8th. World Congress on Computational Mechanics (WCCM8)
5th. European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 – July 5, 2008
Venice, Italy

HIGH INTENSITY FOCUSED ULTRASOUND IN A HUMAN BODY

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Key Words: *Nonlinear Acoustics, Ultrasound Diagnostics, HIFU Therapy, Multi-physics problem, Voxel Model.*

ABSTRACT

The non-invasive ultrasound diagnostic/therapeutic system has been developed to decrease the physical and financial burden of patients [1]. High Intensity Focused Ultrasound (HIFU) therapy is a key of non-invasive cancer treatment, which provides the heat coagulation of tissue around the focal point of ultrasound. When HIFU therapy is applied to the treatment of deeply-placed cancer such as the liver and brain cancer, a problem is the displacement of focal point due to the reflection and refraction of ultrasound at the interfaces of skin, fats and bones. The position control of the focal point by an array transducer is expected [2]. However, it is difficult to estimate the phase delay of arrays of the transducer preoperatively. The numerical simulation is available for the prediction of the focal point of ultrasound which propagates through the inhomogeneous media i.e. human body. Further, the simulation results will provide us the appropriate phase control of the array transducer.

In the present study, the propagation of ultrasound through the voxel modeled human body based on the CT/MRI data is investigated numerically. Our approach is to solve the mass and momentum equations with assumptions of the homogeneous and adiabatic flows, where the nonlinearity is mainly taken into account through the equation of state for media. The basic equations are discretized spatially by the 4th-order central finite difference method to resolve the high frequency wave. FDTD method is applied for the time marching. The non-reflecting boundary condition is represented by Perfectly Matched Layer.

We examined the displacement of the focal point for the ultrasound of 1MHz through a voxel modelled human body based on CT data. A bowl-shaped transducer with the size of 40mm and the focal distance of 40mm is placed near the human body through water and oscillates by the frequency of 1MHz. The numerical domain with the size of 60x80x60(mm) is build around the transducer by the orthogonal mesh of 600x800x600 grids and includes a part of human body. The acoustic properties of media are related to the Hounsfield number of CT data[3]. Fig.1(a) shows an arrangement for brain tumor. The transducer is set side of the skull.

Figure 1 (b) and (c) show the distribution of the instantaneous pressure and the high pressure amplitude region respectively, where a probe indicates the geometrical focal point of the transducer. As shown in Fig.1(b), the propagation of ultrasound are the wavelength of ultrasound in the bone is longer than elsewhere due to the higher speed of sound. The focal point of ultrasound is short of the geometrical focal point and is a little tilted. This is due to the reflection and refraction of ultrasound. The peak pressure at the focal point is 2.12MPa, which is smaller than the peak pressure of 5MPa in the case of the ultrasound propagation through the homogeneous medium.

Previously, we investigated the position control of the focal point of an annular array transducer by a two-dimensional calculation. Now, we have been developing the three-dimensional calculation to consider the array transducer. We will show the results of the three-dimensional position control of the focal point by the array transducer in the presentation.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the Computational Biomechanics Unit of RIKEN for providing the voxel modeled human body. The authors employed the computer resources provided by Research and Development Group for Next-generation Integrated Living Matter Simulation of RIKEN.

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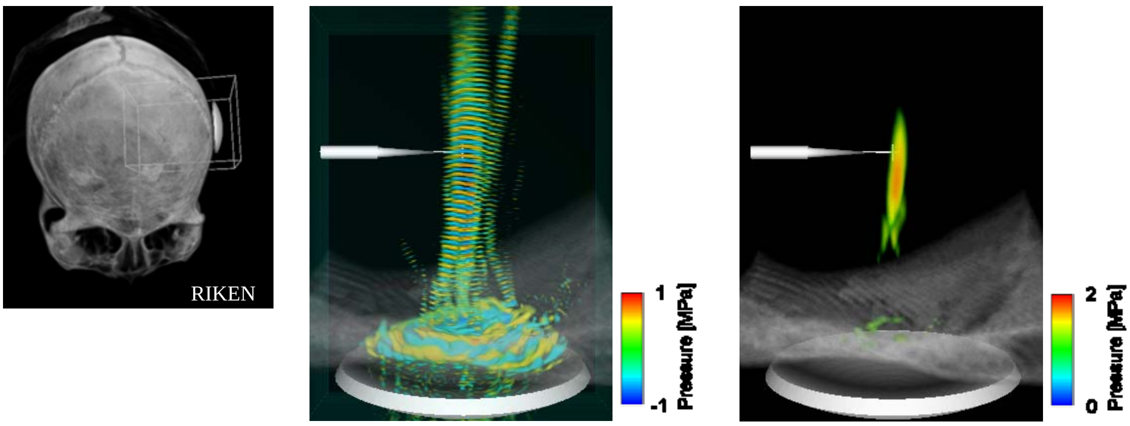

(a) Location of the transducer and numerical domain

(b) Distribution of instantaneous pressure

(c) High pressure amplitude region

Fig.1 Ultrasound propagation through a skull
(results are visualized by V-Isio, http://vcad-hpsv.riken.jp/en/release_software/V-Isio/)