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Investigation on quantitative assessment of fat content in human liver using acoustic velocity-change
超音波速度変化を用いた肝臓内脂肪量の定量的評価法に関する検討

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1. Introduction

The fatty liver is an illness caused by excess accumulation of fat in the human liver. It is very important to diagnose early stage of fatty liver, because it is the major marker linked to metabolic syndrome. Unfortunately, existing ultrasonography and computed tomography are less effective for diagnosis of early stage of fatty liver. 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.[1)] We have showed that the ultrasonic velocity-change image displayed the fat distribution in living rabbits and tissue mimic phantoms.

For diagnosis of fatty liver stages, this paper is an attempt to assess quantitatively fat content in human liver using ultrasonic velocity-change. We performed two experiments. One is about an effective warming way, the other is about asssessment of different fat content in the fatty liver phantom.

2. Quantitative assessment of fat content by ultrasonic velocity-change imaging method

Fig.1 shows the ultrasonic velocity-change imaging system. The echo waveforms are obtained by ultrasonic array transducer and are stored in the personal computer. The low frequency ultrasonic transducer is employed to warm the sample.

The ultrasonic velocity change Δv by the temperature change ΔT is represented as follows,

$$\Delta v / \Delta T = (\Delta v / \Delta T)_w \cdot x + (\Delta v / \Delta T)_f (1 - x) \quad ,$$

where x is the fat content, $(\Delta v/\Delta T)_w$ is the temperature dependence of ultrasonic velocity in water and $(\Delta v/\Delta T)_f$ is that in fat.

The value of ΔT is required for quantitative assessment of fat content ae well as Δv.

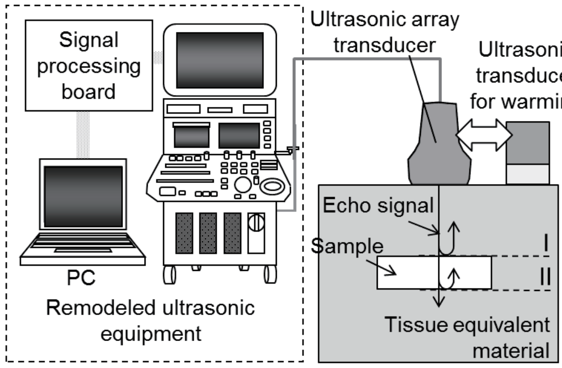

Fig.1 Ultrasonic velocity-change imaing system for quantitative assessment of fat content

3. Experiments

3-1. Flat temperature change distribution in the biological tissue phatom

We investigated formation of flat temperature change by controlling the convergence of ultrasonic transducer for warming. Fig.2(a) shows the experimental set-up to measure the temperature distribution in the phantom. In this experiment, the tissue mimicking material (TMM) phantom (OST Co., Ltd.) whose ultrasonic attenuation coefficient is 0.7 dB/cm/MHz was used. The TMM phantom was warmed by ultrasonic transduser (US-711, ITO Co., Ltd.) . The waveforms of echo signal from the phantom were obtained by ultrasonic array transducer, and the ultrasonic velocity-change was calculated. The ultrasonic velocity-change was converted to the temperature change using the temperature change rate of the ultrasonic velocity (+1.6m/s/degree) in the TMM phantom. Thus, the temperature change distribution in the warming area were obtained. The warming time was 60s and the intensity of the ultrasoic transducer for warming was 1.0 W/cm^2.

Fig.2 shows the temperature change distribution by the warming ultrasonic transducer with or without the acoustic lens (focal length 90mm).

When the acoustic lens was used, the deep area of phantom was warmed effectively. Fig.3 shows the experimental results of temperature profiles along the dotted lines in Fig.2(b). When the phantom was warmed by the ultrasonic transducer without the lens, the temperature change decreased as a function of distance from the transducer. On the other hand, when the phantom was warmed by the transducer with the lens (focal length 90mm), the temperature change increased by conversing acoustic power with the lens.

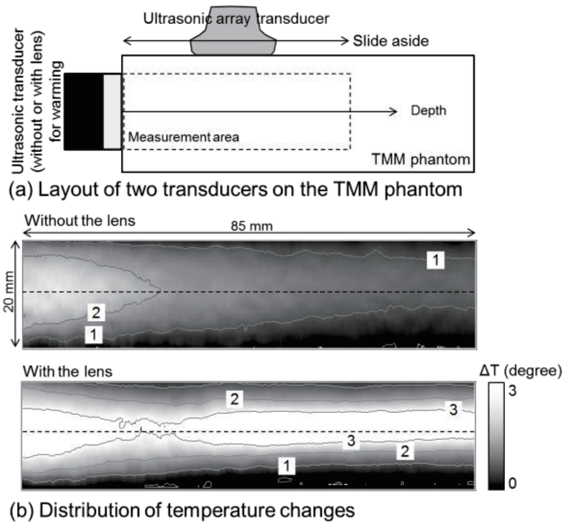

Fig.2 Temperature change distribution obtained by ultrasonic warming

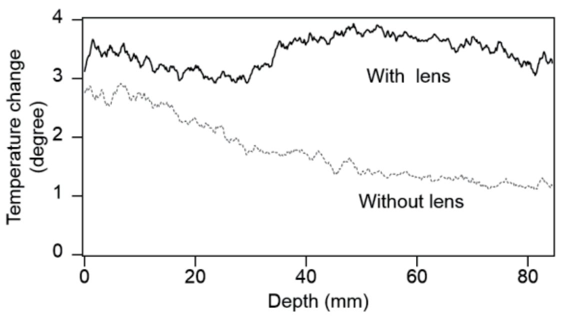

Fig.3 Profiles of temperature change in the phantom along the dotted lines in Fig.2(b)

3-2. Ultrasonic velocity-change images of fat area under flat tenperature change distribution

The measurement system in Fig.1 was used to obtain ultrasonic velocity-change images of the TMM phantoms including fat area. The acoustic lens with 90mm focal length was used to get the flat temperature change distribution. The fatty liver phantom of fat content of 10%, 20%, 30% were inserted into the TMM phantom at the depth of 70mm from the surface. The ultrasonic velocity-change values at fat area correspond to the fat content as shown in Fig.4.

The fat liver phantoms of 30% were inserted into the TMM phantom at 35mm, 50mm and 70mm form the surface, individually. The ultrasonic velocity values are almost independent of the depth from the surface.

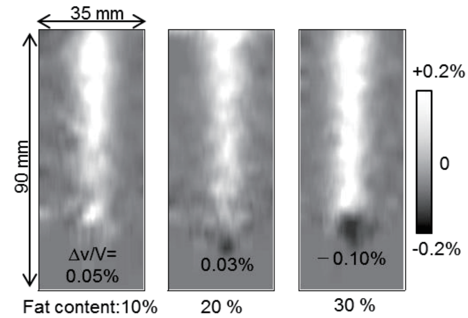

Fig.4 Ultrasonic velocity-change images of tissue phantom including areas with fat content 10%, 20% and 30%, individually.

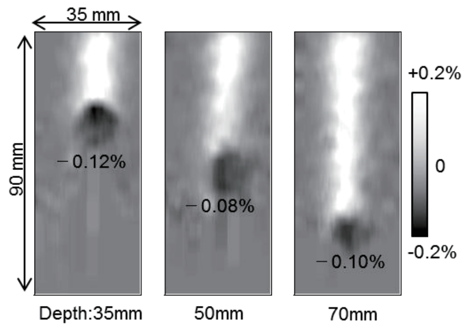

Fig.5 Ultrasonic velocity-change images of tissue phantom including fat areas (fat content of 30%) located at 30mm, 45mm and 70mm in depth from the surface, individually..

4. Conclusion

By compensating the diffusional attenuation of the warming transducer using an acoustic lens, it was possible to achieve the flat temperature change along depth direction in the tissue mimic phantom. It was confirmed that ultrasonic velocity- changes correspond to fat content in the region of flat temperature change of phantom. Experimental results showed the possibility of fatty liver quantitative assessment by ultrasound velocity-change imaging method.

References

1) H.Horinaka et al.:Proc. IEEE Ultasonics Symp. 2010 pp.1416-1419 (2010)