3P5-15

Verification of influence of push pulse irradiation condition on shear wave propagation by actual measurement of phantoms

プッシュパルスの照射条件がせん断波伝播に与える影響の実測検証

Minoru Ito[1†], Daiki Ito[1], Masashi Usumura[1], Takuma Oguri[1,2], Kenji Yoshida[3], Mikio Suga[3], Tadashi Yamaguchi[3] ([1]Grad.School Sci. and Eng., Chiba Univ., [2]Ultrasound General Imaging, GE Healthcare,[3]Center for Frontier Medical Engineering, Chiba Univ.)

伊藤 稔[†], 伊藤 大貴 [1], 碓村 将志 [1],大栗 拓真 [1,2],吉田 憲司 [3] ,菅 幹生 [3] ,山口 匡 [3] ([1] 千葉大院 融合理工,[2]GE ヘルスケア・ジャパン 超音波製品開発部,[3] 千葉大 CFME)

1. Introduction

In Shear wave elastography （SWE）, probe pressure has been shown to adversely affect the reliability of SWE results[1]. Studies on increasing probe pressure on organs located on the surface, such as the breast and thyroid, have reported increased SWE results[2]. SWV changes can be thought of as changes in material composition due to probe pressure. Also, the strain caused by the stress applied to the tissue material can vary depending on the initial strain state of the material and can affect the SWV depending on elasticity of material. Thus, we investigated the effect of the stress change in phantom due to the probe pressure and observed the state of shear wave propagation when the phantom had a different composition.

2. Methods

2.1 Data acquisition of phantoms

The target objects were self-made phantoms. One was a uniform phantom (Phantom A) with SWV: of 2.4 m/s and the other was a phantom (Phantom B) containing circular inclusions harder than their surroundings. The size of circular inclusions was 10 mm and the embedded depth was 23 mm. For the data acquisition of phantoms, we used clinical US scanner Logic S8 and Linear array probe 9L4 (GE Healthcare). A region of interest with 20×18 mm^2 was set at depth of 10-30 mm.

The Phantom A was evaluated with different probe pressure in the situation of simply put on the desk. Then the phantom was placed in a beaker to prevent deformation and evaluated again. The probe was placed perpendicular to the phantom while changing the push-in distance. The Phantom B was evaluated only in relatively less stress condition (not placed in the beaker) with different probe pressure. The push-in distances were 0 mm and0.6 mm (e.g., < 0.3 mm in a typical 30 mm thick breast), and the pressures in each case of push-in distance were (a) 0 kPa and (b) 15-20 kPa, respectively.

2.2 Estimation methods of shear wave propagation and SWV[3]

When the ultrasonic RF signals between two consecutive frames are $rf_1(t')$, $rf_2(t')$, and IQ signals obtained by orthogonal detection of these RF signals are $I_1(t') + Q_1(t')$ and$I_2(t') + Q_2(t')$, the phase difference $\Delta\phi(t')$ between the two frames is calculated from

$$\Delta\phi(t') = tan^{-1}\left(\frac{I_1(t')Q_2(t') - Q_1(t')I_2(t')}{I_1(t')I_2(t') + Q_1(t')Q_2(t')}\right), \quad (1)$$

where the time (t') corresponds to the coordinate in the depth direction and can be converted to the depth assuming the speed of sound of longitudinal wave is 1540 m/s. Using this phase difference, the particle velocity $v(t')$ is calculated from

$$v(t') = \frac{c_1 \Delta\phi(t')}{2\omega_0 \Delta t}. \quad (2)$$

By performing this calculation over the entire measurement range and changing the two frames used in the calculation in sequence, the time variation of the particle velocity distribution can be evaluated.

The propagation of shear wave between two points (x_1 and x_2) on the lateral direction was investigated by cross-correlation $R(\tau)$ of particle velocities v_1 and v_2 at the points, described as

$$R(\tau) = \int v_1(t) v_2(t+\tau) dt. \quad (3)$$

The value of τ where the cross-correlation function $R(\tau)$ is maximized is defined as the propagation time (t_{12}).

$$t_{12} = arg_\tau \max R(\tau) \quad (4)$$

The transverse component c_s of the shear wave velocity propagating between the two points is calculated from

$$c_s = \frac{d}{t_{12}}. \qquad (5)$$

3. Results

Figures 1 and **2** shows the shear wave propagation in Phantom A under no suppressing and suppressing the deformation of the phantom, respectively. Frame acquisition time is displayed on the figure. In Fig. 1, the respective SWV were 2.48 ± 0.6 m/s in (a) 0 kPa, 2.47 ± 0.52 m/s in (b) 15-20 kPa. The effects of the prove pressure on the shear wave propagation and SWV could not be confirmed. In Fig. 2, the amplitude of the shear wave propagation was confirmed to change slightly by increasing the pressure. The SWV is 2.53 ± 0.73 m/s in (a) 0 kPa, 2.55 ± 0.74 m/s in (b) 15-20 kPa.

Figure 3 shows the shear wave propagation in Phantom B. It was found that the shear wave propagated at the depth of 23 mm faster than the other part. This portion agreed with the portion where the circular inclusions was embedded. As well as Phantom A, the effect of the probe pressure on shear wave propagation could not be confirmed.

4. Discussion

Under suppressing the deformation of the phantom, the amplitude of the shear wave propagation was changed slightly by increasing the pressure. The values of SWV were higher compared with less stress condition in all probe pressure conditions. This may be due to an increase in stress due to the probe pressure.

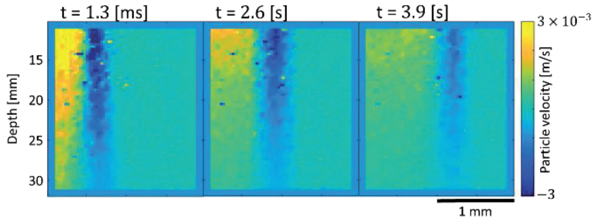
5. Summary

The effect on shear wave propagation was observed only when the material density increased. However, if this is thought to affect the SWV change, further investigation is necessary, such as more increasing the probe pressure or using a phantom with a different composition. In addition, organs have different structures and environments compared to phantoms, so these must be considered.

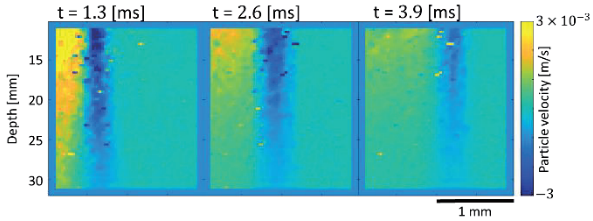
Acknowledgment
This work was conducted as part of the activities of the JSUM SWE Standardization Subcommittee and JRS J-QIBA.

References

1. M. Byenfeldt, A. Elvin et al., Ultrasound Med Biol, 44 (2018), pp. 1606-1615
2. R.G. Barr, Z. Zhang, Ultrasound Med, 31 (2012), pp. 895-902
3. M. Yamakawa, MEDICAL IMAGING TECHNOLOGY Vol.32, No.2, 2014

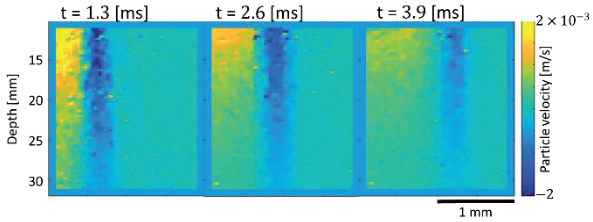


(a) 0 kPa

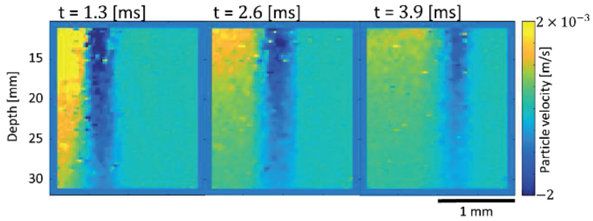


(b) 15-20 kPa

Fig.1 Shear wave propagation (Phantom A)

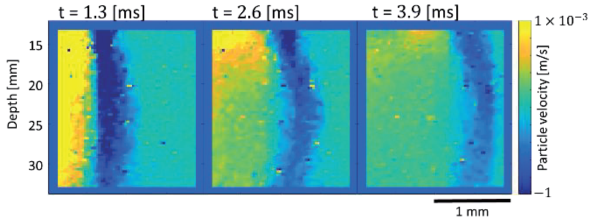


(a) 0 kPa

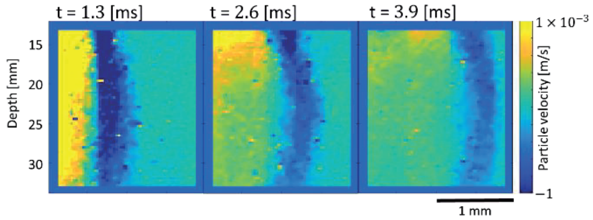


(b) 15-20 kPa

Fig.2 Shear wave propagation (Phantom A) where the deformation of the phantom due to the probe pressure is suppreesed.



(a) 0 kPa



(b) 15-20 kPa

Fig.3 Shear wave propagation (Phantom B)