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Application of Ultrasonic Velocity-Change Imaging for Diagnosis of Visceral Fat

内臓脂肪診断のための超音波速度変化映像法の応用

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1. Introduction

Obesity, a growing epidemic in mature societies, is an excess of body fat that often results in significant impairment of health. Therefore, development of the noninvasive diagnostic equipment for imaging visceral fat in the early stage has been expected. Now, only MRS (magnetic resonance spectroscopy) can quantify level of fat at an early stage. However, MRS is not suitable equipment for daily clinical practice because it is very expensive and large-scale.

We have proposed “Optically Assisted Ultrasonic Velocity-Change Imaging Method” to display the optical absorption area in biological tissue by detecting the ultrasonic velocity change due to light illumination. [1)] Basic experiments have been made to develop the drug distribution monitor for Drug Delivery System.[2,3)] We found that the ultrasonic velocity change by temperature is utilized to characterize the biological tissue because it is different by biological material.

“Optically Assisted Ultrasonic Velocity Change Imaging Method” has been applied to diagnosis the visceral fat. It was succeeded that the fat distribution was imaged in tissue mimic phantoms and extracted fat levers of rabbit by this method. However, the depth of measurement was limited within 2 or 3cm because of optical absorption and scattering of biological tissue.

In this study, we intend to develop the medical equipment which applies to diagnoses the lever located in the deep portion of abdomen. The tissue mimic phantom including fat area was warmed by ultrasonic transducer. The feasibility of non-invasive and portable equipment for diagnosis of visceral fat is shown from the experimental results.

2. Principle of ultrasonic velocity-change image

The ultrasonic pulses emitted from the linear array transducer are reflected from the boundaries of different acoustic impedance in the phantom. When the temperature 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 Δτ, respectively. The velocity change Δv of the light absorption region is represented by

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

The waveform of echo signal correspond to every acoustic scan line was divided into appropriate sections with the width of transmitted pulse. The cross-correlation between the corresponding section of the waveform data stored before and after ultrasonic warming was calculated to obtain the time difference Δτ of the echo signal shift induced by temperature rise. The ultrasonic velocity-change image is constructed from Δτ and τ of echo signal correspond to every acoustic scan lines.

The ultrasonic velocity in water and fat was measured around the body temperature. As shown in Fig.1, 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. The ultrasonic velocity increases in muscle and internal organs with high percentage of water content and decreases in fat. It is thought that temperature dependence of ultrasonic velocity change is useful for identification of the fat distribution in the living body.

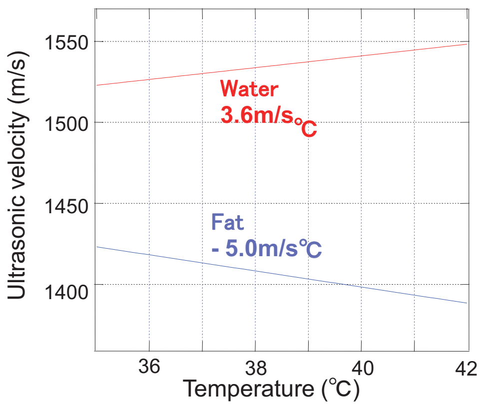

Fig.1 Ultrasonic velocity in water and fat as a function of temperature

3. Experimental set-up

The ultrasonic transducer was employed for warming instead of infrared light source used in previous our experimental set-up for optically assisted ultrasonic velocity-change imaging. Figure 2 shows the experimental set-up. The ultrasonic transducer for warming is attached near by the ultrasonic array transducer for imaging.

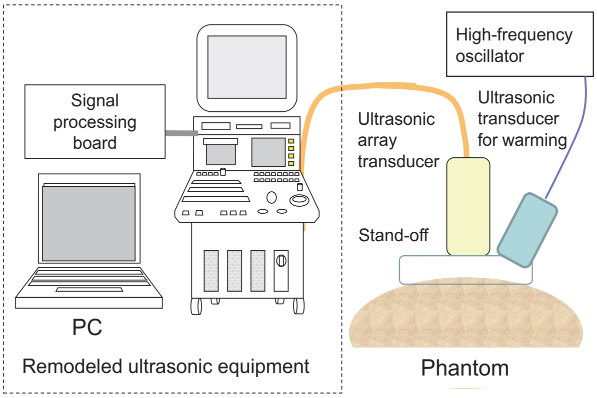

Fig.2 Experimental set-up this imaging method

The temperature change by ultrasonic warming was measured in the water and the chicken meat. Figure 3 shows measured results of temperature change as a distance from the ultrasonic transducer (2MHz) under the driving voltage of 20V. The width of warming area was about 3cm. It was shown that the deep portion could be heated by the ultrasonic transducer.

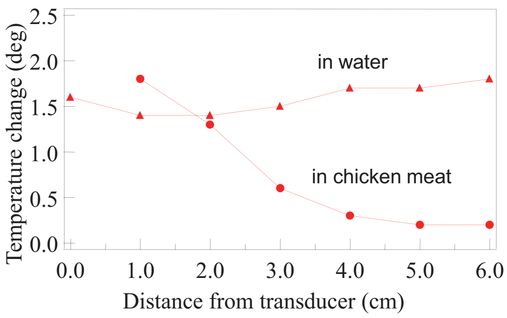

Fig.3 Temperature change by ultrasonic warming in water and chicken meat

4. Experiments

The special phantom was prepared to confirm the identification of ultrasonic velocity-change images by ultrasonic warming. Figure 4 (a) shows the structure of the phantom. Fat layers were inserted into the chicken meat and the agar filled up the circumference of the chicken meat. The fat layer is located at about 35mm in the depth from the surface. The normal B-mode image and the ultrasonic velocity-change image were obtained. The display area is 45mm (width) x 40mm (depth). The fat distribution area is not indentified in the B-mode image shown in Fig. 4 (b). Ultrasonic velocity -change image was constructed from RF echo data acquired before and after ultrasonic warming. Figure 4 (c) shows the gray scale image of the ultrasonic velocity change obtained by ultrasonic warming (exposure time 60s). The gray scale bar on the right side of Fig. 4 (c) shows the ultrasonic velocity change rate. White portion which means decrease in ultrasonic velocity shows fat areas. Fat areas of white portions in Fig. 4 (c) are clearly distinguished.

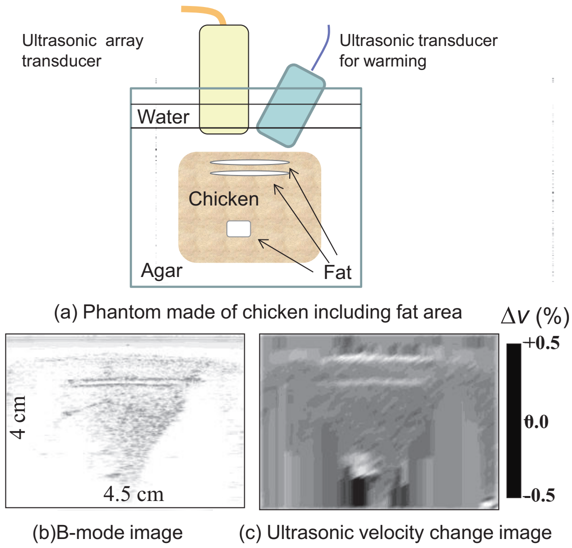

Fig.4 Phantom structure (a), B-mode image (b) and ultrasonic velocity change-image (c)

5. Conclusion

Noninvasive imaging method by detection of ultrasonic velocity change was studied for diagnosis of visceral fat. Ultrasonic warming was applied to construct the ultrasonic velocity -change image of the phantom including fat layers. Experimental results show the possibility of applying this imaging method to diagnosis of human visceral fat.

Acknowledgment

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