Ventricular Tachycardia

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Presenter Disclosure Information
• There are no financial relationships relevant to this presentation.
• Off label use: MRI of patients with implanted devices; Gadolinium for cardiac studies

Delayed Enhancement MRI
• Detailed imaging of scar and viable myocardium
• Extensively validated
• High spatial resolution


Non-Ischemic Cardiomyopathy
Scar can be present and may be the substrate for VT


Scal Patterns: Different Degrees of Transmurality
No Scar
26-75%
76-100%


Scal Patterns predict VT Inducibility
• 7 different morphologies of sustained monomorphic ventricular tachycardia were inducible in 5 patients
• Median cycle length of 300 ms (interquartile range 240-345 ms)

<table>
<thead>
<tr>
<th>Scar Pattern</th>
<th>VT Inducibility</th>
<th>Non-Inducibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Scar</td>
<td>7/10</td>
<td>3/10</td>
</tr>
<tr>
<td>26-75%</td>
<td>4/6</td>
<td>2/4</td>
</tr>
<tr>
<td>76-100%</td>
<td>0/1</td>
<td>5/5</td>
</tr>
</tbody>
</table>

*Data are expressed as median interquartile range or absolute number column percentage
Scar Pattern Predicts Event-Free Survival

• 79 patients
• No ICDs
• EF 25-28%

Ischemic Cardiomyopathy

Hyperechancement may not have uniform intensity

Gray Zone:
Intermediate level of hyperenhancement

Table 2. MRI Indices According to Inducibility Status at Electrophysiology Study

<table>
<thead>
<tr>
<th>Variable</th>
<th>Un inducible</th>
<th>Inducible</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>LV EF (%)</td>
<td>50±2</td>
<td>40±2</td>
<td>0.001</td>
</tr>
<tr>
<td>LV EF, ml</td>
<td>303±112</td>
<td>211±117</td>
<td>0.001</td>
</tr>
<tr>
<td>LV EDV, ml</td>
<td>285±117</td>
<td>221±114</td>
<td>0.001</td>
</tr>
<tr>
<td>LV mass, g</td>
<td>180±60</td>
<td>160±61</td>
<td>0.001</td>
</tr>
<tr>
<td>Total infarct (infarct core)</td>
<td>40±125</td>
<td>45±125</td>
<td>0.001</td>
</tr>
<tr>
<td>Infarct core, g</td>
<td>26±11</td>
<td>25±11</td>
<td>0.001</td>
</tr>
<tr>
<td>Infarct core, g</td>
<td>20±15</td>
<td>16±11</td>
<td>0.001</td>
</tr>
</tbody>
</table>

**Extent of Gray Zone Predicts Survival**

- 144 patients with CAD
- No ICDs
- Mean EF 42-45%

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**Table 1. Inscrutable and Nonscrutable Associations MRI All- zone Mortality**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Univariable Analysis</th>
<th>M &amp; F Analysis 1</th>
<th>M &amp; F Analysis 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>0.7 (0.6-0.9)</td>
<td>0.96</td>
<td>0.14</td>
</tr>
<tr>
<td>Diabetes</td>
<td>1.0 (0.7-1.5)</td>
<td>0.96</td>
<td>0.80</td>
</tr>
<tr>
<td>Previous coronary artery intervention</td>
<td>0.7 (0.5-1.0)</td>
<td>0.96</td>
<td>0.96</td>
</tr>
<tr>
<td>Previous coronary artery intervention surgery</td>
<td>2.1 (0.9-4.7)</td>
<td>0.96</td>
<td>0.96</td>
</tr>
<tr>
<td>LV ejection fraction (%)</td>
<td>3.2 (1.9-5.2)</td>
<td>0.96</td>
<td>0.96</td>
</tr>
<tr>
<td>Left bundle branch block</td>
<td>3.2 (1.9-5.2)</td>
<td>0.96</td>
<td>0.96</td>
</tr>
<tr>
<td>CABG</td>
<td>2.1 (0.9-4.7)</td>
<td>0.96</td>
<td>0.96</td>
</tr>
<tr>
<td>LV ejection fraction (%)</td>
<td>3.2 (1.9-5.2)</td>
<td>0.96</td>
<td>0.96</td>
</tr>
<tr>
<td>VT induction</td>
<td>1.0 (0.6-1.7)</td>
<td>0.96</td>
<td>0.96</td>
</tr>
<tr>
<td>LV ejection fraction (%)</td>
<td>3.2 (1.9-5.2)</td>
<td>0.96</td>
<td>0.96</td>
</tr>
<tr>
<td>CRT</td>
<td>1.0 (0.6-1.7)</td>
<td>0.96</td>
<td>0.96</td>
</tr>
<tr>
<td>LVEF and CRT</td>
<td>1.0 (0.6-1.7)</td>
<td>0.96</td>
<td>0.96</td>
</tr>
<tr>
<td>cSRV*</td>
<td>1.0 (0.6-1.7)</td>
<td>0.96</td>
<td>0.96</td>
</tr>
<tr>
<td>Gray zone</td>
<td>1.0 (0.6-1.7)</td>
<td>0.96</td>
<td>0.96</td>
</tr>
</tbody>
</table>

*Gray zone = Tissue Heterogeneity

**10 Week Swine Infarct Model:**

- Inducible VTs in 8 of 17 pigs
- Gray Zone: 21 ± 8% infarct
- Non-Inducible in 9 of 17 pigs
- Gray Zone: 12 ± 3% infarct

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**What is the Gray Zone?**

**Gray Zone = Tissue Heterogeneity**

High Resolution MRI (0.4x0.4x0.4 mm voxels)

Inducible Non Inducible
What do the images tell us about the mechanisms of VT?

Electroanatomic Correlations

Epicardial Electrograms during VT
Recordings from Multielectrode Epicardial Sock

Epicardial Reentry Registered with Scar:
Reentry Through Viable Tissue in Scar

CL = 150 ms
RV
Anterior LV

A
B
C
D
E
F
G
H
I

CL = 150 ms
RV
Anterior LV

A
B
C
D
E
F
G
H
I

CL = 150 ms
RV
Anterior LV

A
B
C
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E
F
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CL = 150 ms
RV
Anterior LV

A
B
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D
E
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G
H
I

Is the Gray (Heterogeneous) Zone identified on MRI the critical pathway for VT generation?

Ablation in Gray Zone Can Eliminate VTs Chronically

Before ablation

Late

Automatic Detection of Gray Zone

Asutely after ablation

Chronic after ablation

Ashikaga et al, Circ Res, 2007 2
Incomplete ablation of the Gray Zone: Inducible VT

Standard resolution MRI High resolution MRI

Sarcoidosis


Outcomes


Limitations of MRI Scar Imaging

- Motion Effects
- Partial Volume Effects
- Artifacts from ICD
- Nephrogenic Systemic Fibrosis

Motion can Reduce Resolution

Partial Volume Effects can Reduce Resolution
Intensity Averaging with thick slices

Artifacts from ICD
Can Mimic HyperEnhancement
Imaging safe with ICD
- 555 MRI examinations performed in 460 patients
- Special protocol used
- No adverse events
- No clinically significant changes in pacing parameters
- Adequate scar imaging in 60-80%
Fixes are being developed

Nephrogenic Systemic Fibrosis
- Scleroderma like syndrome
- Develops in patients with severe renal disease
  - Generally on dialysis
- Rare, not reversible
- First reported in 2000
- Linked to Gadolinium use in 2006
- Mechanism(s) unknown
- Does not occur in patients with GFR > 30 ml/min

Summary
- Delayed enhancement MRI can accurately identify detailed anatomy of scar
- Multiple VT circuits can exist through and around areas of scar
- Scar transmurality distribution appears to be related to arrhythmogenic potential in Non-Ischemic Cardiomyopathy
- The critical zones for occurrence of VT in ICM are likely areas of tissue heterogeneity (gray zone) that can be imaged with MRI
- The extent of scar heterogeneity is related to the risk of sudden death in ischemic cardiomyopathy
- Delayed enhancement MRI may be very useful in diagnosing cardiac sarcoidosis
- Limitations include motion effects, partial volume effects, and the presence of an ICD

Clinical Implications
- Delayed enhancement MRI may help predict risk of arrhythmias, and possibly sudden death
- Delayed enhancement MRI has added predictive power over that of EF alone in ICM
- Delayed enhancement MRI will likely lead to more accurate indications for ICD placement, and may help guide VT ablation
- Delayed enhancement MRI may be useful in guiding therapy of possible cardiac sarcoidosis

Investigators
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