The role of CMR in the evaluation of athletes and cardiomyopathies

Rory O’ Hanlon
April 15th 2011
### Difficult Scenarios

<table>
<thead>
<tr>
<th>Athlete</th>
<th>Diagnosis of suspected cardiomyopathies</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Abnormal ECG</td>
<td>- Abnormal ecg with suboptimal or normal echo</td>
</tr>
<tr>
<td>- LVH on echo-grey zone 12-15mm</td>
<td>- Syncope evaluation</td>
</tr>
<tr>
<td></td>
<td>- Chest pain/SOB</td>
</tr>
<tr>
<td></td>
<td>- Family screening and follow up</td>
</tr>
<tr>
<td>- Dilated chambers</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- ?early DCM</td>
</tr>
</tbody>
</table>
When to consider CMR

- Not as initial screening strategy
- Concerning symptoms in young patient or an athlete
  - Chest pain, palpitations, syncope
- Abnormal ECG with “normal” or inconclusive echocardiogram
- Answers with single imaging modality
EuroCMR (European Cardiovascular Magnetic Resonance) Registry
Results of the German Pilot Phase

Objectives
During its German pilot phase, the EuroCMR (European Cardiovascular Magnetic Resonance) registry sought to evaluate indications, image quality, safety, and impact on patient management of routine CMR.

Background
CMR has a broad range of applications and is increasingly used in clinical practice.

Methods
This was a multicenter registry with consecutive enrollment of patients in 20 German centers.

Results
A total of 11,040 consecutive patients were enrolled. Eighty-eight percent of patients received gadolinium-based contrast agents. Twenty-one percent underwent adenosine perfusion, and 11% high-dose dobutamine-stress CMR. The most important indications were workup of myocarditis/cardiomopathies (32%), risk stratification in suspected coronary artery disease/ischemia (31%), as well as assessment of viability (15%). Image quality was good in 90.1%, moderate in 8.1%, and inadequate in 1.8% of cases. Severe complications occurred in 0.05%, and were all associated with stress testing. No patient died during or due to CMR. In nearly two-thirds of patients, CMR findings impacted patient management. Importantly, in 16% of cases the final diagnosis based on CMR was different from the diagnosis before CMR, leading to a complete change in management. In more than 86% of cases, CMR was capable of satisfying all imaging needs so that no further imaging was required.

Conclusions
CMR is frequently performed in clinical practice in many participating centers. The most important indications are workup of myocarditis/cardiomopathies, risk stratification in suspected coronary artery disease/ischemia, and assessment of viability. CMR imaging as used in the centers of the pilot registry is a safe procedure, has diagnostic image quality in 98% of cases, and its results have strong impact on patient management.  

(J Am Coll Cardiol 2009;54:1457–66) © 2009 by the American College of Cardiology Foundation
Causes of SCD in the young

So can a single imaging modality reliably in a single scan setting screen for these conditions and potentially provide markers of risk stratification?
What is CMR

Siemens sonata 1.5T
(Bo)

Liquid helium, superconducting coil, far less energy wastage, continuous uniform field within ~ 50cm sphere at centre of bore

2 x 2 x 1.5m

Require fast, high strength gradients for switching during acquisition, for CMR.
Cine Imaging
Tagging
Perfusion
Proximal Coronaries
T2* Iron
Flow Mapping
Late Gadolinium
STIRS
CMR Quantification
CMR Structure and Function
Absolute Values for Left Ventricle

<table>
<thead>
<tr>
<th>EDV [mL]</th>
<th>ESV [mL]</th>
<th>SV [mL]</th>
<th>EF [%]</th>
<th>Mass [g]</th>
</tr>
</thead>
<tbody>
<tr>
<td>229</td>
<td>90</td>
<td>139</td>
<td>61</td>
<td>204</td>
</tr>
</tbody>
</table>

Maceira AM. EHJ 2006.
Maceira AM. JCMR 2006.
Accurate Reproducible Volumes and Mass

- Superior reproducibility allows for reliable follow-up of patients
  - Response to detraining
  - Accurate visualisation of and assessment of wall thickness
    - Basal anteroseptal wall
    - Apical LV
- RV imaging
  - ?ARVC

Bottini. For a 10g difference in LV mass with a novel ant-HTN therapy: Need 505 patients for TTE but only 14 using CMR (90% power, p value 0.05)
Tissue characterisation

- **Intrinsic contrast properties**
  - Cine
  - T1 weighted (FAT)
  - T2 weighted (WATER)

- **Extrinsic contrast properties**
  - Early gadolinium
  - Late gadolinium
Evaluation of Diffuse Myocardial Fibrosis in Heart Failure With Cardiac Magnetic Resonance Contrast-Enhanced $T_1$ Mapping

Leah Ilcs, MBChB,* Heinz Pfluger, MD,* Arintaya Phrommintikul, MD,* Joshi Cherayath, Dip AMIT,† Pelin Aksit, MS,‡ Sandeep N. Gupta, PhD,§ David M. Kaye, PhD,* Andrew J. Taylor, PhD*  
Melbourne, Australia; and Bethesda, Maryland

**Figure 3** Myocardial Collagen Content and Post-Contrast $T_1$ Times  
**Figure 4** Post-Contrast Myocardial $T_1$ Times
O’ Hanlon, Whyte et al. JCMR 2010
# Diverse patterns of myocardial fibrosis in lifelong, veteran endurance athletes

Mathew G. Wilson¹, Rory O’Hanlon², Sanjay Prasad², Amanda Deighan³, Philip MacMillan⁴, David Oxborough⁵, Richard J. Godfrey⁶, Gill Smith², Alicia Maceira⁷, Sanjay Sharma⁸, Keith P. George⁹, and Greg Whyte¹⁰

<table>
<thead>
<tr>
<th>Participant Number</th>
<th>Age (yr)</th>
<th>% of total LGE Mass (g)</th>
<th>LGE Pattern</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>67</td>
<td>18.9</td>
<td>CAD</td>
<td>Probable Dual Infarction</td>
</tr>
<tr>
<td>2</td>
<td>50</td>
<td>8</td>
<td>Non-CAD</td>
<td>Probable myocarditis</td>
</tr>
<tr>
<td>3</td>
<td>66</td>
<td>3</td>
<td>Non-CAD</td>
<td>Nonspecific</td>
</tr>
<tr>
<td>4</td>
<td>60</td>
<td>3</td>
<td>Non-CAD</td>
<td>Nonspecific</td>
</tr>
<tr>
<td>5</td>
<td>50</td>
<td>1</td>
<td>Non-CAD</td>
<td>Nonspecific</td>
</tr>
<tr>
<td>6</td>
<td>51</td>
<td>1</td>
<td>Non-CAD</td>
<td>Nonspecific</td>
</tr>
</tbody>
</table>
Contrast Enhancement

Ischemic

A. Subendocardial Infarct

B. Transmural Infarct

Nonischemic

A. Mid-wall HE

- Idiopathic Dilated Cardiomyopathy
- Hypertrophic Cardiomyopathy
- Myocarditis
- Right ventricular pressure overload (e.g., congenital heart disease, pulmonary HTN)

B. Epicardial HE

- Sarcoidosis
- Myocarditis
- Anderson-Fabry
- Chagas Disease

C. Global Endocardial HE

- Amyloidosis, Systemic Sclerosis, Post cardiac transplantation

NSTEMI

STEMI

DCM
Pathological Validation

O’Hanlon R. JACC 2010
Moon JC. JACC 2004
• 35 yr old female
• Fam Hx HCM
• Normal ECG and TTE
• Normal wall thickness and function.
• LGE

Mis-sense mutation (275G>A) TNNT2 gene
High level triathlete with episodic palpitations and frequent bigeminy and trigeminy on holter

32 yr old male
Combined endurance and weight training
Possible (denied) anabolic steroid use
Admitted with TnI positive ACS
Minor LAD disease on angio
Possible recent hx of flu-like illness
44 yr female veteran athlete - CP
Lateral STEMI
TTE with agitated saline
Syncope in a 32 yr old
HCM Diagnosis


<table>
<thead>
<tr>
<th>Maximum apical thickness by CMR (mm)</th>
<th>Average apical basal ratio by CMR</th>
<th>Echocardiography report</th>
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<tbody>
<tr>
<td>27</td>
<td>1.8</td>
<td>Normal</td>
</tr>
<tr>
<td>16</td>
<td>1.4</td>
<td>Trabeculated apex</td>
</tr>
<tr>
<td>28</td>
<td>3.2</td>
<td>Akinetic apex</td>
</tr>
<tr>
<td>15</td>
<td>1.4</td>
<td>Normal</td>
</tr>
<tr>
<td>16</td>
<td>2.0</td>
<td>Normal</td>
</tr>
<tr>
<td>20</td>
<td>2.5</td>
<td>Normal</td>
</tr>
<tr>
<td>16</td>
<td>2.5</td>
<td>Normal</td>
</tr>
<tr>
<td>17</td>
<td>1.7</td>
<td>Normal</td>
</tr>
<tr>
<td>24</td>
<td>3.2</td>
<td>Poor views, normal</td>
</tr>
<tr>
<td>17</td>
<td>1.9</td>
<td>Normal</td>
</tr>
</tbody>
</table>

Moon. Heart 2004
Phenocopies
Perfusion and LGE

- 42 yr old asymptomatic
- No risk factors for SCD
- Normal angiogram
  - Significant microvascular ischaemia
  - Minimal diffuse fibrosis
- How would one treat him?
Two patients (19 and 21 yrs) with HCM in their 20. Both have NSVT on holter (6 beats). No family hx of SCD. Nil else of note in RF profile. Who has LGE? What to do from now?
30 yr old female.  
Tennis and squash.  
Palpitations and murmur.  
No Fam Hx
Miller C, O’Hanlon R.
LGE and Non-Ischaemic Cardiomyopathy

What do we know?
Gd-CMR and Sudden Death in HCM

Moon JC. JACC 2003; 41: 1561-7
LGE and LV Mass

Olivotto et al. JACC 2008
Rudolph et al. JACC 2009

LV Mass Index:
- Normal
- Mildly Increased
- Markedly Increased

128+/−62 g/m² vs 99+/−38 g/m²
Occurrence and Frequency of Arrhythmias in Hypertrophic Cardiomyopathy in Relation to Delayed Enhancement on Cardiovascular Magnetic Resonance

A. Selcuk Adabag, MD, MS,* Barry J. Mason, MD,† Evan Appelbaum, MD,‡§ Caitlin J. Harrigan, BA,§ Jacqueline L. Buros, BA,§ C. Michael Gibson, MD, MS,§§ John R. Lesser, MD,† Constance A. Hanna, RN,† James E. Udelson, MD,¶ Warren J. Manning, MD,¶§ Martin S. Maron, MD

Figure 1
Prevalence of Arrhythmias on 24-h Holter ECG With Respect to DE in 177 HCM Patients
24 year old
Unexplained syncope
No other risk factors

ICD?
Follow up?
Extensive Myocardial Fibrosis in a Patient With Hypertrophic Cardiomyopathy and Ventricular Tachycardia Without Traditional High-Risk Features

Sergio Bongicanni, MD; Paolo Spirito, MD; Andrea Sibona Masi, MD; Amedeo Chiribiri, MD; Rodolfo Bonamini, MD; Maria Rosa Conte, MD
Prognostic Significance of Myocardial Fibrosis in Hypertrophic Cardiomyopathy

Rory O’Harrow, MD,* Agata Grasso, MD,* Michael Roughan, MSc, † James C. Moon, MD,§
Susan Clark, RN,* Ricardo Wage,* Jessica Webb, MD,* Meghana Kulkarni, MD,*
Dana Dawson, MD, PhD,* Leena Sulaibekh, MD,* Badri Chandrasekaran, MD,*
Chiara Buccarello-Ducci, MD,* Ferdinando Pasquale, MD,§ Martin R. Cowie, MD,†
William J. McKenna, MD,|| Mary N. Sheppard, MD,‡ Perry M. Elliott, MD,|| Dudley J. Pennell, MD,*
Sanjay K. Prasad, MD*
Athletes Heart vs DCM
Fibrosis in DCM explanted heart
DCM

Death/hospitalization

HR 3.4

Assomull. JACC 2006; 48: 1977

Wu KC. JACC 2008.
Abnormal ECG +/- ventricular ectopy
ARVC
CMR Sequences
Incorporation of CMR results to Task Force Criteria would enable a further 30% of ARVC to be detected.
In Conclusion

- SCD in athletes rare
- CMR offers a unique imaging solution to screen for multiple congenital and acquired pathologies
  - Inconclusive imaging
  - Concerning symptoms
  - High clinical suspicion
- Not 1st line test however