Ultrafast Utrasound Imaging for Cardiac Arrhythmias Treatment Guidance and Monitoring

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Abnormal electrical activity of cardiac cells can trigger arrhythmogenic behavior, associated with troubled heart rhythm. In some cases, cardiac arrhythmias might lead to functional and even vital consequences. Clinical standard of care for such severe arrhythmias however remains limited, notably because of the lack of fast and precise enough cardiac mapping methods and direct clinical efficiency assessments. Electromechanical Wave Imaging (EWI) and Passive Elastography are two imaging methods based on ultrafast ultrasound acquisitions which could provide minimally invasive and fast alternatives for cardiac arrhythmias treatment guidance and monitoring, respectively. EWI could allow cardiac activation mapping in tissue thickness whereas PE could be employed to directly visualize changes in tissue stiffness caused by thermal lesion formation which are performed during the intervention.

EWI was performed on ex-vivo (n=3) and in-vivo models (n=3). Electrical pacing was employed to mimic arrhythmogenic behavior either in the left ventricle of ex-vivo swine beating hearts or open-chest swines near the aorta valves and pulmonary arteries, to reproduce typical focal ventricle arrhythmogenic behavior. Cardiac contraction maps were then reconstructed based on local tissue displacement computed from acquired ultrafast ultrasound data. PE was performed before and after thermal lesions (n=22) achieved into ex-vivo swine or veal cardiac tissue samples. Tissue elasticity maps were reconstructed and compared to estimate the presence of a thermal lesion.

Using EWI, 3 blind readers were able to retrieve the cardiac activation source with an average success of 79% on ex-vivo acquisitions. In-vivo data were more challenging to interpret blindly but also depicted coherent cardiac activation sources for some acquisitions. PE demonstrated a local increase in tissue thickness for 18 acquisitions (82%) after thermal lesioning. Lesion length could moderately be evaluated with an average error of 25%.

EWI and PE could thus provide complementary information on cardiac behavior and tissue modification to improve arrhythmias treatment.