Termination of persistent atrial fibrillation by ablating sites that control large atrial areas

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Abstract

Aim: Persistent atrial fibrillation (AF) has been explained by multiple mechanisms which, while they conflict, all agree that disorganized AF is more difficult to treat than organized AF. We hypothesized that persistent AF consists of intersecting organized areas which may engage, collide or coexist, and that those whose areas enlarge by ablation are more likely to succeed and to fail.

Methods and results: We mapped vectorial propagation in persistent AF using wavefront fronts (WFF, constructed from raw unipolar electrograms at 64-pole basket catheters, 1201 patients, N = 20 patients) and cardioversion (Group 2, N = 20 patients). Wavefront field mapping of patients (age 61 ± 13.2 years, left atrium 47 ± 6.9 ms) at baseline showed 4 6 ± 1.0 organized areas, each separated by disorganization. Ablation of sites that led to termination controlled large organized area containing the atrium (44 1 11.5 vs. 22 4 7.0 ms; P < 0.001). In Group 3, ablation progressively enlarged unablated areas (ranging from 32.2 ± 15.7% to 44.1 ± 11.5% of mapped area; P < 0.0001). In Group 2, organized areas did not enlarge but continued during ablation (23.6 ± 6.3% to 15.2 ± 5.6%; P < 0.001).

Conclusion: Mapping wavefront vectors in persistent AF revealed competing organized areas. Ablation that progressively enlarged remaining areas was acutely successful, and sites where ablation terminated AF were surrounded by large organized areas. Large organized areas contained the atrium, and sites where waves emerged during ablation did not exhibit AF termination. Further studies should define how fibrillation activity is organized within such areas and whether this approach can guide ablation.

Introduction

Mechanistic understanding of atrial fibrillation (AF) is unclear. Pulmonary Vein Isolation (PVI) is a cornerstone of AF ablation1, but outcomes remain suboptimal with variable success rates. Several mechanisms are suggested that describe persistent AF as consisting of organized regions of high dominant frequency,2,3 or as propagating electrograms2, which can be explained by waves that collide and result in wavefronts composed of alternating waves2,4 of colliding waves represented by complex electrograms. However, it is unclear how to reconcile these mechanisms to guide therapy.

One notable conceptualization is that the AF a chaotic system in which the ECG wavefronts that represent AF exhibit a spectrum from relatively organized to disorganized activity. This spectrum was demonstrated by Konigsmark et al.1 and, more recently, organized AF of the ECG has been associated with successful cardioversion and ablation1 as measured in the coronary sinus (CS). However, it is currently unclear how to map this spectrum of AF organization clinically to guide or assess the impact of therapy. We hypothesized that persistent AF comprises organized areas of fibrillation interspersed with zones of disorganization. Further, if this hypothesis is true, that successful ablation may remove disorganized areas so that remaining organized areas cover progressively more of the atrial surface. Ultimately, this may result in the atria activating in a 1:1 fashion and no longer fibrillating, i.e. atrial tachycardia or sinus rhythm.

Methods

Patient inclusion: We recruited consecutive patients with persistent AF resistant to one or more antiarrhythmic medications, at catheter ablation, in whom mapping with basket catheters was used throughout the procedure and in whom ablation acutely terminated AF during defined ablation (n = 20). In this same time frame, we recruited consecutive patients without AF termination during ablation (n = 0).

Electrophysiology study: Patients were brought to the EP lab in the post-cardioversion state. All antiarrhythmic medications were discontinued 5-half lives (>30 days for amiodarone). Catheters were placed in the right atrium (RA), CS, and left atrium (LA) via transseptal puncture. Basket catheters (64 poles, FIRM Map, Abbott) were placed in the LA with the tip nearest the SVC atrial septum, and simultaneously (N = 9). Ablation was guided prospectively by a clinical mapping system (EPiQ-3D, Volcano). After catheter placement, a 3-D electroanatomical map was constructed relative to electrodes and in electroanatomical maps. Analysis in this study then focused on WFF streamlines blinded to sites of delivered ablation and outcome.

Results

Ablation causing sinus rhythm: We applied WFF mapping during ablation of persistent AF. Overall, AF terminated to sinus rhythm in nine cases, in each of which eliminating organized areas caused enlargement of residual areas. Elimination of such primary organized areas terminated AF to sinus rhythm in each case.

Ablation with termination to atrial tachycardia: Overall, 6 of 11 cases where ablation terminated AF to atrial tachycardia (n = 8) or atrial flutter (n = 3) showed two competing primary areas controlling most of the atrium, with ablation of one area leaving the remaining area as an organized atrial tachycardia. Three of the 11 cases terminated to atrioventricular flutter, whose ablation resulted in sinus rhythm.

Cases where atrial fibrillation did not terminate by ablation: Of 20 cases in Group 1, 2 cases terminated to sinus rhythm in each case. In Group 2, patients in whom organized atrial areas did not terminate by ablation, areas showed progressive enlargement of organized areas. The remaining two cases showed progressive enlargement of an organized area that was not ablated because it was not identified prospectively or by clinical mapping.

Organized areas between patients in whom atrial fibrillation did not terminate by ablation: For Group 1 patients, organized areas surrounding AF termination sites covered larger atrial areas (44.1 ± 11.1% than the average of contemporaneous competing sites (24.2 ± 7.0%; P < 0.0001). The temporal presence for organized area was also greater for terminating than competing sites (45.1 ± 23.4% vs. 26.1 ± 13.7% of mapped time; P < 0.005).

Limitations

First, this is a relatively small cohort of patients, although they were well mapped over a long duration. Prospective, larger studies will be needed to accurately predict termination based on mapped organized areas. Organized areas were estimated by blinded, visual analysis. Patients in this study were part of multiple protocols, and so long-term outcomes are not available. Global mapping is needed to define organized areas and basket catheters are limited by variable contact, electrode spacing, and movement. Nevertheless, they currently provide the highest available resolution for in-situ area contact mapping. True assessment of areas of control is limited by 2-dimensional displays of the border.

Conclusions

We use novel global mapping of AF propagation to show that AF can be represented as a dynamic interaction of organized areas of control, interspersed by disorganized activity. In successful cases, ablation enabled residual areas to enlarge, and sites surrounded by a critical atrial area were invariably sites where ablation terminated AF. Patients in whom atrial areas did not enlarge did not exhibit ablation failure. Further studies should test if using these results to guide ablation can improve outcomes.

References


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For Group 2 patients, in segments prior to cardioversion, there was no difference in the size of the largest organized area compared with the average organized area (4.8 ± 4.2% vs. 4.8 ± 4.2% of mapped area; P = 0.35).

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