Ventricular Tachycardia Ablation Guided by Imaging

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The VA Substrate and Mechanism

“Critical anatomic substrates sustaining VTs, even in cases of a focal origin, show different degrees of fibrosis / scar”.

IDCM – before explanting the heart

The vast majority of VTs in patients with SHD are due to a re-entry mechanism.

VT Substrate Remodeling – Stability over time
- Ischemic - After AMI
- NICM
Myocardial Scar Remodeling - Long-term
The FOOTPRINT Study

- Mean Scar Mass reduction 45%
- Most BZ channels stable at 6 months, only 48% still present at 4 years

### Images
- Basal-LV-DE-80%
- 6-Month-LV-DE-80%
- 4-Year-LV-DE-80%

### Statistics

<table>
<thead>
<tr>
<th></th>
<th>7 DAYS</th>
<th>6 MONTHS</th>
<th>4 YEARS</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>LVEF (%)</td>
<td>48.6 ± 8.8</td>
<td>52.3 ± 8.5*</td>
<td>52.6 ± 9.7**</td>
<td>*0.002</td>
</tr>
<tr>
<td>iLVEDV (mL/m²)</td>
<td>82.7 ± 2.7</td>
<td>85.4 ± 3.4</td>
<td>86.2 ± 3.5</td>
<td>0.5</td>
</tr>
<tr>
<td>N. of BZ channels</td>
<td>1.48 ± 0.25</td>
<td>1.29 ± 0.24*</td>
<td>1.0 ± 0.19**</td>
<td>*0.01</td>
</tr>
</tbody>
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Myocardial Scar Remodeling - Long-term

Scar Size and Border Zone Channel Remodelling Over a Long-Term Period after an Acute Myocardial Infarction

The FOOTPRINT Study

## Myocardial Scar Remodeling - Long-term

<table>
<thead>
<tr>
<th></th>
<th>First week MRI (08/08/12)</th>
<th>6 months MRI (21/03/13)</th>
<th>4 years MRI (18/04/17)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LVEF (%)</td>
<td>30,4</td>
<td>45</td>
<td>51</td>
</tr>
<tr>
<td>Scar Mass (g)</td>
<td>48,87</td>
<td>35,19</td>
<td>27,22</td>
</tr>
<tr>
<td>BZ Mass (g)</td>
<td>31,63</td>
<td>21,23</td>
<td>19,92</td>
</tr>
<tr>
<td>Core Mass (g)</td>
<td>17,25</td>
<td>13,96</td>
<td>7,29</td>
</tr>
</tbody>
</table>

Myocardial Scar Remodeling - Long-term

The FOOTPRINT Study

Myocardial Scar Remodeling - Long-term Non-Ischemic

4-years myocardial scar remodeling in NICM

96.3% of clinical VTs originate in a LV segment with HE

<table>
<thead>
<tr>
<th></th>
<th>Endocardial successful ablation</th>
<th>Epicardial successful ablation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ischemic</td>
<td>46 (93.9%)</td>
<td>3 (6.1%)</td>
</tr>
<tr>
<td>Nonischemic</td>
<td>16 (57.1%)</td>
<td>12 (42.9%)</td>
</tr>
</tbody>
</table>


LGE-CMR identifies the specific VA site of origin

RULE: “NO LGE – NO VT”
CE-CMR + ECG suggested segment + ECG criteria

Berruezo A. Heart 2010.
Endo/Epicardial initial Approach

• Depends on Infarct Transmurality

Endocardial-only ablation in a case of a transmural MI is an important risk factor for recurrences

Soto-Iglesias, D, et al. Heart Rhythm 2018

1. MRI – The presence of Epi scar does not guarantee Epi substrate – Requires Epi area of >14cm²
2. CT Scan – Epi substrate if wall thickness < 3.59 mm
Myocardial Fibrosis Characterization

Pixel Signal Intensity Maps

ECG

SCAR

Fractionation
Low voltage

Delayed Enhancement

DE-CMR

Correlation

Infarct Core

Border Zone

Normal myocardium

1. VT Substrate Ablation
2. Arrhythmic Event Prediction

MRI-PSI

EAM
Scar Characterization to Predict Life-Threatening Arrhythmic Events and Sudden Cardiac Death in Patients With Cardiac Resynchronization Therapy

The GAUDI-CRT Study

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“Only Scar Burden Counts!!”

METHODS Primary prevention patients with a class I indication for CRT were prospectively enrolled and assigned to CRT-D or CRT pacemaker according to physician’s criteria. Pre-procedure contrast-enhanced cardiac magnetic resonance was obtained and analyzed to identify scar presence or absence, quantify the amount of core and border zone (BZ), and depict BZ distribution. The presence, mass, and characteristics of BZ channels in the scar were recorded. The primary endpoint was appropriate defibrillator therapy or SCD.
235 consecutive Primary Prevention Patients Candidates for CRT-P/D

ce-CMR

217 patients included*

18 patients excluded due to:
- low image quality
- moderate/severe shifting
- artifacts

*Type of ce-CMR
- 1.5T: 144 (66.4%)
- 3T: 73 (33.6%)

Population:
- 65±10 y
- 72% Male
- 39.6% ICM
- LVEF 26±8%
- 95% NYHA II-III

CRT-P (N=63)

CRT-D (N=154)

Follow-Up**

**6 patients lost

Primary Endpoint:
Appropriated ICD Therapy or SCD

Acosta J, et al. JACC Cardiovasc Imaging 2017
A. Example of a surface layer with delineated channel (white) and a short axis slice. B. Tube added (as wireframe mesh) to the centerline of the channel.

**BZ mass** [HR 1.06(1.04-1.08); p<0.001]

**BZ Channel mass** [HR 1.21(1.10-1.32); p<0.001] – **Best Primary Endpoint Predictor**
Risk Stratification Algorithm

**Scar mass <10 g**, in 134 (61.7%) pts NPV 100% for the Primary Endpoint

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**Acosta et al. JACC Cardiovasc Imag 2018**
Example of Scars in 2 patients without events

**NICM and Small Epicardial Scar**  
*10% Layer*  
*25% Layer*

**Big and Homogeneous Scar**  
*10% Layer*  
*25% Layer*

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Acosta J, et al. JAC Cardiovasc Imaging 2017
Example of a BZ channel in a patient with an anterior scar and events.

Scar mass: 59g
BZ mass: 27.7g (46%)
BZ channel mass: 2.1g

Acosta J, et al. JAC Cardiovasc Imaging 2017
Unmet Needs of MRI and Electroanatomical Maps

• **Electroanatomical Map**
  – Highly time consuming / tedious
  – Long training curve / skills
  – Operator dependent
  – Usually low resolution
  – Deep substrate difficult to identify

• **MRI**
  – We would need higher resolution
  – Right ventricle difficult to analyze
  – PM/ICDs/Intracardiac devices artifacts
MRI and VT Substrate Ablation
- MRI-Aided
- MRI-Guided
CMR-Aided Scar Dechanneling  
Influence on Acute and Long-Term Outcomes

Ablation Protocol – Ablation Guided by the EAM – N=159

Scar Dechanneling – Sinus Rhythm

Ablation Protocol

1. Substrate Mapping
   CC identification

2. RF ablation
   CC elimination

3. Re-Mapping
   Residual CC elimination

4. Inducibility Protocol
   Residual VT elimination

HTCs/CCs Identification

CC on EAM
Match with CC on CMR?
Yes

CC on CMR
Match with CC on EAM?
No

False Negative
Ablation

True Positive
Ablation

False Positive
No

CMR-Aided Scar Dechanneling

Integration of LGE-CMR information into the Nav System

PSI Map  EA Map  Hybrid Map

## CMR-Aided Scar Dechanneling

**Influence on Acute and Long-Term Outcomes**

<table>
<thead>
<tr>
<th></th>
<th>Total (159)</th>
<th>CMR-Aided (54)</th>
<th>Non-CMR Aided (105)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Residual VT after SD</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>70 (44%)</td>
<td>17 (32%)</td>
<td>53 (51%)</td>
<td>0.022*</td>
</tr>
<tr>
<td>CMR-Aided</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-CMR Aided</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Procedural success</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>130 (82%)</td>
<td>47 (87%)</td>
<td>83 (79%)</td>
<td>0.3</td>
</tr>
<tr>
<td>Partial</td>
<td>21 (13%)</td>
<td>4 (7%)</td>
<td>17 (16%)</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>8 (5%)</td>
<td>3 (6%)</td>
<td>5 (5%)</td>
<td></td>
</tr>
<tr>
<td><strong>Procedure time (min)</strong></td>
<td>229 ± 66</td>
<td>229 ± 70</td>
<td>230 ± 63</td>
<td>0.919</td>
</tr>
<tr>
<td><strong>RF time (min)</strong></td>
<td>24 ± 15</td>
<td>19 ± 12</td>
<td>27 ± 16</td>
<td>0.006*</td>
</tr>
<tr>
<td><strong>RF applications</strong></td>
<td>33 ± 18</td>
<td>28 ± 18</td>
<td>36 ± 18</td>
<td>0.37*</td>
</tr>
</tbody>
</table>

* Kaplan–Meier curves for the endpoint of VT recurrence

Andreu D, Berruezo A. Heart Rhythm Journal 2017
CMR-Aided Scar Dechanneling
Influence on Acute and Long-Term Outcomes

**False Positives:** HTCs present in the PSI maps but not in the EAM

**Higher Rate of Recurrences:** 29 vs 14%, Log-Rank=0.027

MRI and VT Substrate Ablation

- MRI-Aided
- MRI-Guided
Image-Guided VT Substrate Ablation
No Need for an Electroanatomical Map

No CMR approach

- High density EAM bipolar mapping
- Substrate ablation guided by electrograms characteristics
- Remap and residual substrate ablation
- Conventional ablation of residual VT if needed

CMR-aided approach

- RV or Aortic root reconstruction for image integration
- Substrate ablation guided by electrograms characteristics
- Remap and residual substrate ablation
- Conventional ablation of residual VT if needed

CMR-guided approach

- Image-guided substrate ablation
- Remap and residual substrate ablation
- Conventional ablation of residual VT if needed

Image-Guided VT Substrate Ablation
No Need for an Electroanatomical Map

- Prospective experimental pilot study
  - CMR-Guided: 26 consecutive pts
  - 2 control groups (CMR-Aided and No-CMR):
    - matched by LVEF, cardiomyopathy type, and need for EPI approach

<table>
<thead>
<tr>
<th></th>
<th>Guided-CMR (N=26)</th>
<th>Aided-CMR* (N=26)</th>
<th>No-CMR** (N=26)</th>
<th>P-value*</th>
<th>P-value**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>63±14</td>
<td>66±11</td>
<td>69±9</td>
<td>0,07</td>
<td>0,29</td>
</tr>
<tr>
<td>IHD (%)</td>
<td>21 (81)</td>
<td>20 (77)</td>
<td>22 (85)</td>
<td>0,37</td>
<td>0,45</td>
</tr>
<tr>
<td>Endo(%)</td>
<td>18 (69%)</td>
<td>17 (65%)</td>
<td>17 (65%)</td>
<td>0,95</td>
<td>0,95</td>
</tr>
<tr>
<td>Endo/Epi (%)</td>
<td>8 (31%)</td>
<td>9 (35%)</td>
<td>9 (35%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incessant VT (%)</td>
<td>1 (4)</td>
<td>2 (8)</td>
<td>2 (8)</td>
<td>0.58</td>
<td>0.55</td>
</tr>
<tr>
<td>Arrhythmic storm (%)</td>
<td>6 (23)</td>
<td>2 (8)</td>
<td>5 (19)</td>
<td>0.11</td>
<td>0.73</td>
</tr>
</tbody>
</table>
Image-Guided VT Substrate Ablation
No Need for an Electroanatomical Map

A) Image segmentation

LGE-CMR (HTC & PSI)

Fusion MDCT and LGE-CMR

MDCT

B) EP procedure

FAM of Aortic root

Integration result

QRS-Axis Based VT-Related Channel 10/26 Pts

Andreu D, et al. Heart Rhythm 2018
Target Ablation Site – All BZ Channel Entrances

No Need for an Electroanatomical Map

Electrogram at the Target Ablation Site
No more than 3mV
Delayed component during SR
Hidden Slow Conduction
Image-Guided VT Substrate Ablation
No Need for an Electroanatomical Map

Soto-Iglesias, D, et al. Manuscript in Preparation 2018
Clinical VT
Scar and BZ Channel Visualization for EP
Procedural Approach and Ablation Guidance
CC responsible of the clinical VT
Pace-mapping from CC entrance
Image-Guided VT Substrate Ablation
No Need for an Electroanatomical Map
Ablation exclusively guided by MRI

Specific Channel responsible for the VT and Coronary Artery Branch – Selective Ablation
Summary

- Substrate Imaging for SCD Prevention
  - *Scar Burden should be the New LVEF*
- Substrate Imaging for VA Ablation
  - Before – Approach – **Guidelines**
  - During – Aid and Guide the Intervention
    - Better acute and long-term outcomes - **Guidelines**
- New directions – Imaging-based Substrate ablation
  - Selective – Robotic - Noninvasive ablation
  - Primary prevention?

Ventricular Arrhythmia Substrate Imaging Should be Incorporated into Clinical Practice