CARDIAC RESYNCHRONIZATION THERAPY QUANTIFICATION AND DIRECT ASSESSMENT OF PATIENT RESPONSE WITH 3D-RENDERED ELECTROMECHANICAL WAVE IMAGING.

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Background: Cardiac Resynchronization Therapy (CRT) is an established treatment for Heart Failure (HF) patients with Left Bundle Branch Block and a Left Ventricular Ejection Fraction (LVEF) below 35%. Yet, a third of patients do not respond despite a narrowed QRS complex on their post implant 12-lead ECG. 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 [1]. In previous studies, EWI was established capable of 1) differentiating CRT responders from non-responders on 2D apical 4-chamber views a few months after their implant [2]; and 2) characterizing the 3D electromechanical activation pattern within 24 hours of their device placement and distinguishing the different biventricular (BiV) CRT pacing conditions [3].

Aims: Evaluate the feasibility of 3D-rendered EWI to quantify the amount of myocardium resynchronized (%MR) on the day of the implantation, and determine if %MR is a useful metric to predict patients response at 3- or 6- month follow up.

Methods: A 2.5 MHz diverging wave pulse excited at 2000 Hz PRF (Verasonics Inc., Kirkland, WA, USA) obtained with a P4-2 phased array (ATL/Philips, Andover, MA, USA) was used to image 17 HF patients at a depth of 20 cm, immediately after their CRT implant in four transthoracic apical echocardiographic views. The mean age was 73.6 ± 12.6 years and 88% were male. Axial displacements and strains were computed with 1D RF cross-correlation with a window size of 6.2 mm and 90% overlap, followed by a 5-mm-kernel least-squares estimator. Electromechanical activation times were defined as the timing of the first sign change of the incremental axial strain after the QRS onset. 3D rendering of the isochrones was then generated by registering the multi-2D views around the LV longitudinal symmetry axis, and performing a linear interpolation on the 2D activation times around the circumference [4]. All processing steps were performed in Matlab (Mathworks Inc., Natick, MA, USA) and the resulting 3D-rendered volume was imported and visualized in Amira 5.3.3 (Visage Imaging, Chelmsford, MA, USA). %MR was computed without and with CRT, and was defined as the percent of LV myocardium activated within 120 ms of QRS onset. The QRS duration was assessed on the clinical 12-lead ECGs without and with CRT.

Results: There was a significant increase in %MR ($\%MR_{without}$ 70.5±14.2% vs $\%MR_{CRT}$ 93.4±9.6%, Wilcoxon signed-rank test p<.0001), and a significant reduction in QRS duration (167±23ms without vs 140±21ms with, p=.0004) (Fig.1). Univariate logistic regression showed that $\%MR_{CRT}$ on implant day was predictive of hospitalizations (p=0.043) and trended towards prediction of NYHA class at follow up (p=0.057). Change in QRS duration was correlated (Spearman) with EF improvement (p=0.026), while $\%MR_{CRT}$ was correlated with hospitalizations (p=0.045).

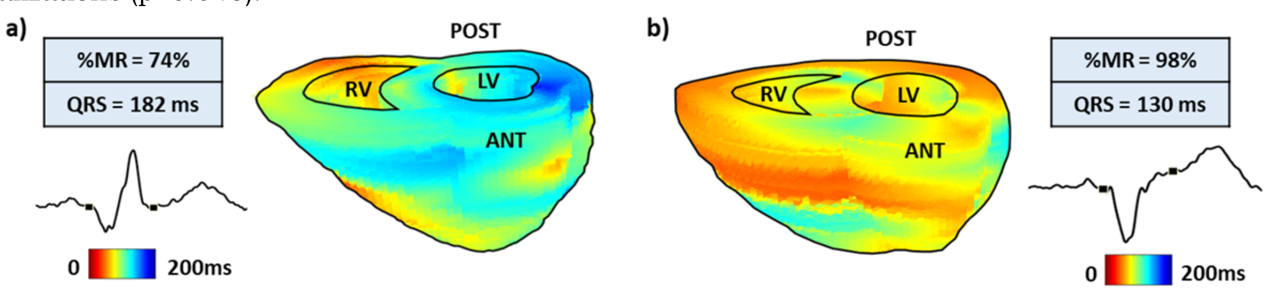

Fig.1: 3D-rendered EWI isochrones in anterior view for the same heart failure patient. a) Without CRT in his baseline: RV pacing only; b) With CRT in his optimized BiV pacing settings. Subject was a super-responder: LVEF improved from 20-25% to 40-45% at 3-month follow up and the patient endorsed an improvement in functional status. Red is the earliest activation, while blue is the latest. LV=left ventricle, RV=right ventricle, POST=posterior and ANT=anterior.

Conclusions: 3D-rendered EWI was shown capable of assessing immediate CRT response on the day of the implantation. These findings indicate that EWI could be a useful tool for CRT evaluation, complementary to the QRS duration, since it can both visualize and quantify myocardial activation, and thereby assess CRT response. In the future, we will evaluate EWI in a larger cohort, and determine if a personalized QRS threshold for %MR computation would increase clinical prediction accuracy.

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References: [1] Provost et al, Proc. Natl. Acad. Sci. 2011. [2] Bunting et al, Pacing and Clinical Electrophysiology 2017. [3] Melki et al, IEEE International Ultrasonics Symposium, Washington DC, 2017. [4] Nauleau et al, Medical Physics 2017.