Electromechanical Cycle Length Mapping for Atrial Arrhythmia Characterization and Cardioversion Success Assessment

Melina Tourni[1], Lea Melki[1], Rachel Weber[1], Elisa Konofagou[1,2], Departments of [1]Biomedical Engineering and [2]Radiology, Columbia University, New York, NY

Background, Motivation and Objective

Direct current cardioversion (DCCV) is an established treatment for persistent atrial fibrillation (AFib) cases with a 90% immediate success rate. Yet, more than 50% revert to AFib shortly thereafter. Electromechanical Cycle Length Mapping (ECLM), developed by our group (Provost et al. 2015), is a high frame rate ultrasound-based technique shown to non-invasively characterize atrial electromechanical activation in paced canines and re-entrant flutters (AF). This study assesses ECLM feasibility for mapping AFib activation pre DCCV, monitoring post DCCV recovery and potentially informing success.

Statement of Contribution/Methods

Subjects (n = 15, 55 ± 23 yo; 11 male; 3 AF; 6 AFib; 6 normal) were imaged transthoracicly in 4 apical views (2.5 MHz phased array, Vantage, 2 s diverging sequence at 2 kHz). All AFib and 1 AF subjects were imaged pre and post DCCV. A standard delay-and-sum beamforming algorithm is used for RF data reconstruction. Incremental axial displacements and strains are estimated with 1D cross-correlation and least-squares estimator, respectively. ECLM histograms result from strain frequency analysis and 2D maps co-registered spatially by case. ECLM activation rates count as the main peak $\in$ (200-260 ms) for AF cycle length (CL) and > 600 ms in normal sinus rhythm (SR). Immediate post DCCV ECLM success prediction markers were retrospectively validated against clinical outcomes: recovered, follow-up drug control, repeat DCCV or ablation. Moreover, strain Sample Entropy (Cervigon et al. 2010) exhibits pre and post DCCV temporal strain variation.

Results/Discussion

ECLM histograms successfully identified activation rates in 100% of AF and normal cases as confirmed by 12-lead EKG. In AF, ECLM maps localized the arrhythmic source and on post successful DCCV histograms, the main AF CL (228 ms) was no longer present (Fig.1b). In AFib, irregular activation rates were visible on pre DCCV ECLM histograms. Post DCCV histograms exhibited noisier SR spectral patterns versus non-arrhythmic (normal) cases (Fig.1a&c bottom), confirming inadequate SR recovery and later AFib recurrence. The Average Sample Entropy metric showed significance pre and post AFib DCCV (Fig.1d). ECLM was thus shown feasible in non-invasively informing DCCV success and could prove useful for simultaneous clinical assessment of DCCV success and optimal treatment of atrial arrhythmias.
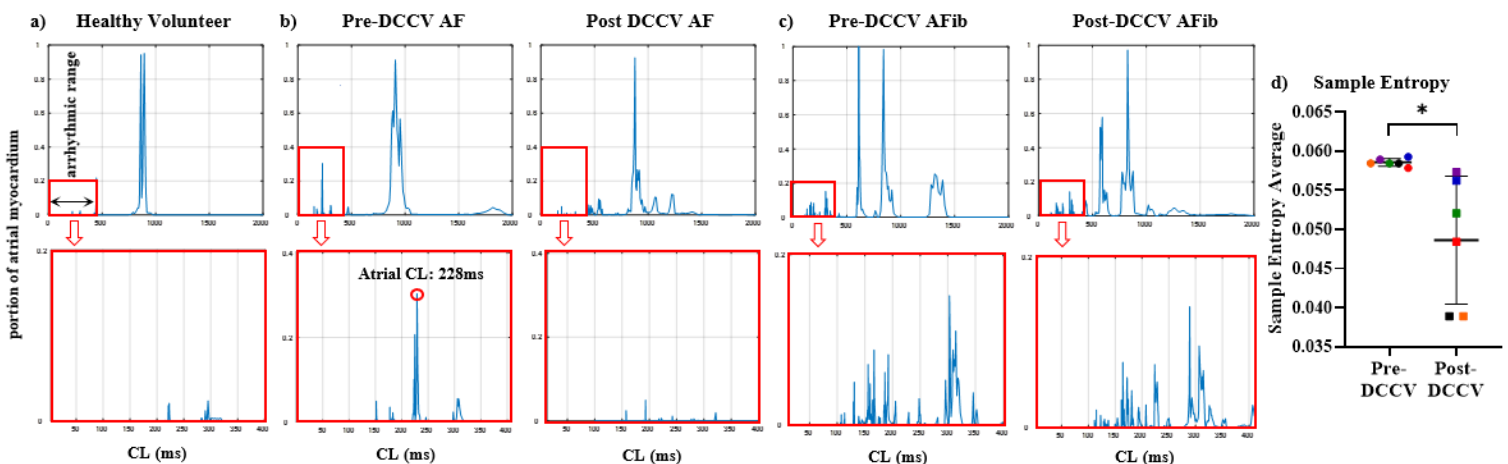

Figure 1: ECLM Analysis Results. Histograms of **(a)** a 27 yo healthy male volunteer in normal sinus rhythm; **(b)** a successful DCCV of a 69 yo male scanned before and after AF DCCV, with no AF reoccurrence mentioned in his health record; **(c)** an unsuccessful DCCV of a 70 yo female scanned before and within half an hour after AFib DCCV, records claimed restored sinus rhythm. Post-DCCV ECLM results differ from non-arrhythmic cases. Patient was re-admitted 6 weeks later for AFib ablation; **(d)** Average Sample Entropy of axial incremental strains for n=6 AFib patients (p=0.02). CL = Cycle Length, AF = Atrial Flutter, AFib = Atrial Fibrillation, DCCV = Direct Current Cardioversion.