# 1P5-5

## Relationship between spatial distribution of intrahepatic tissues and analytical conditions for shear wave velocity evaluation

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### 1. Introduction

Shear wave elastography (SWE) is a diagnostic method that non-invasively measures the stiffness of living organs and is expected to be applied to fatty liver. However, it has been suggested that differences in the evaluation of shear wave velocity (SWV) may differ because of differences in the algorithm used for analysis and the complexity of the tissue structure, and there is a possibility that the acoustic radiation force (ARF) may not be input as expected[1)].

In this study, shear waves propagating in the liver including fat droplets were simulated by the elastic finite difference time domain (FDTD) method[2)] under transmission conditions mimicking distribution of acoustic radiation force in a clinical diagnostic system. The relationship between microstructure and SWV evaluation was verified by changing the analytical conditions of the SWV evaluation.

### 2. Method

### 2.1 Simulation

As shown in **Fig. 1**, push pulses were sent from the top of the simulation space to reproduce the ARF excitation and the shear wave propagation in the Lateral direction in the space using the elastic FDTD method. The focus of the push pulses was 35 mm in the depth of the simulation space (60 mm × 70 mm; 1 pixel = 10 µm). The irradiation conditions of the push pulses were simulated using a diagnostic ultrasound system (LOGIQ S8, GE Healthcare) and a linear probe (9L-D, GE Healthcare), and the irradiation time was 570 µs. In the analysis area of the simulation space, spatial models (5 mm × 5 mm) based on the fatty liver model created from the pathology images were placed as shown in **Fig. 2**, with the fat droplet proportions of 10 and 30%. For computational reasons, the average size of fat droplets is assumed to be about 80 µm. The SWV values for liver tissue and fat droplets were set to 2 m/s and 1 m/s, respectively. To eliminate unwanted reflections from the edges of the simulation space, Beneger's absorbing boundary condition was used.

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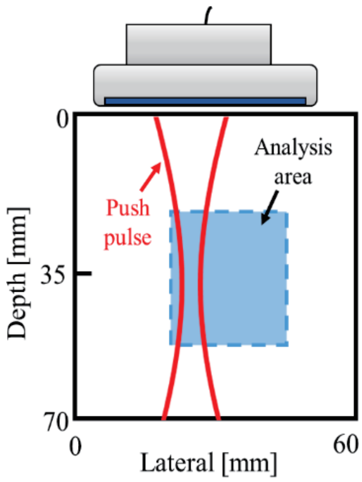


Fig. 1 Schematic images of simulation spaces

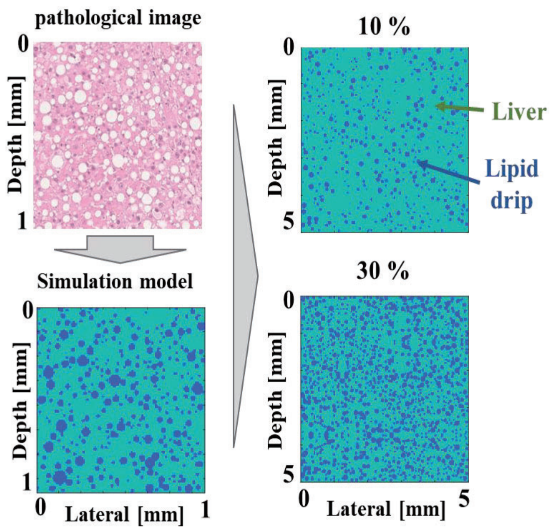


Fig. 2 Simulation model mimicked fatty liver

### 2.2 SWV evaluation

The propagation time difference $\tau$ of the shear wave was calculated by cross-correlation method in the time waveforms of two points on the spatial grid located in the lateral direction. The cross-correlation function $R(\tau)$ was calculated as where the $v_1$ and $v_2$ are the time waveforms of the

$$R(\tau) = \int v_1(t) \cdot v_2(t + \tau)\, dt \qquad (1)$$

particle velocities in the depth direction at two points in the lateral direction, respectively. The shear wave propagation time difference $\tau$ is the time when $R(\tau)$ is maximum.

The SWV was calculated as

$$\mathrm{SWV}(x, y) = \frac{\Delta x}{\tau} \tag{2}$$

where the propagation time difference $\tau$ and the distance $\Delta x$ between the spatial grids between two adjacent points[3]. In this study, it was verified the relationship between the resolution of SWV evaluation and microstructure by changing the $\Delta x$ as 10, 100 and 300 µm.

## 3. Results

**Figure 3(i)** shows the wavefronts of shear waves propagating at 0.5 ms intervals from 4.5 ms to 10 ms after the ARF was applied. At the boundary of fat droplets, the shear wave is affected by scattering and refraction, which causes disturbance to the wavefront of the shear wave. As the percentage of fat droplets increases, the disturbance of the wavefront of the shear wave increases and the wavefront interval gets closer.

**Figures 3(ii)** ~**(iv)** show the results of SWV evaluation at 10, 100 and 300 µm resolution, respectively. In **Fig. 3(iii)** and **(iv)**, the SWV evaluation is stable, and the SWV evaluation results decrease consistently with the increase in fat mass. This is because when the resolution of SWV evaluation is sufficiently detailed, the effect of fat droplets can be traced, but when the resolution of SWV evaluation is coarse, only the smoothed results are obtained. In actual clinical applications, smoothed results were calculated for SWV evaluation of fatty liver, which suggests that SWV evaluation may be able to estimate the average percentage of fat content in the liver.

## 4. Conclusion

The FDTD simulation results showed that the shear wave propagation becomes more complicated as the fat mass increases, and the SWV evaluation results varied, but it was confirmed that the SWV evaluation results were smoothed by coarsening the resolution of the SWV evaluation and that the evaluation results were stable. The effect of the ARF not being irradiated as expected was also examined, and it was shown that the evaluation performance may be decreased in this case as well.

**Acknowledgment**

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## References

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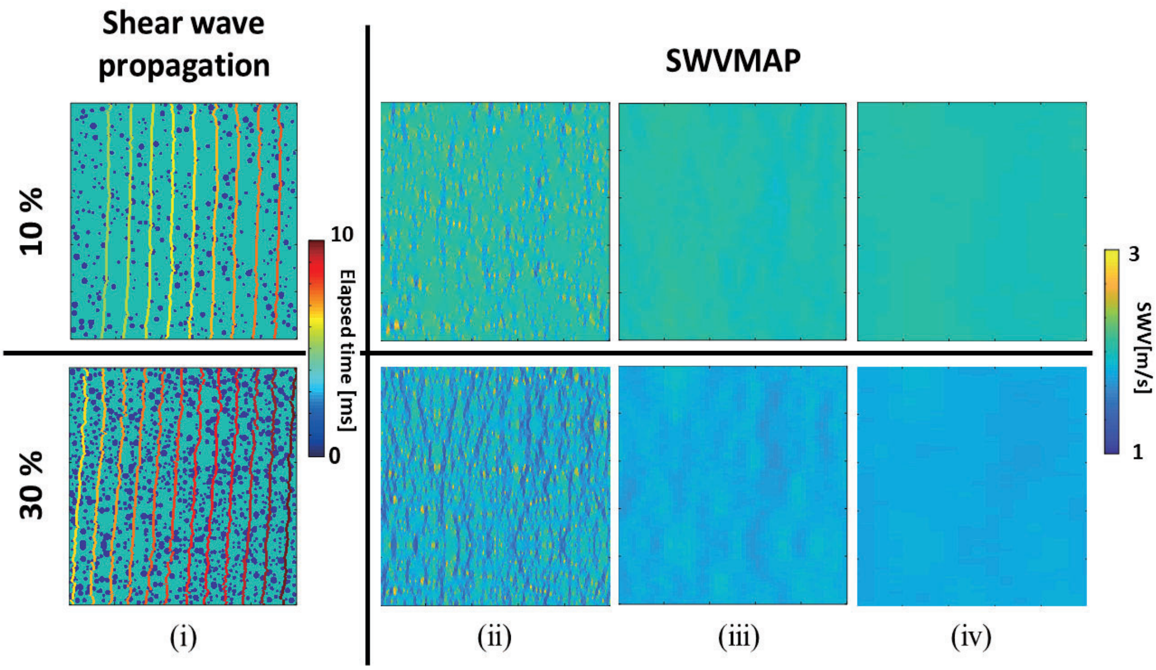


Fig. 3 Simulation results of shear wave propagation in livers with different fat mass.