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Influence of heartbeat in the detection of unstable plaque using ultrasonic velocity-change method and its removal method

超音波速度変化法による不安定プラーク検出における拍動の影響とその除去方法

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1. Introduction

Vascular plaque is one of the symptoms of arteriosclerotic lesions. The instability of the vessel plaques is thought to be related to the size and distribution of the lipid core in the plaque. Especially fragile plaques, called unstable plaques, sometimes rupture. The rupture of unstable plaque causes serious diseases such as brain or heart infarction. Therefore, an effective method for detecting unstable plaque is desired. Although some detection methods using intravascular ultrasound (IVUS), optical tomographic interferometry (OCT) and MRI have already used, burdens on patient are large such as insertion of a catheter and administration of a contrast medium.

We have investigated a non-invasive method to identify an unstable plaque using the ultrasonic velocity-change (UVC) method. We succeeded in detecting the fat region in the carotid artery phantom. In this report, we discribe the method of removing the influence of noise due to vibration components such as pulsation.

2. UVC method

The temperature dependence of ultrasonic velocity depends on the medium where ultrasonic waves propagate. Around body temperature, the temperature change rate of ultrasonic velocity in water is +1.9 $m \cdot s^{-1} \cdot {}^{\circ}C^{-1}$ and that in fat is −4.9 $m \cdot s^{-1} \cdot {}^{\circ}C^{-1}$. Using this feature, lipid areas in vessel plaques can be detected. **Fig. 1** shows a tissue phantom including a fat region. By acquiring the echo signal before and after applying the temperature change to the tissue phantom, the fat region is specified from the shifts of the echo signals caused by the ultrasonic velocity change.

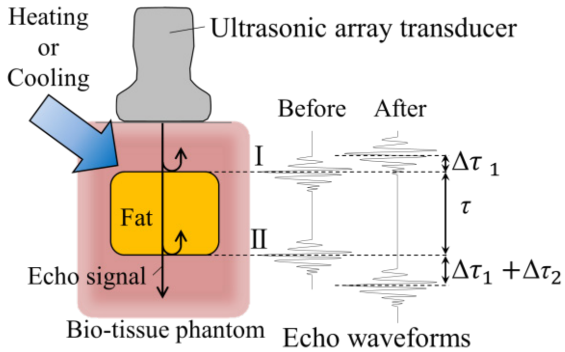

Fig. 1 Illustration of the UVC imaging method

3. Experiment and UVC calculation

We fabricated a carotid artery phantom from a tissue mimicking material (TMM, OST corp.), sheep and pig intestines, and a piece of fat, as shown in **Fig. 2**. A piece of fat wrapped with the sheep intestine was fixed 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 point of the pig intestine to a tube pump. The pseudo heartbeat (the flow rate of 500 mL/min and 50 strokes/min) was generated with a pulsatile blood pump (HARVARD).

Fig. 3a shows a brightness-mode (B-mode) image of the cross section of the carotid artery phantom. The motion-mode (M-mode) time series waveform observed in 0.3 seconds at the position of the white line in **Fig. 3a** is shown in **Fig. 3b**. The M-mode waveform is divided into 1000 time steps, forming 1000 echo signals. It is found that the echo signals are greatly disturbed in the presence of the pseudo heartbeat in Fig. 2b and those echo signals are not available in the UVC method. To extract the appropriate echo signal from the 1000 echo signals,

So, the disturbance must be removed. We devise a method to remove the influence of heartbeat by using M mode signal in UVC method. The correlation value is calculated at intervals of 100 for 1000 echo signals acquired in M mode signal , such as the 1st and 101th steps, 2nd and 102th steps, …, nth and n+100th steps. By choosing a waveform from a high correlation value portion with the 1st to 300th lines, it is possible to eliminate the influence of the pulsation.

After cooling for 30 minutes, echo signals were acquired with the ultrasonic array transducer (7.5 MHz) every 3 seconds in a temperature relaxation process. From the viewpoint of preventing noise caused by motion, the UVC should be calculated from the difference information as short as possible. Then, since the calculated ultrasonic velocity change is minute, it is difficult to identify the medium. Therefore, as shown in **Fig. 4**, the calculated data were displayed serially. $\Delta v/v$ is the rate of ultrasonic velocity change. The blue areas indicating the minus UVC rate correspond to lipid areas in the phantom.

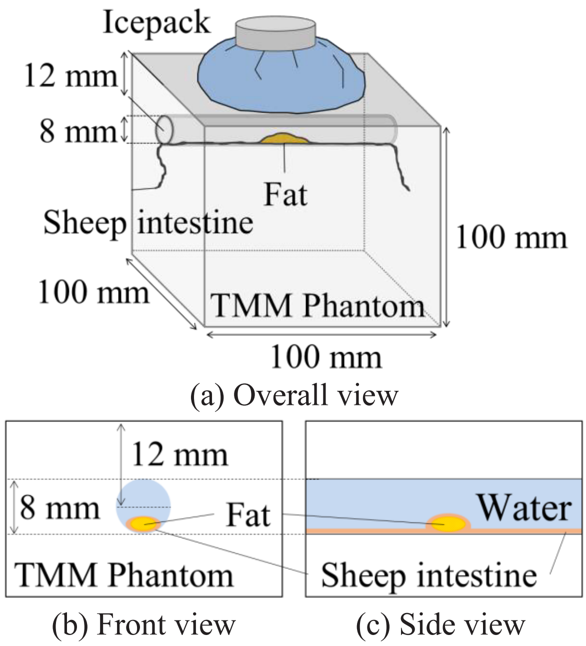

Fig. 2 Experimental setup for the detection of lipid areas inside the carotid artery phantom

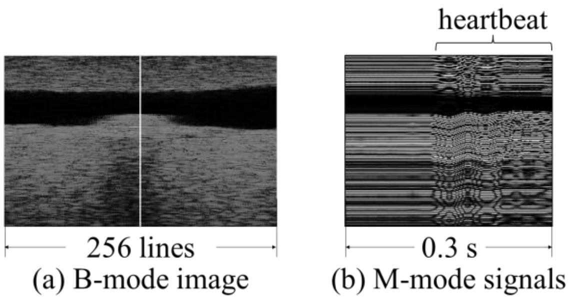

Fig. 3 Echo display modes

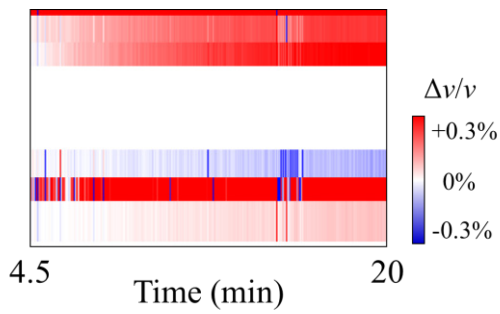

Fig. 4 UVC time series data

4. Conclusion

We examined a method for removing influences such as pulsation which is a problem when applying the UVC method to the living body. By using the M-mode signal to obtain UVC, fat area in a carotid artery phantom under the pseudo environment of heartbeat could be detected.

However, not only the influence of pulsation but also the movement of muscles of the human body are problems. For this reason, we need some ingenuity to improve the probe fixture.

References

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