Cardiac Magnetic Resonance in Treatment of Atrial Fibrillation: Follow-Up and Prognosis

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Disclosures:
Research Grant Support: Biotronik, GE, Medtronic, St. Jude, Toshiba
What is the Role of CMR in Follow-Up and Prognosis after AFIB Ablation?

- Diagnosing Complications of AFIB Ablation.
- Predicting Patient Outcome and Prognosis.
Pulmonary Vein Stenosis Complicating Ablation for Atrial Fibrillation

Clinical Spectrum and Interventional Considerations

David R. Holmes, Jr, MD, Kristi H. Monahan, RN, Douglas Packer, MD

Rochester, Minnesota
Pulmonary Vein Stenosis

1-3 % of Atrial Fibrillation Ablation Procedures
CT Scanning Pulmonary Vein Stenosis

Holmes, et at. JACC CV Interventions 2009
Intracardiac Ultrasound Rotational Imaging

Pre Ablation

Area = 2.97 cm$^2$
Area = 1.47 cm$^2$
Area Change = 50.5%

Post Ablation

Area = 1.49 cm$^2$
Area = 1.26 cm$^2$
Area Change = 15.4%

David Schwartzman et al.
Intracardiac Echo-Doppler

Pre-Ablation

David Schwartzman et al.
Intracardiac Echo-Doppler

Post-Ablation

David Schwartzman et al.
Detecting of Esophageal Injury From Atrial Fib. Ablation
Cross-Sectional Imaging Obtained Immediately Following Radiofrequency Atrial Fibrillation Ablation Does Not Predict Endoscopic Evidence of Esophageal Injury

Darcie R. Gorman · Kathryn A. Peterson · John Fang · Jeffrey Olpin · Daniel O. Sommers · Molly McFadden · Jack H. Morshedzadeh · Nazem Akoum · Marcos Daccarett · Nassir Marrouche · Douglas G. Adler

n = 76 patients

<table>
<thead>
<tr>
<th>EGD score</th>
<th>$n$</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum score of two observers (score)</td>
<td>60</td>
<td>78.95</td>
</tr>
<tr>
<td>Normal (0)</td>
<td>60</td>
<td>78.95</td>
</tr>
<tr>
<td>Erythema (1)</td>
<td>9</td>
<td>11.84</td>
</tr>
<tr>
<td>Mucosal break 0–5 mm (2)</td>
<td>4</td>
<td>5.26</td>
</tr>
<tr>
<td>Mucosal break 5–10 mm (3)</td>
<td>2</td>
<td>2.63</td>
</tr>
<tr>
<td>Mucosal break &gt;10 mm (4)</td>
<td>1</td>
<td>1.32</td>
</tr>
</tbody>
</table>
Cross-Sectional Imaging Obtained Immediately Following Radiofrequency Atrial Fibrillation Ablation Does Not Predict Endoscopic Evidence of Esophageal Injury

Darcie R. Gorman · Kathryn A. Peterson · John Fang · Jeffrey Olpin · Daniel O. Sommers · Molly McFadden · Jack H. Morshedzadeh · Nazem Akoum · Marcos Daccarett · Nassir Marrouche · Douglas G. Adler

n = 60 CMR scans, 16 CT scans

“we found that there was no agreement between imaging studies and endoscopic studies for findings of esophageal inflammation following radiofrequency ablation for atrial fibrillation.”
CT of Esophageal Perforation After Atrial Fibrillation Ablation

Courtesy of David Schwartzman, MD
Esophageal Perforation After Atrial Fibrillation Ablation

Courtesy of David Schwartzman, MD
CT of Esophageal Perforation After Atrial Fibrillation Ablation

Courtesy of David Schwartzman, MD
Detection of Complications Following A Fib Ablation 2011:
Multimodality Imaging
Principal Challenge for Ablation for Atrial Fibrillation:

Appropriate Patient Selection To Predict Optimal Outcome
Continuum of Response to A Fib Ablation

Most Likely To Respond

- Paroxysmal Atrial Fib.
- Smaller Atrial Size
- Preserved Atrial Contractile Function
- Triggered Dominant

Least Likely To Respond

- Persistent Atrial Fib.
- Larger Atrial Size
- Loss of Atrial Contractile Function
- Substrate Dominant
Characterizing The Substrate: Lessons Learned from the LV

HEART FAILURE PROGRESSION

Reversible → Irreversible

Time

SCAR
Gadolinium Enhancement with Magnetic Resonance Imaging

Normal myocardium
Acute infarction
Scar

Intact cell membrane
Ruptured cell membrane
Collagen matrix

Louise E.J. Thomson, MB ChB, Raymond J. Kim, MD, Robert M. Judd, PhD

Late Gadolinium Enhancement and Myocardial Fibrosis

Cardiac Magnetic Resonance
Extensive LV Apical Scar

Late Gadolinium Enhancement
Cardiac Magnetic Resonance
LV Posterobasal Aneurysm

Late Gadolinium Enhancement
DILATED CARDIOMYOPATHY
LATE GADOLINIUM ENHANCEMENT

Dilated CMP

Mid-LV Wall Enhancement

Normal
LATE GADOLINIUM ENHANCEMENT Associated With Poor Outcome

Wu K...Lima J et al. J Am Coll Cardiol 2008;51:2414–21
Atrial Fibrosis Helps Select the Appropriate Patient and Strategy in Catheter Ablation of Atrial Fibrillation: A DE-MRI Guided Approach

NAZEM AKOUM, M.D., MARCOS DACCARETT, M.D., CHRIS MCGANN, M.D., NATHAN SEGERSON, M.D., GASTON VERGARA, M.D., SUMAN KUPPAHALLY, M.D., TROY BADGER, M.D., NATHAN BURGON, B.S., THOMAS HASLAM, B.S., EUGENE KHOLMOVSKI, Ph.D., ROB MACLEOD, Ph.D., and NASSIR MARROUCHE, M.D.

From the Comprehensive Arrhythmia Research and Management (CARMA) Center, University of Utah, Salt Lake City, Utah, USA

(J Cardiovasc Electrophysiol, Vol. 22, pp. 16-22, January 2011)
Quantifying Atrial Fibrosis with Cardiac Magnetic Resonance Imaging
Persistent Atrial Fibrillation is Associated with Greater Degrees of Atrial Fibrosis
Degrees of Atrial Fibrosis and Outcome Following AFIB Ablation
Evaluation of Left Atrial Lesions After Initial and Repeat Atrial Fibrillation Ablation: Lessons Learned From Delayed-Enhancement MRI in Repeat Ablation Procedures
Troy J. Badger, Marcos Daccarett, Nazem W. Akoum, Yaw A. Adjei-Poku, Nathan S. Burgon, Thomas S. Haslam, Saul Kalvaitis, Suman Kuppahally, Gaston Vergara, Lori McMullen, Paul A. Anderson, Eugene Kholmovski, Rob S. MacLeod and Nassir F. Marrouche

*Circ Arrhythm Electrophysiol* 2010;3;249-259; originally published online March 24, 2010:
Characterizing Atrial Scar Following AFIB Ablation
Characterizing Atrial Scar Following AFIB Ablation

<table>
<thead>
<tr>
<th></th>
<th>Posterior Wall</th>
<th>Left Pulmonary Veins</th>
<th>Right Pulmonary Veins</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>First Ablation</strong></td>
<td><img src="image1" alt="Image" /></td>
<td><img src="image2" alt="Image" /></td>
<td><img src="image3" alt="Image" /></td>
</tr>
<tr>
<td><strong>Second Ablation</strong></td>
<td><img src="image4" alt="Image" /></td>
<td><img src="image5" alt="Image" /></td>
<td><img src="image6" alt="Image" /></td>
</tr>
</tbody>
</table>

*Badger...Marrouche et al. Circ Arrhythm Electrophysiol 2010;3;249-259*
Circumferential Pulmonary Vein Scar Predicts Outcomes

Circumferential PVA Scar and Clinical Outcome

First Procedure: # of PVs with Complete Scar

- No AF Recurrence
- AF Recurrence

Badger...Marrouch et al. Circ Arrhythm Electrophysiol 2010;3;249-259
Evaluation of the left atrial substrate in patients with lone atrial fibrillation using delayed-enhanced MRI: Implications for disease progression and response to catheter ablation

Christian Mahnkopf, MD, Troy J. Badger, MD, Nathan S. Burgon, BSc, Marcos Daccarett, MD, Thomas S. Haslam, Christopher T. Badger, Christopher J. McGann, MD, Nazem Akoum, MD, Eugene Kholmovski, PhD, Rob S. Macleod, PhD, Nassir F. Marrouche, MD, FHRSS

From the Comprehensive Arrhythmia and Research Management (CARMA) Center, University of Utah School of Medicine, Salt Lake City, Utah.

Left Atrial Substrate in Lone Atrial Fibrillation

Stroke Risk in Atrial Fibrillation

Marrouch et al. 2011
Is There a Relationship Between Atrial Contractile Function and Atrial Fibrosis in Atrial Fibrillation?
Left Atrial Function Predicts Atrial Fibrillation Recurrence After Catheter Ablation

- 63 pts. AFIB Catheter Ablation
- 75% PAF, 25% Persistent AF
- 18±12 months of follow-up

Atrial Fibrillation

No Recurrence Group (n = 34; 54%)

Recurrence Group (n = 29; 46%)

Left Atrial Strain Rate

Positive Peak Strain Rate

Early Negative Peak Strain Rate

Late Negative Peak Strain Rate
Left Atrial Strain

Positive Peak Strain

Negative Peak Strain

Total Strain
Left Atrial Function Predicts Atrial Fibrillation Recurrence After Catheter Ablation


Peak Systolic LA Lateral Wall Longitudinal Strain

Atrial Fibrillation Recurrence Group (n = 29; 46%)

No Recurrence Group (n = 34; 54%)
Atrial Strain and Atrial Fibrosis

Kuppahally...Marrouche et al. Circ Cardiovasc Imaging. 2010;3(3):231-9
Atrial Strain and Atrial Fibrosis

Kuppahally...Marrouche et al. Circ Cardiovasc Imaging. 2010;3(3):231-9
Characterization of Left Atrial Strain in AFIB Ablation

Group 1 patient: Preablation (A) and post ablation (B) average strain (25% vs. 50%) and strain rate (0.95 vs. 2.2 cm/sec)

Group 2 patient: Preablation (C) and post ablation (D) average strain (11% vs. 14%) and strain rate (0.74 vs. 0.80 cm/sec)

Atrial Remodeling is Associated with Reoccurrence of Atrial Fibrillation

Treatment Strategy Utilizing Utah LA Fibrosis Score

VERGARA and MARROUCHE, Cardiovasc Electrophysiol; 22:481-487, April 2011
Correlation between AF Substrate Ablation Difficulty and Left Atrial Fibrosis Quantified by Delayed-Enhancement Cardiac Magnetic Resonance

JULIEN SEITZ, M.D., JÉRÔME HORVILLEUR, M.D., JÉRÔME LACOTTE, M.D., DARACH O H-ICI, M.D., YAMINA MOUHOUB, M.D., ALICE MALTRET, M.D., FIORELLA SALERNO, M.D., DARREN MYLOTTE, M.D., MEHRAN MONCHI, M.D., and JÉRÔME CAROT, M.D., Ph.D.

From the Institut Cardiovasculaire Paris Sud, Hôpital Privé Jacques Cartier, Massy, France

Correlation between AF Substrate Ablation Difficulty and Left Atrial Fibrosis Quantified by Delayed-Enhancement Cardiac Magnetic Resonance

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Correlation between AF Substrate Ablation Difficulty and Left Atrial Fibrosis Quantified by Delayed-Enhancement Cardiac Magnetic Resonance

Pulmonary vein anatomy and long-term outcome after multi-electrode pulmonary vein isolation with phased radiofrequency energy for paroxysmal atrial fibrillation

Anton A.W. Mulder*, Maurits C.E.F. Wijffels, Eric F.D. Wever, and Lucas V.A. Boersma

Department of Cardiology, St Antonius Hospital, Nieuwegein, PO Box 2500, 3430 EM, The Netherlands
Pulmonary Vein Diameter and Long Term A Fib Outcome

“In patients who have undergone PVI with phased RF energy and PVAC multi-electrode ablation, long-term efficacy is not significantly affected by PV anatomy or number of applications”

Table 3 Diameter of pulmonary veins

<table>
<thead>
<tr>
<th>Number of patients</th>
<th>Success at 12 months&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Failure at 12 months&lt;sup&gt;a&lt;/sup&gt;</th>
<th>P value and OR for success&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
<td>P value</td>
</tr>
<tr>
<td>Diameter PVs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left superior PV</td>
<td>17 ± 3</td>
<td>17 ± 3</td>
<td>0.82</td>
</tr>
<tr>
<td>(mm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left inferior PV</td>
<td>15 ± 3</td>
<td>16 ± 2</td>
<td>0.14</td>
</tr>
<tr>
<td>(mm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right superior PV</td>
<td>17 ± 3</td>
<td>18 ± 3</td>
<td>0.09</td>
</tr>
<tr>
<td>(mm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right middle PV</td>
<td>8 ± 2</td>
<td>8 ± 2</td>
<td>0.25</td>
</tr>
<tr>
<td>(mm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right inferior PV</td>
<td>17 ± 3</td>
<td>18 ± 3</td>
<td>0.42</td>
</tr>
<tr>
<td>(mm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left common PV</td>
<td>23 ± 6</td>
<td>25 ± 8</td>
<td>0.41</td>
</tr>
<tr>
<td>(mm)</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

PV, pulmonary vein.

<sup>a</sup>For definition of success and failure see text.
Limitations of Left Atrial Fibrosis by CMR Late ENhancement

- Left Atrial Wall is a Thin Structure, and Difficult to Image.
- Experience with a Rigorous Method for LA Late Enhancement Quantification is Limited to a Few Expert Centers.
- Widespread Clinical Use Has Not Yet Been Adapted, and Some Consider this A Research Application.
Continuum of Response to A Fib Ablation

Most Likely To Respond

• Paroxysmal Atrial Fib.
• Smaller Atrial Size
• Preserved Atrial Contractile Function
• Triggered mechanism

Least Likely To Respond

• Chronic Atrial Fib.
• Larger Atrial Size
• Lost Atrial Contractile Function
• Substrate-Based Mechanism

Utah stage 1
Utah stage 4
Conclusions:
Atrial Fib. Ablation
CMR, Follow-Up and Prognosis

1) For Detecting Post-procedure Complications, CMR Has Not Yet Emerged As Favored, And A Multi-modality Imaging Approach Is Currently Preferred.

2) Exciting New CMR Data To Late Enhancement to Quantify Atrial Fibrosis May Characterize The Substrate of Atrial Fibrillation and Has Been Associated With LA Contractile Function.

3) Atrial Fibrosis by CMR Late Enhancement Has Been Associating with Ablation Procedural Difficulty, Reoccurrence of Atrial Fibrillation, and Stroke Risk, and Appears Promising to Predict Prognosis.

4) Future Work is Needed to Define Its Role in Clinical Practice.