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Investigation on application conditions of the ultrasonic velocity change imaging method to living body

生体に対する超音波速度変化イメージング法の適用条件に関する検討

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1. Introduction

We are investigating the application of the ultrasonic velocity change (UVC) imaging [1] as a non-invasive method to the depiction of carotid plaque [2] and the estimation of liver fat content [3]. The UVC method is built by determining the phase shifts of two echo signals based on the temperature change from the difference information of two echo images (paired images) obtained before and after the temperature change of the target region. Therefore, the UVC method is strongly susceptible to movements of the target region caused by heartbeat. We applied the UVC method to a biological phantom under the pseudo-heartbeat condition and showed that the effect of the heartbeat can be removed by setting the time difference between the pair images [4]. However, it was found that estimating the original temperature change from the phase shift caused by a small temperature change in a short time resulted in an overestimation. In this paper, therefore, we estimate the appropriate time difference between paired images in the UVC method using a tissue mimicking material (TMM) phantom.

2. UVC method

The UVC method was proposed to identify the medium component from the change in ultrasonic velocity that occurs when the medium is subjected to a temperature change. In particular, a temperature change around the body temperature, the ultrasonic velocity changes at a rate of +1.9 m・s^{-1}・℃$^{-1}$ for water, and at a rate of -4.9 m・s^{-1}・℃$^{-1}$ for fat, which are the main components of a living body. These changes in ultrasonic velocity cause phase shifts in the ultrasonic echo signals before and after the temperature change in the target region; the UVC method uses the phase shift to estimate the ultrasonic velocity change (UVC) ratio and identify the characteristics of the target region.

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3. Experiment and UVC imaging

Figure 1 shows the experimental setup. A TMM biological phantom (OST corp., 95 × 95 × 97 mm^3) was prepared and an ultrasonic heater (ITO corp., 1 MHz) was set on the top of the TMM phantom. The TMM phantom was warmed for 60 s by the ultrasonic heater operating with an irradiation intensity of 0.6 W/cm^2. The warming process was observed by acquiring 300 B-mode images for 10 seconds using an ultrasonic linear array transducer (ALOKA SSD6500, center frequency of 13 MHz) set at 20 mm from the top on the side surface of the TMM phantom. Two paired images were selected at an arbitrary time difference (corresponding to the difference in image numbers) among these images, and normal cross-correlation (ZNCC) was performed to extract pairs of paired images with high correlation values. Then, the UVC images were drawn using those extracted pair images and integrated to reduce the noise. Using this procedure, the difference in the number of images was varied from 1 to 290, and the integrated UVC images were drawn in respective cases.

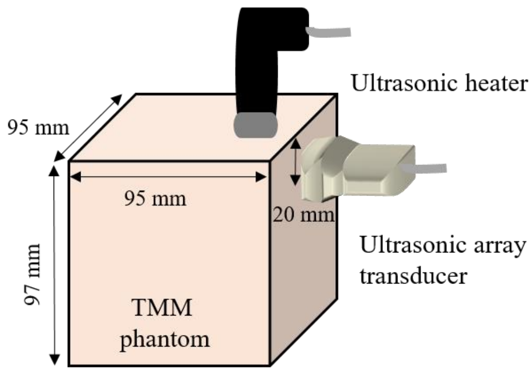

Fig. 1 The experimental setup for monitoring the warming process of a TMM phantom.

4. Results

Figure 2 shows the integrated UVC images obtained when the difference in image numbers was (a) 1 and (b) 50, respectively. In the UVC image using the TMM phantom, the region where the temperature rises (falls) with time is depicted in red (blue). The red region in the image (b) is enlarged compared to the image (a), indicating that the information on the temperature increase due to ultrasonic heating is properly reflected. Then, the temperature change averaged within the warmed region in the UVC image was estimated.

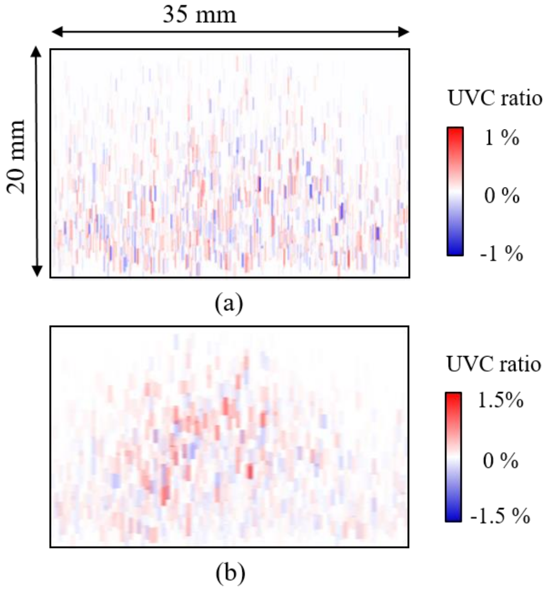

Fig. 2 The integrated UVC images obtained when the difference in image numbers was (a) 1 and (b) 50, respectively.

Figure 3 shows a variation of the estimated temperature change in one minute as a function of the difference in image numbers. As the difference in image numbers increases and reaches around 50, the overestimation of the temperature change in one minute is greatly improved. When the difference in the image numbers is more than 150, the temperature change in one minute is close to that measured by a platinum resistance thermometer, indicating that the UVC method provides a correct estimation. However, when applying the UVC method to a living body, it is desirable to have as short a time difference as possible between the paired images because of the strong influence of irregular movements based on heartbeat. Therefore, when applying the UVC method to a living body, it may be appropriate to prepare paired images with around 50 difference of image numbers (corresponding to a time difference of about 1.5 seconds), although this procedure may involve a slight overestimation.

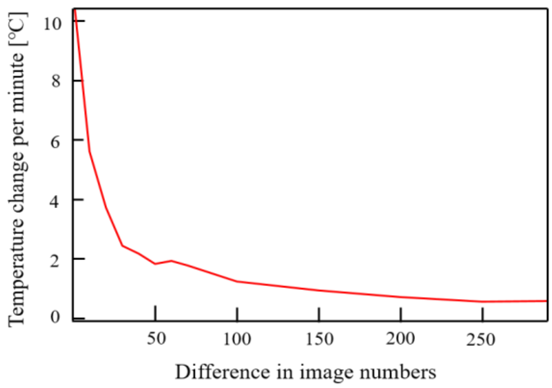

Fig. 3 A variation of the estimated temperature change in one minute as a function of the difference in image numbers.

5. Conclusion

We conducted UVC experiments using the TMM phantom and estimated that a time difference of about 1.5 seconds between paired images is appropriate when applying the UVC method to living body, in order to suppress the effects of overestimation of temperature change and heartbeat.

References

[1] H. Horinaka, T. Iwada, Y. Kanetaka, F. Ogushi, T. Matsuyama, K. Wada, T. Matsunaka, and Y. Cho: Jpn. J. Appl. Phys. **42** (2003) 3287.

[2] K. Mano, M. Sakai, S. Tanigawa, K. Wada, T. Matsunaka, and H. Horinaka: Electron. Lett. **51** (2015) 16.

[3] Y. Aotani, Y. Kumagai, M. Kameda, K. Wada, T. Matsunaka, H. Morikawa, and H. Horinaka: Jpn. J. Appl. Phys. **57** (2018) 07LF18.

[4] M. Kameda, Y. Inuzuka, T. Matsuyama, K. Wada, K. Okamoto, T. Matsunaka, and H. Horinaka: Jpn. J. Appl. Phys. **58** (2019) SGGE17.