Natural mechanical wave detection using ultrafast ultrasound and velocity Clutter Filter Wave Imaging

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Introduction

Assessing the mechanical properties of soft tissues can be extremely valuable to characterize their degree of pathology. This can be performed in both the heart and along the arteries by imaging and estimating the propagating velocity of mechanical waves that are naturally produced due to the cardiac activity. Indeed these velocities can be linked to mechanical properties by models of different degree of complexity and characterize for instance the degree of fibrosis of the heart muscle [1] or the degree of development of atherosclerosis in the arteries [2].

Methods

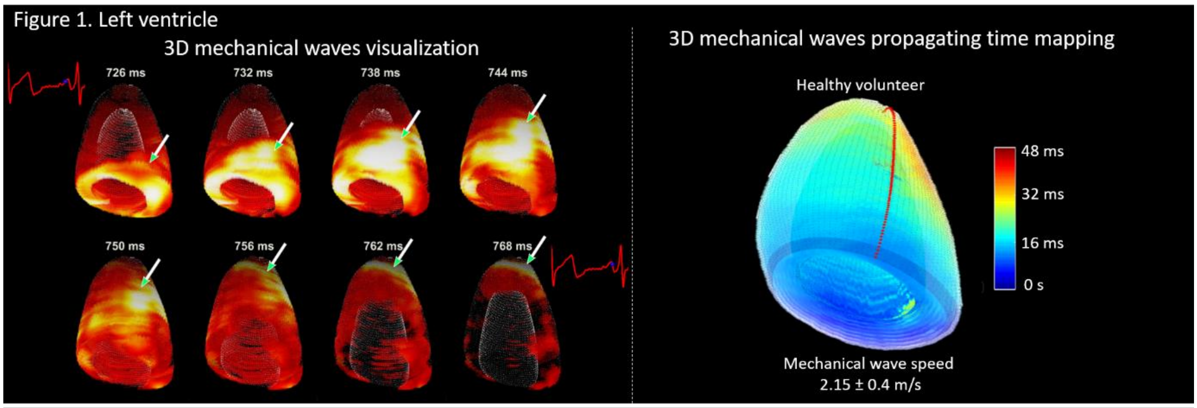
We propose a generic approach to image the propagation of mechanical waves in both the heart and the arteries using high frame rate ultrasound imaging combined with a new extremely sensitive motion detection method called Clutter Filter Wave Imaging (CFWI) [3]. Then, the propagation times are estimated by tracking the maxima of the wavefront.

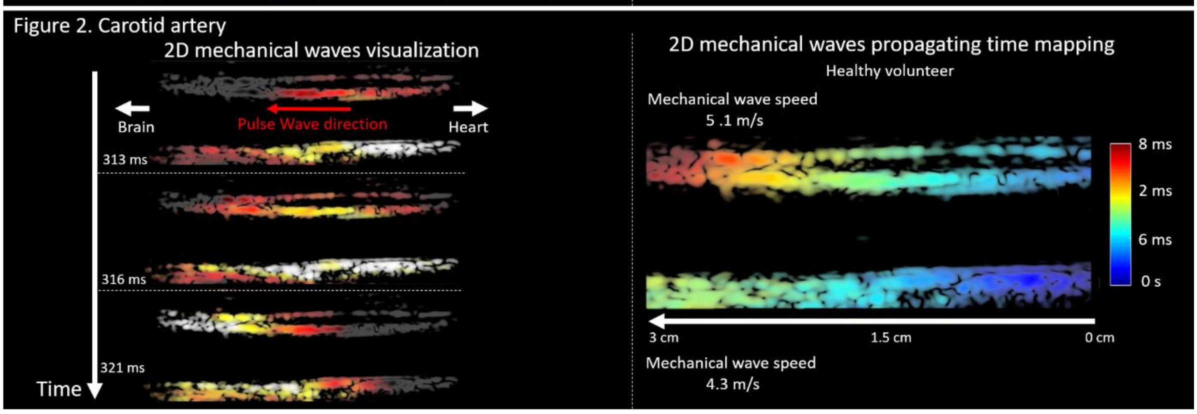
On one side, high frame rate volumes of the left ventricle were acquired using a modified GE Vivid E95, by transmitting 20 planes waves to cover a sector of 60° (820 volumes/s when stitching over 4 cardiac cycles). On the other side, the right carotid artery from healthy volunteers was imaged with a Verasonics Vantage 256 system coupled to a linear array probe. Here only one horizontal plane wave transmission without compounding was used (4000 images / s).

Results/Discussion

Figure 1. shows the 3D propagation of the mechanical waves which occurred during the late peak diastolic a'. We noticed that the a' waves propagate from the base to the apex in a longitudinal direction. The corresponding wavefront time is depicted on the right. By assuming the propagation direction going from the AV plane to the apex the average MW velocities estimated for the healthy volunteers was 2.15 ± 0.4 m.s^{-1}.

Figure 2. shows the 2D propagation of the PW which occurred during the dicrotic notch. The corresponding wavefront time is depicted on the right. We noticed that the PW propagates at different speeds between the upper wall and lower wall. Knowing the propagation direction going from the heart (right) to the brain (left) the average PW velocities estimated for the healthy voluntaries was 5.1 m.s^{-1} for the upper wall and 4.3 m.s^{-1} for the lower wall.





Conclusion

This work allowed to achieve the detection of MWs produced by natural cardiac events and propagating in the carotid artery (2D) and the LF (3D) using ultrafast ultrasound and CFWI. Moreover, the regional MW velocities were estimated for both cases, which could give a stiffness indication of the tissue. Our future work will be focused on trying to asses a relationship between both waves.

References

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