2P5-5

Detection of unstable vessel plaques using ultrasonic velocity-change imaging under cold exposure
冷却による超音波速度変化イメージングを用いた不安定血管プラークの検出

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1. Introduction

Vessel plaques are disease occurring in the lumen of a blood vessel due to a progress of atherosclerosis. The instability of the vessel plaques is thought to be related to the size and distribution of the lipid core in the plaques. The rupture of vessel plaques leads to brain or heart infarction. While currently available non-invasive diagnostic methods can image the structure of plaques, they have diffculty in imaging the property of plaques.

We have investigated a imaging method of unstable vessel plaques by using ultrasonic velocity-change:UVC. So far, we obtained the UVC image of tissue phantom by warming method. In this report, we describe the UVC imaging of unstable vessel plaques under cold exposure in consideration of the safety.

2. Ultrasonic velocity-change imaging

The temperature dependence of ultrasonic velocity depends on the medium where ultrasonic waves propagate. In water, the temperature change rate of ultrasonic velocity is +1.9 m/s/deg C around body temperature and that in fat is -4.9 m/s/deg C. Using this feature, lipid areas in vessel plaques can be determined by estimating ultrasonic velocity changes Δv before and after temperature change. Δv is calculated using the following equation,

$$\Delta v = (\Delta\tau / \tau) \cdot v \,, \qquad (1)$$

where v is the ultrasonic velocity in the tissue mimicking material:TMM(OST), τ is round-trip time of an echo signal before temperature change, and $\Delta\tau$ is the shift of the echo pulse in a round-trip time after the temperature change. The UVC image can be constructed from Δv of echo signals in every acoustic scan lines. It is possible to obtain a large temperature change in a short time using temperature relaxation after cold exposure.

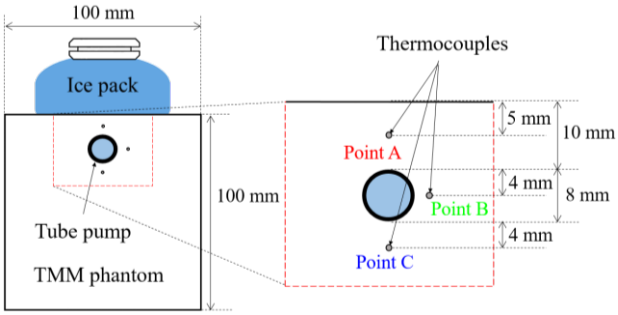

Fig. 1 Illustration of the TMM phantom including a through-hole. The placement of an ice pack for cold exposure and thermocouples for temperature-measuring are shown.

3. Temperature change under cold exposure

We conducted the experiments to investigate temperature change in the TMM phantom (100 × 100 × 100 mm) under cold exposure. Corresponding to carotid artery, a through-hole of 8 mm in diameter was drilled at the position of 14 mm from the top surface of the TMM phantom, as shown in **Fig. 1**. Thermocouples were placed at depths of 5 mm (Point A), 14 mm (Point B) and 22 mm (Point C), respectively. Water was shed in the through-hole using a tube pump. The flow rate was set to 400 mL/min, corresponding to blood flow. The phantom was cooled for 30 minutes using an ice pack, and was left for 30 minutes after removing the ice pack.

Figure 2 shows the experimental result of temperature changes in the phantom acquired every 5 seconds. The maximum temperature change was obtained as -8.5 deg C at Point A, -4.0 deg C at Point B, and -2.0 deg C at Point C, respectively. It is thus found that sufficient temperature change is obtained even at the place just below the through-hole. The temperature relaxation was clearly seen at all measuring points after removing the ice pack. This tendency of the temperature relaxation enables to obtain UVC images.

4. Detection of lipid areas in a carotid artery phantom

We made a carotid artery phantom using sheep and pig intestines. As shown in **Fig. 3**, a piece of fat and the sheep intestine was placed in the inferior portion of the through-hole, which was regarded as a lipid core of the plaque. Water was shed by connecting the termination of the pig intestine to the tube pump. In the experimental setup of **Fig. 4**, after cooling for 30 minutes, B-mode images were acquired with the ultrasonic array transducer (7.5 MHz) every 1 minute in a temperature relaxation process. **Figures 5** (a) and (b) show the B-mode images of the front and side views of the phantom, respectively. Although the phantom structure is observed, lipid areas (places surrounded by white dashed lines in B-mode images) are not identified. Figures 5 (c) and (d) show the corresponding UVC images of Figs.5 (a) and (b), respectively. The blue areas indicating the minus UVC rate correspond to lipid areas in the phantom.

5. Conclusions

In order to apply the UVC imaging under cold exposure to the detection of unstable vessel plaques, temperature changes of a carotid artery phantom just behind and after cold exposure were examined. As a result, the carotid artery phantom placed in the inferior portion of the through-hole was effectively cooled even under water flow in the through-hole. Therefore, lipid areas in the carotid artery phantom clearly identified by the UVC imaging.

However, since it seems that the effect of temperature relaxation due to blood flow is larger in the human body, verification by a living body is necessary to demonstrate the validity of UVC imaging for minute temperature change.

References

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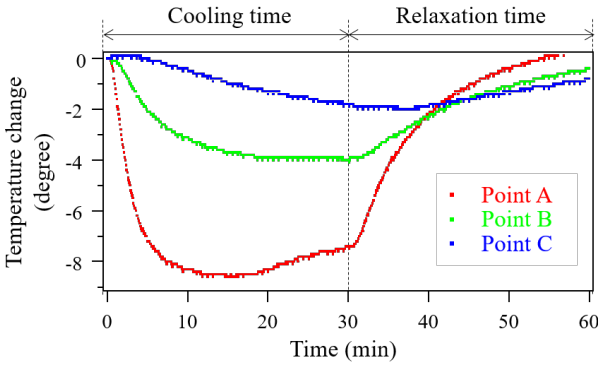

Fig. 2 Temperature changes in the TMM phantom under and after cold exposure.

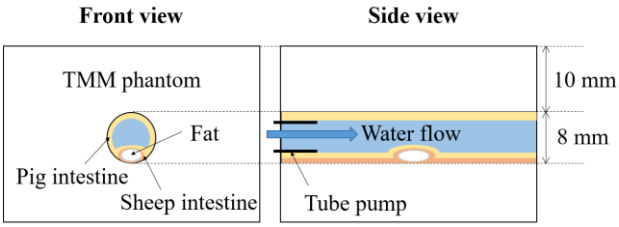

Fig. 3 Configuration of a carotid artery phantom.

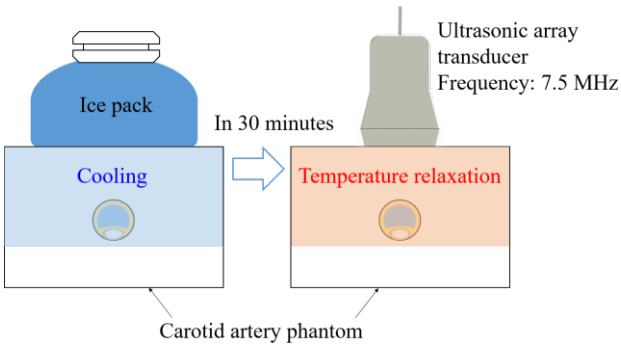

Fig. 4 Experimental setup to detect lipid areas in the carotid artery phantom.

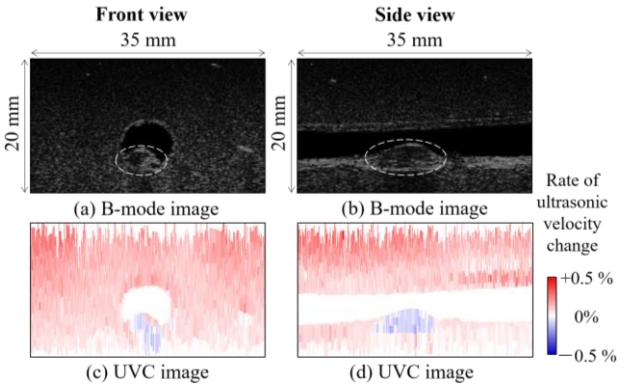

Fig.5 (a), (b) B-mode images and (c), (d) UVC images of the carotid artery phantom.