

Continuous Mechanical Wave Imaging: Towards automated cardiac stiffness imaging

Sebastien Salles^{1,2}, Torvald Espeland³, Mohammad Mohajery¹, Solveig Fadnes^{2,3}, Lasse Lovstakken²
¹Laboratoire d'Imagerie Biomédicale, Sorbonne Université, CNRS UMR 7371, INSERM UMR S 1146, Paris, France, ²CIUS, Dept. of Circulation and Medical Imaging, NTNU, Trondheim, Norway, ³Møre og Romsdal Hospital Trust, Women's Health, Child and Adolescent Clinic, Ålesund Hospital, Ålesund, Norway, ⁴Children's Clinic, St. Olavs University Hospital, Trondheim, Norway.

Background, Motivation and Objective

Myocardial fibrosis is known as a physio-pathologic substrate of several cardiovascular diseases. Knowing that fibrosis causes increased myocardial stiffness, natural mechanical wave (MW) imaging has shown potential for detection of fibrotic tissue. Conventionally the MW speed is estimated using the slope of a 2D spatiotemporal map obtained by selecting an anatomic m-mode line along the myocardium. This procedure has to be done for each MW within a cardiac cycle which can be cumbersome and operator dependent. Here, we propose a continuous MW imaging approach that allows estimating and mapping the velocity of several MW (AVC, MVC, and AK) automatically.

Statement of Contribution/Methods

A 2D high frame rate setup was implemented on GE Vivid E95 with the M5Sc-D phased array, by transmitting 6 steered plane waves (820 images/s). MWs were detected using the clutter filter wave imaging technique. 2D time propagation maps were estimated by detecting the maxima of the waves front. Assuming the MW follows the shorter path between two spatial points, the 2D local MW velocity was estimated by computing the 2D gradient of the time propagation map. This procedure was performed in a sliding temporal window of 80 ms, along the full ultrasound sequence. The MW speed was then mapped on the B-mode images (A). N=13 healthy volunteers and N=18 patients with aortic stenosis were investigated.

Results/Discussion

An example is shown in B (blue curve) for a specific region of interest. Interestingly, several flat regions (red curve) emerged and matched (for the most part) at mechanical wave events. The size of the flat regions is linked to the MW propagation time. As expected the estimated AVC, MVC, and AK velocities were higher than the AK MW velocity (C). Moreover, the method distinguishes the healthy volunteer group from the patient with all the mechanical waves produced by the heart. In this work, we presented a method able to estimate simultaneously, locally and automatically the velocity of several MW produced by the heart

