Role of MRI in Ventricular Tachycardia

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Role of MR Imaging in Ventricular Tachycardia

1. Detection of Scars (Regional Fibrosis) : LGE
2. Diffuse Interstitial Fibrosis Imaging: T1 mapping
3. Other Imaging Techniques
Ventricular Scars

- Myocardial infarction
- Replacement fibrosis in non-ischemic cardiomyopathy (NICM)
- Cardiac surgical repairs: TOF repair etc.
Myocardial Fibrosis Assessment by LGE is a Powerful Predictor of VT in Ischemic and Nonischemic LV Dysfunction

- 2850 pts in 19 studies,
- 423 arrhythmic events, FU of over 2.8 yrs

The prognostic power of LGE is particularly strong in patients with severely decreased EF, which suggests its potential to improved patient selection for ICD implantation.

<table>
<thead>
<tr>
<th>LGE-CMR</th>
<th>% of LGE+</th>
<th>% LGE-</th>
<th>OR (95% CI)</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Studies</td>
<td>Patients</td>
<td>% AER</td>
<td>AER*</td>
<td>AER*</td>
</tr>
<tr>
<td>Total</td>
<td>19</td>
<td>2,850</td>
<td>5.3</td>
<td>8.6</td>
</tr>
<tr>
<td>ICM</td>
<td>5</td>
<td>358</td>
<td>8.9</td>
<td>13.2</td>
</tr>
<tr>
<td>NICM</td>
<td>8</td>
<td>1,443</td>
<td>3.7</td>
<td>7.6</td>
</tr>
<tr>
<td>Mixed population</td>
<td>6</td>
<td>1,049</td>
<td>6.8</td>
<td>8.8</td>
</tr>
<tr>
<td>Mean EF ≤30%</td>
<td>11</td>
<td>1,178</td>
<td>6.6</td>
<td>10.3</td>
</tr>
<tr>
<td>Mean EF &gt;30%</td>
<td>8</td>
<td>1,672</td>
<td>4.6</td>
<td>7.4</td>
</tr>
</tbody>
</table>

Disertori et al. JACC Img 2016;9:1046-55
LGE and the risk for ventricular arrhythmia or sudden death in DCM

- 2948 patients in 29 studies, LV EF 20-43%

Presence of LGE is associated with arrhythmic endpoint (OR:4.3, p<0.001), independent of other covariates, including LVEF.
Prognostic value of LGE CMR in non-ischemic DCM

- 4554 patients in 34 studies
- LGE in 44.8%

Patients with LGE

- Increased cardiovascular mortality (OR 3.4)
- Increased ventricular arrhythmic event (OR 4.52)
- Increased rehospitalization for HF (OR 2.66)

Absence of LGE

- LV reverse remodeling (OR 0.15)
LGE (+) vs. LGE (-)

Pattern
Extent

LGE is not uncommon.
Pattern of LGE predicts arrhythmic events in non-ischemic CMP

- 365 patients
- Outcome: major arrhythmic events
- 44.3 mo FU
- LGE extent ≥ 8%, subepicardial LGE

Shin et al. Int J Cardiol 2016; 222:9-15
Cardiac Sarcoidosis

- Active inflammation
- Development of myocardial scar as the inflammation heals
- Side effect of corticosteroid treatment itself

Myocardial Damage in Cardiac sarcoidosis

↑ Risk of death & life-threatening arrhythmias

“Patchy” disorder involving only small amount of myocardium
→ Poor diagnostic sensitivity (ECG, Echo, MPI, Bx)
Prognosis of Myocardial Damage in Sarcoidosis Patients with HFpEF

- 205 patients with EF>50% and confirmed extracardiac sarcoidosis
- LGE(+) 41, LGE(-) 164
Relationship between the quantitative extent of LGE and burden of NSVT in HCMP

- 14 day Holter monitoring

LGE extent is independently associated with a greater burden and longer episodes of NSVT in HCMP.

Fibrosis and Arrhythmogenesis

In severe form, Zig-zag conduction

The least arrhythmogenic

Arrhythmogenic slow conduction, spiral wave formation

Zig-zag conduction

S Rohr. Circ Arrhythm Electrophysiol. 2012;5:442-452
Limitation of LGE CMR

Diffuse Myocardial Involvement

T1 mapping ECV fraction
T1 mapping and ECV

**LGE CMR**
Differential degree of spatial accumulation of Gd agent

**T1 mapping CMR**
Variation in intrinsic myocardial tissue properties.

ECV: (1-hematocrit) =

\[
E_{\text{CV}} = \left(1 - \frac{1}{T_{1\text{myo post}}} - \frac{1}{T_{1\text{myo pre}}} \right) \cdot \left(1 - \frac{1}{T_{1\text{blood post}}} - \frac{1}{T_{1\text{blood pre}}} \right)
\]
T1-Mapping and Outcome in Nonischemic Cardiomyopathy: All-Cause Mortality and Heart Failure

International T1 Multicentre CMR Outcome Study

Chi² 47.5 (p < 0.001), HR 12.0 (4.9 – 29.6)

Chi² 42.7 (p < 0.001), HR 4.4 (2.7 – 7.2)

Puntmann et al. J Am Coll Cardiol Img 2016;9:40–50
Myocardial tissue characterization by CMR T1 mapping predicts ventricular arrhythmia in ischemic and non–ischemic cardiomyopathy patients with ICD

- 130 patients with ischemic and nonischemic CMP with ICD

Quantitative myocardial tissue assessment using T1 mapping is an independent predictor of ventricular arrhythmia in both ischemic and non–ischemic cardiomyopathies.

Chen et al. Heart Rhythm 2015;12:792-801
Increased Myocardial Native T1 in Patients With Nonischemic Dilated Cardiomyopathy With Complex Ventricular Arrhythmia

Global native T1 was independently associated with ComVA, after adjusting for LV function and LGE.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Control (n = 10)</th>
<th>+Com VA (n = 50)</th>
<th>-Com VA (n = 57)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>LV ESV (ml)</td>
<td>44.6 ± 9.0</td>
<td>212.5 ± 107.0</td>
<td>179.1 ± 92.2</td>
<td>0.09</td>
</tr>
<tr>
<td>LV ESV index (ml/m²)</td>
<td>26.1 ± 4.1</td>
<td>104.1 ± 48.7</td>
<td>89.3 ± 42.2</td>
<td>0.10</td>
</tr>
<tr>
<td>LV stroke volume (ml)</td>
<td>67.7 ± 13.3</td>
<td>84.9 ± 22.5</td>
<td>75.0 ± 20.8</td>
<td>0.02</td>
</tr>
<tr>
<td>LV stroke volume index (ml/m²)</td>
<td>39.4 ± 4.9</td>
<td>41.6 ± 10.0</td>
<td>37.8 ± 9.9</td>
<td>0.05</td>
</tr>
<tr>
<td>LV ejection fraction (%)</td>
<td>60.3 ± 2.7</td>
<td>33.1 ± 12.3</td>
<td>32.6 ± 12.6</td>
<td>0.85</td>
</tr>
<tr>
<td>LV mass (g)</td>
<td>66.5 ± 16.9</td>
<td>142.4 ± 60.1</td>
<td>138.0 ± 53.8</td>
<td>0.69</td>
</tr>
<tr>
<td>LV mass index (g/m²)</td>
<td>38.5 ± 6.7</td>
<td>69.5 ± 26.4</td>
<td>68.8 ± 23.9</td>
<td>0.90</td>
</tr>
<tr>
<td>LGE, n (%)</td>
<td>0 (0)</td>
<td>18 (36%)</td>
<td>17 (30%)</td>
<td>0.50</td>
</tr>
<tr>
<td>LGE volume (g)</td>
<td>—</td>
<td>8.1 (2.8-13.3)</td>
<td>4.4 (2.8-7.4)</td>
<td>0.09</td>
</tr>
<tr>
<td>LGE volume / LV mass (%)</td>
<td>—</td>
<td>6.7 (2.8-7.9)</td>
<td>3.5 (1.8-5.4)</td>
<td>0.03</td>
</tr>
<tr>
<td>Heart rate (beats/min)</td>
<td>68 ± 10</td>
<td>74 ± 18</td>
<td>75 ± 14</td>
<td>0.71</td>
</tr>
<tr>
<td>Native T1 (msec)</td>
<td>1073 ± 25</td>
<td>1131 ± 42</td>
<td>1107 ± 45</td>
<td>0.006</td>
</tr>
<tr>
<td>T1 in basal slice (msec)</td>
<td>1088 ± 24</td>
<td>1124 ± 42</td>
<td>1104 ± 50</td>
<td>0.03</td>
</tr>
<tr>
<td>T1 in mid slice (msec)</td>
<td>1061 ± 35</td>
<td>1130 ± 58</td>
<td>1104 ± 50</td>
<td>0.02</td>
</tr>
<tr>
<td>T1 in apical slice (msec)</td>
<td>1078 ± 35</td>
<td>1144 ± 61</td>
<td>1115 ± 49</td>
<td>0.009</td>
</tr>
<tr>
<td>Native T1 without LGE segments (msec)</td>
<td>1124 ± 36</td>
<td>1102 ± 44</td>
<td>—</td>
<td>0.006</td>
</tr>
</tbody>
</table>

Nakamori et al. JMRI 2018;47:779-786
Risk stratification using CMR

LVEF

ICD as a primary prevention

Regional fibrosis (LGE)

Diffuse fibrosis (T1 mapping: native T1, ECV, $\lambda_{\text{Gd}}$)

• Current criterion
  - Low sensitivity and low specificity for SCD prediction
  - DANISH trial

LVEF > 35% with extensive scarring?
LVED <35% who would not likely benefit from ICD therapy?
Abnormal EGM are strongly associated with presence of scar even in patients with active disease and are located in segments with higher scar transmurality with less evidence of inflammation.
Regional Strain by CMR Improves Detection of RV Scar Compared With LGE on a Multimodality Scar Evaluation in Patients With ARVC
Myocardial calcifications on CT were more common in post-infarct VT ablation patients than controls.

Larger calcifications were associated with VT: cut-off > 0.538 cm³ (AUC 0.87, sensitivity 0.87, specificity 0.88)

- Non-confluent calcification pattern localized VT target sites (p = 0.01)

When registered to electroanatomic map, myocardial calcifications:
- Corresponded to inexcitable tissue
- Identified >1/3 of all VT target sites

Myocardial calcifications:
- Indicate inexcitable scar bordering VT circuits
- Allows for focused mapping and ablation
- May have value for risk stratification

Alyesh et al. Circ Arrhythm Electrophysiol; 2019(12):e007023
Summary

CMR in VT

1. Fibrosis Imaging: Detection and Quantification
2. Risk Stratification
3. Guidance on Decision Making, Image integration to guide ablation