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Behaviour of Ultrasonic Wave Propagation in Human Body – Investigation of Experimental and Simulated Data using 3-D Elastic Human Model

人体内を伝搬する超音波の挙動 ～ 実測と３次元モデルシミュレーションによる検討

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1. Backgrounds and Objectives

There are many previous studies about numerical simulations focusing on specific area of human body [1-7]. As comparative studies between simulations and experimental measurements, our group has also worked on behaviours of ultrasonic waves in cortical bones, cancellous bones, bone marrows [1-5], and sound distributions in human heads [6,7]. Nagatani *et al*. constructed a digital model for acoustic simulation including whole body [8], however, the reliability of the simulation results was not confirmed because the data was not supported by the experimental observation.

If the reliability of the acoustic simulation system including whole body was confirmed, the model would be an useful tool in medical, welfare, and engineering fields: e.g. giving us new point of view and validating safeness on developing new medical equipments, diagnosis simulators for young doctors etc.

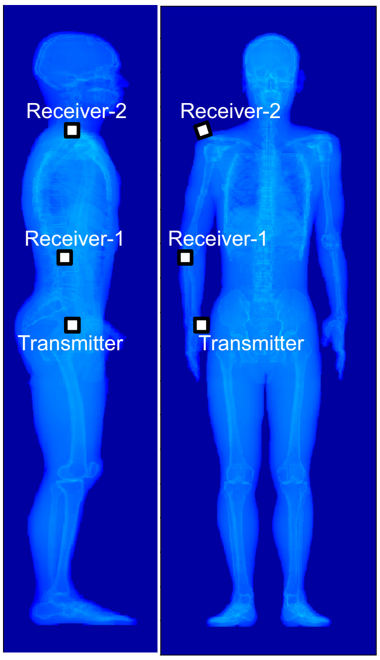

Figure 1: Simulation model and transducer setup. The brightness indicates the acoustic impedance of the model and square icons indicates the points where transducers were set. (Transmitter: Palm, Receiver-1: Elbow, Receiver-2: Shoulder)

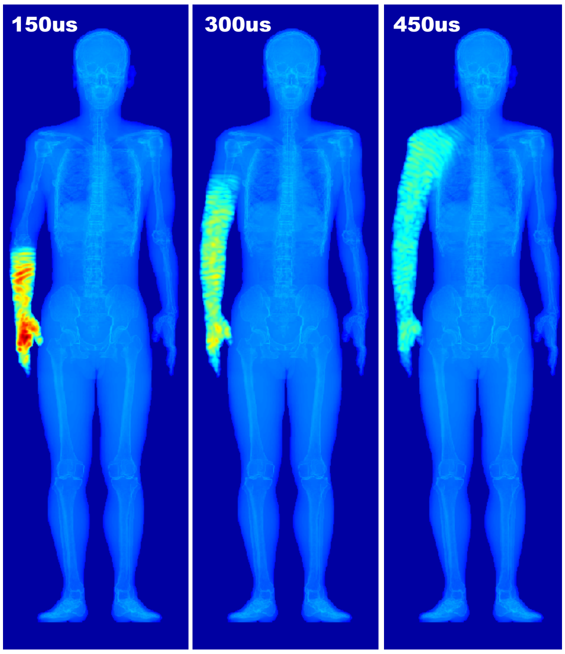

Figure 2: Screen shots of the simulation data at (a) 150μs, (b) 300μs, and (c) 450μs. The brightness of the images indicates the sound pressure (or stress in elastic media). The complex propagation behaviour can be seen.

Therefore, the comparative study of simulation and experimental measurement of the ultrasonic wave propagation in human body was investigated in this study.

2. FDTD Simulation

As a model, the male data in the “Realistic High-Resolution Whole-Body Voxel Models” constructed by Nagaoka *et al.* was used [9]. The model describes consisting tissues of normal Japanese person with the resolution of 2 mm.

Using the model, elastic properties of the tissues are assigned to water, fat, cortical bone, bone marrow, and air [8]. The elastic coefficients and attenuation of cortical bone and bone marrow used are experimentally measured values [3-5].

As an initial waveform, a single sinusoidal pulse at 1 MHz was virtually impressed to the palm as shown in **Fig. 1**. The wave propagation was calculated by three-dimensional elastic FDTD (finite-difference time-domain) method developed by our group.

Figures 2 show the screenshots of the simulated data. The brightness of the images indicates the sound pressure (or stress in elastic media). The complex propagation can be seen. After propagating along the arm as an "acoustic tube", the soundwave expands to the chest and neck part.

3. Experimental Measurement

In order to confirm the reliability of the simulation system, the ultrasonics wave propagation in human body was experimentally observed. In this study, three participants (Japanese male, 27.3±4.5 years old, 167.7±0.5cm tall) were employed.

Similar to the simulation condition, a single pulse at 30 kHz was impressed to the palm, and the vibration of the skin at elbow and shoulder part was observed. As a transmitter and receiver, ceramic piezoelectric transducer, whose resonance frequency was about 40kHz, were used.

4. Results and Discussions

An example of the received waveform and simulated waveforms at elbow and shoulder point are shown in Figs. 2. The long-tail behaviour of the experimental data comes from the resonance of the transducer.

In Fig. 2(a), the arrival times seem to be similar and two groups of waves can be seen both in measured and simulated waveforms. The arrival time at elbow and shoulder are shown in **Table I**. Although the measured times were faster than simulation data at both positions, the values were quite simular. This tells us the possibility of the experimental measurement of the ultrasonics wave propagation in human body and the reliability of the simulation system.

The first arrival wave at wavefront part are considered coming from the propagation via bone area in arm (i.e. ulna or radius), however, more precise investigations are required.

5. Conclusions

In this study, the comparative study of simulation and experimental measurement of the ultrasonic wave propagation in human body was investigated. In response to the wave transmission to the palm, the arrival time at elbow and shoulder part showed similar value in measured and simulated data. The precise investigations are required as the future work.

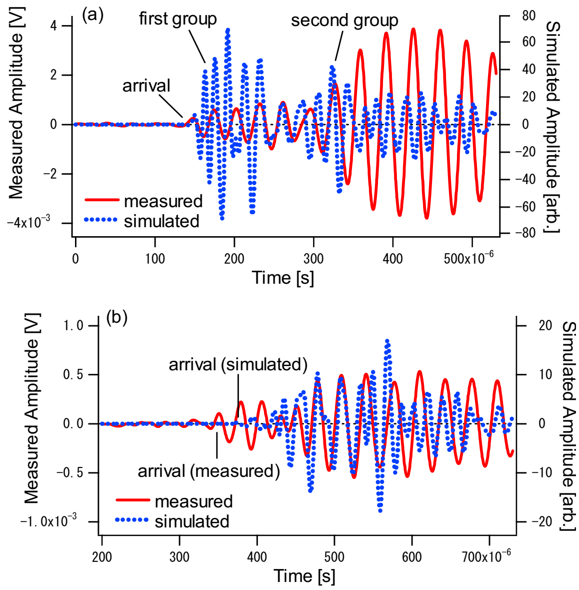

Figure 2: Examples of experimentally measured waveforms and simulated waveforms. (a) at elbow (receiver-1 in Fig. 1) and (b) at shoulder (receiver-2).

Table I: The arrival time of received/simulated waveforms. The experimental data shows the mean value and standard deviation of three participants.

	Elbow	Shoulder
Experimental Measurement	134.3±11.4 μs	349.6±24.6 μs
Simulation	137.0 μs	359.4 μs

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