ABSTRACT

Background and objective: Ultrasound phantoms mimic the acoustic and mechanical properties of native tissues. Polyvinyl alcohol (PVA) phantoms are extensively used as models for quality testing of ultrasound elastography approaches. However, the viscous properties of these cryogel phantoms have not been investigated adequately. Glycerol is a viscous liquid that can increase the viscosity of fluids and increase the speed of sound of hydrogels. This study aims to assess the acoustic and viscoelastic properties of PVA phantoms without and with glycerol at varying concentrations.

Methods: Cryogel phantoms were fabricated with 10% w/v PVA in water and either 0, 10, 15 or 20% v/v of glycerol. The phantoms were subjected to either one, two, or three 24-hour freeze-thaw cycles. Silicon carbide particles (63 microns, 2% w/v) were used as acoustic scatterers. Three samples were tested for each combination of phantom composition and freeze-thaw cycles. The longitudinal sound speed and attenuation coefficient were determined using a through-transmission system with 5 to 18 MHz bandwidth. The homogeneity of phantoms was shown by acquiring B-mode images. The storage and loss moduli were measured using a rheometer. The microstructural changes in the phantoms were observed through scanning electron microscopy (SEM).

Results: The measured longitudinal sound speeds of all PVA phantoms ranged from 1497-1500 m/s. Attenuation coefficient measurements of all phantoms were between 0.45-0.65 dB/cm/MHz. These results were in agreement with previous reports for soft tissues. Viscoelasticity of PVA phantoms decreased with 10% glycerol and increased with 15 and 20% glycerol. The values of shear modulus and viscosity, assuming a Kelvin-Voigt model, were within the range of healthy and diseased tissues. SEM images of PVA phantoms without glycerol showed a porous hydrogel network. However, phantoms with glycerol had non-porous structure.

Conclusion: Phantoms fabricated in this study possess tunable acoustic and viscoelastic properties within the range reported for healthy and diseased tissue. Customised PVA phantoms can be manufactured with varying glycerol concentrations depending on the tissue of interest, which can help validate ultrasound elastography approaches.