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Study of acquisition method of ultrasound image for expansion of measurable region in MBE-SWE

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1. Introduction

Metabolic dysfunction-associated steatohepatitis (MASH) carries a high risk of progressing to cirrhosis or hepatocellular carcinoma. Liver fibrosis in MASH is the most significant prognostic indicator. Therefore, a minimally invasive and accurate diagnostic method for liver fibrosis is desired. One of the quantitative diagnostic methods is shear wave elastography (SWE). In SWE, the (static) liver stiffness can be quantitatively and non-invasively estimated based on the shear wave speed (SWS) within the liver. However, the SWS actually shows frequency dispersion due to the viscosity of the liver. In this study, we have proposed mechanical burst excitation SWE (MBE-SWE) which can measure SWSs at various frequencies [1]. The dynamic viscoelasticity of liver can be estimated based on the frequency characteristics of SWS.

2. MBE-SWE

The measurement setup for MBE-SWE is illustrated in **Fig. 1**. The object's surface is vibrated through the longitudinal motion of the vibration shanker. The frequency of the vibration (excitation) can be arbitrarily determined. The shear wave is generated from the excitation point and spherically propagates in the object. The ultrasound images are acquired near the excitation point, and the lateral direction of the prove is aligned parallel to the direction of the propagation.

Signal processing of MBE-SWE is shown in **Fig. 2**. Vibration within the object due to the shear wave propagation is detected from the consecutive ultrasound images. The interframe displacement in the depth direction can be calculated from the phase difference between the adjacent ultrasound images (RF echo signals). Then, the displacements at each pixel are integrated in the frame direction to measure the vibration. The SWS corresponds to the time delay of the vibration for the surrounding pixels. Therefore, SWSs can be measured at the appropriate direction.

In the previous method for MBE-SWE, SWSs could be measured only where the region closes to the excitation point in the ultrasound image. Therefore, a method of ultrasound imaging with beam steering for expansion of measurable region of MBE-SWE is proposed. In this report, the proposed

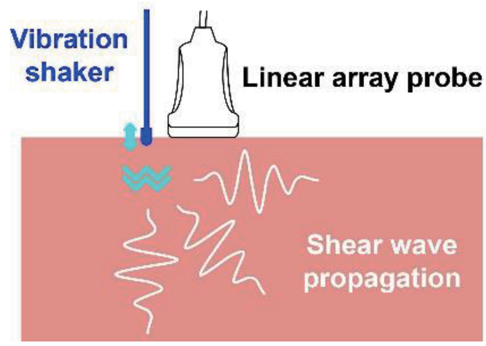

Fig. 1 Measurement setup for MBE-SWE.

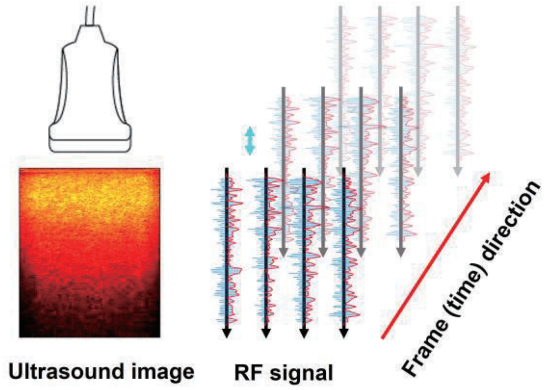

Fig. 2 Signal processing of MBE-SWE.

method is demonstrated through the phantom experiment.

3. Method

3.1 Phantom fabrication

The viscoelasticity phantom was composed of mixing acrylamide (the polymer main chain), N-N'-methylenebisacrylamide (the crosslinker), distilled water, and adding aluminum oxide powder as scatterers, polymerization initiator, and polymerization accelerator [2]. The phantom was formed within a cylindrical container with a diameter of 200 mm and a height of 140 mm, and the MBE-SWE experiment was also performed there.

3.2 Experimental procedure

The phantom was excited using the Smart Shaker (The Modal Shop, USA). The burst wave was created with the function generator 33522A (Keysight Technologies, USA). The burst wave was

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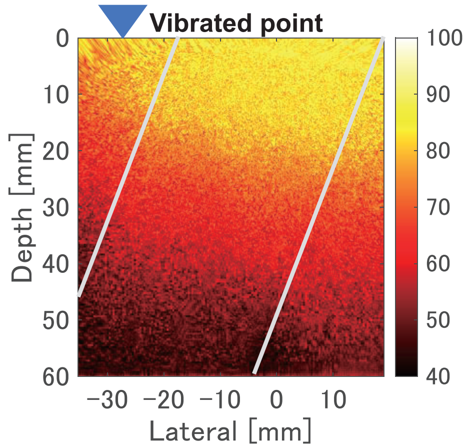

Fig. 3 Ultrasound image with the delay-and-sum beamforming.

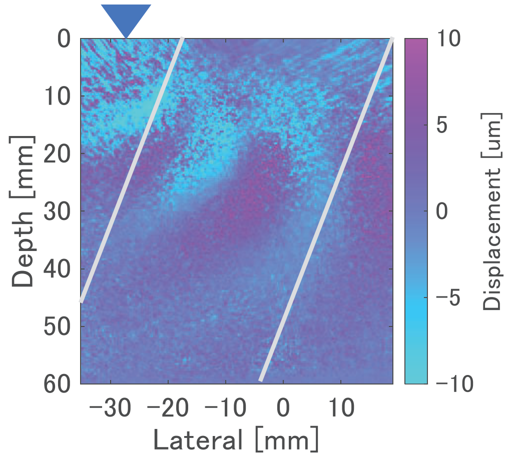

Fig. 4 Phase differences between the consecutive ultrasound images

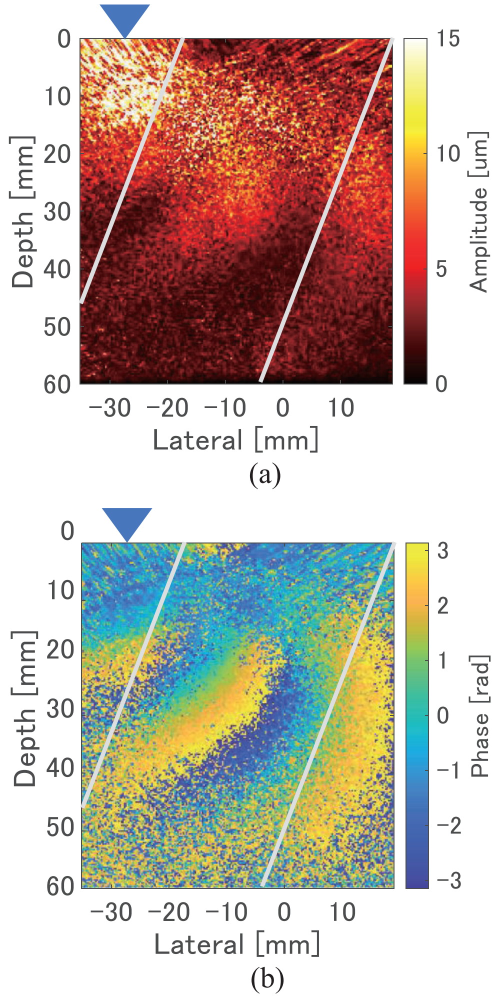

Fig. 5 Measured parameters of SW propagation, (a) amplitude of SW, (b) traveling time from the excitation.

sine wave with a signal length 100 ms, and the driving frequencies were 30-270 Hz. The research ultrasound system Vantage 256 and the linear-array probe L11-5v (Verasonics, USA) were used to acquire RF echo signals. The aperture width of the linear array probe is -19.2~19.2 mm in lateral. The central frequency was 7.8125 MHz. Two cycles of a sine wave at the central frequency were transmitted as a plane wave. The steering angle was -20°. The pulse repetition frequency was 2.5 kHz. The received signals were stored at a sampling frequency of 62.5 MHz. The function generator and the research ultrasound system were synchronized.

4. Results and Discussion

Fig. 3 shows the ultrasound image with the delay-and-sum beamforming. The region in the ultrasound beam is inside the gray line shown in the figure. The phase difference between the consecutive ultrasound images were calculated, as shown in **Fig. 4**. In the region under the excitation point, the measurement could not be conducted in the previous method. However, displacements correspond to phase differences can be observed by the beam steering of the proposed method. Displacements were integrated to obtain vibrations at each pixel. **Fig. 5 (a)** shows the amplitude of the vibration. The initial phase of the vibration corresponds to the traveling time of SW from the excitation. SWSs can be measured from the traveling time at the region in the ultrasound beam, as shown in **Fig. 5 (b)**.

5. Conclusion

In this report, we discuss the expansion of the measurable region in MBE-SWE. It was confirmed that SWSs can be measured by the beam steering even in the region not under the ultrasound probe.

Acknowledgment

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References

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