3P5-5

Investigation on dependence of initial value of statistical factor in estimation of temperature distribution inside biological tissue

超音波による生体組織内部温度分布推定における統計因子の初期値依存性に関する検討

Michio Takeuchi[1†], Yuta Matsui[1], Toshihiko Sakai[1], Ryo Nagaoka[2], and Hideyuki Hasegawa[2] ([1]Tateyama Kagaku Industry Co., Ltd.; [2]Grad. School of Sci. and Eng. for Research, Univ. of Toyama)

竹内道雄 [1†]，松井裕太 [1]，坂井俊彦 [1]，長岡　亮 [2]，長谷川英之 [2] ([1] 立山科学工業, [2] 富山大院理工学研究部)

1. Introduction

Number of research groups have focused on a study on non-invasive measurement of internal body temperature for many years. The existing approach for non-invasive detection of internal body temperature is divided roughly into two methods. One is drawing on the temperature dependence of proton chemical shift measured by Magnetic Resonance Imaging (MRI) instrument.[1)] Another is an approach using the propagation velocity of ultrasonic wave.[2)] However, unfortunately nobody has developed a device, which can measure internal body temperature practically and non-invasively, due to some issues.

Within this context, in this decade, some research groups proposed a prospective new method for the non-invasive measurement of internal body temperature.[3)] The new method is also based on acoustic technology. However, what is novel in comparing the new acoustic method to the existing one is that the proposed new method utilizes statistical parameters obtained from ultrasonic scattered echoes in non-invasive estimation of temperature. We have also studied non-invasive measurement of internal body temperature by statistical analysis of ultrasonic scattered echoes. We showed that selecting a proper size of a region of interest (ROI) is crucial when deformation of biological tissue specimen occures.[4)] In this study, we found out a intriguiting phenomenon, i.e., the magnitude of the change in Nakagami shape parameter *m* due to a temperature increase in biological tissue specimen has dependence on the initial *m* value. We carried out statistical analysis with consideration of the initial *m* value dependence for measurement of the internal temperature distribution in locally heated biological tissue specimen.

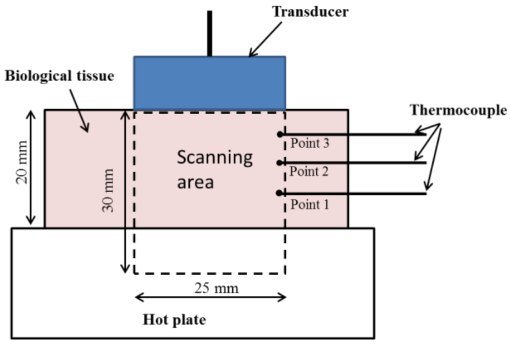

Fig. 1. Cross section of experimental setup

2. Material and method

In this study, pork Boston butt was prepared as a biological tissue specimen. A temperature gradient inside the tissue specimen was created to examine whether the proposed method could evaluate local temperature inside the tissue specimen. We heated the specimen from 17.0 up to 36.0 °C using a hot plate placed at the bottom of the specimen. The reference temperatures at three points (Point 1, 2, and 3) inside the tissue specimen were measured by thermocouple temperature sensors. The temperature difference between Point 1 and 3 was finally about 4.0 °C. In this study, basically, we use temperatures measured at Point 1 as a reference temperature. Ultrasonic echoes scattered from the biological tissue specimen were

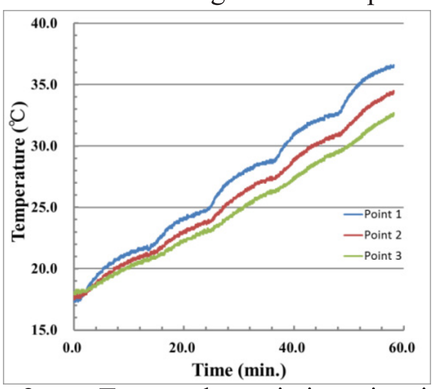

Fig. 2. Temporal variation in internal temperature of tissue specimen

†m-take@tateyama.or.jp

measured using an ultrasonic measurement system (Microsonic RSYS0002) with a linear array transducer (Hitachi UST-5412). The experimental setup is illustrated in Fig. 1. The temporal change in temperature inside the tissue specimen is shown in Fig. 2.

The Nakagami shape parameter *m* was obtained by statistical analysis by fitting the Nakagami distribution function to the histogram of the amplitudes of measured ultrasonic scattered echoes. By estimating the Nakagami shape parameters *m* at different temperatures, we evaluated temperature and initial value dependences of the Nakagami shape parameter *m*.

3. Analysis and discussion

The mean values of *m* calculated with an ROI size of 1.2 × 1.2 mm^2 as a function of reference temperature are plotted in Fig. 3. In this study, the mean values of *m* slightly decrease from 0.615 down to 0.564 with increasing temperature. However, in previous studies,[3,4] the mean values of *m* for soft tissue specimen increase with elevation of temperature. Fig. 4 shows initial *m* value dependence of changes in *m* due to increase of temperature. In Fig. 4, it can be clearly seen that Δ*m* becomes large when the initial *m* value is large.

In order to show internal temperature changes in the tissue specimen, we made hot-scale images indicating absolute values of ratio changes of *m* values, *α*, using the following equation

$$\alpha = \left|\gamma \cdot \log_{10}\left(\frac{m_T}{m_{T_R}}\right)\right|, \tag{1}$$

where m_{TR} and m_T are the Nakagami shape parameter *m* at a baseline temperature and at each temperature, respectively, and γ denotes the multiplying factor for the ratio changes of *m* values. The multiplying factor γ was defined to be proportional to m^{-1}. The hot-scale *m*-parameter images estimated by setting the ROI size at 1.2 × 1.2 mm^2 at T_R = 17.3 °C are shown in Fig. 5. We excluded *α* calculated from the bottom region of the scanned area, where the hot plate was placed, and the upper region with feeble echo signals. The

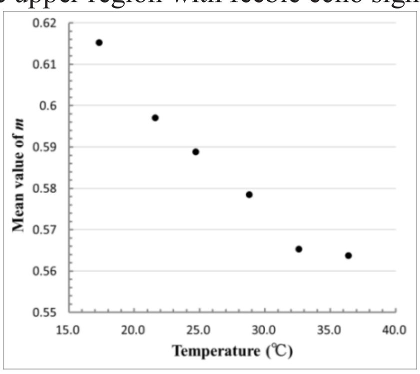

Fig. 3. Temperature dependence of mean value of *m*

area used for obtaining *m* values and *α* is shown by the closed red dotted line in Fig. 5. In Fig. 5, we can obviously see the temperature distribution in the tissue specimen. Moreover, the behavior of the temperature distribution observed in the hot-scale images seems reasonable as well as that in Fig. 2.

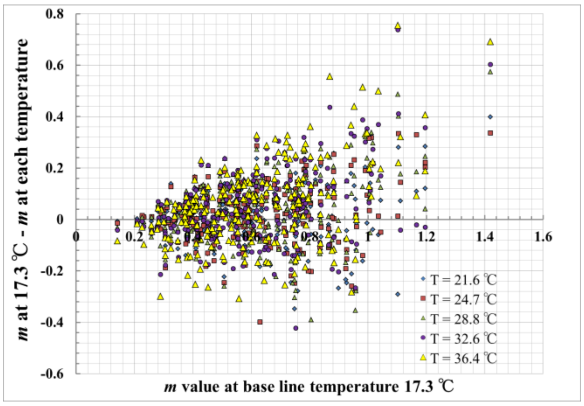

Fig. 4. Initial *m* value dependence of Δ*m*

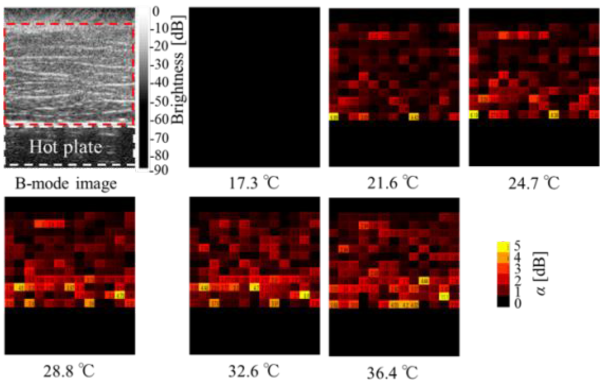

Fig. 5. B-mode image and hot-scale images indicating absolute value of ratio changes of *m* values, *α*

4. Conclusion

We found out that the variation of *m* values of biological tissue specimen due to temperature increase has initial *m* value dependence. Also, we proposed a method, by which the temperature distribution in the tissue specimen could be detected clearly by hot-scale *m*-parameter images considering the initial *m* value dependence.

References

1. K. Kuroda, E. Kumamoto, Y. Matsuoka, A. Okada, B. Keserci, D. Harada, and D. Kokuryo, Med. Imaging Technol. **21**, 201 (2003).
2. M. Fujii and X. Zhang, Exp. Therm. Fluid Sci. **24**, 107 (2001).
3. B. Gambin and E. Kruglenko, Acta Phys. Pol. A **128**, A-72 (2015).
4. M. Takeuchi, Y. Matsui, T. Doi, Y. Takano, G. Andocs, and H. Hasegawa, Jpn. J. Appl. Phys. **57**, 07LB17 (2018).