Numerical Simulation of Cavitation-enhanced HIFU Therapy

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ABSTRACT

Medical applications of ultrasound such as High Intensity Focused Ultrasound, Extracorporeal Ultrasound Lithotripsy and Ultrasound-Mediated Gene Transfection have recently been the subject of much interest. In these applications, acoustic cavitation facilitates the medical treatment by improving the image quality and enhancing the therapeutic effects through acoustic emission, localized heating and erosion. During the ultrasound therapy, it is important to control the focal region on the targeting area, which is defocused by the distribution of acoustic impedance of organs and tissues along the pass way of ultrasound and is moving by the respiratory motion, for the reliable treatment. Ultrasound guide is one of the effective way to track the targeting area compensating the defocusing and the respiratory motion. For this purpose, it is important to control the size and location of focal region.

Cavitation-enhanced diagnostics is useful to obtain the clear image of targeting area utilizing the acoustic emission from the existing micro bubbles during the cavitation-enhanced HIFU [1] where cavitation bubbles are generated at the targeting area to enhance tissue heating. In all these applications, it is essential to understand the cavitation phenomena, including bubble and bubble cloud dynamics. The bubble and bubble cloud behavior are strongly influenced by the thermal phenomena inside and outside bubbles and the applied ultrasound wave forms which accelerate therapeutic effects by the cavitation bubbles. They are resulted by the complex interactions between bubble oscillation and ultrasound. Those depend on not only the exposure parameters of ultrasound but also the physical properties of surrounding tissues and remaining microbubbles which are often employed as cavitation nuclei for decreasing cavitation threshold pressure and for controlling cavitation region.

It is also significant to estimate the ultrasound focusing process in the heterogeneous acoustic impedance field like human body by the numerical simulation [2]. Thus, the numerical simulator treating cavitation/microbubble in the ultrasound field has been developed for investigating the influences of various parameters in the cavitation-enhanced HIFU therapy. The simulator takes into account the heat generation due to oscillating cavitation bubbles as well as the rectified diffusion which has important role in the initial stage of cavitation bubble growth. Bubble dynamics equation considers the elasticity of the surrounding tissue and the surfactant shell of microbubbles, and is strongly coupled with mixture phase to reproduce the interaction between ultrasound and bubble oscillation. Thus, the model can reproduce cavitation bubble growth from nuclei around focus. In the present paper, the numerical results for the cavitation/microbubble-enhanced HIFU therapy in the heterogeneous acoustics impedance field will be presented.

REFERENCES

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