Rotational Drivers in Atrial Fibrillation

Are Multiple Techniques Circling Similar Mechanisms?

See Article by Calvo et al

Junaid A.B. Zaman, MA, BMBCh, MRCP
Albert J. Rogers, MD, MBA
Sanjiv M. Narayan, MSc, MD, PhD

There is an urgent need to define the mechanisms that sustain atrial fibrillation (AF), as ablation at anatomic and empirical targets has not improved outcomes over pulmonary vein isolation alone.[1–4] Rotational drivers are promising mechanistic targets which are highly topical, yet for which data continue to accumulate. Scientifically, rotational drivers maintain AF using the gold standard of optical mapping,[5] across most species including human atria. Clinically, several studies of rotor ablation show promising results,[6] although divergent data[7] have to be reconciled. Because AF mechanisms may vary with mapping technique, novel mapping studies in this space are welcome.

Present Study

In this issue of *Circulation: Arrhythmia and Electrophysiology*, Calvo et al[8] studied patients with long-standing persistent AF using a novel technique (CartoFinder) and identified sites of rotational activity. These sites fluctuated yet remained spatially stable over time and, when ablated, the impact on local and remote tissue was consistent with elimination of mechanistic drivers. The authors found stable sites of rotational activity (defined as >3 cycles, observed mean 9.2±2.2) in both right and left atria, stabilized in attractor regions over time. Clinically, driver sites were bisected after pulmonary vein isolation using ablation lesions of 3.5 cm length taking an average of 9 minutes. Ablation altered AF dynamics locally and remotely, with elimination of frequency gradients consistent with eliminating a rapid driver. Termination of AF to sinus rhythm was also seen in cases by rotor domain ablation, but not by pulmonary vein isolation. Clinical outcomes were excellent for patients with long-standing persistent AF, with 70% in sinus rhythm at 12 months.

The authors should be congratulated on this study. CartoFinder is a novel mapping approach, yet uses phase and activation analyses[9] which seem similar to existing systems.[10,11] Elimination of frequency gradients indicating loss of rapid regional activity is an intriguing electrophysiology end point[12] compared with prior end points such as prolonged AF cycle length. However, frequency gradients are confounded by spatiotemporal instability[13] and the study is limited by lack of detailed mapping of intra-atrial frequency (only appendages were used). Finally, the study was small, with only 13 patients (men, average age 53 years, 30% prior ablation) which limits its generalizability. Because remapping of AF after ablation was not done, it is unproven if ablation directly abolished rotational circuits.

Correspondence to: Sanjiv M. Narayan, MSc, MD, PhD, Department of Cardiology, Stanford University, CJ250F, 780 Welch Rd, Stanford, CA 94305. E-mail sanjiv1@stanford.edu

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Table. Summary of Mapping Studies Showing Similar Properties of AF Drivers

Mapping Technique	AF Type	N	Atrial Location	Driver Dynamics	Impact of Ablation: Acute	Impact of Ablation: Chronic
FIRM						
Narayan et al,[14] Miller et al,[6] Spitzer et al,[15] Sommer et al[16]	Paroxysmal, persistent and long-standing persistent	3–4	LA 2/3 RA 1/3 PV 40%	Stable with precession for >10 min	Term in 20% to 30% (2/3 to sinus)	Improves over PVI
Endocardial phase						
Alhusseini et al[17] (used basket data, Kuklik et al[18] method)	Paroxysmal, persistent and long-standing persistent	3–4	LA 2/3 RA 1/3 PV 40%	More meander than FIRM	Similar to FIRM	Similar to FIRM
ECGI						
Haissaguerre et al,[19] Knecht et al[20]	Persistent	4–5	LA 2/3 RA 1/3 PV 40%	Unstable in same regions 24 h (stable?)	Term in 40% to 70% (1/5 to sinus)	Improves over PVI
CartoFinder						
Daoud et al,[9] Honarbakhsh et al[21]	Paroxysmal and persistent	3–4	LA 2/3 RA 1/3 PV 40%	Stable with precession for >10 min	Term in 20% to 30% (2/3 to sinus)	...
Electrogram dispersion						
Seitz et al[22]	Paroxysmal and persistent	4–6	LA 4/5 RA 1/5 PV 80%	No remaps	Term in >90%	Improves outcome
Dominant frequency						
Atienza et al[12]	Paroxysmal and persistent	2–5	LA 4/5 RA 1/5 PV>70%	No remaps	Term 30% to 40%	Equal to PVI
Body surface dominant frequency						
Rodrigo et al[23]	Computer modeling	3	PV>70%	Greater precession	N/A	N/A
CartoFinder						
Calvo et al[8]*	Long-standing persistent AF	1.8	LA 2/3 RA 1/3 PV 21%	Highly repetitive and recurrent rotational activity	Term 15% (all to sinus)	70% freedom from AF after 12 mo

AF indicates atrial fibrillation; ECGI, electrocardiographic imaging; FIRM, Focal Impulse and Rotor Modulation; LA; left atrium; PV, pulmonary vein; PVI, pulmonary vein isolation; and RA, right atrium.

*Current study.

SAME MECHANISMS, DIFFERENT NAMES?

This study adds to an apparent convergence in AF mapping results by diverse methods (Table). Why, then, is there controversy in the field of AF mapping? We attribute this to 3 main factors: (1) lack of a consistent nomenclature, (2) absence of randomized trials showing clinical benefit of driver ablation, and (3) unappreciated qualitative similarities between mapping methods.

First, in terms of definitions, rotor, rotational activity, localized reentrant driver, phase singularity and repetitive activation patterns have all been used to describe clinical phenomena that in many respects are qualitatively similar.[5,17,24] The Table shows that, for instance, whether an AF driver is stable in space with temporal fluctuations, or transient but remaining in constrained regions over time may be semantic. Other features, such as spatial location (2/3 in left atrium) and acute impact of ablation are also qualitatively similar between studies.

A second reason for controversy is the important question of whether mapped sites are mechanistically central? Ultimately, this will be addressed only by randomized clinical trials compared with traditional pulmonary vein isolation, which are ongoing.

A third reason for conflicting data is that some mapping methods are clearly more sensitive for AF drivers than others. Traditional AF maps are based on marking electrogram onset, which can be difficult in complex or fractionated signals, and often show partial rotations. In recent reports, traditional maps showed partial rotations precisely where other methods (eg, phase) reveal stable rotational circuits and where ablation terminated persistent AF.[24] One future approach to reconcile AF mapping is compare methods with complementary strengths, for instance phase mapping (sensitive for rotations) with traditional mapping (specific[24]). Recent efforts are making AF mapping software and data freely available online.[25]

FUTURE DIRECTIONS IN DEFINING AF DRIVERS

Better mapping tools are needed. Current baskets may have sufficient resolution to resolve drivers,[26,27] yet should be improved. One approach to minimize unmapped regions is to deploy baskets in multiple positions to fill in undersampled areas. Similar criticisms can be applied to body surface mapping, which may not map the septum and pulmonary vein antra. The optimal ablation approach for drivers is also undefined. Studies with dense lesions have better results[16] than those with sparse lesions,[28] and some authors suggest that connection to a boundary is vital.[29,30] Finally, the clinical end point remains unclear. Is it required to abolish drivers on remapping, or is the current approach to abolish frequency gradients sufficient? Such studies are clearly needed.

CONCLUSIONS

Calvo et al[8] should be congratulated for adding novel data to a growing convergence in the literature that localized circuits may drive human AF. The authors use an emerging clinical mapping system and demonstrate the efficacy of ablation using the physiological end point of abolition of dominant frequency gradients. Despite these recurring motifs, randomized studies of ablation outcomes and further definition of differences between comparative mapping approaches are urgently needed to advance the field.

AFFILIATIONS

From the Department of Medicine, Stanford University, CA (J.A.B.Z., A.J.R., S.M.N.); and Imperial Centre for Cardiac Engineering, Electrocardiomaths Programme, Imperial College London, United Kingdom (J.A.B.Z.).

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FOOTNOTES

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