Characterization of mechanical activation during ventricular arrhythmias using high-resolution electromechanical wave imaging

Jade Robert[1], Francis Bessière[1,2], Elodie Cao[1], Ali Zorgani[1], Loic Daunizeau[1], Stefan Catheline[1], Fanny Vaillant[3], Bruno Quesson[3], Cyril Lafon[1]; [1]LabTAU, INSERM, Centre Léon Bérard, Université Lyon 1, Univ Lyon, 69003, LYON, France; [2] Hôpital cardiologique Louis Pradel, Hospices Civils de Lyon, 69677 Lyon, France; [3]Institut Liryc, Université Bordeaux, 33604 Pessac, France

Background, Motivation and Objective

Cardiac arrhythmias originate from electrical dysfunction of specific regions in the myocardium. Current methods used for arrhythmias diagnosis can't provide electrical conduction maps into the cardiac wall thickness to localize precisely these regions to plan the ablation. Electromechanical Wave Imaging (EWI) is an ultrasound imaging method based on ultrafast acquisitions which could provide electromechanical information in tissues depth. Previous studies showed EWI's ability to provide global mechanical activation maps of the myocardium, which follows electrical activation, during sinus and stimulated rhythms. This study aims to demonstrate EWI's ability to precisely characterize activation into the myocardium thickness at high temporal and spatial resolution.

Statement of Contribution/Methods

An isolated heart model was set up in recirculating mode to mimic cardiac electrophysiological behavior. Pacing electrodes were screwed at three sites of the left ventricles on two swine hearts. Three ECG-gated acquisitions were performed consecutively at each site during sinus rhythm, endocardial and epicardial pacing for each heart (n = 54). Data were acquired at 4000 fps using a 15MHz probe in a single cardiac cycle. Displacement maps were computed using an RF-based phase tracking algorithm. Propagation of the EW front was tracked to retrieve the pacing method without prior knowledge.

Results/Discussion

78±5% of the pacing methods were accurately retrieved by three raters. Overall Fleiss' kappa value of 0.67±0.06 emphasized substantial agreement between raters. Activation during sinus rhythms could originate simultaneously from several regions and tended to start before QRS complex, recorded on ECG, whereas first activation during stimulated rhythms were more localized. Shape, location and timing of first mechanical activation thus allowed to determine if the heart was paced and if so, the corresponding stimulated surface, in most cases. Propagation direction of the mechanical activation also helped differentiating endocardial from epicardial pacing, when first activation occurred into the muscle. Mechanical activation pattern tracked by EWI could thus allow characterizing electromechanical behavior of ventricular arrhythmias with high precision.

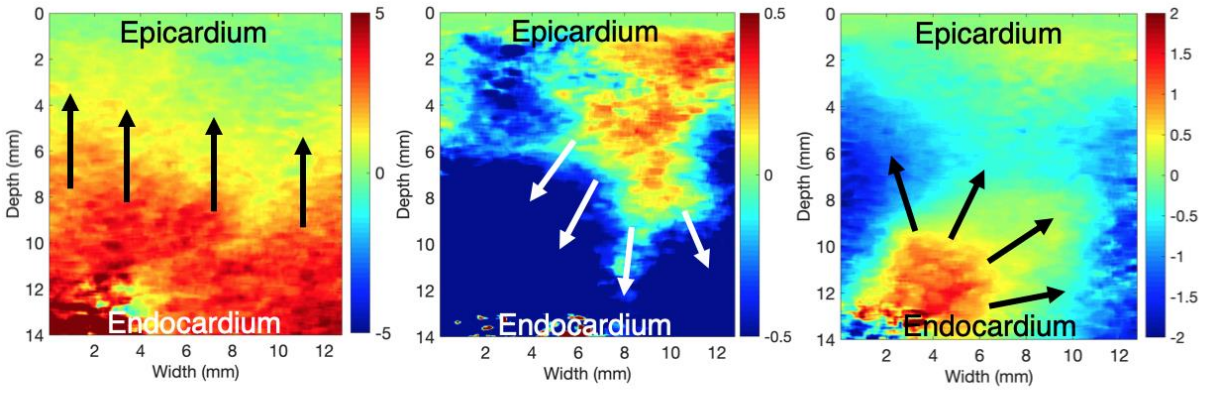

Fig.1. Displacement maps in left ventricle wall thickness during sinus or stimulated rhythms (in µm). Probe was positioned at depth = 0mm. During sinus rhythm (left), multiple regions are simultaneously activated and propagation is towards epicardium. During epicardial (middle) and endocardial (right) pacing, first activation is localized in a specific region and propagation is towards the opposite surface.