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3-D Electromechanical Wave Imaging in the heart in silico and in vivo

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Background, Motivation and Objective

Electromechanical wave imaging (EWI) is an ultrasound-based methodology that can map the electromechanical activation of the heart at high temporal resolution. Previous reports have shown strong correlation between EWI-based and electrical activation times. However, EWI has been performed only with 2D echocardiography, which cannot map the full cardiac volume in a single heartbeat. Our objective in this study was to show the feasibility of 3D EWI in silico and in vivo.

Statement of Contribution/Methods

A 3-MHz 32x32 array was simulated in Field II. The right and left ventricular geometry and displacement fields were obtained from a computational electromechanical model based on a real human heart anatomy. Ultrasound radiofrequency (RF) channel data were simulated at 1000 Hz using diverging wave imaging and inter-volume axial displacements and strains were estimated together with electromechanical activation times. Estimated axial displacements, strains and activation times were compared against their computational equivalents. To investigate in vivo feasibility, RF signals were reconstructed from channel data using a 32x32 array (Vermon) connected to two synchronized Verasonics Vantage systems in an open-chest canine heart and the inter-volume axial displacements and strains were estimated from diverging wave acquisitions at 500 frames per second.

Results/Discussion

Estimated and computational axial displacements in silico were found to be strongly correlated (R2=0.99) in both the right and left ventricles using 3D EWI. Good agreement was found between the estimated electromechanical activation times and the computational electrical activation times (Fig.1). The 3D electromechanical wave propagation was also imaged at different phases of the cardiac cycle in vivo, with earlier contraction in the atria than in the ventricles.

This study shows for the first time that 3-D EWI is feasible and opens new avenues for non-invasive cardiac arrhythmia characterization in 3D.

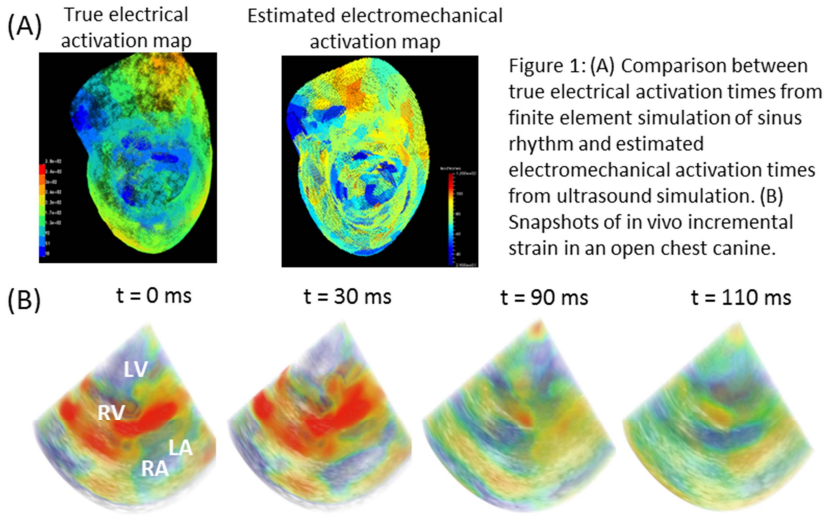

Figure 1: (A) Comparison between true electrical activation times from finite element simulation of sinus rhythm and estimated electromechanical activation times from ultrasound simulation. (B) Snapshots of in vivo incremental strain in an open chest canine.