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A trial of human bone cross-sectional imaging *in vivo*, using ultrasonic echo waves
超音波エコー波による生体の骨断層画像の試み

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1. Introduction

The ultrasonic diagnostic systems for *in vivo* tissues are widely used. Imaging has become possible by the echo waves from the boundaries of different acoustic impedance. However, the internal imaging of bone is still very difficult, because the transmission loss of ultrasound is greater at the boundary between the soft tissue and the bone. The internal imaging of bone *in vivo* is possible by using the Magnetic Resonance Imaging system (MRI) or X-ray Computed Tomography (CT), but if it is realized by ultrasound, the real time and simple diagnosis is possible.

The authors have developed an ultrasonic bone densitometer LD-100 (OYO Electric) based on the principle of ultrasonic two wave phenomenon (fast and slow waves) in the cancellous bone. The densitometer has been used for the evaluation of the radius bone of the wrist in clinical practice[1)].

In this study, we have tried internal imaging of the distal forearm bone by the echo waves making use of the LD-100 system.

2. Methods

The experimental system of LD-100 was used. A pair of focused ultrasonic transducers was arranged in the water tank and the wrist of male volunteer aged 30's was set between the transducers. The echo waves were observed at palm side and back side of the forearm. The measurement sites were 5.5% and 20% from the distal end of the forearm. The transducers measured echo waves at 57 points while moving straight from the thumb side to little finger side at intervals of 1 mm. Then the echo images were created. One cycle square wave (0.25 microsecond width, 50 volts) was applied to the transducers. In addition, the same sites of the same subject were measured by X-ray CT system (Densiscan 1000: SCANCO MEDICAL, voxel size: 0.332 mm). Identification of the bone structure by ultrasonic echo images was performed by comparing the images to the X-ray CT images.

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3. Results and discussion

3.1. Identification of the cortical bone

At 5.5% site, the ultrasonic echo images (**Fig. 1**) were compared to the X-ray CT image (**Fig. 2**). In Fig. 1, the cortical bone "A" at back side and the cortical bone "B" at palm side can be identified. Not only outside line but also inside line of the cortical bone "A" can be identified (Fig. 1(1)). The line of the cortical bone "B" is not clear (Fig. 1(2)). The reason of the unclear line seems that the echo waves reached to the transducer little because the incident angle of the echo waves to the cortical bone surface was not vertical, and then the arrival times of echo waves were not unique.

At 20% site, the ultrasonic echo images (**Fig. 3**) were compared to the X-ray CT image (**Fig. 4**). In the echo image of back side, the outside line and the inside line of the cortical bone "C" and the inside line of the cortical bone "D", total 3 lines, can be identified (Fig. 3(1)). In the echo image of palm side, not only 3 lines but also the deeper outside line of the cortical bone "C", total 4 lines, can be identified (Fig. 3(2)). The reason of these 3 or 4 lines seems that the arrival times of the echo waves were unique because the incident angles of echo waves to the cortical bone surface were almost vertical. This was realized because of the circular cross section and the constant diameter at 20 % site. The other reason seems that the echo waves reached deeper tissue because of few cancellous bone responsible for the small attenuation of echo waves.

3.2. Waveform

In **Fig. 5**, the echo waveform close to vertical incidence at 20 % of palm side is shown. The wave reflected at the inside interface of the cortical bone "D" has reverse polarity to the wave reflected at the outside interface of the cortical bone "D" and the wave reflected at the inside interface of the cortical bone "C". This is caused by the negative reflection coefficient of the boundary. Between the wave reflected at inside interface of the cortical bone "D" and the wave reflected at inside interface of the cortical bone "C", the multiple reflection of the cortical bone "D" and the information of the cancellous bone are included.

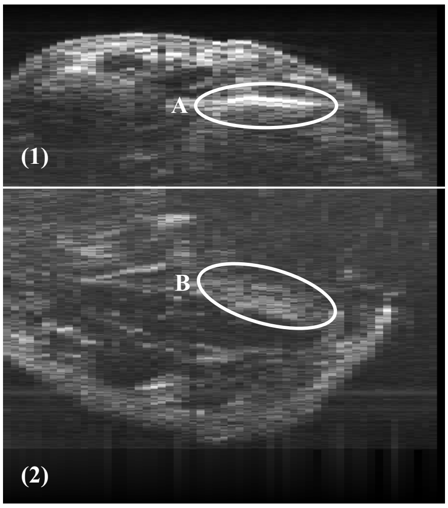

Fig.1 Echo images of ultrasound at 5.5 % site from distal forearm
(1)back side (2)palm side

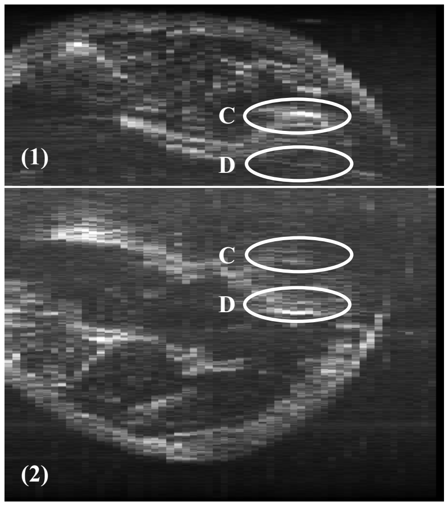

Fig.3 Echo images of ultrasound at 20 % site from distal forearm
(1)back side (2)palm side

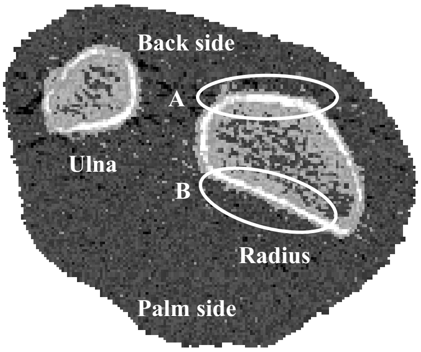

Fig.2 Cross-sectional image of X-ray CT at 5.5 % site of distal forearm

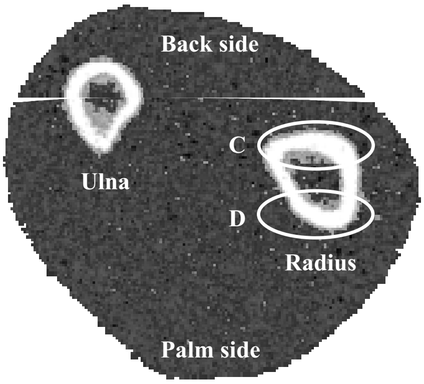

Fig.4 Cross-sectional image of X-ray CT at 20 % site of distal forearm

The waveform amplitudes in the area "P" and "Q" are larger than noise level. They seem to reflect scattering from thin cancellous inside layers which can be identified near the cortical bone "C" and "D" in Fig. 4.

Conclusions

From the echo wave which entered vertically to the bone surface, the outside and the inside surfaces of the cortical bone were identified. In order to realize human bone cross-sectional imaging *in vivo* by ultrasonic wave, the ultrasonic technique of the vertical incidence to the bone surface is required in the future. Furthermore, if an array type transducer is adopted and bone cross-sectional imaging *in vivo* is carried out in real time, it will be useful for the clinical practice, such as fracture treatment.

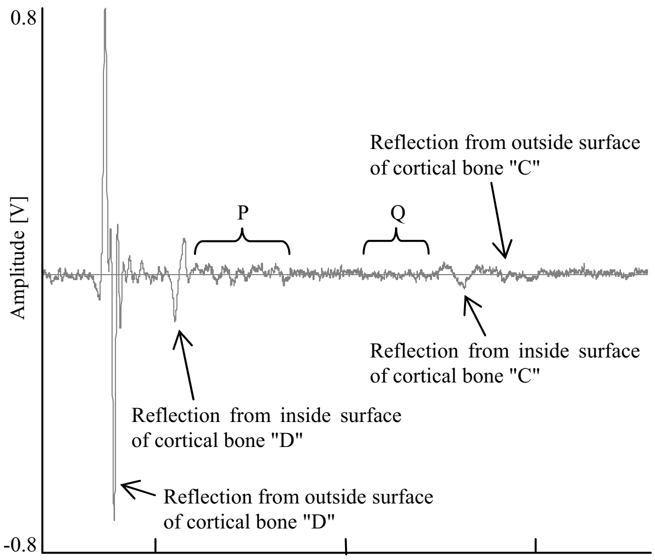

Fig.5 Echo waveform to the palm side at 20 % site

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References

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