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Ultrasonic Monitoring of High Intensity Focused Ultrasound Lesions Using Sub-Image Correlation

部分画像相関を用いた強力集束超音波による組織凝固領域の超音波モニタリング

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1. Introduction

High Intensity Focused Ultrasound (HIFU) has been under investigated for its feasibility to perform noninvasive treatment which induces thermal coagulation to target tissue such as cancer. In order to fully exploit its nature for noninvasive treatment, monitoring method for HIFU therapy in a noninvasive manner is also required.

Current methods for monitoring HIFU therapy include magnetic resonance imaging (MRI) and diagnostic ultrasound (US) imaging. Although MRI has the ability to monitor tissue necrosis and temperature changes in the target region, it has some limitations such as a high expense and the lack of portability. Therefore, US imaging methods for monitoring and assessment of HIFU-induced lesions have been considered due to its low expense, portability, and real-time imaging capability.[1)]

Several US imaging techniques have been introduced to characterize and monitor HIFU therapy utilizing the fact that acoustic parameters in tissue vary through thermal coagulation.[1-2)]

In this study, ultrasound images have been utilized to observe changes before and after HIFU exposure. Ultrasound RF signals were acquired for signal processing. Correlation was calculated using block matching between sub-images of two RF images to evaluate changes in thermal lesion.

2. Materials and Methods

2.1. HIFU Exposure

Fresh porcine liver was obtained from slaughter yard on the day of experiment. The liver was perfused with degassed saline to eliminate gas within it, and then cut into pieces for samples. As shown in **Figure 1**, a liver sample was set in a tank containing degassed water. The sample was exposed to a single element transducer with a center frequency of 3 MHz, which generated focused ultrasound to induce lesions within the sample. The focused ultrasound power was set so as not to cause cavitation. After HIFU exposure, the sample was sliced to measure the lesion size.

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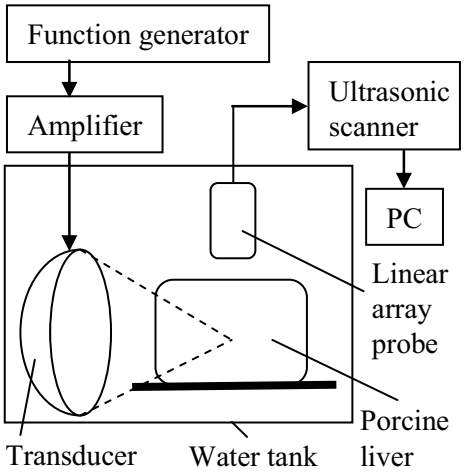

Fig. 1. Schematic of experimental setup

2.2. Ultrasound Monitoring

A diagnostic ultrasound scanner (SSD-α10, Aloka) with a linear array probe was used for monitoring the HIFU exposure. The probe had a nominal center frequency of 7.5 MHz. The imaging plane was set perpendicular to the longitudinal axis of the HIFU focal spot. Ultrasound RF data were acquired before and after the exposure and stored to a PC for further analysis.

2.3. Signal Analysis

A block matching algorithm based on a correlation method was applied to estimate the similarity between two images and to compensate motions occurred within the samples due to coagulation. RF data acquired before and after the HIFU exposure, s_1, s_2 respectively, were used to calculate a correlation coefficient $C(z,x;n,m)$ to estimate similarity between two images. The correlation coefficient was calculated as:

$$C(z,x;n,m)=\frac{\sum_{k=-z_0/2}^{z_0/2}\sum_{l=-x_0/2}^{x_0/2}s_1(z+k,x+l)s_2(z+k+n,x+l+m)}{\sqrt{\sum_{k=-z_0/2}^{z_0/2}\sum_{l=-x_0/2}^{x_0/2}s_1^{\,2}(z,x)}\sqrt{\sum_{k=-z_0/2}^{z_0/2}\sum_{l=-x_0/2}^{x_0/2}s_2^{\,2}(z+k+n,x+l+m)}} \quad (1)$$

where z, x are the longitudinal and lateral axes of the image, respectively, n, m are the longitudinal

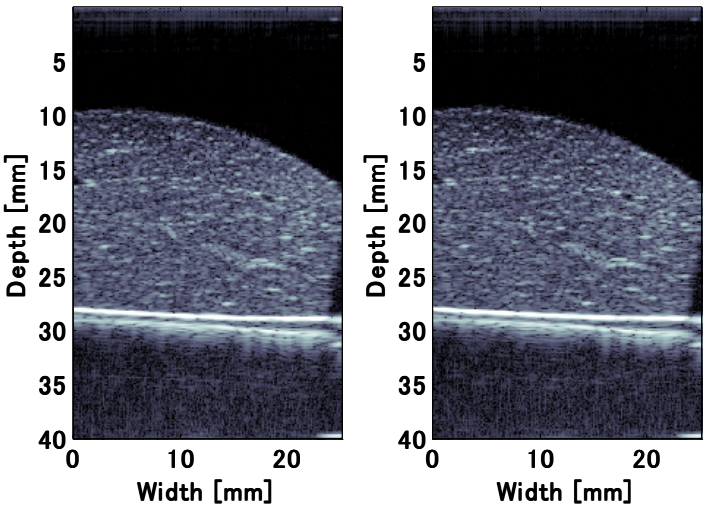

Fig. 2. B-mode images of a sample before (left) and after (right) HIFU exposure

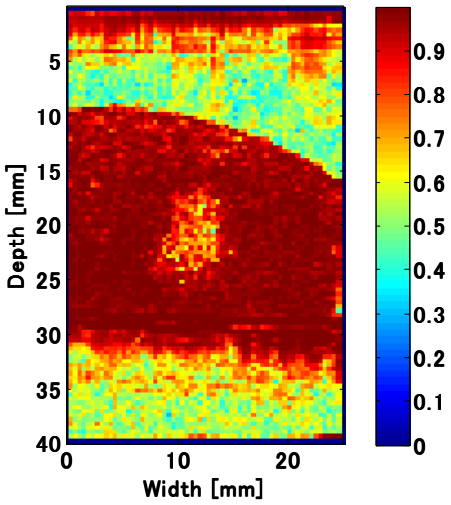

Fig. 3. Distribution of maximum correlation coefficient value

and lateral shifts for block matching, respectively, and z_0, x_0 are the size of sub-image generated for block matching, respectively. The maximum value of correlation coefficient calculated for each sub-image was stored to construct an image that represents the similarity of two images before and after the exposure.

3. Results and Discussion

Figure 2 shows B-mode images acquired before and after the HIFU exposure. Note that difference due to tissue coagulation may not be clearly seen in these B-mode images. However, decrease in B-mode brightness has been observed in this result and may need to be investigated.

Estimation of similarity between the two images before and after the HIFU exposure is shown in **Figure 3**. The bar scale on the right side of the figure indicates the magnitude of correlation coefficient, which corresponds to the level of similarity between the two images. It can be seen that the values of correlation coefficient at the central region, which corresponds the focal spot of HIFU exposure, are rather low compared to the region surrounding it. This indicates that similarity of tissue varies significantly due to coagulation. Figure 4 shows the photograph of the HIFU exposed sample which was sliced along the imaging plane. The white spot appeared in the sample, indicated by a red circle, is the coagulated region. The measured size of the thermal lesion induced by HIFU exposure was about $3\times3(mm)$. However, as shown in figure 3, the size of the region with low correlation was larger than the size of the white spot induced by the HIFU exposure. This may be caused by coagulation due to the temperature rise beyond the outer boundary of the focal spot.

Fig. 4. Slice of sample after HIFU exposure

4. Conclusion

In this study, two images before and after the HIFU exposure were compared using block matching based on a correlation method. It has been shown that correlation coefficient of a HIFU focal region decreased due to tissue coagulation. However, the size of HIFU-induced lesion estimated using the proposed method differed from the actual size of lesion. Other methods for monitoring and detecting HIFU-induced lesions should be combined for more precise estimation.

References

1. H. Zhong et al.: Ultrasound in Med. & Biol. **33** (2007)
2. N. R. Miller, J. C. Bamber and G. R. ter Haar: Ultrasound in Med. & Biol. **30** (2004)