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The effect of ultrafast imaging on shear wave observations

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Background, Motivation and Objective

Shear wave elastography (SWE) most often relies on single or compounded plane wave imaging to capture the shear wave (SW) propagation at ultrafast frame rates. However, it is unclear to what extent the applied ultrafast acquisition influences SW visualization and tissue characterization methods in complex cardiovascular tissue configurations. Therefore, we developed a multiphysics modeling approach, which generates virtual SWE images with the true biomechanics behind the image fully known. This strategy was validated with SWE-experiments on a left ventricular (LV) PVA phantom.

Statement of Contribution/Methods

Experiments: SW's were generated in an LV phantom (fig. A-B) using the Aixplorer system: push frequency of 8 MHz, 1.5 F# and excitation voltage of 50 V. Subsequently, SW's were imaged with (-2°, 0°, 2°) and without (0°) coherent plane wave compounding (fig. C). The phantom tissue was mechanically characterized via uniaxial tensile tests.
Simulations: A corresponding numerical model was created in the finite element (FE) software Abaqus. Fig. D shows the modeled SW propagation after applying an acoustic radiation force, obtained by mimicking the experimental SW excitation in Field II. Next, the ultrafast imaging was modeled in Field II, representing the LV phantom by point scatterers propagating during the scan according to FE tissue displacements (fig. E).

Results/Discussion

The virtual SWE images (fig. F) are in good qualitative correspondence with the experiments (fig. C). These virtual images show lower tissue velocities and broader SW fronts compared to the FE model (fig. D), especially for the 3 angle acquisition. The SW pattern for 1 and 3 plane wave angles significantly differ, for simulations (fig. F) and experiments (fig. C). The downward velocity wave front (yellow-red) has split in two for 1 angle, while only one front is visible when using 3 angles. This implies compound imaging conceals dispersion, though clearly present for 1 angle and FE ground truth. Furthermore, the time-of-flight method (~ no dispersion) leads to a different shear modulus than phase speed analysis (~ dispersion): 16.5 kPa for compound imaging vs 26.2 kPa for 1 angle, the latter closer to the uniaxial test value of 24.3 kPa. Hence, one should be cautious when choosing a tissue characterization method based on the observed SW pattern as this might be affected by the applied imaging setup.