2P5-12

Development of Visualization Method for Wide Range of Temperature Rise Induced by High Intensity Focused Ultrasound Using Tissue-mimicking Phantom

生体模擬ファントムを用いた強力集束超音波による広レンジ温度上昇可視化手法の開発

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1. Introduction

In High-Intensity Focused Ultrasound (HIFU) treatment, ultrasound is focused at tumors from outside the body and the tareget tumors are coagulated with heat induced by ultrasound. To improve the efficiency and safety of HIFU treatment, it is nessary to evaluate the heated region induced by HIFU before the treatment. The method using the commercial micro-capsulated thermochromic liquid crystal (MTLC) to evaluate the temperature rise distribution caused by HIFU in a media was developped in previous study[1]. However, the color-coded temperature range of commercial MTLC was 10 °C and it is not sufficient to measure the temperature rise in a media during the HIFU exposure. In this study, two layers of tissue-mimicking phantom, having different color-coded temperature ranges were produced and the new visualaization method utilizing axi-symmetric pressure distribution of the focal field was developed to measure wider range of temperature rise than that of conventional method during HIFU exposure.

2. Material and Methods

2.1 Two-layer temperature sensitive phantom

We used the urethane material mixed with MTLC to fabricate a reproducible phantom because the urehane was transparent and colorless ,which is suitable for optical measurement. The concentration of MTLC in urethane was 0.01%. In this study, two types of temperature sensitive phantom whose sensitivity is from 45 to 55 °C and from 55 to 65 °C were produced. At first, the phantom, having the sensitivity range of 55 - 65°C was produced as a lower layer and then the lower temperature sensitive phantom (45-55°C) was produced on a lower layer (55-65°C). A schamtic of two-layer temperature sensitive phantom is shown in **Fig.1**. As shown in **Fig.1**, spherical HIFU transducer was set so that focal point of HIFU was alined to the bundary between two layers of the phatom.

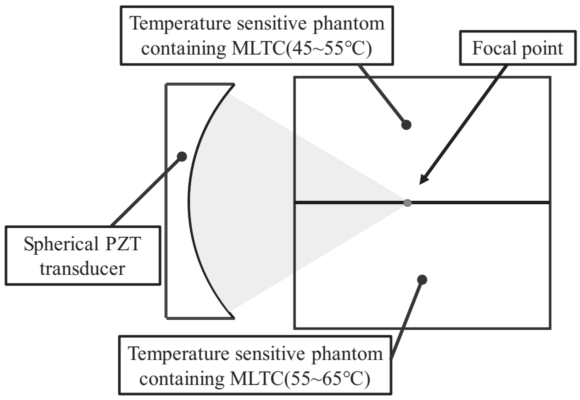

Fig.1　Two-layer temperature sensitive phantom

2.2　Experimental Setup

A schematic of the experimental setup is shown in **Fig. 2**. In this experiment, 2-D plane of temperature rise distribution at focal area in a phantom during HIFU exposure was captured by CCD camera, illuminating a phantom with a light sheet. The light sheet, whose width of 4 mm was produced by xenon slit light source. The upper and lower parts of time-series images are partially inverted along the axial direction of HIFU during first and second half of the exposure period, and then 2-D temperature rise distribution of all focal region for entire exposure was produced, assuming axi-symmetric pressure distribution of HIFU. Calibration process is needed to convert a color image (RGB values) to the temperature rise distribution. Before the experiment, thermocouple was inserted into each phantom (upper and lower layer), and the relationship between RGB values and the temperature rise was investigated by heating each phantom with HIFU. Figure 3 shows the relationship between temperature rise and RGB values in each temperature sensitive phantom. The temperature rise distribution was produced from color images using the dataset in **Fig.3**. The suggested calibration algorithm in previous study[1] was appllied to the color images in this study. The driving frequency of HIFU was 1.67 MHz. The water was degassed [dissolve doxygen (DO): 20–30%] and kept at 36 °C. The spatial-peak

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temporal-peak intensity (I_{SPTP}) and exposure time was 126 W/cm2.

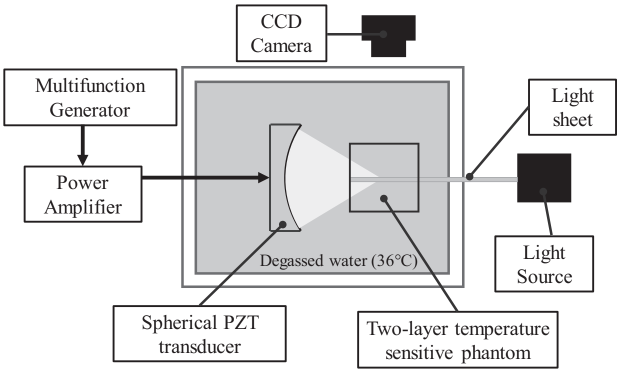

Fig.2 Schematic of experimental setup

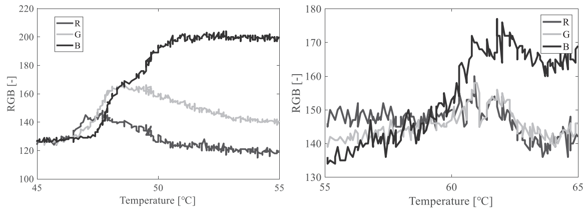

Fig.3 Relationship beteen temperature rise and RGB values in upper and lower layers

3. Results and Discussion

Figure 4 shows the 2-D color images captured by the CCD camera during HIFU exposure. HIFU was exposed from left to right in these figures. As shown in **Fig.4**, the focal region in upper layer (45-55°C) firstly started to be colored and then the focal region in lower layer (55-65°C) was colored as increasing the exposure time. The colored region has been gradually disappeared after stopping the HIFU exposure. The colored region in upper layer was broader than that of lower layer because the temperature sensitivity range of upper layer was lower than that of lower layer.

Figure 5 shows that time series of temperature rise at focal point of HIFU after producing the time-series of 2-D temperature rise distribution during HIFU exposure. As shown in **Fig.5**, the total range of measured temperature rise was two times wider than that of conventional method. This method has the potential for measuring wider range of temperature rise but still has some challenges. The range of measured temperature in upper layer was relatively low (45-49°C) and so there is the discontinuity between the estimated temperature using upper and lower layers (see around 7s in Fig.5). This is thought to be because that the calibration data (the relationship between RGB values and the temperature) was not matched to the color values of image captured in the exposure experiment. The system has to be developed to measure both the calibration data and the images in the exposure experiment with the same measuring conditions. In this study, the exposure experiment was repeated several times after enough cooling time and almost the same color values could be captured. These results imply that the developed phantom has the durability and reproducibility and it is suitable for the on-site measurement of temperature rise distribution induced by HIFU before the treatment.

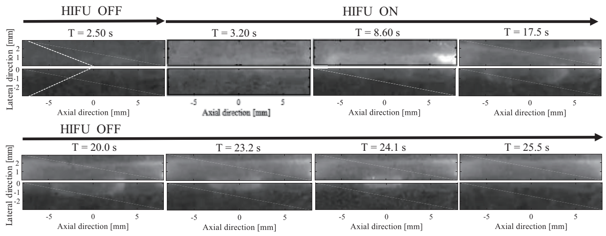

Fig.4 Time series of captued color images during HIFU exposure

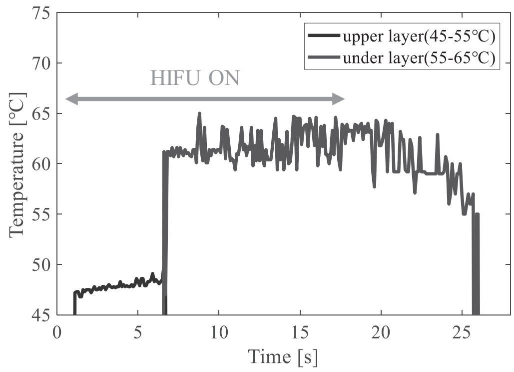

Fig.5 Temperature rise at focal point of HIFU measured by the proposed method

4. Conclusion

In this study, the new visualaization method was developed to measure wider range of temperature rise during HIFU exposure. The total range of measured temperature rise was two times wider than that of the conventional one. These results imply that the proposed method has the potential to be used to evaluate the temperature rise distribution caused by HIFU although there are still challenges.

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References

1. T. Iwahashi et al: Adv Biomed Eng. **7**:1-7 (2018) .