Image Based Approaches for Atrial Fibrillation:

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Disclosures

Who would pay me, I am a PhD?

Thank Goodness for the NIH!
Paradox
Things We All Know about Sweden
Kingston
For Your Information (Ego)

Most PhDs per capita
1 Kingston, Ont. 1.67%
2 Guelph, Ont. 1.4%
3 Victoria, B.C. 1.27%
4 Ottawa-Gatineau, Ont. 1.22%
5 Saskatoon, Sask. 1.05%

Least PhDs per capital
1 Barrie, Ont. 0.15%
2 Oshawa, Ont. 0.20%
3 Brantford, Ont. 0.22%
4 Saint John, N.B 0.24%
5 Abbotsford, B.C. 0.28%

Los Alamos, New Mexico

or

Madison, Wisconsin

or

Ghana

or

Israel
Infarct
Ischemia
VT
The VENTRICLES
Reentry
The ATRIA
Fibrillation
Flutter
The ATRIA

Fibrillation

Flutter
What is Atrial Fibrillation?

= Afib = AF
Normal Contraction

Atrial Fibrillation
AF Prevalence

Projected Number of Persons With AF (millions)

Year


Current age-adjusted AF incidence
 Increased age-adjusted AF incidence

We All Get Older

So What?
20% of Strokes

$20 billion/year
What Causes AFib?
Substrate
+
Trigger
Substrate: Fibrosis


Complex Propagation

de Groot, ..., Allessie MA. Circ. 2010: 1674-1682.
Substrate: Extension of muscle sleeves
Triggers

Left Atrium

Pulmonary Veins
Nervous System

Clinical Result

Normal conduction

Atrial fibrillation

SA Node

Normal electrical signals

SA Node

Disorganized electrical signals
Clinical Result
Treatment?
Electroanatomical Mapping
Imaging?
MR Angiography

Pre

First Pass

Subtraction
Dark Blood MRI

Pre-treatment

24 Hours Post

3 Months Post
Late Gadolinium Enhancement

Pre-treatment 3 month Post
Patient Workflow

Evaluation → Treatment → Followup
Fibrosis and Outcome Evaluation

Patient 1
Enhanced (fibrosis?)
Low-voltage

Patient 2
Enhanced (fibrosis?)
Low-voltage

Success

Failure
Fibrosis Predicts Outcome

Evaluation

Recurrence by Pre-Ablation Delayed Enhancement

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

Days since Ablation

Proportion of Patients in Sinus Rhythm

<5% SRM  5-20% SRM  20-35% SRM  >35% SRM

SCI

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CARMA
Utah Scoring Scheme

Evaluation

Fibrosis Imaging

Evaluation

Pixel Intensity

Frequency
Corview Evaluation
Something Really New!
Enhancement is Fibrosis
Enhancement is Fibrosis
Enhancement is Fibrosis

epi

endo
Patient Workflow

Evaluation → Treatment → Followup
Real Time MRI
Real Time MRI
Experiments!
Don’t Try This At Home

The following clips will provide an impression, what forces are exerted on ferromagnetic objects and what dangers they can pose.

University of Utah 2005
Experiments!
Real Time MRI
Real Time MRI

March, 2011
Lesion Imaging

Ablation: 30 Watts, 30 sec

Vergara et al. HRS 2011 vol. 8 (2) pp. 295-303
Segmentation for Guidance

Seg3D 2.0

Treatment
Electrogram Recording

Treatment

Pre-ablation EGM

Post-ablation EGM

T2w HASTE, T=0

T2w HASTE, T=40s
Electroanatomical Mapping
EAM vs. MRI

Followup
Scar Predicts Outcome

McGann et al. JACC,52(15): 1263-1272, 2008

Unsuccessful PVAI
Successful PVAI
Repeat Ablation

Patient 1

First PVAI - Posterior
Incomplete Isolation
Left

Second PVAI - Posterior
Complete Isolation
Left

Patient 2

First PVAI - Posterior
Incomplete Isolation
Left

Second PVAI - Posterior
Complete Isolation
Left

McGann et al. JACC, 52(15): 1263-1272, 2008
Immediate Response

Pre-Ablation | Lesion Map | 30 min Post Ablation

PA

AP
“No Reflow”

LGE

pre

< 1hr post
Predicting Success

LGE (pre)  T2w (<1hr)  LGE (<1 hr)  LGE (3 mo)
Open Challenges

Evaluation → Treatment → Followup

Image quality
Signal Acq./Proc.
LA Segmentation
Fibrosis Characterization
Scar Description
Lesion Imaging
Patient Specific Modeling/Simulation
Animal Models of AFib
Utah Cooperative Arrhythmia Program

Development of chronic AF animal model

DE-MRI of structural changes

MRI analysis and fibrosis quantification

Electrophysiological studies

Pathology and histology of fibrosis

Serum markers of inflammation

Hematology

Pathology

Utah State University

UCAIR, Radiology

SCI

Clinical EP, Cardiology

Utah State University

UCAIR, Radiology

SCI

Clinical EP, Cardiology

Hematology

Pathology

UCAP
Where Are We?
Figure 1. A series of left atrial MRI 3D reconstructions displayed in the RAO and PA projections illustrating areas of fibrosis (bright green) across the 4 stages of fibrosis. Utah stage 1: <5% fibrosis, Utah stage 2: 5–20% fibrosis, Utah stage 3: 20–25% fibrosis, Utah stage 4: >35% fibrosis.

Data Analysis
Statistical analysis was performed using STATA 11 (StataCorp, College Station, TX, USA). Continuous variables are reported as means and standard deviations and categorical variables are reported as percentages of the cohort. Student’s t-test was used to compare continuous variables and Chi-square test to compare proportions. A Cox proportional hazard multivariate regression model was used to determine significant predictors of AF recurrence following ablation. To avoid overfitting, nonsignificant predictor variables were removed from the regression model in a stepwise fashion. Two-sided P-values < 0.05 were considered significant.

Results
Pre-Ablation Fibrosis/Structural Remodeling Based Staging
DE-MRI scans were of adequate quality to obtain quantification of pre-ablation SRM in 120 of the 144 total patient cohort (85%). Motion artifact often due to AF at the time of MRI acquisition was the main contributing factor for poor scans quality.

Of the 120 patients successfully quantified, the average pre-ablation fibrosis was 18.06 ± 13.49% of the LA wall volume. These patients were then divided into 4 categories as follows: Utah stage 1 or minimal fibrosis (at least 1 standard deviation below the cohort mean, i.e., <5% enhancement), Utah stage 2 or mild fibrosis (5–20% enhancement), Utah stage 3 or moderate fibrosis (20–35% enhancement) and Utah stage 4 or extensive fibrosis (greater than 35% enhancement). Figure 1 shows examples of patients in each of these stages. Of the patients with successful quantification, 10 (7%) were in Utah stage 1, 71 (49%) in Utah stage 2, 23 (16%) in Utah stage 3 and 16 (11%) in Utah stage 4. Age at the time of initial MRI acquisition, prevalence of hypertension, coronary artery disease, congestive heart failure, diabetes and left ventricular ejection fraction were comparable across the 4 groups. The patients' characteristics are detailed in Table 1.

<table>
<thead>
<tr>
<th>Utah Stage</th>
<th>N</th>
<th>Age (years)</th>
<th>HTN (%)</th>
<th>Diabetes (%)</th>
<th>Coronary disease (%)</th>
<th>CHF (%)</th>
<th>LV EF (%)</th>
<th>Paroxysmal/persistent AF (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (&lt;5%)</td>
<td>10</td>
<td>58 ± 14</td>
<td>50.0</td>
<td>10</td>
<td>30</td>
<td>10</td>
<td>57.2</td>
<td>60/40</td>
</tr>
<tr>
<td>2 (5–20%)</td>
<td>71</td>
<td>62 ± 13</td>
<td>53.5</td>
<td>7.0</td>
<td>12.7</td>
<td>5.6</td>
<td>51.8</td>
<td>45/55</td>
</tr>
<tr>
<td>3 (20–35%)</td>
<td>23</td>
<td>67 ± 13</td>
<td>56.5</td>
<td>21.7</td>
<td>13.0</td>
<td>4.3</td>
<td>49.7</td>
<td>35/65</td>
</tr>
<tr>
<td>4 (&gt;35%)</td>
<td>16</td>
<td>68 ± 8</td>
<td>43.8</td>
<td>6.3</td>
<td>18.8</td>
<td>12.5</td>
<td>44.8</td>
<td>25/75</td>
</tr>
</tbody>
</table>

ns = nonsignificant.
Paradox

The ATRIA

Fibrillation

Flutter

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