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Ultrasonic velocity change imaging of blood vessels in the forearm of living body

生体前腕部血管の超音波速度変化イメージング

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1. Introduction

We have been investigating the application of the ultrasonic velocity change (UVC) method [1], which requires a change in the temperature of the target area, to noninvasively obtain information on the stability of carotid plaque [2,3]. Ultrasound heating is thought as a method to get temperature change. However, we have recently found that it is difficult to effectively warm plaques within the safety standards of ultrasound intensity because ultrasound wave radiated from the skin surface are absorbed by subcutaneous fat. We therefore propose a method to get temperature change by cooling the blood vessels around the plaque. Unfortunately, we have not yet acquired UVC images of the vessels. In this paper, we report the acquisition of UVC images of the forearm artery, which is relatively easy to measure because it is less affected by heartbeat.

2. UVC method

The UVC method is a method to identify the medium by using the fact that the temperature dependence of the ultrasonic velocity varies with the medium through which the ultrasonic wave propagates. Around body temperature, the rate of temperature change of ultrasonic velocity in water is +1.9 $\mathrm{m \cdot s^{-1} \cdot {}^\circ C^{-1}}$, and that in fat is -4.9 $\mathrm{m \cdot s^{-1} \cdot {}^\circ C^{-1}}$. This feature can be used to separate fat regions from water-rich muscle regions in living body. Specifically, a temperature change is applied to the target area in living body, and echo images are acquired before and after the temperature change. From echo signals constructing these images, the shift of the echo signal caused by the change in ultrasonic velocity is obtained to identify the fat area. If the fatty area in the vascular plaque is large (called unstable plaque), the vascular plaque will easily peel off and cause serious diseases such as cerebral infarction or myocardial infarction. Therefore, early detection of unstable plaque is critically important, and we believe that the UVC method can achieve this task non-invasively.

3. Experiment and data processing

As a preliminary step to depicting unstable plaque in this study, we applied the UVC method to measure the temperature change of the vessel. **Fig. 1** shows the experimental setup. A prepared ice pack was placed on the palm of the hand and cooled for 10 minutes. To avoid the effect of vascular contraction and expansion, 300 echo images of the arteries in the forearm were acquired in 9 seconds using an ultrasound system (ALOKA-SSD6500, linear transducer: center frequency of 13 MHz) while maintaining that state.

Any two images were selected as paired images from the obtained image data, and normalized cross-correlation (ZNCC) was applied to extract the paired images with high correlation. Then, the UVC method was applied to these images to obtain the phase shift due to temperature change. In order to eliminate the effects of heartbeat and hand motion, a threshold was set for the phase shift.

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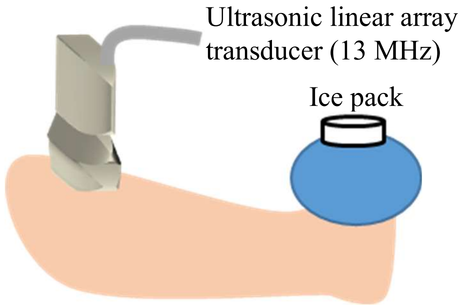

Fig. 1 Experimental

4. Results and Discussion

Fig. 2 shows an example of (a) the observed B-mode image and (b) the corresponding UVC image. The artery of the forearm is observed in the center of the B-mode image. For the UVC images, the image acquisition time difference between paired images was set to about 1.3 seconds to reflect the temperature change, and 33 UVC images were integrated. The reliability of the UVC images seemed to be high because there was not much difference in contrast between the individual UVC images.

In the UVC image, the region where the ultrasound velocity increases (decreases) with time between image pairs is depicted in red (blue). Since the arteries are watery regions, the ultrasound velocity becomes faster (slower) when the temperature rises (falls) around the body temperature. Therefore, the result in Fig. 2(b), where the arterial region is shown in blue, indicates that the arterial temperature has decreased. The rate of temperature change averaged in the artery is estimated to be -0.08°C/1.3 s.

In contrast, the most part of the regions around the arteries is shown in red, indicating that the temperature of the muscle parts (and veins) with high water content has increased due to heat exchange with the artery.

5. Conclusion

Our ultimate goal is to confirm the stability of the vascular plaque using the UVC method, and we proposed to give the temperature change of the target region necessary for the UVC method by cooling. In this study, we investigated the temperature change of the artery in the forearm using the UVC method. When the capillaries of the hand were cooled, the temperature of the arterial portion of the forearm decreased, while the temperature of the peripheral portion, such as the veins surrounding the arteries, increased. This is due to heat exchange between the juxtaposed veins and arteries.

In the carotid artery, since the veins and arteries are also juxtaposed, it is thought that a similar heat exchange can occur by devising a method to provide a temperature change. In the future, we will aim to acquire UVC images of vascular plaque by using the temperature change in such cases.

References

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

[2] S. Tanigawa, K. Mano, K. Wada, T. Matsunaka, and H. Horinaka: Opt. Rev. **23** (2016) 369.

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

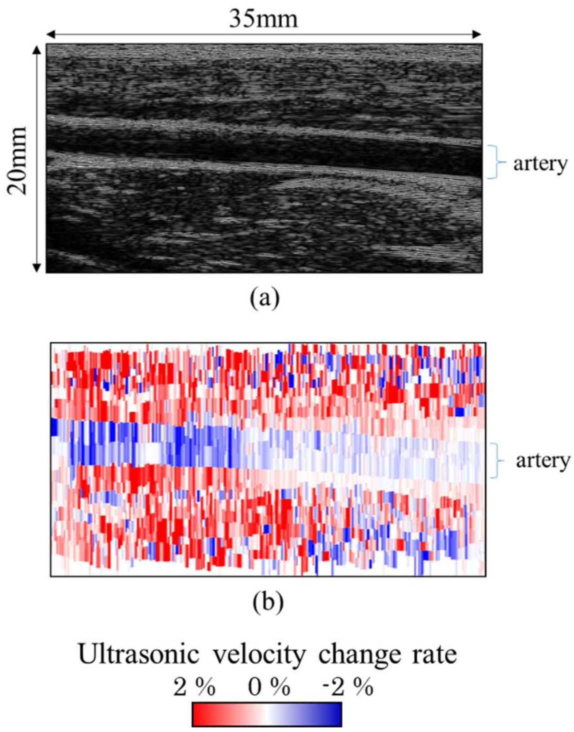

Fig. 2 (a) Observed B-mode image of the artery in the forearm and (b) the corresponding UVC image.