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Measurement of temperature distribution in tissue equivalent phantom using ultrasonic velocity-change imaging
超音波速度変化イメージング法による生体擬似ファントム内の温度分布の測定

Kazune Mano†, Shohei Tanigawa, Kenji Wada, Toshiyuki Matsunaka , and Hiromichi Horinaka (University of Osaka Prefecture)
真野 和音†，谷川 昇平，和田 健司，松中 敏行，堀中 博道(大阪府立大学 工学研究科)

1. Introduction

It is very important to diagnose early stages of fatty liver which is the major marker linked to metabolic syndrome. However, ultrasonography and computed tomography are less effective for diagnosis of early stages fatty liver.[1] We already proposed the ultrasonic velocity-change imaging method to diagnose fatty liver by using the fact that the temperature dependence of ultrasonic velocity is quite different in water and in fat.[2,3] This method was applied to obtain velocity-change images of fatty livers of live rabbits, and we found that these imases ware related to the amount of accumulated fat in rabbit's livers.[4] To achieve the quantitative diagnosis of liver fat, we must know not only the ultrasonic velocity-change but also the temperature change in the measurement area. In this study, a measuring method of the temperature distribution at the necessary depth for human liver diagnosis was considered, and the method was applied to the tissue mimicking material (TMM) phantom with temperature distribution.

2. Ultrasonic Velocity-Change Imaging Method

The temperature dependence of ultrasonic velocity-change depends on the medium. The temperature change rate of the ultrasonic velocity in water is +1.9 m/s degree and that in fat is -4.9 m/s degree. As the temperature increases, the ultrasonic velocity increases in the body tissue with high percentage of water content and decreases in the fatty area. Therefore, it is thought that temperature dependence of ultrasonic velocity-change can be utilized for identification of the fat distribution in the living body.

The ultrasonic pulses emitted from the linear array transducer are reflected from the boundaries of different acoustic impedance of the medium. When the temperature of the medium is increased by ultrasonic irradiation, the echo pulses reflected at the boundaries shift owing to ultrasonic velocity change based on the temperature rise.

Fig. 1 shows the ultrasonic pulses reflected at the boundary I and the boundary II of body tissue. Then, the fatty area of tissue is warmed. The echo pulse from the boundary II is thought to be delayed by $\Delta\tau$ because the ultrasonic velocity decreases in the fatty area. The ultrasonic velocity-change Δv is determined from the shift $\Delta\tau$ of echo pulse. The ultrasonic velocity-change image is constructed from $\Delta\tau$ of echo signal correspond to every acoustic scan lines.

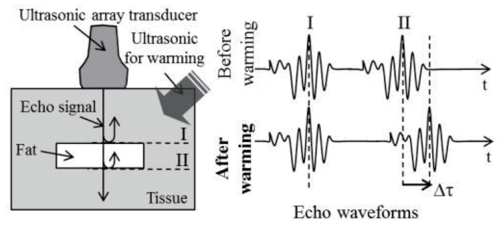

Fig.1 Principle of ultrasonic velocity-change imaging

3. Experimental System

Fig. 2 shows the experimental set-up to get ultrasonic velocity-change images of the TMM phantom. A 1 MHz ultrasonic transducer for warming the phantom was placed near the ultrasonic array transducer. The ultrasonic velocity-change imaging equipment consisted of diagnostic ultrasound equipment (ALOKA, ProSound II SSD 6500SV, 13MHz Probe), signal processing board and a personal computer.

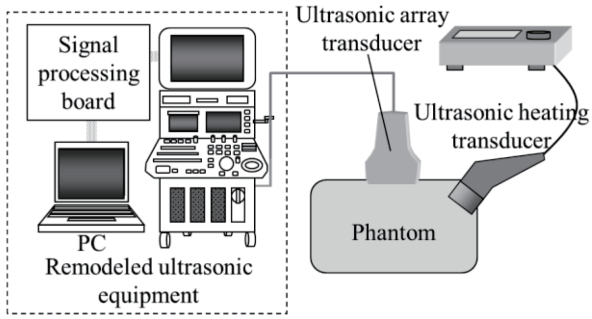

Fig.2 Experimental set-up for measuring the ultrasonic velocity-change image

4. Experimental Procedures

In cases where the ultrasonic velocity-change method is applied to a phantom known the amount of fat, we can evaluate the temperature changes induced by ultrasonic warming. In this experiment, TMM phantom (OST Co., Ltd.) whose ultrasonic attenuation coefficient is 0.6 dB/cm/MHz was used. The phantom was warmed for 60 s by ultrasonic transducer (Intensity: 1.0 W/cm^2) as shown in **Fig. 3**. Ultrasonic velocity-change images from 1 to 6 cm in depth were obtained by ultrasonic B-mode images before and after ultrasonic warming. Then, temperature changes in each depth were measured by a thermocouple. Using the values, the ultrasonic velocity-changes were converted to the temperature changes, and temperature distribution images in the phantom were obtained.

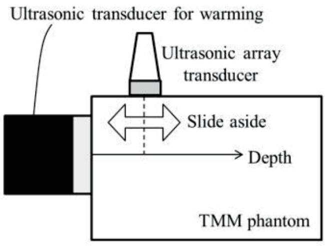

Fig.3 Layout of the transducers and the TMM phantom

4. Results

Figures 4(a) and (b) show the ultrasonic B-mode images and temperature distribution images in each depth, respectively. In Fig. 4(b), the warmed area in the phantom was two-dimensionally-measured.

The temperature changes in the phantom by ultrasonic warming was simulated with solutions of bioheat transfer equation. In Fig. 5, open circles show the simulation results, and filled circles show the experimental results at the dotted lines in Fig. 4(b). Fig. 5 indicated a comparison between the simulation and the experimental results.

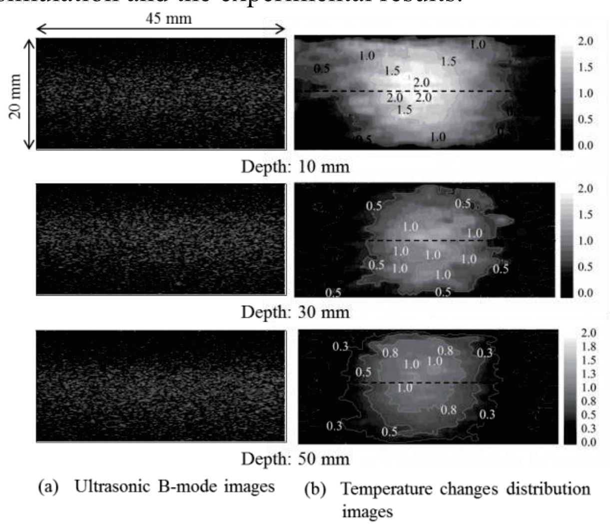

Fig.4 Ultrasonic B-mode images, and temperature changes distribution images of the TMM phantom

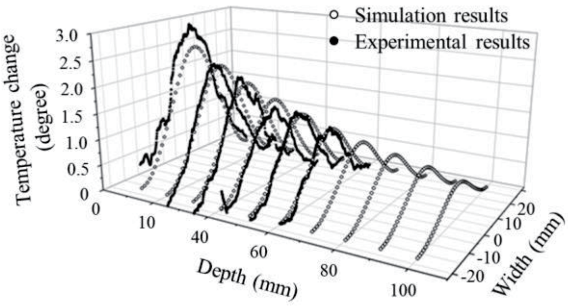

Fig.5 Experimental and simulation results of temperature changes in the TMM phantom

5. Conclusion

The temperature distributions at different depths in the TMM(Tissue Mimicking Material)phantom were obtained. Then, the temperature changes in the phantom were simulated, and the simulation results were in good agreement with the experimental results. In this way, it was thought that the temperature changes in living body may be calculable. The ultrasonic velocity-change method has the possibility as a useful method of quantitative measure of accumulated fat in the human liver.

Acknowledgment

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