3D mechanical wave trajectory mapping in the left ventricle using Clutter Filter Wave Imaging.

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Background, Motivation and Objective

Myocardial fibrosis is recognized as a physio-pathologic substrate of several cardiovascular diseases. Knowing that fibrosis causes increased myocardial stiffness, elastography techniques, e.g. shear wave imaging, has shown potential for detection of fibrotic tissue. In this work, a specific mechanical wave (MW) produced at the atrial contraction, and propagating along the left ventricle wall is studied. The main objectives are to estimate the 3D mechanical wave trajectory (MWt) and to compare this measure for a healthy subject and aortic stenosis patient.

Statement of Contribution/Methods

A 4D high frame rate imaging setup was implemented on GE Vivid E95 with the 4V matrix array, by transmitting 20 planes waves to cover a sector of 60x60°, resulting in 820 volumes/s when stitching over 4 cardiac cycles. Sequentially, 2 cardiac cycles were used to acquire high-quality 3D B-mode images for segmentation of a 3D LV model. One healthy volunteer and one patient with delayed contrast enhancement on MRI were investigated.

The MW were detected using clutter filter wave imaging (CFWI) with further developments, including a fully 3D MW velocity (MWv) estimation process.

The 3D time propagation maps were estimated by detecting the maxima of the waves front. By assuming the MW follows the shorter path between two spatial points, the 3D local MWv were estimated by computing 3D-gradient of the time propagation map. Then, the MWt were reconstructed by following the orientation of the 3D MWv vectors. Finally, the MWv and MW orientation were mapped on the trajectory lines.

Results/Discussion

a) shows the 3D MWv mapped on the 3D trajectory line. The average MWv estimated for the healthy volunteer was 2.1 ± 0.8 $m.s^{-1}$, while 3.2 ± 0.9 $m.s^{-1}$ for the patient. b) shows the MW orientation, according to the X, Y, Z axis, mapped on the 3D trajectory line. For the healthy volunteer, the MW of interest propagates globally from the AV plane to the apex. As for the assumed fibrotic left ventricle, the results exhibit circumferential trajectories, especially for high MWv. More patients and other MW will be presented to confirm this result.

This work demonstrates the feasibility to map and estimate 4D left ventricle MW trajectory, which could provide a pathway to retrieve the location of the MW source, a better understanding of MW behavior, a possible new pathologic marker, and a global indicator of the fiber orientation.