Atrial Scar delineation to guide individualised lesion prescription: role of MR and voltage mapping

Matt Wright
St. Thomas’ Hospital, London
Conflict of Interest

• Consulting
  – Philips Research

• Speaking Honoraria
  – St. Jude Medical, Biosense Webster, Philips, Bard

• Conference Support
  – St. Jude Medical, Biosense Webster, Bard
Atrial Scar delineation to guide individualised lesion prescription: role of MR and voltage mapping
Anatomical Approach vs Electrophysiological Approach
Pragmatic vs Idealistic
Atrial Scar delineation to guide individualised lesion prescription: role of MR and voltage mapping

MR Imaging of the atria
- Non invasive
- Pre & post-procedural
- Limited centres

Voltage Mapping
- Invasive
- Reliable
- Widespread
Who & What

MRI

Voltage Mapping
What are we trying to measure?
• 54/81 patients with Carto XP >100 points
• 18 LA regions on MR and EAM
• 4 reviewers
• MR:
  – 0 = no enhancement
  – 1 = mild enhancement
  – 2 = moderate enhancement
  – 3 = extensive enhancement

• EAM
  – 0 = healthy (>1mV)
  – 1 = mild illness (>0.1mV, <0.5mV)
  – 2 = moderate illness (>0.1 to <0.5mV)
  – 3 = significant scarring (<0.1mV)

• Qualitative assessment of relationship between EAM and MRI

Remodelling, voltage & outcome

- 54 patients with Carto XP > 100 points
- 18 LA regions on MR and EAM
- 4 reviewers
- MR:
  - 0 = no enhancement
  - 1 = mild enhancement
  - 2 = moderate enhancement
  - 3 = extensive enhancement
- EAM
  - 0 = healthy (>1mV)
  - 1 = mild illness (>0.5mV, <1mV)
  - 2 = moderate illness (>0.1 to <0.5mV)
  - 3 = significant scarring (<0.1mV)
- Qualitative assessment of relationship between EAM and MRI

DECAAF

Marrouche et al; JAMA 2014
Atrial Fibrillation

DECAAF

Marrouche et al; JAMA 2014
Atrial Fibrillation Ablation Outcome Is Predicted by Left Atrial Remodeling on MRI

<table>
<thead>
<tr>
<th>Stage I</th>
<th>Stage II</th>
<th>Stage III</th>
<th>Stage IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>(n=133)</td>
<td>(n=140)</td>
<td>(n=71)</td>
<td>(n=42)</td>
</tr>
<tr>
<td>Age, y</td>
<td>63±13</td>
<td>65±11</td>
<td>66±13</td>
</tr>
<tr>
<td>%</td>
<td>0.17</td>
<td>0.06</td>
<td>0.81</td>
</tr>
<tr>
<td>Women, %</td>
<td>33.8</td>
<td>33.7</td>
<td>42.8</td>
</tr>
<tr>
<td>Hypertension, %</td>
<td>82.8</td>
<td>81.1</td>
<td>57.8</td>
</tr>
<tr>
<td>Diabetes mellitus, %</td>
<td>11.4</td>
<td>12.9</td>
<td>21.1</td>
</tr>
<tr>
<td>Coronary disease, %</td>
<td>19.6</td>
<td>12.6</td>
<td>24.4</td>
</tr>
<tr>
<td>Congestive heart failure, %</td>
<td>6.1</td>
<td>13.0</td>
<td>12.7</td>
</tr>
<tr>
<td>LV ejection fraction, %</td>
<td>58±12</td>
<td>59±10</td>
<td>57±12</td>
</tr>
<tr>
<td>CVATIA, %</td>
<td>0.1</td>
<td>0.9</td>
<td>11.8</td>
</tr>
<tr>
<td>Paracatal AF, %</td>
<td>0.1</td>
<td>0.8</td>
<td>49.3</td>
</tr>
<tr>
<td>Persistent AF, %</td>
<td>38.4</td>
<td>59.0</td>
<td>50.7</td>
</tr>
<tr>
<td>Previous AAD use, %</td>
<td>32.6</td>
<td>12.9</td>
<td>18.8</td>
</tr>
<tr>
<td>Atrial volume/BSA, mL/m²</td>
<td>48±18</td>
<td>51±18</td>
<td>52±21</td>
</tr>
<tr>
<td>LA fibril, %</td>
<td>6.7±2.0</td>
<td>15.2±2.9</td>
<td>23.3±2.8</td>
</tr>
</tbody>
</table>

AF Group (n=386) Non-AF Group (n=21) | PValue
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>64±12</td>
<td>54±17</td>
</tr>
<tr>
<td>Women, %</td>
<td>36</td>
<td>38</td>
</tr>
<tr>
<td>Hypertension, %</td>
<td>62.0</td>
<td>4.7</td>
</tr>
<tr>
<td>Diabetes mellitus, %</td>
<td>15.2</td>
<td>19.8</td>
</tr>
<tr>
<td>Coronary disease, %</td>
<td>16.0</td>
<td>14.3</td>
</tr>
<tr>
<td>Congestive heart failure, %</td>
<td>9.8</td>
<td>0</td>
</tr>
<tr>
<td>LV ejection fraction, %</td>
<td>58±11</td>
<td>61±10</td>
</tr>
<tr>
<td>CVATIA, %</td>
<td>8.8</td>
<td>0</td>
</tr>
<tr>
<td>Left atrial fibril, %</td>
<td>16.6±11.2</td>
<td>3.5±2.3</td>
</tr>
<tr>
<td>Atrial volume/BSA, mL/m²</td>
<td>51±29</td>
<td>31±10</td>
</tr>
</tbody>
</table>

Atrial Fibrillation Ablation Outcome Is Predicted by Left Atrial Remodeling on MRI

Table 3. Univariate and Multivariate Predictors of Arrhythmia Recurrence After Catheter Ablation: 1-Year Follow-Up

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Hazard Ratio</th>
<th>95% CI</th>
<th>P Value</th>
<th>Hazard Ratio</th>
<th>95% CI</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (per 10-y increase)</td>
<td>1.22</td>
<td>1.08-1.43</td>
<td>&lt;0.01</td>
<td>1.12</td>
<td>0.94-1.34</td>
<td>&lt;0.12</td>
</tr>
<tr>
<td>Women</td>
<td>1.09</td>
<td>0.75-1.67</td>
<td>&lt;0.39</td>
<td>0.84</td>
<td>0.56-1.25</td>
<td>&lt;0.33</td>
</tr>
<tr>
<td>Hypertension</td>
<td>1.61</td>
<td>1.06-2.38</td>
<td>&lt;0.016</td>
<td>1.33</td>
<td>0.88-2.04</td>
<td>&lt;0.15</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>1.80</td>
<td>1.18-2.75</td>
<td>&lt;0.006</td>
<td>1.61</td>
<td>1.03-2.61</td>
<td>&lt;0.056</td>
</tr>
<tr>
<td>Coronary disease</td>
<td>1.19</td>
<td>0.75-1.88</td>
<td>&lt;0.466</td>
<td>0.75</td>
<td>0.45-1.24</td>
<td>&lt;0.250</td>
</tr>
<tr>
<td>Congestive heart failure</td>
<td>1.19</td>
<td>0.68-2.07</td>
<td>&lt;0.543</td>
<td>1.17</td>
<td>0.66-2.08</td>
<td>&lt;0.007</td>
</tr>
<tr>
<td>Persistent AF</td>
<td>1.47</td>
<td>1.06-1.99</td>
<td>&lt;0.116</td>
<td>1.09</td>
<td>0.76-1.55</td>
<td>&lt;0.040</td>
</tr>
<tr>
<td>LA volume index (10 mL/m²)</td>
<td>1.8</td>
<td>1.07-1.28</td>
<td>&lt;0.0001</td>
<td>1.05</td>
<td>0.86-1.17</td>
<td>&lt;0.270</td>
</tr>
</tbody>
</table>

AF indicates atrial fibrillation; CI, confidence interval; LA, left atrial; and SRM, strain remodeling.

Days since end of blanking period

Marrouche et al JAMA 2014;311:498-506

Voltage Mapping

- 20 patients with Carto XP/3 >100 points
- 10 first time PAF; 10 redo cases
- 12 patients with MRI
- Point by Point voltage map
- CT or MRI merged if available
- No contact force

Kapa et al; JCE 2014
1. Increasing LGE SI correlated with lower endocardial voltage

2. No further reduction in voltage with SI > 5 SD above reference

3. Similar relationship for unipolar voltage (n=5)
Cardiac magnetic resonance and electroanatomical mapping of acute and chronic atrial ablation injury – a histological validation study

Pre-ablation  Acute  Chronic

3.3mV  0.6mV  0.3mV

Harrison et al Eur Heart J 2014;35:1486-95
Importance of an accurate SI threshold

Average MRI volume divided by average histology volume

Number of standard deviations from mean reference signal intensity

LGE acute
T2W acute
LGE chronic
T2W chronic

Harrison et al Eur Heart J 2014;35:1486-95
Cardiac magnetic resonance and electroanatomical mapping of acute and chronic atrial ablation injury – a histological validation study

1. LGE CMR SI thresholds of 2.3SD (acutely) and 3.3SD (chronically) above the mean SI of the atrial blood pool best approximate macroscopic volumes of injury in the pig model

2. T2W CMR overestimates the volume of ablation injury acutely and underestimates the volume of injury chronically

3. Mean endocardial voltage at the centre of the CMR-confirmed linear atrial ablation lesion is 3.3mV pre ablation, 0.6mV immediately post ablation and 0.3mV chronically

Harrison et al Eur Heart J 2014 (epub ahead of print)
Comparison of Left Atrial Bipolar Voltage and Scar Using Multielectrode Fast Automated Mapping versus Point-by-Point Contact Electroanatomic Mapping in Patients With Atrial Fibrillation Undergoing Repeat Ablation

- 20 patients with Carto 3
- All repeat ablation
  - Minimum 100pts PBP
  - Minimum 350pts MEM
- Lasso catheter 2-6-2 used for mapping
- Contact force >10g
- Scar based at 0.2mV
Low-voltage areas detected by high-density electroanatomical mapping predict recurrence after ablation for paroxysmal atrial fibrillation

- 80 patients with Carto 3 >2000 points
- Lasso catheter 2-6-2 used for mapping
- PVAI only unless clear extra PV trigger
- Ablation
  - 8-25g contact force
  - Upto to 35W anterior 30W posteriorly
  - 20 second lesions
  - No AI/Visitag
Low-voltage areas detected by high-density electroanatomical mapping predict recurrence after ablation for paroxysmal atrial fibrillation

- 2 Cutoff values for low voltage
  - 0.25mV; 0.4mV
- Classified according to area
  - Stage 1 <10%
  - Stage 2 10- <20%
  - Stage 3 20- <30%
  - Stage 4 >30%

At 0.4mV
  - Stage 1 46%
  - Stage 2 40%
  - Stage 3 4%
  - Stage 4 10%
Atrial fibrillation following lung transplantation: double but not single lung transplant is associated with long-term freedom from paroxysmal atrial fibrillation

Geoffrey Lee¹, Harry Wu², Jonathan M. Kalman¹,³, Don Esmore², Trevor Williams⁴, Greg Snell⁴, and Peter M. Kistler¹,²,³,⁵,*

Freedom from late atrial fibrillation

Study group
- Double lung transplant
- Single lung transplant
- Thoracic surgery

Patient freedom from AF (%)

Years after surgery

European Heart Journal 2010
Impact of Voltage Mapping to Guide Whether to Perform Ablation of the Posterior Wall in Patients With Persistent Atrial Fibrillation

**STUDY DESIGN**

- **Atrial Fibrillation (Persistent)**
  - Standard Ablation: n=76
  - Voltage-Guided Ablation: n=65

- **Posterior Wall Voltage Mapping in Sinus Rhythm (Low voltage ≤ 0.5 mV)**: n=38
  - NO LOW VOLTAGE Pulmonary Vein Antral Isolation Only: n=38

- **Pulmonary Vein Antral Isolation + Additional Ablation at Operator Discretion**: n=76
  - Low Voltage Pulmonary Vein Antral Isolation + Posterior Wall Isolation: n=27
Impact of Voltage Mapping to Guide Whether to Perform Ablation of the Posterior Wall in Patients With Persistent Atrial Fibrillation

Normal Voltage Posterior Wall
38 patients = 58%

Low Voltage Posterior Wall
27 patients = 42%

Pulmonary Vein Isolation

Pulmonary Vein Isolation + Posterior Wall Isolation
# Impact of Voltage Mapping to Guide Whether to Perform Ablation of the Posterior Wall in Patients With Persistent Atrial Fibrillation

## TABLE 2
Procedural and Postprocedure Characteristics

<table>
<thead>
<tr>
<th></th>
<th>Standard n = 76</th>
<th>Voltage-Guided n = 65</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Presented in AT/AF</td>
<td>53%</td>
<td>65%</td>
<td>0.56</td>
</tr>
<tr>
<td>Posterior wall ablation</td>
<td>57%</td>
<td>42%</td>
<td>0.11</td>
</tr>
<tr>
<td>Posterior wall ablation using the box technique</td>
<td>21%</td>
<td>37%</td>
<td>0.06</td>
</tr>
<tr>
<td>Demonstrated posterior wall isolation</td>
<td>20%</td>
<td>31%</td>
<td>0.19</td>
</tr>
<tr>
<td>SVC isolation</td>
<td>95%</td>
<td>92%</td>
<td>0.81</td>
</tr>
<tr>
<td>Isoproterenol challenge</td>
<td>91%</td>
<td>88%</td>
<td>0.75</td>
</tr>
<tr>
<td>Radiofrequency ablation time (minutes)</td>
<td>90 ± 34</td>
<td>78 ± 26</td>
<td>0.02</td>
</tr>
<tr>
<td>Adherence to protocol D/C antiarrhythmic</td>
<td>93%</td>
<td>92%</td>
<td>0.80</td>
</tr>
<tr>
<td>Completed All monitoring</td>
<td>72%</td>
<td>77%</td>
<td>0.67</td>
</tr>
</tbody>
</table>
Impact of Voltage Mapping to Guide Whether to Perform Ablation of the Posterior Wall in Patients With Persistent Atrial Fibrillation

![Graph showing AFAT Free Survival over time for Voltage-Guided and Standard groups with HR, 95% CI, and p value.]

![Graph comparing AFAT Free Survival for Voltage-Guided with and without Posterior Wall Ablation and Standard with and without Posterior Wall Ablation.]

Cutler et al JCE 2016;27:13-21
Summary

• MRI and Voltage mapping are complementary methods of assessing patients

• Dense ablation scar ~0.3mV

• Low voltage regions ~0.3mV-0.6mV

• Specific lesion sets/ outcomes not proven