Στροφείς (rotors) και πραγματικότητα.

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Mechanisms that sustain Atrial Fibrillation

✓ multiwavelet hypothesis, since 1964

✓ a critical number of wavelets, which travel throughout the atria, colliding, combining or dividing and generating new wavelets that perpetuate the process.
What is a Rotor?

- 1990
- localized sources generating wavefronts
- spiral wave

- conduction velocity, depends on wavefront curvature
- unexcited but excitable tissue
- no fixed wavelength in rotor generated spiral waves.
Phase Mapping of Rotors and Singularities

- Phase mapping technique by Gray et al, in 1998

- Tracking of the spiral and its tip dynamics, in space, over time.

- Each color represents a phase in the excitation recovery cycle, and a PS is defined as a site where all of the phases converge.
✓ meandering around a relatively fixed core
✓ rotors may drift over larger distances.
Dominant frequency

✓ a small number of high-frequency rotors in the LA maintain the overall activity

Circ Res. 2013;112:849-862
Treatment of Atrial Fibrillation by the Ablation of Localized Sources

CONFIRM (Conventional Ablation for Atrial Fibrillation With or Without Focal Impulse and Rotor Modulation) Trial

(82.4% (FIRM-guided) vs 44.9% (FIRM-blinded) free of AF after median 273 days)

J Am Coll Cardiol 2012;60: 628–36)
✓ freedom from AF was higher for FIRM-guided than conventional therapy (77.8% vs. 38.5% at 890 days)
✓ Single procedure success rate after mean 18 months of follow-up was 30% free from documented AF recurrence and 21% free from atrial tachyarrhythmias.
✓ FIRM-identified rotor sites do not exhibit distinctive electrophysiological characteristics with regard to dominant frequency or Shannon entropy;
✓ rotational activation (>1 rotation) on electroanatomic mapping was not observed at FIRM-identified rotor sites
Impact of Rotor Ablation in Nonparoxysmal Atrial Fibrillation Patients
Results From the Randomized OASIS Trial

BACKGROUND: Hemodynamically significant studies have reported local tissue tempera
ture from FIRM-guided ablation to be superior to pulmonary vein ablation (PVA) for the preven
tion of early and late recurrences of atrial fibrillation (AF).

OBJECTIVES: The study sought to compare efficacy and safety of the two tech
niques: without PVA versus PVA + non-PVA. The primary outcome was freedom from atrial fibrillation (AF).

METHODS: Nonparoxysmal atrial fibrillation undergoing first ablation were randomized to: FIRM-only (group 1), PVA + PVA (group 2), or PVA + non-PVA (group 3). Primary endpoint was freedom from AF (sustained or paroxysmal) at 1 year. No antiarrhythmic drugs were allowed for at least 1 month prior to enrollment.

RESULTS: A total of 96 patients were included (49 in group 1, 24 in group 2, and 23 in group 3). Group 1 had lower recurrence rates (47% vs 60%) and higher freedom from AF (59% vs 97%) at 1 year. In group 2, recurrence rates were significantly lower in group 3 versus group 1 (38% vs 10%, p = 0.002). In group 1 and group 2, acute success of ablation was achieved in 17 patients (47%) and 18 patients (59%). 100% and 75% of patients were on AF-free at 1 year, respectively. After 1 year of hemodynamic follow-up, freedom from AF (47% vs 75%) and PAF (100% vs 75%) were significantly higher in group 3 patients (p = 0.001) and 12 patients (p = 0.002), respectively. At 1 year of follow-up, freedom from AF (59% vs 97%) and PAF (50% vs 97%) were significantly higher in group 3 patients (p = 0.001) and 12 patients (p = 0.002), respectively.

CONCLUSION: The study found that non-PVA + non-PVA ablation had significantly longer procedure time and lower recurrence rates compared to FIRM-only ablation. Outcomes of different ablation strategies in patients with persistent atrial fibrillation (PAF) were not significantly different. No antiarrhythmic drugs were allowed for at least 1 month prior to enrollment.

Keywords: Atrial Fibrillation (AF), Nonparoxysmal Atrial Fibrillation (NPAF), Pulmonary Vein Ablation (PVA), Radiofrequency (RF) Ablation.
reasons for FIRM ablation discrepancy

- selected population (a different prevalence of nonparoxysmal AF)
- statistical variation due to the small sample size
- learning curve effect
- The detection of rotors may be limited by the electrode density of the Constellation basket catheter.

Ablation success rates ranging from as high as 82% to as low as 21%
“Different nets catch different fishes”

✓ Simultaneous electrode-tissue contact with a basket catheter is often less than satisfactory at some, if not most, of the electrodes, limiting the fidelity of the data.

✓ The interpolation algorithm is devised to demonstrate mainly rotational activity.

✓ Cardiac motion may also exacerbate problems associated with interpolation.
✓ the multipolar basket catheter provides inadequate coverage of the LA, with half the surface area unsampled, and decipherable atrial electrograms from only 48% of electrodes
✓ ablation of rotor sites, even when accompanied by PVI, did not result in AF termination in the majority (20/24; 83%) of patients.
Differences Between Rotor Mapping Approaches

rotor stability
Spatiotemporal stability

How many rotations?

What is the precise area of rotors activity?

Different criteria lead to different results
ECGI system with additional signal processing that included filtering, wavelet transform, and phase mapping and observed active AF sources.

- Driver ablation alone terminated 75% and 15% of persistent and long-lasting AF.
- The number of targeted driver regions increased with the duration of continuous AF.
- The number of rotations detected by the ECGI system is much less than that detected by the FIRM approach,
- Median 2.6 rotations.
- A mean duration of 449 ± 89 ms.
- 1–5 discrete regions in each patient.
Percentage of time with rotors (top) and rotor duration (bottom) in surface phase maps from unfiltered and HDF-filtered surface potentials over a cohort of 14 AF patients.

- Instability of rotors on the body surface and the strong effect of the HDF bandpass filtering on their stability.
- Increasing far-field effects on the electrical recordings.
- Percentage of time with rotors (top) and rotor duration (bottom) in surface phase maps from unfiltered and HDF-filtered surface potentials over a cohort of 14 AF patients.
Absence of rotational activity detected using 2-dimensional phase mapping in the corresponding 3-dimensional phase maps in human persistent atrial fibrillation.

<table>
<thead>
<tr>
<th>Type</th>
<th>Percentage ± SD</th>
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<tbody>
<tr>
<td>Single wavefronts</td>
<td>36.6% ± 8.3%</td>
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<tr>
<td>Focal activations</td>
<td>34.0% ± 8.6%</td>
</tr>
<tr>
<td>Disorganized activity</td>
<td>23.7% ± 6.1%</td>
</tr>
<tr>
<td>Rotors</td>
<td>3.3% ± 3.4%</td>
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<tr>
<td>Multiple wavefronts</td>
<td>2.4% ± 3.9%</td>
</tr>
</tbody>
</table>

Pathik et al, Heart Rhythm 2017::1–11
Single Wavefronts In 3D Phase Map At Site of 2D Phase Detected Rotor

2D Phase Map

Superior Mitral Annulus
LAA

Transient Clockwise Rotor (4 Rotations)

3D Phase Map

Broad Single Wavefronts Arising Near LSPV
Two Independent Mapping Techniques Identify Rotational Activity Patterns at Sites of Local Termination During Persistent Atrial Fibrillation

Technique 1 (activation/phase mapping, FIRM)

VS

Technique 2 (unipolar electrograms/phase maps of activation)

Revealed a source in 12 of 12 (100%) cases with spatial concordance in all cases and similar rotational characteristics

Alhusseini et al, J Cardiovasc Electrophysiol, Vol. 28, pp. 615-622, June 2017
Efficacy and safety of driver-guided catheter ablation for atrial fibrillation: A systematic review and meta-analysis

✓ 31 reports
✓ 2 full RCTs
✓ 29 reports were of nonrandomized or observational studies
Multicentre evaluation of non-invasive biatrial mapping for persistent atrial fibrillation ablation: the AFACART study

- ECVUE system
- 252 vest electrodes
- PVI + ROTORS ABL ± left atrial linear ablation
- seven regions
- ≥1.5 rotations
- in an area of < 2 cm²
- high rates of AF termination (64% of patients) and favourable outcomes at 1 year (78% freedom from AF recurrence).
a single-center 1-group study, FIRM + PVI

the median number of rotors per patient was 3.0

wider range of electrodes as well as more flexible catheter tip.

single procedure, 13 (52%) patients were free of atrial tachyarrhythmia after a follow-up period of 13 ± 1 months
The CARTOFINDER system

- CF software in combination with a basket catheter and a 3-dimensional mapping system

- Drivers with rotational activation were predominantly mapped to sites of low-voltage zones (81.8%).

- High reproducibility in finding the same RAP at different times
Ongoing trials

✓ Five randomized, prospective, controlled trials

✓ assign a total of >1,000 patients to either FIRM ablation or control.

<table>
<thead>
<tr>
<th>Trial</th>
<th>Description</th>
<th>Sponsor</th>
<th>Primary outcome</th>
<th>Estimated enrollment</th>
<th>Estimated completion</th>
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<tbody>
<tr>
<td>REDO-FIRM52</td>
<td>Multicentre, randomized, open-label assessment of effectiveness and safety of FIRM-guided versus conventional &quot;redo&quot; radiofrequency ablation procedures for AF</td>
<td>Abbott Electrophysiology</td>
<td>Freedom from AF or adverse effects</td>
<td>268</td>
<td>December 2018</td>
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<td>(NCT02799043)</td>
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<td>FIRMAP-AF53</td>
<td>Multicentre, randomized, single-blind, assessment of effectiveness and safety of FIRM-guided versus conventional radiofrequency ablation for paroxysmal AF</td>
<td>Abbott Electrophysiology</td>
<td>Freedom from AF at 3 and 12 months after single procedure</td>
<td>170</td>
<td>December 2018</td>
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<tr>
<td>SUBSTRATE84</td>
<td>Randomized, open-label assessment of safety and efficacy of FIRM-guided ablation versus conventional ablation (wide-area pulmonary vein isolation)</td>
<td>University of California, San Diego, USA</td>
<td>Freedom from AF at 12 months after procedure</td>
<td>120</td>
<td>September 2021</td>
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<td>(NCT02169037)</td>
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<td>RECONFIRM96</td>
<td>Randomized, open-label safety and efficacy comparison of FIRM-guided ablation (FIRM plus pulmonary vein isolation) versus pulmonary vein isolation alone for symptomatic AF</td>
<td>Stanford University, USA</td>
<td>Freedom from AF at 12 months after procedure</td>
<td>120</td>
<td>July 2019</td>
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<td>REAFFIRM98</td>
<td>Multicentre, randomized study of safety and effectiveness of FIRM procedures followed by conventional ablation including pulmonary vein isolation versus standard pulmonary vein isolation</td>
<td>Abbott Electrophysiology</td>
<td>Freedom from AF at 3 and 12 months after procedure</td>
<td>350</td>
<td>October 2018</td>
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CONCLUSIONS

✓ The concept of rapidly activating spiral rotors as a mechanism for AF-maintenance is still controversial.

✓ Lack of established criteria regarding to spatiotemporal stability of rotors

✓ Substantial heterogeneity exists among AF rotors mapping technologies

✓ Large randomized trials with long-term follow-up are needed to determine the clinical impact of rotors elimination