The Use of Spectral Analysis and Noncontact Mapping to Study the Impact of Circumferential Ablation on Atrial Fibrillation

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Introduction:
Although wide area circumferential ablation (WACA) is extensively used to treat persistent atrial fibrillation (AF), it is unclear by which mechanisms it affects the AF, which often persists immediately after ablation. Spectral analysis allows the identification of the dominant frequency (DF) contributing to an apparently chaotic fibrillatory signal. We studied the impact of WACA on left atrial (LA) activation during AF by performing spectral analysis of simultaneous global LA signals. The use of this technique to study the effects of WACA has not previously been reported.

Methods:
Patients with persistent AF underwent WACA whereby pairs of pulmonary veins were encircled bilaterally and mitral isthmus and roof lines added. A noncontact multielectrode array (Ensite 3000) was deployed in the LA and used to guide ablation and record persistent AF. The system has previously been described elsewhere and validated in AF in humans. A geometric reconstruction of the LA surface was created using a locator signal to record the ablation catheter tip’s position relative to the array (figure 1). AF was recorded before and after WACA at the array’s 64 electrodes and virtual unipolar electrograms at 3360 points on the LA geometry were reconstructed mathematically by the system. Signals were filtered at 1 to 150 Hz. Virtual unipolar electrograms were used in analysis. The far field ventricular component was subtracted from the raw signals and the output subjected to Hanning windowing and fast Fourier transformation (figure 2). The highest peak in the 3 to 15 Hz range of the resultant frequency power spectrum was selected as the DF for this electrode and was plotted at the location of the electrode on a 3-dimensional map of the LA surface (figure 3).

Results:
Six patients completed the protocol and AF persisted in all patients immediately after WACA. Three consecutive 7 second segments of AF were analysed before and after WACA in each patient. Mean DF of all 256 sites was reduced by WACA (5.5±0.2 to 4.8±0.2 Hz (means±SE); P=0.03). LA surface area supporting the highest frequency activation, defined as 90% or more of the maximal DF seen before ablation, was also reduced (34.3±9.4 to 12.1±3.4 cm²; P=0.03). In contrast, the maximal DF observed anywhere in the chamber did not change significantly following ablation (7.3±0.1 to 7.6±0.5 Hz, P=0.75). Before WACA high DF areas were usually located near the pulmonary veins and base of the left atrial appendage. Following WACA the septum and base of the left atrial appendage (areas not encircled by WACA) were the most common site of high DFs (figure 4).

Discussion and Conclusions:
Simultaneous DF mapping of AF throughout the LA, performed before and after WACA, provided unique insights into the impact of WACA on AF. Although the area of left atrial substrate sustaining high frequency activation is reduced, the highest frequencies persist at alternative locations, usually in areas which are not encircled. Sites of high DF have previously been retrospectively correlated with sites of ablation success. Targeting of the remaining high DF areas following WACA has never been reported and may improve clinical success rates in treating persistent AF. Simultaneous global DF mapping could provide a tool to guide this additional substrate modification.

Literature Cited

Figure 1. LA geometry reconstructed with Ensite 3000. Orientation indicated by torsos. WACA lesions displayed in red. LSPV indicates left superior pulmonary vein, LIPV, left inferior pulmonary vein; RSPV, right superior pulmonary vein; RIPV, right inferior pulmonary vein; LAA, left atrial appendage; MVA, mitral valve annulus.

Figure 2. Signals from a single virtual electrode. A: raw signal, time points for ventricular signal subtraction marked with vertical lines. B: signal following subtraction of ventricular component. C: signal following Hanning windowing. D: frequency power spectrum following fast Fourier transformation.

Figure 3. Three-dimensional LA map displaying DFs at virtual electrodes after WACA.

Figure 4. Regional distribution of high DFs before and after WACA. Abbreviations as above.