Demonstrating Localized Electrical Rotors that Perpetuate Human Atrial Fibrillation
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1. PURPOSE

Ablation of human atrial fibrillation (AF) is challenged by a lack of clear targets (source mechanisms) that perpetuate AF. In elegant animal models, AF is perpetuated by localized electrical rotors or focal impulses; yet recent human studies have reported that such AF-sustaining mechanisms are rare or absent. Notably, prior studies may have been limited by lack of human atrial data on determinants of functional reentry (rate-dependent repolarization and conduction velocity) during or prior to AF initiation.

HYPOTHESIS: Electrical rotors and focal beats may be revealed in human AF by analyzing multisite electrogams and the dynamics (rate dependence) of action potential duration (APD) and conduction velocity (CV).

2. METHODS

- In 80 patients prior to AF ablation (age 61 ± 9 years; 54 persistent), we utilized a novel computational system for mapping AF prior to ablation.
- We recorded AF from bipolar or unipolar electrogams from 64 pole basket catheters in left (n=26) or both (n=54) atria (fig 1A) to accelerate data collection. Electrode contact was confirmed by electrogams, fluoroscopy and intracardiac echocardiography (fig 1B, C).
- APD was defined within the atria (n=50) via monophasic action potential (MAP) catheters (fig 1A) in AF, or incremental pacing from CL 600 ms to AF onset.
- Conduction velocities were estimated regionally within the atria by conduction times from pacing to each bi-atrial basket electrode en route to AF.
- Spatial organization in AF was computed intraprocedurally using patient-specific computational models of functional reentry and the Hilbert transform.

3. RESULTS

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Persistent AF</th>
<th>Paroxysmal AF</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>AF Cycle Length, ms</td>
<td>169±22</td>
<td>192±24</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>APD Rest Slope (n=25)</td>
<td>1.1±0.5</td>
<td>1.2±0.5</td>
<td>NS</td>
</tr>
<tr>
<td>APD Alt Onset CL (n=25)</td>
<td>411±94</td>
<td>372±72</td>
<td>NS</td>
</tr>
<tr>
<td>Patients with sources</td>
<td>51/54 (94%)</td>
<td>26/26 (100%)</td>
<td>NS</td>
</tr>
<tr>
<td>Number Sources/pt.</td>
<td>2.0±0.8</td>
<td>1.5±0.8</td>
<td>NS</td>
</tr>
</tbody>
</table>

- N=77/80 patients (96%) showed electrical rotors or focal beats in AF, with 1.8±0.8 concurrent rotors (76% of sites) or focal impulses (14%; table).
- Rotors and focal beats were present for > 60 minutes.
- Figure 2 shows that APD alternans is unrelated to restitution in AF patients, and may arise at very slow heart rates.
- Figure 3 shows that CV restitution may be steep in AF patients, with sudden slowing at critical heart rates.
- Figure 4 shows a RIGHT ATRIAL rotor (colored isochrones around a core) in a 47 year old man with intractable persistent AF despite prior ablations. Ablation at this site (local Impulse and Rotor Modulation, FIRM) terminated AF in 5 minutes 22 seconds prior to any other lesions. The patient is AF-free at 1 year, monitored via CIED.
- Figure 5 shows a LEFT ATRIAL rotor (color-coded isochrones). Real-time ablation (FIRM) at this site terminated AF in < 1 minute.

4. CONCLUSIONS

- Electrical rotors can be revealed in human AF using novel patient-tailored physiological imaging, utilizing data on rate-response of repolarization and conduction.
- Localized sources were observed in nearly all AF patients.
- Direct ablation at only these sites (local Impulse and Rotor Modulation, FIRM) can terminate AF acutely, suggesting a novel target for ablation.