Ventricular tachycardia re-entry mapping with 3D electromechanical wave imaging

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Background, Motivation and Objective:

Myocardial infarction resulting from coronary artery occlusions can alter electrical conduction in the infarct region, where re-entry loops can form and lead to ventricular tachycardia (VTach) and fibrillation. Localization of the re-entrant pathway is critical to treat the arrhythmia and is performed invasively with an electrical mapping catheter under fluoroscopy in the clinic. 3D electromechanical wave imaging (EWI) is an ultrasound-based methodology that can map the electromechanical activation of the full heart at high volume-rate in a single heartbeat. The objective of this study is to show the feasibility of mapping the origin of VTach with 3D EWI in vivo.

Methods:

A myocardial infarct was induced in a canine model by ligating the left anterior descending (LAD) artery. Three days after the infarct formation, VTach was induced after 10-20 s of ventricular pacing with a cycle length of 160-280 ms in the infarct border zone and sustained for 5-30 min. A 32x32-element array, with 3-MHz center frequency and connected to two Verasonics Vantage systems with a 2:1 multiplexer was used for 3D EWI. Ultrasound radiofrequency channel data were acquired at 1000 Hz using diverging wave imaging and inter-volume axial displacements were estimated using 1-D normalized cross-correlation. Inter-volume axial strains were estimated with a least-squares estimator and the electromechanical activation times were calculated as the time of first zero-crossing. Electrical mapping of the epicardial surface was performed with 3D electroanatomical mapping (EnSite, St. Jude Medical). 3D EWI and electrical mapping were both performed during sinus rhythm and VTach.

Results, discussion and conclusions:

Good agreement was found between 3D EWI and electrical activation times in an infarcted canine after LAD ligation during both sinus rhythm and VTach (Figure 1). The site of origin of VTach was found to be in the anterior region at the mid-level in the territory perfused by the LAD. During VTach, the earliest (0-40 ms) and latest (150-200 ms for EWI and 80-90 ms for electrical) activation sites were adjacent, which indicates that the underlying mechanism for this VTach is a re-entry loop in that area. This study shows that 3-D EWI can map the site of origin of VTach, which could potentially open new avenues for noninvasive VTach diagnosis and treatment monitoring in a clinical setting.

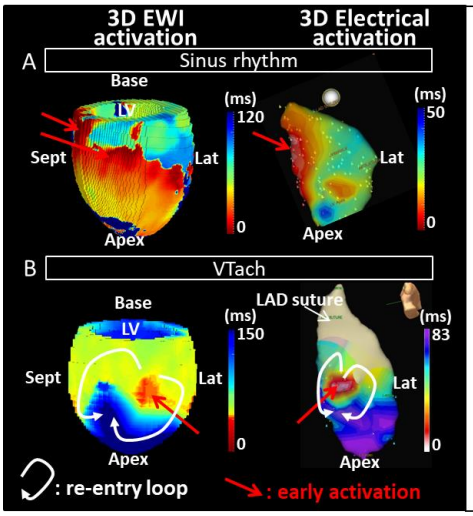

Figure 1: 3D EWI and electrical activation times in the left ventricle of an infarcted canine after left anterior descending ligation during sinus rhythm (A) and ventricular tachycardia (B). Sites of early activation (red arrows) are in good agreement between electromechanical and electrical mapping. Sept: Septal, Lat: Lateral, LV: left ventricle