A diffraction correction to quantify shear wave attenuation in transverse isotropic tissues: preliminary results

Background, Motivation and Objective

Shear wave velocity (SWV) and attenuation (SWA) are related to the mechanical properties of tissue given by its storage and loss moduli. To estimate the mechanical properties of tissue, SWA should be corrected by diffraction effects induced by the shear wave source. A cylindrical correction has been proposed for isotropic media when ultrasound radiation force is used to generate shear waves [1,2]. However, to our knowledge, a diffraction correction for SWA in transverse isotropic tissue (TIT) has not been reported. Thus, in this work we address this problem to provide a full mechanical characterization of TIT.

Methods

To this end, experimental measurements were combined with numerical simulations. Experiments were conducted in a meat sample ("peceto" type) bought at the local butcher. An 7 MHz probe driven by a Verasonics Vantage system was used to generate and track shear waves. The pushing sequence consisted of four pushing points (150 μs duration each) at 4 different depths (10, 15, 20 and 25 mm). Then, the shear wave was tracked using plane wave insonification at 5 kHz framerate. Measurements were carried out with the probe parallel (//) and perpendicular (⊥) to the fibers orientation and repeated 5 times for each orientation. To quantify diffraction effects, a simulation of the experiment was conducted under the assumption of a purely elastic TIT. Under these conditions the SWA can be attributed completely to diffraction effects. Simulation was divided in two steps. First, the radiation force field was computed using FieldII [3] and used as a shear wave source to calculate the displacement field using a Green's function algorithm [4]. The SWV// and SWV⊥ to the fibers were recovered from experimental measurements and used as input in the simulation. Finally, SWA results for meat samples were corrected using simulation results by subtracting attenuation obtained through simulation (caused by diffraction) to the experimental values.

Results/Discussion

SWV at 100 Hz along both axis were SWV// = 4.5 ±0.7 m/s and SWV⊥ = 3.2 ±0.3m/s. SWA coefficients before correction at the same frequency were $\alpha_{//}$ = 89±14 Np/m, $\alpha_{\perp}$= 135±20 Np/m, which after correction became $\alpha_{//}$ = 68±14 Np/m, $\alpha_{\perp}$= 112±20 Np/m. These results are in good agreement with [5]. The methodology presented allowed diffraction correction in TIT, which avoids overestimation of the SWA. Further studies are needed to fully verify this approach. Future work will also address the possibility of obtaining an analytical correction for SWA in TIT. Applications in sports medicine and food industry are also envisaged.

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[1]Budelli PMB 2017 [2] Bernard IEEE-UFFC 2017 [3] Jensen JASA 1991 [4] Chatelin PMB 2015 [5] Catheline JASA 2004