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EDITORIAL COMMENT

# AFib Rotors

## Are We in the "Driver" Seat?*

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Great strides in catheter-based ablation of paroxysmal atrial fibrillation (AF) have been made with pulmonary vein isolation serving as the cornerstone of the ablative approach. However, the optimal ablation strategy for persistent and long-term persistent AF remains unknown (1,2). Long-term maintenance of sinus rhythm still presents challenges because the precise mechanisms perpetuating AF are not fully understood. In this issue of the *iJACC*, Ravelli et al. (3) investigate the anatomic distribution of possible rotor sources in patients

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with AF by fusion of biatrial computed tomography (CT) images with bipolar catheter recordings. The underlying assumptions are that AF-sustaining rotors can be mapped in the human atria and display 2 basic characteristics: atrial depolarization is very rapid and very stable. The investigators quantify and display these 2 attributes by measuring atrial cycle length (CL) and wave similarity (WS), respectively. The CL analysis provides a local measure of the fibrillatory rate, determining among organized sources those with the shortest CL. The algorithm for WS analysis was previously developed by the investigators (4,5) and is a technique to assess directional organization during fibrillation. It measures the degree of repetitiveness of electrogram activation waveforms over 10-s duration. In other words, the algorithm compares the similarity of the bipolar signal morphology of all recorded atrial signals. If the morphologies are very similar to each other, a high-similarity index (close to 1) is assigned. If the signals are highly variable and fractionated, a low-similarity index (close to 0) is calculated. Using these measurements, the investigators define potential driver sources as having high similarity between atrial signals (similarity index >0.5) and rapid CL.

This study was comprised of 20 patients with persistent AF. Seventy-five percent of patients had structural heart disease consisting mostly of hypertensive and/or valvular etiologies. All patients underwent cardiac multidetector CT imaging within 24 h before catheter ablation. Catheter acquisition of 10-s bipolar electrograms were recorded from 123 ± 14 mapping points per patient using an externally irrigated ablation catheter with a 30- to 500-Hz band-pass filter and 1-Hz sampling frequency. All data were pre-processed and analyzed off-line. Temporal stability of WS and CL was checked in a surrogate fashion by analyzing the similarity and CL of coronary sinus electrograms during the entire study.

The investigators found that areas with regular and repetitive activity were present in most patients with persistent AF and were localized at the pulmonary veins (82.3%), left atrial appendage (23.5%), superior caval vein (41.2%), and right atrial anterior wall (23.5%). Potential AF rotors, defined as the fastest area with a similarity index of >0.5, were found in the pulmonary veins in 47.1%, the left atrial appendage in 11.8%, and the right atrium in 23.5%.

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These are important findings. An increased understanding of potential AF rotors with possible integration into current ablation approaches, not only would enhance our conceptual understanding of AF, but may even usher in an era of a more mechanistically based AF ablation. Although localized rotors have been demonstrated in animal studies (6), definitive proof of their existence in human atrial fibrillation is still missing. Consequently, to date, no consensus on the correct definition or the correct measuring algorithm exists for the identification of an AF rotor. However, ablation strategies that are based on intracardiac AF signal recordings and provide a possible, more mechanistic approach to AF ablation have been applied for several years. Complex fractioned atrial electrograms are defined as fractionated, low-voltage electrograms ($\leq$0.15 mV) with a cycle length of $<$120 ms with a common geometric distribution pattern and a strong spatial and temporal stability. They are thought to reflect the AF substrate (and possibly AF rotors), and present additional AF ablation targets (7). Using fast Fourier transformation, sites with a high dominant frequency can be determined, which are thought to represent rotors of AF. Targeted ablation at those sites has been shown to result in slowing and termination of AF (8). Fast Fourier transformation spectral mapping has even been used to identify possible high-frequency signals in the atrial electrograms in sinus rhythm that may correspond to fibrillar myocardium (AF nests) (9). Recently, Narayan et al. (10) developed a novel computational simultaneous mapping approach (11) based on monophasic action potentials recorded from atrial basket catheters, defining possible AF rotors visually as rotational activity around a center sustained for $>$50 cycles. They found AF rotors in widespread locations in the left atrium (76%), including sites outside the pulmonary veins, such as the posterior, inferior, roof, and anterior regions, and septal regions. After 9 months of follow-up, patients who underwent rotor ablation and pulmonary vein isolation had higher freedom from AF (82.4% vs. 44.9%; $p < 0.001$).

Ravelli et al. (3) present a different definition of AF rotors based on WS/CL that the group has carefully developed over the last several years based on right atrial basket and decapolar coronary sinus mapping in several dozen patients with mostly paroxysmal AF (4,5). One of the features of this technology would be the use of standard bipolar mapping catheters for rotor identification, which could potentially facilitate its integration into current ablation approaches. It remains to be determined whether sequential point-by-point mapping would be preferred over simultaneous mapping of the atrium with basket catheters to identify AF rotors.

A few limitations of the presented method are worth mentioning. First, the investigators did not assess for possible AF rotors in the coronary sinus itself. Second, demonstration of spatiotemporal stability of the AF rotor was derived from coronary sinus recordings. Previous work demonstrated spatial stability only of the WS algorithms recorded from the right atrium alone during a 20-min observation interval (5). Further spatial validation in the left atrium and an assessment of temporal stability of the CL analysis would be desirable. Third, the algorithm would have to be applicable in real time to reach clinical utility. A central challenge in identifying AF rotors is that they could also represent passive phenomena as a result of wave collision, scars, or far-field events (12). AF rotor algorithms would need to effectively discriminate between these mechanisms.

Although the investigators focus mostly on the three-quarter of AF drivers in the left atrium, interesting observations are presented concerning both atria. Eleven of the 17 analyzable patients (65%) had areas qualifying as potential AF drivers. The lack of identifiable drivers in more than a third of patients suggests a different AF mechanism, or might be due to technical limitations, and will require further studies. The fact that nearly a quarter of the potential drivers were found in the right atrium is very similar to the 27% of right atrial rotors described by Narayan et al. (10) in 49 patients with mostly persistent AF. If confirmed, this may be a potential contributor to the ~70% to 80% ceiling of AF ablation success using a left atrial ablation approach alone.

Ultimately, as with any emerging concept, the results need to be validated in a larger randomized multicenter trial to determine whether the underlying AF rotor hypothesis, as well as the developed algorithm using WS/CL indexes, would yield incremental success in the maintenance of sinus rhythm.

In the past decade, catheter ablations have evolved to the point of being able to eliminate arrhythmias even in those with long-lasting AF and structural heart disease. Our understanding of the mechanisms underlying AF is rapidly evolving. Hopefully, tools will become available that allow tailoring of AF ablations to an individual patient.

Only then will we be in the driver's seat of a more mechanistic/substrate-based AF ablation.

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