</tbody>
</table>
Presentation, Patterns of Myocardial Damage, and Clinical Course of Viral Myocarditis

Pattern of DE:
Guido to biopsy
Predictor of outcome

PBV 19
Good prognosis

HHV 6
Poor prognosis

Mahrholdt H, Circ 06
Pattern of Delayed Enhancement

- **Ischemic**
  - Subendocardial
  - Transmural

- **Non-ischemic**
  - Midwall
    - HCM, Right ventricular overload
  - Midwall
    - Dilated cardiomyopathy, myocarditis
  - Midwall
    - Sarcoidosis, myocarditis, Anderson-Fabry, Chagas

- Global Endocardial
  - Amyloidosis, scleroderma, post-cardiac transplant

- Epicardial
  - Sarcoidosis, myocarditis
    - Anderson-Fabry, Chagas

- ARVC
Value of Delayed Enhancement

### Table

<table>
<thead>
<tr>
<th></th>
<th>Low Voltage by Carroll's ECG Criteria</th>
<th>Abnormal DT ((&lt;=150) ms) on Doppler Echocardiography</th>
<th>Combined ECG-Echocardiography Criteria</th>
<th>Presence of DHE-CMR</th>
</tr>
</thead>
<tbody>
<tr>
<td>True positive</td>
<td>13</td>
<td>6</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>True negative</td>
<td>10</td>
<td>13</td>
<td>6</td>
<td>19</td>
</tr>
<tr>
<td>False positive</td>
<td>11</td>
<td>8</td>
<td>15</td>
<td>2</td>
</tr>
<tr>
<td>False negative</td>
<td>4</td>
<td>11</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>76%</td>
<td>35%</td>
<td>88%</td>
<td>88%</td>
</tr>
<tr>
<td>Specificity</td>
<td>48%</td>
<td>62%</td>
<td>29%</td>
<td>90%</td>
</tr>
<tr>
<td>Positive predictive value</td>
<td>54%</td>
<td>43%</td>
<td>50%</td>
<td>88%</td>
</tr>
<tr>
<td>Negative predictive value</td>
<td>71%</td>
<td>54%</td>
<td>75%</td>
<td>90%</td>
</tr>
</tbody>
</table>

- **HCM**
- **Amyloid**
- **Sarcoid**
- **CRT**
Iron Overload

Myocardial iron-content estimation

Normal values $T2^*$: $33.3 \pm 7.8$ ms
Myocardial iron overload <20 ms

My Top 7

- Chest pain of unknown origin and + Trops
- Myocardial viability
- Evaluation of cardiomyopathies (function, etiology, morphology)
- Aortic pathology (coartaction, FU aneurysms/dissection)
- Evaluation of congenital heart disease (morphology, Qp/Qs, pulmonary vasculature)
- Characterization of cardiac masses
- Diagnosis of pericardial constriction
Take Home Message

- MRI provides a comprehensive evaluation of cardiovascular morphology and function
- MRI is being more and more used as a noninvasive tool in the diagnosis and management of heart disease
- Accurate, reproducible and sometimes unique information on cardiovascular morphology, function, perfusion, and tissue characteristics can be obtained
- Imaging protocol needs to be tailored to clinical question
- Ideally suited for follow-up
- Improvement in outcome to be proven