3D direct visualization and non-invasive localization of atrial and ventricular arrhythmias using Electromechanical Wave Imaging in patients

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Background, Motivation, and Objective:

Arrhythmia localization prior to catheter ablation is critical for clinical decision making and treatment planning. The current standard lies in 12-lead ECG interpretation, but this method is non-specific and anatomically limited. Accurate localization requires intracardiac catheter mapping prior to ablation. Electromechanical Wave Imaging (EWI) is a high frame-rate ultrasound modality capable of non-invasively mapping the electromechanical activation in all cardiac chambers in vivo. In this study, we evaluate 3D-rendered EWI as a technique for consistently localizing the origin in different atrial (flutter, tachycardia) and ventricular (Wolff Parkinson White, premature contraction) arrhythmias in patients.

Statement of Contribution/Methods:

A 2 kHz diverging sequence (Verasonics) was used to image 40 patients (age: 7-89, median 34, 53% male) with evidence of ECG abnormalities (10/40 atrial arrhythmias), immediately prior to catheter ablation in four transthoracic apical views. Electromechanical strains were computed with 1D RF cross-correlation followed by a 5 mm kernel least-squares estimator. Activation times were defined as the timing of the first sign change in incremental axial strain after the QRS and the p-wave onset, for the ventricles and atria respectively. 3D rendering of the activation maps was then generated by registering the multi-2D views around the left ventricle longitudinal symmetry axis and performing a linear interpolation around the circumference. Two electrophysiologists predicted the arrhythmic location on 12-lead ECG. Double-blinded EWI isochrones and clinician assessments were compared to the ground truth (successful ablation site) using a segmented template of the heart with 21 ventricular and 3 atrial regions.

Results/Discussion:

3D-rendered EWI was shown capable of consistently localizing abnormal regions in (37/40) 92.5% of arrhythmic cases (Fig. 1) and 100% of the cases when excluding the three poor quality B-modes. Clinical ECG interpretation correctly predicted the origin
with an accuracy of 69%. Our method also differentiated irregular beats from sinus rhythm on the same patients (Fig. 1 b-c). These findings indicate that EWI could inform current diagnosis and expedite treatment planning of various arrhythmias in tandem with an ultrasound scan within the standard clinical routine.

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Fig. 1: EWI activation maps in two different arrhythmic subjects prior to their catheter ablation. 

a) Patient 1: 3D rendered atrial isochrones of a focal tachycardia coming from the mid posterior right atrium in both anterior (left) and posterior (right) views, b) Patient 2: 3D rendered ventricular map of a premature ventricular contraction originating from the left anterior papillary muscle in anterior view, c) Patient 2: same patient imaged in a consecutive non ectopic beat (sinus rhythm) in anterior view.

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