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NEW RESEARCH PAPERS

Temporal Stability of Rotors and Atrial Activation Patterns in Persistent Human Atrial Fibrillation

A High-Density Epicardial Mapping Study of Prolonged Recordings

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ABSTRACT

OBJECTIVES This study aimed to determine the spatiotemporal stability of rotors and other atrial activation patterns over 10 min in longstanding, persistent AF, along with the relationship of rotors to short cycle-length (CL) activity.

BACKGROUND The prevalence, stability, and mechanistic importance of rotors in human atrial fibrillation (AF) remain unclear.

METHODS Epicardial mapping was performed in 10 patients undergoing cardiac surgery, with bipolar electrograms recorded over 10 min using a triangular plaque (area: 6.75 cm^2; 117 bipoles; spacing: 2.5 mm) applied to the left atrial posterior wall (n = 9) and the right atrial free wall (n = 4). Activations were identified throughout 6 discrete 10-s segments of AF spanning 10 min, and dynamic activation mapping was performed. The distributions of 4,557 generated activation patterns within each mapped region were compared between the 6 segments.

RESULTS The dominant activation pattern was the simultaneous presence of multiple narrow wave fronts (26%). Twelve percent of activations represented transient rotors, seen in 85% of mapped regions with a median duration of 3 rotations. A total of 87% were centered on an area of short CL activity (<100 ms), although such activity had a positive predictive value for rotors of only 0.12. The distribution of activation patterns and wave-front directionality were highly stable over time, with a single dominant pattern within a 10-s AF segment recurring across all 6 segments in 62% of mapped regions.

CONCLUSIONS In patients with longstanding, persistent AF, activation patterns are spatiotemporally stable over 10 min. Transient rotors can be demonstrated in the majority of mapped regions, are spatiotemporally associated with short CL activity, and, when recurrent, demonstrate anatomical determinism. (J Am Coll Cardiol EP 2015;1-2:14–24)

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The mechanisms by which human atrial fibrillation (AF) is perpetuated remain unclear, with considerable ongoing debate as to the prevalence, nature, and importance of rotors as AF drivers (1,2).

Previous high-density epicardial mapping studies, with activation mapping and detailed analysis of electrogram (EGM) progression, have not observed rotors (3,4) or have reported only infrequent transient rotational activity (5). Such studies have evaluated short segments of AF lasting only seconds, potentially a significant limitation when considering the presence of transient rotors. These studies have suggested that AF is maintained by multiple wavelet propagation, with multiple dissociated wave fronts (WFs) in the remodeled atrium separated by regions of fibrosis and poor tissue coupling (3). Observations in these studies have also suggested that dissociation between epicardial and endocardial layers allows "endo-epi" WF breakthrough, which may aid perpetuation of fibrillation (4).

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An alternative hypothesis invokes focal drivers of fibrillation. Experiments in vitro and in animals have demonstrated the presence of high-frequency rotors involved in driving fibrillation (6–8). Findings from studies in humans using low-density endocardial mapping and phase analysis (9,10) suggest that AF in humans may be driven by a small number of rotors that are highly stable over prolonged time periods (11). Ablating these circuits has been reported to be effective in acutely terminating AF and in maintaining sinus rhythm in the intermediate term (10,12–14). In contrast, "panoramic" atrial mapping through phase analysis of body surface potentials has demonstrated a very different type of rotor activity, these rotors appearing unstable and persisting for only 2 to 3 rotations (15). These disparate results remain unexplained. The paucity of regular monomorphic EGMs or repetitive sequential activation around the presumed path of the rotor within existing reports, and observations such as the strong dependence of rotor demonstration on the band pass filter applied to body surface potentials, have raised important methodological questions (16).

In the present study, we used high-density epicardial mapping over 10-min periods to identify the presence of rotors and to characterize their spatiotemporal stability and relationship to short cycle-length (CL) activity in patients with longstanding, persistent AF.

ABBREVIATIONS AND ACRONYMS

AF = atrial fibrillation

AVI = aortic valve implantation

CABGS = coronary artery bypass graft surgery

CL = cycle length

EGM = electrogram

LAPW = left atrial posterior wall

MVR = mitral valve replacement

WF = wave front

METHODS

Ten patients with longstanding, persistent AF undergoing a first elective cardiac surgical procedure were studied (**Table 1**). Participants were undergoing coronary artery bypass graft surgery (CABGS) (n = 3), aortic valve implantation (AVI) (n = 2), mitral valve replacement (MVR) (n = 2), CABGS/AVI (n = 2), or CABGS/MVR/AVI (n = 1). Antiarrhythmic medications were ceased ≥5 half-lives prior to surgery. All participants gave written informed consent, with the protocol approved by the Melbourne Health Human Research and Ethics Committee.

EPICARDIAL MAPPING PROTOCOL. High-density atrial epicardial mapping was performed after median sternotomy and pericardial division and prior to cardioplegia and cardiopulmonary bypass. Mapping involved a triangular plaque comprising 128 silver-plated copper electrodes (117 bipoles), with inter-electrode spacing of 2.5 mm and a mapping area of 6.75 cm^2. The plaque was positioned by the operating surgeon (M.L, V.A., P.A., J.G., A.R., M.O.K.), and bipolar signals were recorded for a minimum of 10 min. Nine prolonged recordings from the left atrial posterior wall (LAPW) were made, with 4 from the right atrial free wall. Bipolar EGMs, with a sampling frequency of 1,000 Hz and a band pass filter of 0.05 to 400 Hz, were recorded using the UnEmap mapping system (UniServices, Auckland, New Zealand). After the entire recording was visually scanned, 6 discrete 10-s AF segments with high-quality signal across the entire plaque were analyzed. These 6 segments

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