Basic 2: Anatomy for EP
Cardiac image and Arrhythmia

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Agenda

• Imaging modalities for AF treatment
• Ischemic VT
• Non-ischemic VT
  - Dilated CM (DCMP)
  - Hypertrophic CM (HCMP)
  - Arrhythmogenic RV cardiomyopathy (ARVC)
  - Sarcoidosis, Giant cell disease...
Increased LA size in AF

**LAV_{max} index**
- Control
- PAF
- PeAF

**LAV_{min} index**
- Control
- PAF
- PeAF

**Emptying volume**
- Control
- PAF
- PeAF

**Ejection fraction**
- Control
- PAF
- PeAF

Park MJ, etc International J Cardiol. 2011
Function and volume of LA in AF

- Reservoir for blood draining the pulmonary veins during ventricular systole
- Conduit for that blood during early diastole
- Muscular pump to complete the process of LV filling (15-30%) before ventricular contraction and mitral valve closure in the late diastole

AF-risk being highest for subjects with concomitant LA emptying fractions <49% and LA volume >38 ml/m² (hazard ratio 9.3, p=0.003)

574 subjects with NSR, mean 74 yrs old, 2 yr f/u
LA strain and fibrosis

Global PALS showed the best diagnostic accuracy to detect LA fibrosis (area under the curve 0.89) than LAVI, LAEF, E/E' (46 pts, OP for MR)
LA endocardial voltage in AF

Marin K. Stiles, etc., J Am Coll Cardiol. 2009; 53:1182-91
Correlation between LA strain and LGE-MRI

- 65 pts with AF.
- LA wall fibrosis by delayed-enhancement MRI is inversely related to LA strain and strain rate, and these are related to the AF burden.
Prediction of RFCA outcome by MRI
Stroke and LA endocardial voltage

A. LA voltage (No Stroke)

B. LA voltage (Stroke)

C. LA volume/BSA

D. Mean LA Voltage

Park JH, HN Pak, Europace (2011) 13, 1541–1549
Flow velocity in LAA by cMRI was lower in AF than those in NSR

M Markl et al.
Circ Cardiovasc Imaging. 2016 Sep;9(9):e004984
EHJ – Cardiovascular Imaging (2016) 17, 1259–1268
Image modalities and Ventricular arrhythmia
Scar related VT in ischemic CM

- Slow conduction
- Areas of conduction block that may be functional or fixed
- An initiating mechanism (a premature impulse, change in autonomic tone, or particular sequence of R-R intervals)

Raymond JM. Curr Probl Cardiol 2009;34:225-270
Pre-ablation evaluation by using cMRI

- TTE: Akinesia with thinning and scarring at LAD territory, aneurysmal change in apex
  - LVEDD=65mm, LVEF=20%
- 3-D Cardiac MRI can represent the scar area of LV
Pre-ablation evaluation by using cMRI

- **A**
  - S-QRS = 168ms
  - PPI-TCL = 11ms

- **B**
  - S-QRS = 180ms
  - PPI-TCL = 5ms

- **C**
  - S-QRS = 224ms
  - PPI-TCL = 2ms
Critical arrhythmic events in Ischemic vs. Non-ischemic CM

- Ischemic VT
- Non-ischemic VT
  - Dilated CM (DCMP)
  - Hypertrophic CM (HCMP)
  - Arrhythmogenic RV cardiomyopathy (ARVC)
  - Sarcoidosis, Giant cell disease...
- Catecholaminergic polymorphic VT (CPVT)
- Brugada syndrome, Long QT syndrome
- Idiopathic VT
- ......
Critical arrhythmic events in Ischemic vs. Non-ischemic CM

- Ischemic VT
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- ......
Midwall fibrosis in non-ischemic CM

In Ewha and Severance Cardiac MRI database

- Prospective registry of ICD / CRT in CHF patients (Clinicaltrial.gov / NCT02139449)
- 408 patients with non-ischemic CM (Cardiac MRI)
  - 253 (62%) male, 58.3±14.7 years
  - NYHA 2.6±0.8
  - LVEF 26.3±13.9%, LVEDV 292.0±168.9ml
  - BMI 27.5 ±33.9kg/m²

- Late gadolinium enhancement (LGE) : 300 (73.5%)
  - Intamural 186 (28.7%), Transmural : 34 (11.3%)
  - Subendocardial : 23 (7.7%), epicardial 22 (7.3%)

- Death 83 (20.3%), Hospitalization 149 (36.5%)
- Arrhythmia events (Non-sustained VT, sustained VT, VF) : 57 (14.0%)
  - Major ventricular arrhythmia : non-sustained VT, sustained VT, VF
  - Fatal ventricular arrhythmia : sustained VT, VF
Analysis of LV-LGE

Case #6 M/66

- **Base(6) / mid-ventricle(6) / apex(4)**

- **DHE (%) = \[\frac{\text{Volume of LGE}}{\text{Volume of total myocardium}}\] %**

LGE of left ventricle

Subendocardial  
Subepicardial  
Transmural

Midwall  
Patchy

Shin DG, Park JB, Joung B. Int J Cardiol. 2016 Nov 1;222:9-15
LV – LGE and clinical outcome

A. Event free survival of major arrhythmia

- Overall Log rank $p < 0.001$
- 1 vs. 2 $p = 0.005$
- 1 vs. 3 $p < 0.001$
- 2 vs. 3 $p = 0.001$

B. Event free survival of ventricular arrhythmia

- Overall Log rank $p = 0.003$
- 1 vs. 2 $p = 0.411$
- 1 vs. 3 $p = 0.002$
- 2 vs. 3 $p = 0.002$

Legend:
- 1. No LGE
- 2. Other pattern LGE
- 3. Subepicardial pattern LGE

Shin DG, Park JB, Joung B. Int J Cardiol. 2016 Nov 1;222:9-15
Late gadolinium enhancement confined to the right ventricular insertion points in hypertrophic cardiomyopathy: an intermediate stage phenotype?

Paco E. Bravo¹,²*, Hong-Chang Luo², Iraklis Pozios², Stefan L. Zimmerman², Celia Pamela Corona-Villalobos², Lars Sorensen², Ihab R. Kamel², David A. Bluemke³, Richard L. Wahl², M. Roselle Abraham², and Theodore P. Abraham²
LV-RV junction LGE and clinical outcome

![Graph showing incidence of various endpoints with statistical significance]

- Composite endpoint: 149 cases (41.4%)
  - No LGE: 102 cases
  - RVIP-LGE: 30 cases
  - LV/RVIP-LGE (+/-): 121 cases
  - LV/RVIP-LGE (++): 87 cases

- All-cause death: 63 cases (17.5%)
  - p < 0.0001

- Worsening of HF: 110 cases (30.7%)
  - p < 0.06

- Major arrhythmical event: 49 cases (13.6%)
  - p < 0.0001

Yi JE, Joung B, Park JB. KSC 2016 Oral presentation
LV-RV junction LGE and clinical outcome

- Composite endpoints
- Death
- LGE confined to the RVIP among NICM patients did not significantly increase the risk of adverse cardiac events
- Hospitalization by heart failure
- Major arrhythmic events

Yi JE, Joung B, Park JB. KSC 2016 Oral presentation
Inferior f-QRS and LGE

- Fragmented QRS represents depolarization abnormality or conduction delay in myocardium and has a high prognostic value of arrhythmic events and mortality in various cardiac diseases.
- 307 patients with DCMP. (With enrollment, all patients underwent cMR imaging, EKG monitoring and echocardiogram)
- All EKG were analyzed on the presence of fQRS, J wave at all 12 leads.

And all patients were followed up and analyzed for the following outcomes:
- fatal arrhythmic events (Ventricular tachycardia, Ventricular fibrillation)
- hospitalization due to heart failure
- sudden cardiac death (SCD)
## Inferior f-QRS vs. Non-inferior f-QRS

<table>
<thead>
<tr>
<th></th>
<th>All</th>
<th>Non-inferior f QRS</th>
<th>inferior f QRS</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Geometric parameters</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LV Ejection fraction (%)</td>
<td>26.3±11.1</td>
<td>25.7±10.0</td>
<td>26.1±11.4</td>
<td>0.812</td>
</tr>
<tr>
<td>LV EDV/BSA (ml/m²)</td>
<td>174.6±97.7</td>
<td>171.2±104.1</td>
<td>191.7±78.4</td>
<td>0.293</td>
</tr>
<tr>
<td><strong>The quantification of LV LGE</strong></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Presence of LV LGE (%)</td>
<td>73%</td>
<td>72%</td>
<td>93%</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>The ratio of LV LGE / LV (%)</td>
<td>4.2±7.2</td>
<td>3.8±6.6</td>
<td>8.5±9.5</td>
<td>0.006</td>
</tr>
<tr>
<td>The ratio of LV LGE ≥ 3.5% (median)</td>
<td>50%</td>
<td>47%</td>
<td>77%</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td><strong>The pattern of LV LGE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subepicardial (%)</td>
<td>2%</td>
<td>3%</td>
<td>0</td>
<td>0.24</td>
</tr>
<tr>
<td>Mid-wall (%)</td>
<td>46%</td>
<td>45%</td>
<td>50%</td>
<td>0.572</td>
</tr>
<tr>
<td>Subendocardial (%)</td>
<td>4%</td>
<td>3%</td>
<td>11%</td>
<td>0.021</td>
</tr>
<tr>
<td>Transmural (%)</td>
<td>8%</td>
<td>7%</td>
<td>18%</td>
<td>0.009</td>
</tr>
<tr>
<td>Patch (%)</td>
<td>35%</td>
<td>37%</td>
<td>39%</td>
<td>0.867</td>
</tr>
<tr>
<td><strong>The location of LV LGE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anterior (%)</td>
<td>5%</td>
<td>5%</td>
<td>7%</td>
<td>0.518</td>
</tr>
<tr>
<td>Interventricular septum (%)</td>
<td>46%</td>
<td>47%</td>
<td>49%</td>
<td>0.778</td>
</tr>
<tr>
<td>Inferior (%)</td>
<td>8%</td>
<td>8%</td>
<td>5%</td>
<td>0.471</td>
</tr>
<tr>
<td>Lateral (%)</td>
<td>4%</td>
<td>3%</td>
<td>5%</td>
<td>0.601</td>
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<tr>
<td>Junction between LV-RV (%)</td>
<td>30%</td>
<td>34%</td>
<td>23%</td>
<td>0.147</td>
</tr>
<tr>
<td>N of involve Segment ≥ 3</td>
<td>14%</td>
<td>12%</td>
<td>33%</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

HJ Lee, JB Park. HRS 2017 and Europace 2107. Oral presentation
HW Cho, HJ Lee, JB Park. In revision
Ventricular arrhythmic events according to inferior fQRS

Ventricular arrhythmia and SCD

Non-sustained VT (NSVT; %)
Sustained VT (SuVT; %)
VF (%)
Sudden cardiac death (SCD; %)

Non inferior f QRS
Inferior f QRS

HJ Lee, JB Park. HRS 2017 and Europace 2107. Oral presentation
HW Cho, HJ Lee, JB Park. In revision
LV-LGE in a Smoker (multi-segment involves) vs. Never-smoker

M/51, EF 40%, Smoker
LGE 49.7%, multi-segment involvement

M/73, EF 32%, Never-smoker
LGE 4.1%, anterior / inferior wall involvement

M/63, EF 44%, Never-smoker
No LGE
Ventricular arrhythmic events according to smoking

A

Ventricular arrhythmia and SCD

- Non-sustained VT (NSVT; n, %)
- Sustained VT (SuVT; n, %)
- VF (n, %)
- Sudden cardiac death (SCD; n, %)

Never-smoking  Smoking

B

Combined ventricular arrhythmic events and SCD

- Major Ventricular arrhythmia (MVAE=NSVT+SuVT+VF; n, %)
- Fatal ventricular arrhythmia (FVAE=SuVT+VF; n, %)
- MVAE + SCD (n, %)
- FVAE + SCD (n, %)

Never-smoking  Smoking

C

Ventricular arrhythmia and SCD

- Non-sustained VT (NSVT; n, %)
- Sustained VT (SuVT; n, %)
- VF (n, %)
- Sudden cardiac death (SCD; n, %)

Never-smoking  Ex-smoking  Current-smoking

D

Combined ventricular arrhythmic events and SCD

- Major Ventricular arrhythmia (MVAE=NSVT+SuVT+VF; n, %)
- Fatal ventricular arrhythmia (FVAE=SuVT+VF; n, %)
- MVAE + SCD (n, %)
- FVAE + SCD (n, %)

Never-smoking  Ex-smoking  Current-smoking

\[ P < 0.05 \]
Smoking and LV-LGE and clinical outcome

A. FVA free survival. p=0.02

B. FVA+SCD free survival. p=0.005

Park JB, Joung B. 2016 HRS Oral presentation
Mechanism of ventricular arrhythmia in smokers

M/51, EF 40%, Smoker
LGE 49.7%
Multi-segment involvement

Park JB, Joung B. 2016 HRS Oral presentation
Summary

• Imaging modalities for AF treatment
  – LA remodeling remains a central focus of imaging assessment for AF
  – Increased LA volume, increased LA fibrosis, and impaired LA function are the main hallmarks of LA remodeling.
  – LAA is particularly associated with risk of stroke.
  – Blood stagnation, and thrombus formation, assessed with TEE or 4D flow Cardiac MRI.

• Imaging for Ventricular arrhythmia
  – The LV scar mapping is important to understand the mechanism of VT in ICMP
  – Cardiac MRI may characterize the spatial extent of myocardial scar of LV, including its topography and transmularity in ICMP / non-ICMP
  – In non-ischemic CM without definite fibrotic change, cardiac MRI may be useful to predict cardiac mortality and arrhythmic events.
Thank you for your attention!!

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