Modeling tissue response to a cavitation bubble in histotripsy

Lauren Mancia
Mech. Eng., Univ. of Michigan, 2016 Walter E. Lay Automotive Lab, Ann Arbor, MI 48109-2133, lamancha@umich.edu
Eli Vlaisavljevich and Zhen Xu
Biomedical Eng., Univ. of Michigan, Ann Arbor, MI
Eric Johnsen
Mech. Eng., Univ. of Michigan, Ann Arbor, MI

ABSTRACT

Histotripsy is a noninvasive focused ultrasound procedure that uses cavitation bubbles generated by high-amplitude ultrasound pulses to mechanically homogenize soft tissue. Experimental studies of histotripsy-induced cavitation in tissue phantoms and animal models have shown that tissue mechanical properties such as viscosity and elasticity affect cavitation threshold and bubble behavior. At present, however, the mechanisms responsible for tissue damage observed in histotripsy and other cavitation-inducing ultrasound treatments remain difficult to quantify. In this study, we simulated the dynamics of a single, spherical bubble in a Kelvin-Voigt-based viscoelastic solid, with nonlinear elasticity to better represent nanometer to micron-scale bubble growth. We applied the numerical model to calculate stress, strain, and strain rate distributions produced by a cavitation bubble exposed to forcing representative of a tensile histotripsy cycle. We found that stress and strain in excess of the ultimate tensile strength and fractional strain of most soft tissues occur at the bubble wall and decrease by at least two orders of magnitude within 50 microns from the bubble. Tissue mechanical properties were found to affect the magnitudes of stress and strain developed at different distances from the bubble. We will relate these results to experimentally observed correlates of tissue damage.