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Basic investigation on identification of tissue composition based on propagation speeds of longitudinal and shear waves

縦波とせん断波の伝搬速度に基づく組織組成識別の基礎検討

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1. Introduction

The elastic modulus of tissue as a useful index for disease detection can be quantitatively evaluated based on the shear wave speed (SWS) measured on the shear wave elastography. In addition, the longitudinal wave speed (LWS) has been also expected to be a promising index for disease detection, but the influence of elasticity may not be always dominant because the LWS is affected by the bulk modulus, water content and molecular level factors. That is, the LWS and SWS may reflect different properties each other, and the simultaneous measurement of both speeds may be useful for identifying tissue compositions. Therefore, in this study, the relationship between ultrasonically measured LWS and SWS and the compositions of phantoms mixing the ultrapure water with agar and glycerin was investigated.

2. Materials and Methods

Three cubic homogeneous phantoms (80 mm x 80 mm x 80 mm) based on combinations of agar with 1.3 and 2.1 weight percent concentration (wt%) and glycerin with 0 and 20 wt% were prepared as shown in the following #1 to #3. Here, 0.4 wt% polyethylene powder was uniformly mixed in all phantoms as scatterers.

#1: (Agar, Glycerin) = (1.3 wt%, 0 wt%)
#2: (Agar, Glycerin) = (2.1 wt%, 0 wt%)
#3: (Agar, Glycerin) = (1.3 wt%, 20 wt%)

Figure 1 shows a setup of phantom experiment for the measurements of LWS and SWS. A prepared homogeneous phantom was placed on an absorber plate with a thickness of 10 mm, and a linear array probe (L7-4, Philips) for measuring the LWS and SWS was attached on the top surface of the phantom. To emit the push pulse for the SWS measurement and collect data for the LWS and SWS measurements, a research platform (Vantage 64LE, Verasonics) was used.

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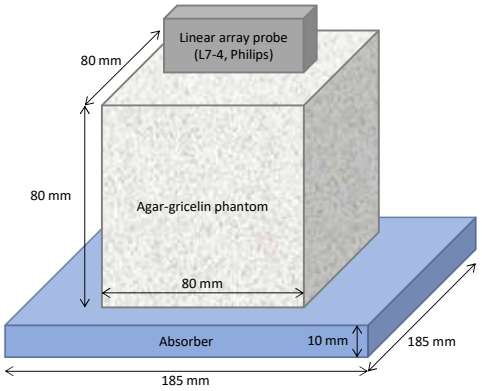

Fig. 1 A setup of phantom experiment for the measurements of LWS and SWS.

First, the SWS measurements were conducted. A single push pulse with a frequency of 5.2 MHz and a focal depth of 15 mm was radiated and then the plane waves for measuring the local particle displacement were transmitted. After the shear wave propagation was visualized, the speed of the shear wave propagating in the lateral direction around the focal point of push pulse was measured by the time of flight (TOF) method. Figure 2(a) shows the tracking result of the peak position of the shear wave amplitude in each frame, and the slope of each plot corresponds to the SWS.

Next, a wire with a diameter of 0.65 mm, which is made of the phosphor bronze plated with nickel, was embedded at a depth of 20 mm from the top of the phantom, and the LWS was measured by the Focusing method[1)] using channel data of backscattered waves. Figure 2(b) shows the amplitude profile based on the aperture synthesis compensated by the delay time involving each test LWS, and the peak position in each plot corresponds to the estimated value of LWS.

After measuring the LWS and SWS as described above, the effects of the weight concentration of agar on the LWS and SWS measurements were investigated based on the combination of #1 and #2. Similarly, the effects of the weight concentration of glycerin on the LWS

and SWS measurements were investigated based on the combination of #1 and #3. The temperature inside the phantom was 17 °C when the LWS and SWS measurements were conducted.

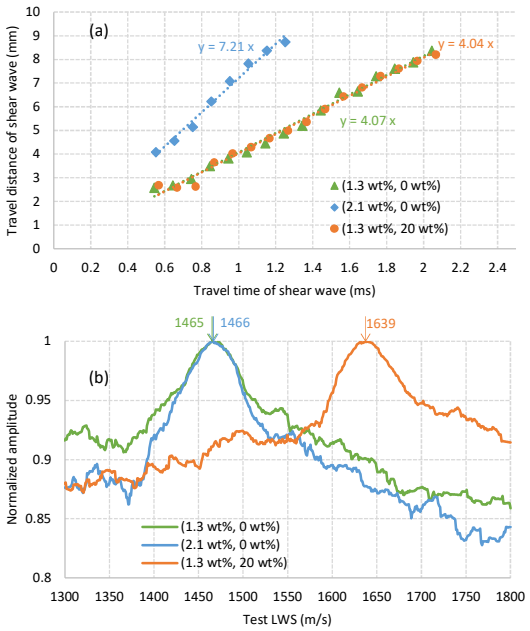

Fig. 2 (a) SWS measurement based on the time of flight of shear wave. (b) LWS measurement based on the Focusing method using channel data of backscattered waves.

3. Results

The results of the measured LWS and SWS are shown in Fig. 3. Each measurement was repeated 6 times and the mean and standard deviation were calculated. Figures 3(a) and 3(b) show the effects of the weight concentration of agar on the results of LWS and SWS measurement, based on the combination of #1 and #2. As is well known, the SWS increased when the agar concentration increased. Therefore, there was a significant difference of SWSs between 1.3 wt% and 2.1 wt%. On the other hand, there was no significant difference in the results of the LWS measurement. This might be affected by the measurement accuracy of the Focusing method. Meanwhile, the measured LWS values were reliable and close to the LWS of water at 17 °C.

Figures 3(c) and 3(d) show the effects of the weight concentration of glycerin on the results of LWS and SWS measurement, based on the combination of #1 and #3. There was no significant difference of SWSs between 0 wt% and 20 wt%. This tendency was the same in the results of Young's modulus measured by the mechanical compression test. On the other hand, there was a significant difference of LWSs between 0 wt% and 20 wt%.

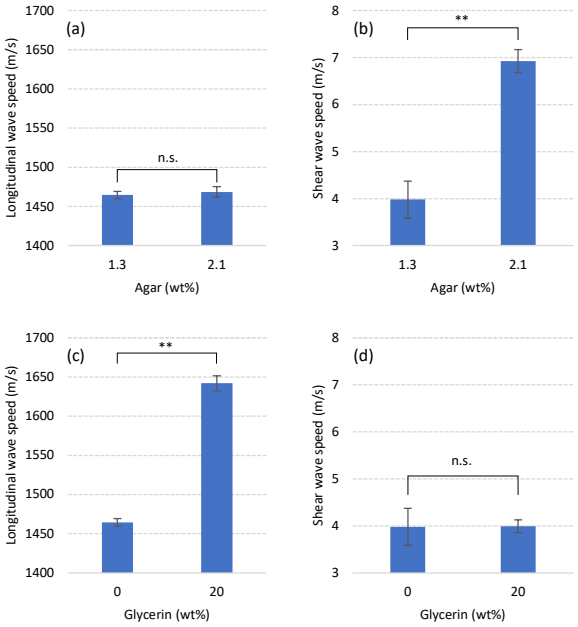

Fig. 3 Results of LWS and SWS measurements. (a) and (b) show the effects of agar concentration on the results of LWS and SWS, respectively. (c) and (d) show the effects of glycerin concentration on the results of LWS and SWS, respectively.

4. Conclusion

In summary, although the LWS measured in this study could not significantly discriminate the difference in the weight concentration of agar, the LWS could significantly discriminate the difference in the weight concentration of glycerin. Conversely, although the SWS measured in this study was able to significantly discriminate the difference in the weight concentration of agar, the SWS could not significantly difference in the weight concentrations of glycerin. Although it should be noted that these results depend on the measurement accuracy of LWS and SWS, these results also suggest that the ultrasonically measured LWS and SWS may reflect different tissue compositions or physical-chemical properties. Consequently, it can be suggested that the simultaneous measurement of both LWS and SWS may help identify tissue composition.

Acknowledgment

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References

1. N. Nitta et al.: Jpn. J. Appl. Phys. 60 (2021) SDDE18.