Use of Stationary Focused Ultrasound Fields for Characterization of Tissue and Localized Tissue Ablation

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Ultrasound-induced blood stasis has been observed for more than 30 years. The physical understanding of the phenomenon has not been fully explored. Analytical descriptions of the acoustic interaction with spheres in suspension have been derived but the physical implications and limitations have not been demonstrated. The analytical expressions will be tested against physical observations using numerical simulations. The simulations will begin with stationary spheres and continue with the inclusion of moving spheres and a moving suspending fluid.

To date, experimental observations of acoustically induced blood stasis have been either /in vitro /or invasive. We demonstrate ultrasound-induced blood stasis in murine normal leg muscle versus tumor-bearing legs, observed through noninvasive measurements of optical spectroscopy, and discuss possible diagnostic uses for this effect of ultrasound. We derive the optimal optical wavelengths for measuring the effects of the ultrasound at small source detector separations. Using optical oximetry performed at the optimal wavelengths, we demonstrate that effects of ultrasound can be used to differentiate tumor from normal leg muscle tissue in mice. To provide a statistical analysis of the experiments, we propose a novel diagnostic algorithm that quantitatively differentiates tumor from nontumor with maximum specificity 0.83, maximum sensitivity 0.79, and area under receiver-operating-characteristics curve 0.90.

Ultrasound has long been known to cause tissue heating when applied in high intensities. More recently, interest has arisen in the area of High Intensity Focused Ultrasound (HIFU) for localized tissue heating effects, specifically thermal ablation. All present techniques employ focused traveling high intensity acoustic waves to create a region of elevated temperature. Such high intensity traveling waves can be damaging to normal tissue in the vicinity of the focal region, and have demonstrated surface burns and caused patient discomfort in certain clinical trials. Use of lower intensity ultrasound can minimize the side-effects presented by HIFU. We demonstrate the use of low intensity multiple beam ultrasound resulting in stationary acoustic fields which are capable of heating a very small and more precisely located region of tissue. We simulate the fields formed by traveling waves and stationary waves created by two opposing sources and two orthogonal sources. The simulations are compared to experimental results where the intensity of the individual ultrasound beams is within FDA diagnostic ultrasound limits (0.720 W/cm2). Temperature elevation that would cause cell death was achieved in tissue-mimicking phantoms after short exposures to the acoustic field in the region of beam overlap.