EXPERIMENTAL AND NUMERICAL STUDY OF CIRCUMFERENTIAL AND AXIAL CYLINDRICAL WAVES IN PVA PHANTOMS SURROUNDED BY WATER OR EMBEDDED INTO SOFTER PVA MATERIAL.

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Background: Shear wave elastography (SWE) in arteries is traditionally applied along the artery's main axis to measure the shear wave propagation speed (SWS) during the cardiac cycle [1]. However, the blood pressure exhibits load mostly applied perpendicular to the vessel's wall and due to the artery's anisotropic properties. This leads to more stiffness variation in the cross-sectional view [2]. Moreover, as collagen fibers are circumferentially oriented, investigating changes in their structure (e.g. collagen remodeling) would be more obvious in that view [2]. Therefore, it is relevant to study SWE imaging and circumferentially propagating shear waves (SWs).

Aims: To investigate SWs in thin-walled (3 mm) linear elastic tubular phantoms using both experiments and computational modeling, two types of boundary conditions (BCs) were considered, with the tube phantoms embedded in water or a softer medium.

Methods: 2 PVA phantoms (2 freeze-thaw cycles, 10% PVA; SWS_{Bulk} in plates were 6.6 and 7 m/s, respectively; Fig. A, E) were constructed with one phantom as a single tube and another tube surrounded by softer PVA medium (SWS_{Bulk}=5.3m/s). SWE measurements were performed with phantoms pressurized under a water column with pressure ranging from 0 mmHg to 70 mmHg with a step of 10 mmHg. SWE was studied in both longitudinal and cross-sectional views. Afterwards, a single 3 mm tube at 0 mmHg pressure was modeled numerically in Abaqus (Simulia, Dassault Systemes, USA) taking into account surrounding water.

Results: Derived SWS results were calculated based on the time-of-flight algorithm (Fig. B,F). In the tube surrounded by water, pressurizing the phantom led to an increase in SWS in the cross-sectional view, while it decreased in the axial direction. A similar trend was observed for the embedded tube in the cross-sectional view. The reference value (SWS_{Bulk}) was in between the values obtained from both views. In Fig. C, G complex SWs patterns are shown at 0.5 ms with downward velocities smaller in the embedded tubular phantom. In Fig. D numerical results are shown, revealing patterns similar to the experimental SWs patterns of Fig. C, with a SWS of 4.8 m/s.

Conclusions: SWS values measured in tubes at different pressure levels demonstrate different behavior for different views and BCs. Though the material is linear elastic, such behavior could be partially due to the acoustoelastic effect related to internal stresses and waves being guided inside the wall. Moreover, post-processing SWS data in such thin phantoms is a challenging task and a proper approach has to be followed. Numerical simulations with a known ground truth will allow for a better understanding of SWs propagation in such complex settings and minimize the influence of the post-processing methods.

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