Role of Magnetic Resonance Imaging in Cardiac Arrhythmias Ablation

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Cardiac MRI
CMR: A useful instrument in clinical cardiovascular practice

- It provides a very precise “in vivo” tissue characterization
- identifies the presence of
  - Fat
  - water (oedema)
  - Blood
  - fibrosis and scar

Sabiha Gati et al. JIMG 2018
Which information is useful for the arrhythmologist?

❖ LGE: late images which make possible the identification and quantification of myocardial areas with scar/fibrosis

Elia De Maria et al. World J Cardiol 2017
Main fields of application of CMR in Arrhythmology

- Arrhythmic and sudden cardiac death (SCD) risk stratification in different heart diseases
- Decision-making in cardiac resynchronization therapy (CRT) device implantation
- Substrate identification for guiding ablation of complex arrhythmias
  - atrial fibrillation
  - ventricular tachycardias

Elia De Maria et al. World J Cardiol 2017
Atrial tissue information: LGE-CMR

- Assessment of left atrial fibrosis
- Identification of pulmonary vein gaps after PV Isolation
- Identification of critical isthmuses in atrial atypical flutter

Elia De Maria et al. World J Cardiol 2017
Assessment of atrial fibrosis

❖ The total volume of fibrotic tissue is calculated as a percentage of the LA wall volume
LGE-CMR: Two principal aims in AF patients

❖ To characterize the pre-existing LA scar burden prior to AF ablation for prognostic and therapeutic purposes

❖ To characterize the post-ablation scar burden and distribution, both for prognosis and for potential planning of redo ablation procedures

Spragg et al. Arrhythm Electrophysiol Rev. 2013
prior to AF ablation...
Detection and Quantification of Left Atrial Structural Remodeling Using DE MRI in AF

Abnormally enhanced regions on MRI correlate closely with low voltage areas on the EA maps

Oakkes…Marrouche et al. Circulation 2009
LA enhancement as a predictor of ablation success

Results of DE-MRI Analysis and Patient Outcome

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Mild Enhancement (n=45)</th>
<th>Moderate Enhancement (n=36)</th>
<th>Extensive Enhancement (n=5)</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extent of Structural Remodeling (% of LA Volume)</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>17.1±14.2</td>
<td>8.0±4.3</td>
<td>21.3±5.8</td>
<td>50.1±15.4</td>
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<tr>
<td>Location of Enhancement (&gt;50% of Surface Enhanced)</td>
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<tr>
<td>LA Posterior Wall</td>
<td>51 (63.0%)</td>
<td>18 (41.0%)</td>
<td>25 (83.3%)</td>
<td>8 (100.0%)</td>
<td>&lt;0.001</td>
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<tr>
<td>LA Anterior Wall</td>
<td>13 (16.0%)</td>
<td>3 (7.0%)</td>
<td>2 (6.7%)</td>
<td>8 (100.0%)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Atrial Septum</td>
<td>24 (29.0%)</td>
<td>7 (16.3%)</td>
<td>9 (30.0%)</td>
<td>8 (100.0%)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Type of Atrial Fibrillation - Baseline</td>
<td></td>
<td></td>
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<tr>
<td>Paroxysmal</td>
<td>41 (50.0%)</td>
<td>28 (65.1%)</td>
<td>13 (43.3%)</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Persistent</td>
<td>40 (49.4%)</td>
<td>15 (25.0%)</td>
<td>17 (56.7%)</td>
<td>8 (100%)</td>
<td>&lt;0.001</td>
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<tr>
<td>Recurrence</td>
<td></td>
<td></td>
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<tr>
<td>Time to recurrence analysis using Cox regression</td>
<td></td>
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<tr>
<td>Hazard Ratio 2.4</td>
<td></td>
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<tr>
<td>95% CI [1.38-4.08]</td>
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</tr>
</tbody>
</table>

Oakkes...Marrouche et al. Circulation 2009
Noninvasive evaluation of left atrial fibrosis using delayed enhancement MRI was independently associated with procedural outcomes.

Marrouche et al. JAMA. 2014
improve patient selection for AF ablation
avoiding unnecessary AF ablation procedures
Improve patient selection for AF ablation
Fibrosis-guided treatment flow chart

LGE-MRI to individualize patients with atrial fibrillation based on Utah Classification

- Utah I: Ablation
- Utah II: Ablation
- Utah III: Localized fibrosis, Diffuse fibrosis, Medication
- Utah IV: Ablation, Medication

AF patients

DE-MRI tissue characterization

- Utah stage I
- Utah stage II
- Utah stage III
- Utah stage IV

Fibrosis patch size and distribution assessment

- High chance of ablation success
- Low chance of ablation success

Higuchi...Marrouche Heart 2014

P. Gal and N.F. Marrouche European Heart Journal 2017
Post AF ablation
Residual fibrosis after AF ablation is a strong predictor of arrhythmia recurrence…

…irrespective of AF type and PV encirclement!
Ablation scar recovery is significantly stronger in AF free patients

- Assessment of changes of fibrotic alterations might give new insights into AF treatment strategies in case of recurrence after CA
- Left atrial fibrosis and its progression should be considered before and after initial and repeat ablative therapy
Complete pulmonary vein isolation
AF PVI Redo

- Assessment of potential gaps prior to redo ablation procedure
- Integration in navigation system
MRI-guided PV Reisolation

- Left atrial lateral projection of the LGECMR model showing a gap at the carina (white arrow). Lasso catheter into left superior pulmonary vein (LSPV) and ablation catheter located in the gap.

- The gap in CMR correlates with D-2 Lasso dipole position (white circle), showing earliest PV potential (dotted line).

- Lasso catheter electrograms after radiofrequency application.

Bisbal et al. Am Coll Cardiol Img 2014
Selecting Appropriate Candidates for Treatment Post-Ablation Recurrence
Management of pts with AF Recurrence by the use of LGE-MRI

Management of AF, guided by fibrosis imaging

- **Fibrosis <10%**
  - Healthy tissue
  - No fibrosis progression

- **Fibrosis ≥10%–<20%**
  - Localized fibrosis
  - Extensive post-ablation scarring
  - ? Connection and homogenization of existing scar

- **Fibrosis ≥20%–<30%**
  - Scattered fibrosis
  - Post PVI scarring
  - ? Re-isolation of PVs + connection of ablation scar + flutter line

- **Fibrosis ≥30%**
  - Non-ablative management or homogenization of fibrosis (awaiting DECAAF II)
  - Extensive postablation progression of fibrosis

Post-ablation recurrence

Johannes Siebermair, Eugene G. Kholmovski and Nassir Marrouche JACC 2017
MRI Guided Ablation in Persistent AF

Efficacy of DE-MRI-Guided Fibrosis Ablation vs. Conventional Catheter Ablation of Atrial Fibrillation

The role of atrial fibrosis as a potential target for catheter ablation of AF
LIMITATIONS
...is the poor reproducibility of the results

- The prevalence of baseline LGE in patients submitted to a first AF ablation differs significantly.
- The reliability of CMR in assessing the presence and distribution of ablation lesions ranged.
- Not every study that can detect post-ablation scar can also detect gaps.
- The correlation between the AF clinical type and the degree of structural remodeling ranged.

Giulia Pontecorboli et al. Europace 2017
Numerous potential sources of diversion can be found in image acquisition and processing.
Image acquisition protocols are not well standardized

- Surface coil proximity
- Contrast dose
- Delay time of image acquisition after contrast injection
- Individual characteristics
  - such as body mass index
  - renal function
  - Haematocrit
  - adherence to the exam

...leading to different (and sometimes contradictory) results

Giulia Pontecorboli et al. Europace 2017
Image processing techniques are even less standardized

❖ The choice of the threshold from which tissue should be considered border zone or scar is still an open issue

❖ This choice can change the perception of presence or absence of pre-ablation atrial fibrosis and its quantification

Giulia Pontecorboli et al. Europace 2017
Image processing techniques are even less standardized

- The total burden of fibrosis detected by the three different methods differed widely as did the ‘border-zone’ area, when assessed.
Validating the capability of LGE-CMR to detect fibrosis in the atria is a controversial issue.

- The most secure and reliable validation should come from histological.
- Studies usually compare LGE-CMR intensities to voltage maps analysis.
Future perspectives

- New software, advanced technology, and improvement in MRI resolution
Cardiac MRI and VT Ablation
LGE-CMR in patients with ventricular tachycardia

- Scar burden
- Scar distribution
- Scar transmurality
- The critical isthmus site
- In particular the central isthmus
- The conducting channels

LGE Distribution Patterns

- Ischemic
- Non-ischemic

Mrinal Yadava, Michael D. Shapiro, Curr Treat Options Cardio Med 2016
Usefulness of LGE-CMR

- Localize the ablation target and plan the procedure
  - endocardial vs. epicardial VA origin, especially in non-ischaemic patients
  - RV vs. LV approach for septal scar-related VA

Andreu et al. Eur Heart J. 2014
Scar area and conducting channels with LGE-CMR

❖ Scar area in patients with healed myocardial infarction decreases from the endocardium to the epicardium

Fernández-Armenta et al. Circ Arrhythm Electrophysiol. 2013
Detection of conducting channels in LGE-CMR

A further step in reducing recurrences after ablation

Andreu et al. Heart Rhythm 2017
Conducting channels as the target for VT ablation

A

1. RV/Aorta Mapping  
   LGE-CMR registration
2. Substrate Mapping  
   CC identification
3. RF ablation  
   CC elimination
4. Re-Mapping  
   Residual CC elimination

B

CC on EAM

No

False Negative

True Positive

False Positive

Match with HTC on CMR?

Yes

Match with CC on EAM?

No

HTC on CMR

No

Andreu et al. Heart Rhythm 2017
Conducting channels as the target for VT ablation

- The use of LGE-CMR to guide the VT substrate ablation is associated with a lower rate of recurrence during the follow-up

Andreu et al. Heart Rhythm 2017
From the era of electrical signals…

- For a successful ablation, the correct identification of underlying arrhythmogenic substrates is critical.
- With the use of standard electroanatomic mapping techniques, substrates are identified only indirectly, with local voltage amplitudes as a surrogate of the state of surrounding myocardium.
…to the era of imaging

- This approach, lacks sensitivity for deep scar and lacks specificity when there is poor catheter contact or thinner myocardium
- Improved strategies to define arrhythmogenic scar substrates would be welcome
Cardiac MRI...

- Could give an important contribution due to its ability to characterize cardiac anatomy, function and tissue without exposing the patient to additional radiation.