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Effect of Burst Length and Amplitude of Push Pulse on Imaging Area in Ultrasonic Shear Wave Imaging

Shear wave imaging の適用範囲に対する
push pulse のバースト長と振幅の影響

Hideki Yoshikawa, Marie Tabaru, Rei Asami, and Kunio Hashiba (Hitachi Ltd., CRL)
吉川秀樹†，田原麻梨江，浅見玲衣，橋場邦夫 （日立 中央研究所）

1. Introduction

Shear wave imaging (SWI) is emerging as a novel modality to visualize tissue elasticity, which is tightly related to disease stages and properties. The radiation force induced by focused ultrasound is the source of shear waves utilized in SWI. Tissue elasticity is estimated based upon the measurement of the velocity (V_s) of the shear wave with an ultrasound scanner. SWI is now clinically evaluated for staging and sizing of various diseases such as breast tumors, liver tumors and liver fibrosis.

In SWI, the imaging size in lateral direction with one “push pulse” of focused ultrasound is dominated by the amplitude of the shear waves induced by the pulse due to the damping of the waves as they propagate in tissues. It is thus very important to control the tissue displacement induce by an ultrasound pulse, however, until now, such a controlling method is not established.

The purposes of this study are as follows: 1) development of experimental methods to visualize the shear wave propagation, and 2) clarifying the relation between the imaging size of SWI and acoustic parameters, input amplitude and burst length.

2. Materials and Method

Experimental setup and acoustic parameters investigated in this study are shown in **Fig. 1** and **Table 1**, respectively. Focused ultrasound was irradiated into gel phantom which has controlled V_s of approximately 3 m/s.

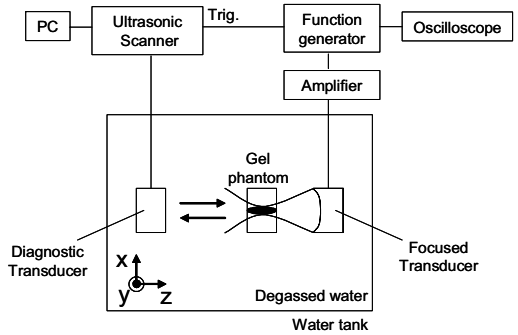

Figure 1. Experimental setup.

hideki.yoshikawa.zq@hitachi.com

Table 1. Acoustic parameters of radiation force source

Frequency	3.3 MHz
Aperture (circular)	30 mm
F-number	2
Amplitude	80, 100, 120 V_{pp}
Burst length	0.5, 1.0, 2.0, 3.0 ms

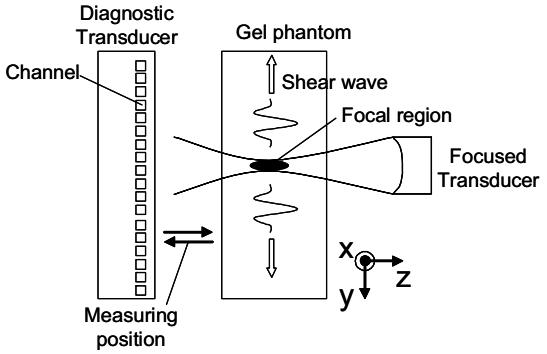

Figure 2. Illustration to explain the way of Vs measuring.

Figure 2 shows the top view of the experimental setup shown in Fig. 1, including an explanation how V_s were measured. Shear waves radially propagate in an x-y plane from focal region, and an A-mode pulse transmit/receive sequence is executed with an ultrasonic scanner to measure the temporal displacement of a tissue at a pulse reputation frequency of 8 kHz. Measuring positions are set at 1.92, 5.76, 9.60, 13.4, and 17.3 mm from the focal region in the lateral direction. Acquired RF data are transferred to a standalone Windows® based computer from the scanner, and then relative tissue displacement between consecutive two receiving pulses is calculated by a correlation-based algorithm[1]. Initial displacement at the measuring position of 1.92 mm and axial length, which is the length of the absolute value of the relative displacement over 0.01 μm along z-axis, are calculated at each burst length and amplitude.

3. Results and Discussion

Figure 3 illustrates a typical shear wave propagation visualized by using the A-mode imaging described in the previous section. Input amplitude and burst length applied were 100 V_{pp}

and 2.0 ms, respectively. In the figure, the propagation is clearly shown as the change of time of the negative displacement to arrive at each measuring position. From the arrival time of the negative displacement of the shear wave in each measuring position, V_s of gel phantom were measured in each data obtained with the various burst length and amplitude. The accuracy of V_s (ideal value is 3 m/s) measured was 95%, which is enough to distinguish between healthy tissue and fibrosis in liver[2].

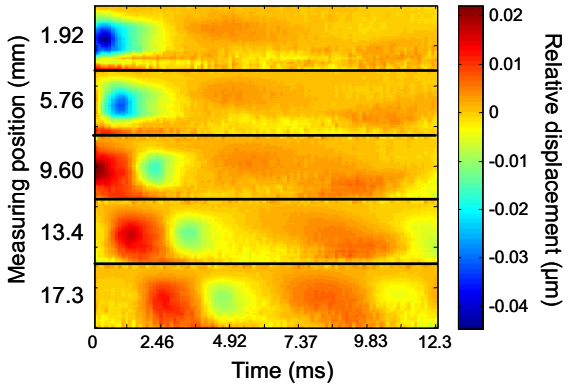

Figure 3. Relative tissue displacement induced by shear wave propagation inside gel phantom.

Figures 4 show the relation between the initial displacement (a) and burst length and amplitude (b). As shown in Figs. 4-(a) and (b), initial displacement increases as the increase of either burst length or amplitude increase. The displacement reached a plateau at 2.0 ms of burst length, while linearly increased with the amplitude increase.

Figures 4-(c) and (d) show the dependency of the axial length on burst length and amplitude, respectively. In Fig. 4-(c), it is clear that as burst length become longer, axial length increases and the shear wave propagates to longer distance. Further, the data with burst length at 2.0 and 3.0 ms are almost identical, which correlate well with the result in Fig. 4-(a). Figure 4-(d) shows that the axial length and the propagating distance of shear waves linearly increase with amplitude increase. Obtained results suggested that the imaging area of SWI can be controlled by adjusting the burst length and amplitude of push pulse.

The physical mechanism how the burst length threshold value is 2.0 ms in Figs. 4-(a) and 4-(c) is to be studied for the further understanding of share wave propagation in tissues. It is reported that 2.0 ms is a burst-length threshold for suppressing thermal effects[3] in living tissues, thus, 2.0 ms can be a 'magic number' in SWI. By using phantoms with different acoustic parameters may give information on the generality and mechanism of the threshold. In the study, cavitational effects are to be considered as well as thermal one in SWI. For the prevention of cavitation, burst length and ultrasound intensity is to be minimized. Clarifying the mechanism how burst length threshold is decided is, thus, very important for the development of a safe and widely applicable SWI.

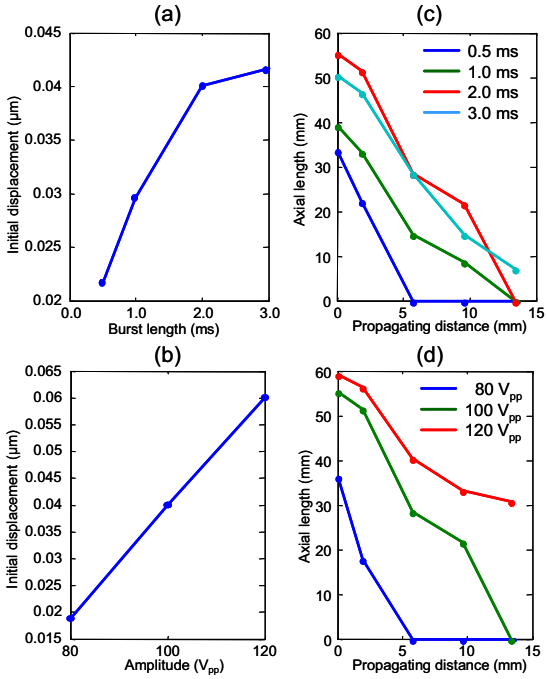

Figure 4 Initial displacement ((a) and (b)) and axial length ((c) and (d)) at various burst length (upper) and amplitude (bottom).

4. Conclusions

A novel method for visualizing shear wave propagation was established and accurate measurement of V_s in gel phantoms was achieved. With the method, it was found that long burst and high amplitude significantly enlarge the imaging area in SWI, still, further studies are needed for avoiding unwanted bioeffects such as thermal effects. For further understanding the mechanism of shear wave propagation in tissues, experiments with changing other parameters such as frequency and F-number will be performed in a future work.

References

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