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

Lea Melki[1], Christopher S. Grubb[2], Pierre Nauleau[1], Rachel A. Weber[1], Hasan Garan[2], Eric S. Silver[3], Leonardo Liberman[3], Elaine Wan[2], Elisa E. Konofagou[1,4]

[1]Biomedical Engineering, Columbia University, New York, NY, United States, [2]Medicine - Division of Cardiology, Columbia University, New York, NY, United States, [3]Pediatrics - Division of Pediatric Cardiology, Columbia University, New York, NY, United States, [4]Radiology, Columbia University, New York, NY, United States

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.

NIH support R01 HL140646 01

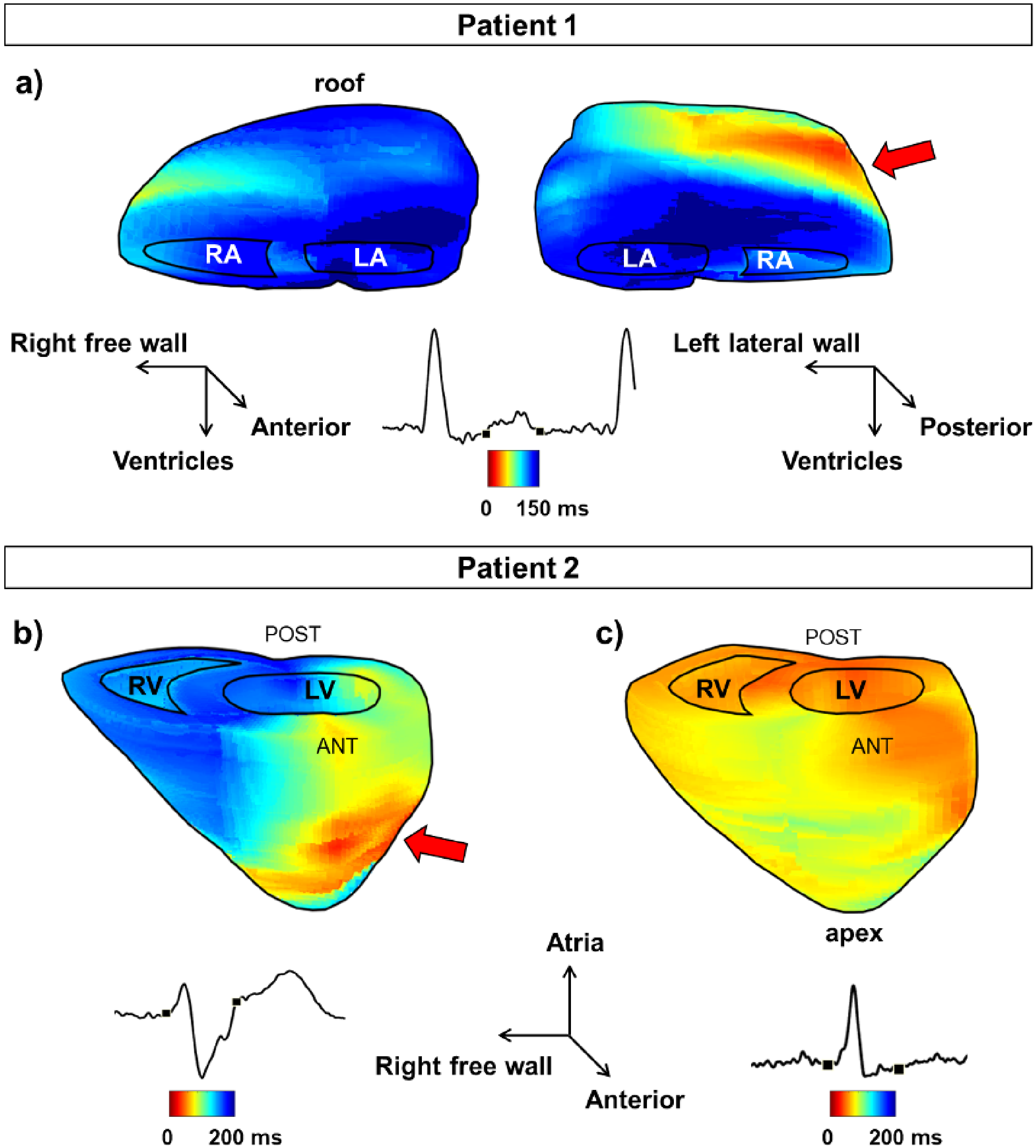

Fig.1: EWI activation maps in two different arrhythmic subjects prior to their catheter ablation. a) Patient 1: 3D rendered atrial isochrones of a focal tachycardia coming from the mid posterior right atrium in both anterior (left) and posterior (right) views, b) Patient 2: 3D rendered ventricular map 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.

(ViewSubmissionFile.aspx?sbmID=365&fileID=1465)

Print Close