Analysis of Unipolar Electrogram Eigenvalue Dispersion for the Detection of Atrial Fibrosis

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Background

Atrial fibrosis plays a meaningful role in the pathogenesis of atrial fibrillation (AF). Areas with peak-to-peak amplitude of bipolar electrograms (b-EGMs) lower than 0.5 mV are detected as scar tissue and targeted for AF ablation procedures. However, this approach disregards the spatiotemporal information held in the signal and is influenced by b-EGMs dependence on catheter orientation.

Objective

To overcome these limitations, in this study, we propose to use the dominant-to-remaining eigenvalue dominance ratio (EIGDR) of unipolar electrograms (u-EGMs) within a group of nearby electrodes (clique) as a measure of the voltage wavefront roughness and correlate it with the presence of fibrosis.

Methods

We simulated u-EGMs from a 2D atrial tissue, including a circular patch of diffuse fibrosis, following the Courtemanche model. They were corrupted with one hundred different realizations of real noise with level $\sigma_n = 33\ \mu V$. One hundred different maps of three EIGDRs ($\mathcal{R}$: ratio of first eigenvalue of u-EGMs correlation matrix to the sum of all the others; $\mathcal{R}^{\mathcal{A}}$: same ratio after u-EGMs time alignment within the clique; and $\Delta\mathcal{R}^{\mathcal{A}}$: the gain in eigenvalue concentration produced by alignment) were obtained using two clique sizes (3×3 and 2×2) and three catheter orientations (0°, 30° and 45°). The maximum accuracy for fibrosis detection (ACC) was used as performance measurement. The threshold for maximum accuracy was obtained jointly for the three orientations, assuming that the angle between the propagation direction and the catheter is not known a priori. For performance comparison, maps of peak-to-peak voltage of b-EGMs in each of the two catheter directions (V^{b-x} and V^{b-y}) and of their maximum (V^{b-m}) were also tested.

Results

The proposed EIGDR indices show the following average performance (mean ± standard deviation): ACC = 0.84 ± 0.01, 0.88 ± 0.01 and 0.80 ± 0.02 for $\mathcal{R}$, $\mathcal{R}^{\mathcal{A}}$ and $\Delta\mathcal{R}^{\mathcal{A}}$, respectively, when 2×2 cliques are used. With the 3×3 configuration, ACC = 0.87 ± 0.02, 0.95 ± 0.02 and 0.88 ± 0.02 for the same indices. Bipolar voltage maps achieve ACC = 0.69 ± 0, 0.86 ± 0.01 and 0.91 ± 0.01, for V^{b-x}, V^{b-y} and V^{b-m}, respectively.

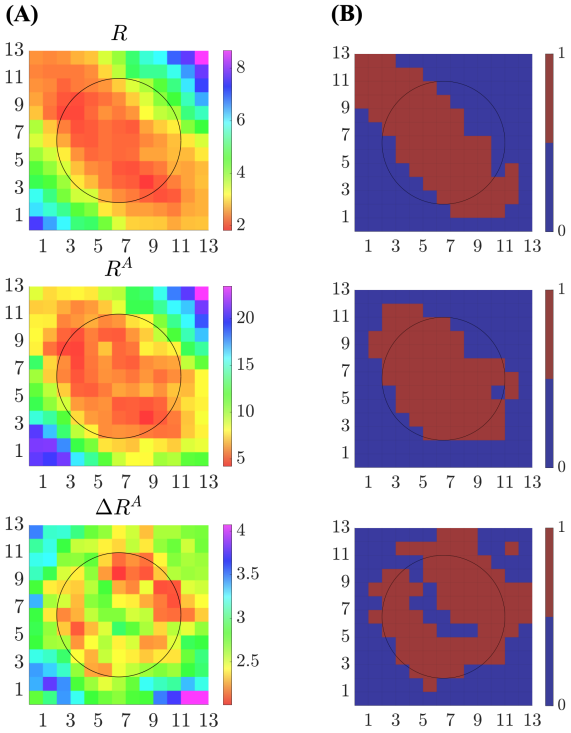

Figure 1: **(A)**: EIGDR maps for 3×3 cliques and 45° catheter for one noise realization. **(B)**: identification masks for ACC thresholds.

Discussion

EIGDR approach allows to discriminate fibrotic from non-fibrotic tissue, improving its performance when clique alignment is considered and 3×3 configuration is used, providing slightly improved performance to standard voltage maps for the 3×3 aligned EIGDR maps.