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NUMERICAL SIMULATION OF HIGH-INTENSITY FOCUSED ULTRAOUND TREATMENT FOR BREAST CANCER

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INTRODUCTION

Therapeutic application of ultrasound is of interest for a tumor treatment without damaging intervening tissue. High-intensity focused ultrasound (HIFU) provides the ability to localize the deposition of acoustic energy within the body, which can cause tissue necrosis[1]. Issues as the defocusing and distortion of ultrasound in the body decrease not only the controllability and performance but also the safety of HIFU treatment. Numerical simulation is required to resolve the issues and to assist the early development of the advanced HIFU system which employs ultrasound imaging for guidance instead of MRI.

A HIFU simulator[2] has been developed to reproduces the propagation of ultrasound emitted from a HIFU device through the body including tissues of various acoustic properties. Figure 1 shows the schematic diagram of data flows to HIFU simulation. The transducer defined by CAD is represented by signed distance funcetion (SDF), and the voxel phantom is constructed from CT/MRI images. The simulator (ZZ-HIFU-K) is now available from the ISLiM project[3].

In the present study, HIFU therapy for breast cancer is taken up as a specific problem. Ultrasound propagation through a breast model constructed from MRI as shown in Fig. 2 is simulated, and a focus control by means of a 56ch phased array transducer is demonstrated.

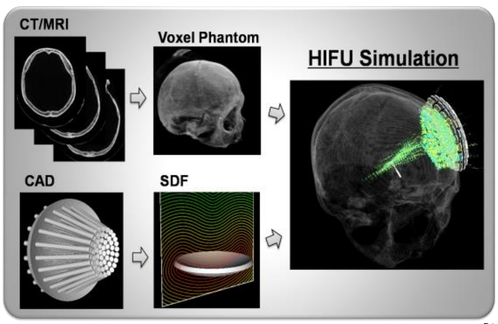


Fig.1 Input data flows to HIFU simulation[2].

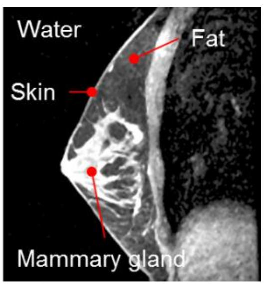


Fig.2 MRI of breast

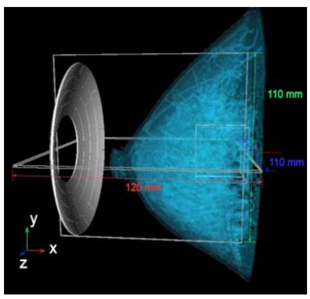


Fig.3 Numerical model

METHODS

The propagation of ultrasound through an inhomogeneous media in consideration of the nonlinearity of media is reproduced by solving momentum equation for multi-media with constitutive equation for viscous fluid or viscoelastic body, where physical properties of tissue referred from the paper[4] are employed. The bioheat equation is additionally solved to obtain a temperature distribution. The basic equations are discretized finite difference method by 6th order central difference method in space and are developed in basis of the FDTD method. Both process and thread parallelization are respectively implemented by MPI with domain decomposition and by OpenMP.

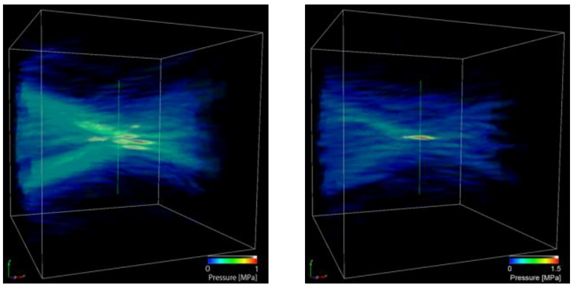
Figure 3 shows a numerical model of the HIFU treatment for breast cancer with a 56ch phased array transducer (2MHz), whose aperture and focal length are both 100mm. The size of the numerical domain is 120x110x110 mm which is resolved by 1200x1100x1100 grids.

RESULTS

Figure 4 shows the ultrasound fields around the target for without and with focus control based on time reversal[5]. As shown in Fig.4(a), the ultrasound is highly distorted due to the heterogeneity of tissue structure in the breast, and the some focuses are observed around the target without focus control. On the other hand, as shown in Fig.4(b), the ultrasound focuses on the target correctly and the peak of the focus increases by means of focus control. To find the cause of the distortion of focus, HIFU for the breast model without skin is considered as shown in Fig.5. The ultrasound is distorted as shown in Fig.5(b), which is similar to Fig.4(a).

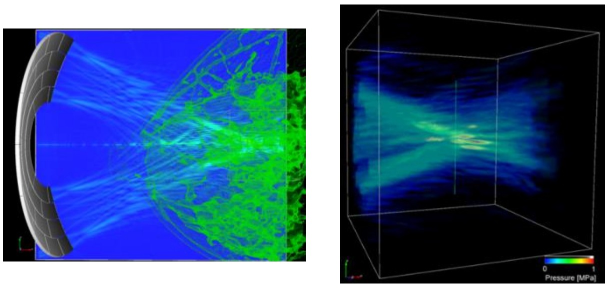
CONCLUSION

The focus was highly distorted even though the ultrasound propagated through soft tissues, and the focus control based on the time-reversal was effective. Numerical simulation resulted that the distortion of focus depends on the structure of fat and mammary gland in the breast.



(a) w/o focus control (b) w/ focus control

Fig.4 Ultrasound field around target



(a) Ultrasound field (b) focusing

Fig.5 HIFU simulation without skin.

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