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Ultrasonic Velocity-Change Images of Fatty Liver in Living Rabbit by Ultrasound Warming

超音波加温による生体兎の脂肪肝の超音波速度変化画像

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1. Introduction

Realization of the inexpensive diagnostic imaging equipment of visceral fat in the early stage has been eagerly desired because the visceral fat often results in significant impairment of health. Now, only MRS (magnetic resonance spectroscopy) can quantify the level of fat accumulation at an early stage. However, MRS is not suitable equipment for daily clinical practice because it is very expensive and large-scale.

It has been known that ultrasonic velocity of each biological tissue shows the different temperature dependence. Therefore, the fat distribution in living body may be identified using temperature dependence of ultrasonic velocity in biological tissue.

We already proposed the new imaging method using ultrasonic velocity-change caused by the light illumination or the ultrasonic irradiation [1-3]. In this study, we tried to quantify the level of fat accumulation in livers of living rabbits using the ultrasonic velocity-change imaging method. The ultrasonic transducer was employed to warm livers of rabbits instead of light irradiation because the ultrasonic wave could reach to deep-lying tissue beneath the body surface. Experimental results suggest feasibility of noninvasive and portable imaging equipment for diagnosis of visceral fat.

2. Principle of ultrasonic velocity-change imaging

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. The round trip time τ of the echo pulse between boundaries and its time difference are denoted by τ and $\Delta\tau$, respectively. The velocity change Δv of the warming region is represented by

$$\Delta v = v\frac{\Delta\tau}{\tau},$$ where v is the ultrasonic velocity.

The ultrasonic velocity-change image is constructed from $\Delta\tau$ and τ of echo signal correspond to every acoustic scan lines.

The temperature change rate of the ultrasonic velocity in water is +3.6 m/s degree and that in fat is -5.0 m/s degree around body temperature. The ultrasonic velocity increases in muscle and internal organs with high percentage of water content and decreases in fat.

3. Experimental set-up

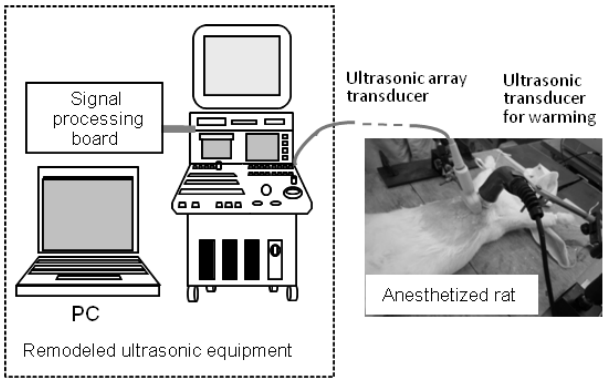

Fig.1 Experimental set-up this imaging method

Figure 1 shows the experimental set-up to get ultrasonic velocity-change images of fat in livers of living rabbits. The ultrasonic transducer for warming is attached near by the ultrasonic array transducer.

4. Experiments

The special phantom was prepared to confirm the verification of ultrasonic velocity-change images by ultrasonic warming. Figure 2 (a) shows the structure of phantoms made of the chicken meat including three fat layers. The normal B-mode image and the ultrasonic velocity-change image were obtained. The fat distribution area is not indentified in the B-mode image shown in Fig. 2 (b). Ultrasonic velocity-change image was constructed from RF echo data acquired before and after

ultrasound warming. Figure 2 (c) shows ultrasonic velocity-change images; the upper figure shows the image focused on the area of only positive Δv and the lower figure shows the image focused on the area of only negative Δv. The negative Δv area corresponds to the fat layers in the chicken meat.

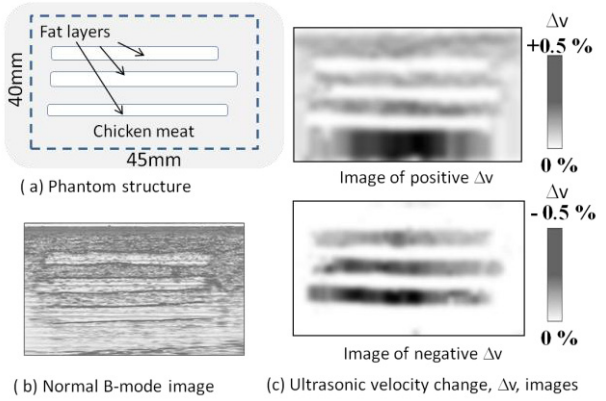

Fig.2 Phantom structure (a), B-mode image (b) and ultrasonic velocity change-images (c)

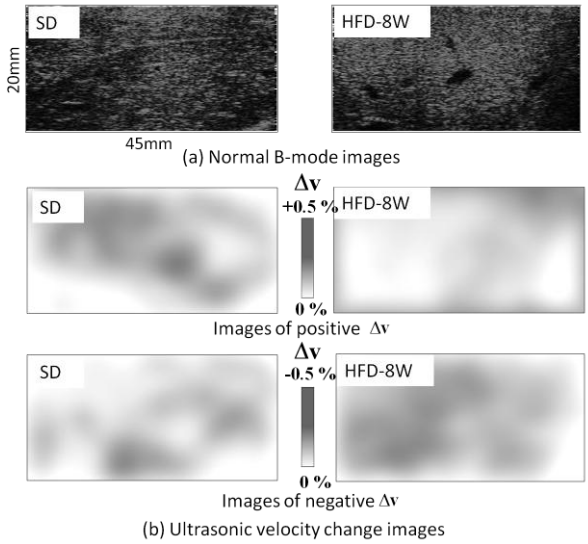

Fig.3 Normal B-mode images (a) and the ultrasonic velocity-change images (b) of livers in living rabbits fed on the standard diet (SD) and the high fat diet for 8 weeks (HFD-8W).

We used two groups of rabbits to characterize livers of living rabbits. One group is fed on the standard diet and the other group is fed on the high fat diet. Ultrasonic echo RF signals from the liver of rabbits under anesthesia were detected by the ultrasonic array transducer before and after ultrasound warming

The ultrasound irradiation time was 20s and the irradiation acoustic power was 1W/cm^2 within the sufficient safety. The normal B-mode images and the ultrasonic velocity-change images were constructed from the RF data.

Figure 3 (a) show the normal B-mode images of rabbits fed on the standard diet (SD) and the high fat diet for 8weeks (HFD-8W). The difference between two normal B-mode images is not be distinguished. Figure 3 (b) shows ultrasonic velocity-change images corresponding to rabbits of SD and HFD-8W. These images were displayed in similar manner shown in Figure 2(c).The sign and the amount of Δv give the information about fat content rate in the rabbit liver. The negative Δv area is dominant in HFD-8W.

Figure 4 shows the histogram of Δv in the ultrasonic velocity change images measured on rabbits fed on the standard died, the high fat diet for 3 weeks, 6weeks and 8weeks, individually. The peak value of these histogram Δv_c in Fig.4 shifts toward the left side. This means that the fat rate of rabbit livers increases as the feeding period.

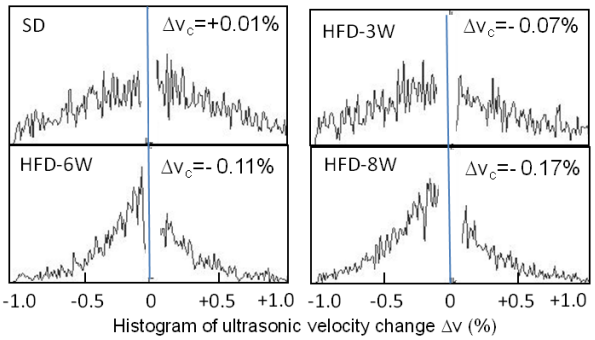

Fig.4 Histogram of Δv in ultrasonic velocity images of living rabbits fed on the standard diet (SD) and the high fat diet for 3weeks (HFD-3W), 6weeks (HFD-6W) and 8weeks (HFD-8W).

5. Conclusion

Noninvasive imaging method by detection of ultrasonic velocity change using ultrasound warming was studied for diagnosis of visceral fat. It is confirmed that the ultrasonic velocity-change images reflect the fat accumulation level in liver of rabbit fed on the standard diet and that on the high fat diet. The ultrasonic velocity-change imaging method has the possibility of application to the quantitative diagnostic monitor of fat accumulation level in a living human lever

Acknowledgment

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References

1. H. Horinaka, T. Matsunaka et al.: Jpn. J. Appl. Phys, **41** (2002) 3555
2. H. Horinaka, T. Matsunaka et al.:Jpn. J. Appl. Phys., 45, 5B, 4761-4763 (2006)
3. H. Horinaka, T. Matsunaka et al. : Electronics Letters, **43** (2007) 1254-1255