Non-invasive 3D Electromechanical Cycle Length Mapping for Atrial Fibrillation Mapping and PVI Ablation Response Prediction

Background, Motivation and Objective

Source-agnostic pulmonary vein isolation (PVI) success rate for first-time Atrial Fibrillation (AF) ablation remains 50-70%, requiring additional procedures upon recurrence. Intracardiac low voltage (≤.5 mv) mapping offers low sensitivity, missing potential AF targets. To improve treatment efficacy, the need for personalized treatment planning is evident. Electromechanical Cycle Length Mapping (ECLM) is a novel high framerate, ultrasound-based tool, shown to non-invasively and quantitatively characterize cardiac electromechanical activation rates in all cardiac chambers in healthy, atrial flutter and AF subjects, and inform on AF cardioversion response. This study accesses ECLM feasibility to localize and quantify AF electromechanical activation rates and inform on long-term atrial ablation response.

Statement of Contribution/Methods

Sixteen AF (66.3 ± 8.8 yo; 7 male) subjects undergoing first-time PVI received transthoracic ECLM in four standard apical echocardiographic views (2.5 MHz phased array, Verasonics Vantage, 2 s diverging sequence at 2 kHz), with simultaneous 3-lead ECG, pre and post- successful RF ablation. Electromechanical strains were computed with 1D RF cross-correlation followed by a 5mm kernel least-squares estimator. A Fast Fourier Transform (FFT) was applied on the 2 s interframe strain signals, and the dominant frequency peaks were selected across the myocardium. 3D-rendered atrial ECLM cycle length (CL) maps and spatial CL histograms are obtained. CL Dispersion (CLD) and percentage of arrhythmic CLs (%ACL≤333ms) across the atrial myocardium are computed transmurally. Intracardiac pre-ablation voltage maps were acquired in N=8 subjects. The 3-month timepoint was used as a long-term response classification mark of the ECLM metrics, and multiple logistic regression (MLR) analysis was performed. Follow-up ECLM upon arrhythmia recurrence was performed in non-responders.

Results/Discussion

ECLM maps localized extensive irregular and widely spread atrial activation rates pre-ablation (mean %ACL 17.5±13.8%, mean CLD 130.8±12.0ms), and confirmed immediate post-ablation success in all cases, visualizing significantly reduced mean %ACL (11.2±12.0% p=.0057) and CLD (104.2±47.1ms p=.0226). Five patients reverted back to AF within three months post-ablation. Pre-ablation CLD served as an independent predictor of long-term AF ablation response (MLR AUC 0.83, CLD Odds Ratio: 1.033 [95%CI: 1.012;1.060], p = .0051, Fig 1.e,d). Representative ECLM results of a 66yo female non-responder highlight AF triggers pre-ablation (Fig 1a), not present in the intracardiac map (Fig 1b), that reduce post-ablation (Fig 1c) yet relapse after AF recurrence as potential missed and future AF ablation targets (Fig 1d). These early findings support the key role of ECLM in the clinic for non-invasive echocardiography-based AF mapping, ablation procedure guidance, and response estimation.