A Light in the Dark: Cardiac MRI and Risk Mitigation

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Dr. Mikolich has NO financial disclosures relative to industry

Use of gadolinium as a MRI contrast agent is OFF LABEL

J. Ronald Mikolich, MD
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Sharon Regional Medical Center
How are Cardiac MRI Images Generated?
Effect of a Magnetic Field
Generation of a Cardiac MRI image
Generation of a Cardiac MRI Image
3 Most Common Cardiac Imaging Planes

2 chamber long axis

2 chamber short axis

4 chamber
What is a Pulse Sequence?

Why Use Multiple Pulse Sequences?
Pulse Sequences
What Are the Common Uses of CMR?

- Structure and function assessment
- Assessment of inflammatory heart disease
- Stress perfusion imaging
- Assessment of myocardial viability, i.e., detection of infarct scar
Diffuse Pattern
Pericardial Delayed Enhancement Imaging with Gadolinium
CMR detects pericardial effusions too small for 2-D echo
CE-MARC trial

- CE-MARC comparatively looked at SPECT stress and CMR stress imaging.
  - Invasive coronary arteriography was used as a gold standard.
  - Claimed CMR was a superior imaging modality

- CE-MARC, prospectively enrolled patients scheduled for invasive coronary arteriography.
CE-MARC trial

These are some images that the CE-MARC trial used as comparison between all the imaging techniques.

Figure 1: Three examples of CMR, SPECT, and angiographic findings

(Greenwood, et al., 2012)
CE-MARC trial

- 1-specificity represents the number of people that had a coronary heart disease
- Sensitivity represents the methods (CMR or SPECT) to correctly detect the problem

Figure 2: Receiver operating characteristic curves of summed stress scores by population and coronary heart disease definition
How does the superior performance of CMR stress perfusion imaging translate into practical application in the everyday care of patients with cardiac symptoms?
EFFECT OF THIRD PARTY PAYOR PRE-AUTHORIZATION POLICY ON CONCORDANCE OF NUCLEAR STRESS PERFUSION IMAGING AND CORONARY ARTERIOGRAPHY

Brendan Malik; J. Ronald Mikolich; Amitha Dhingra; John Lisko;
Concordance of MPI and Cath

BMI kg/m²

1st QTR 2010
1st QTR 2012
<table>
<thead>
<tr>
<th>Cardiac Diagnostic Test</th>
<th>Medicare $</th>
<th>Private Insurance $</th>
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<tbody>
<tr>
<td>EKG</td>
<td>17.42</td>
<td>30.00</td>
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<tr>
<td>Holter</td>
<td>87.49</td>
<td>195.00</td>
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<td>EP</td>
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<td>Nuclear Stress Test</td>
<td>770.55</td>
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<tr>
<td>Echocardiograph</td>
<td>355.78</td>
<td>625.31</td>
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<tr>
<td>Stress-Echocardiograph</td>
<td>355.78</td>
<td>504.25</td>
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<tr>
<td>TEE</td>
<td>286.48</td>
<td>447.00</td>
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<tr>
<td>CT</td>
<td>430.51</td>
<td>641.50</td>
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<td>Catheterization</td>
<td>1,900.00</td>
<td>2,400.00</td>
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<tr>
<td>MRI (75563 &amp; 75565)*</td>
<td>661.49</td>
<td>1,346.64</td>
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<tr>
<td>MRI (75557 &amp; 75565)*</td>
<td>306.53</td>
<td>942.41</td>
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<tr>
<td>MRI (75561 &amp; 75565)*</td>
<td>455.55</td>
<td>760.00</td>
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</table>

* Indicates Code Number for MRI imaging test
1 year Cost of Imaging for Obese Patients (BMI > 35)

- Medicare: $1,768
- Private Payor: $2,673.02 and $1,610.46
## Radiation Dose Considerations

<table>
<thead>
<tr>
<th>Cardiac Diagnostic Test</th>
<th>Radiation Exposure (mSv)</th>
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<tbody>
<tr>
<td>EKG</td>
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<tr>
<td>Holter Monitor</td>
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<td>EP</td>
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<tr>
<td>Non-Imaging Stress Test</td>
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<tr>
<td>Nuclear Stress Test</td>
<td>12.5</td>
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<tr>
<td>Echocardiography 2-D</td>
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<tr>
<td>Stress-Echocardiography</td>
<td>0</td>
</tr>
<tr>
<td>TEE</td>
<td>0</td>
</tr>
<tr>
<td>Coronary CT angio</td>
<td>10.5</td>
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<tr>
<td>Coronary Arteriography</td>
<td>12.0</td>
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<tr>
<td>CMR</td>
<td>0</td>
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Initial Cardiac Diagnostic Testing: A Radiation Perspective
Julianne Matthews MPH, Nicholas Boniface MPH, Brandon Mikolich MD, and J. Ronald Mikolich MD
Northeast Ohio Medical University and Sharon Regional Health System
What about the use of CMR in non-obese patients?
Average 1 Year Cost per Patient: CMR vs 2D or MPI
For Medicare and Private Insurance Patients

<table>
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<tr>
<th></th>
<th>Medicare</th>
<th>Private</th>
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<tbody>
<tr>
<td><strong>2D or MPI</strong></td>
<td>$7,967</td>
<td>$12,344</td>
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<tr>
<td><strong>CMR</strong></td>
<td>$1,842</td>
<td>$3,446</td>
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What About AICDs?

• Current guidelines, based on late 80’s and early 90’s 2-D echo data recommend AICD implantation for patients with LVEF < 35%

• Have you ever wondered why so many of those patients NEVER have an ICD discharge?

• Maybe it has something to do with the prognostic tool we’re using.
Identification of Myocardial Scar

Normal myocardium appears “black”

Gadolinium (Gd) is taken up in the spaces between fibrin in scar

Gd is 400 times brighter than myocardium

4 chamber view
Late Gadolinium Enhancement (LGE)
Septal MI via Gadolinium Enhancement

2 Chamber short axis view
Quantification of Myocardial
AICD Outcome Data

• Kim et al at Duke studied 137 patients who underwent AICD implantation based on 2-D echo criteria, per current guidelines
• All patients had a cardiac MRI study pre-ICD including ejection fraction and % myocardial scar
• 3 year follow-up for sudden cardiac death or ICD discharge
Outcomes: EF vs % Scar

A

Percent with Death or ICD-discharge

≥55%  40 - <55%  30 - <40%  20 - <30%  <20%

Left Ventricular Ejection Fraction

B

Percent with Death or ICD-discharge

0  >0 - 5  >5 - 10  >10 - 15  >15 - 20  >20

Scar Size (% LV)

Igor Klem et al. JACC 2012;60:408-420
A

Death or ICD discharge

<table>
<thead>
<tr>
<th>Scar &gt;5% (LVEF ≤30%)</th>
<th>Scar ≤5% (LVEF ≤30%)</th>
<th>HR (95% CI)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>vs. Scar ≤5% (LVEF ≤30%)</td>
<td></td>
<td>3.9 (1.2-13.1)</td>
<td>0.03</td>
</tr>
<tr>
<td>vs. Entire Group with LVEF &gt;30%</td>
<td></td>
<td>0.8 (0.2-2.8)</td>
<td>0.71</td>
</tr>
</tbody>
</table>

Scar >5%, LVEF ≤30%
(3-yr event rate 47%)

Scar ≤5%, LVEF ≤30%
(3-yr event rate 47%)

Entire group, LVEF >30%
(3-yr event rate 19%)

Number at risk

| Scar >5%, LVEF ≤30% | 46 | 31 | 11 | 1 |
| Scar ≤5%, LVEF ≤30% | 19 | 17 | 7  | 2 |
| Entire group LVEF >30% | 72 | 60 | 37 | 5 |

Igor Klem et al. JACC 2012;60:408-420

American College of Cardiology Foundation
So, do you want your AICD implanted on the basis of your LV ejection fraction or your percentage of myocardial scar?
The Future: Lighting the Dark

• A test which could differentiate myocardial ischemia from non-cardiac chest pain in less than 15 min
• A test which does not require contrast
• A test which does not involve radiation exposure
• A test with 97% accuracy
Since myocardial cells are mostly water, changes in myocardial water content will alter the T1 relaxation time.
Increased T1 Relaxation Time

- Myocardial edema
- Acute myocardial infarction
- Acute myocarditis
- Global myocardial injury due to sepsis
- Myocardial fibrosis
- Myocardial amyloidosis
More Recent Findings of T1 Relaxation Times

- Increase in coronary blood flow, i.e., exercise, vasodilation with adenosine
- T1 relaxation times can now be “mapped” and color coded on CMR images
Increase in Myocardial Flow Causes an Increase in Myocardial Water
Increase in Myocardial Flow and Water Causes an Increase in T1 Relaxation Time

Normal T1

Increased T1

Adenosine

Cardiomyocyte
Mobile water
Collagen fiber
CENTRAL ILLUSTRATION: CMR Stress T1 Mapping for the Assessment of Epicardial and Microvascular CAD

Stress ΔT1 >4.0%
Likely no obstructive epicardial CAD or microvascular dysfunction

Stress ΔT1 1.5 - 4.0%
Likely microvascular dysfunction

Stress ΔT1 <1.5%
Likely obstructive epicardial CAD

ΔT1 1.5% for detecting ischemia as FFR < 0.80

- True Positive
- True Negative
- False Negative
- False Positive

Alexander Liu et al. JACC 2018;71:957-968
Alexander Liu et al. JACC 2018;71:957-968
How Can CMR Help You in Your Practice at Your Hospital?

- Better detection and quantification of many common cardiac pathologies
- More accurate assessment of myocardial ischemia and scarring for therapeutic decisions
- Reduction in cost
- Reduction in patient radiation exposure
- Detection of inflammatory heart disease