Strain Imaging for Arterial Wall with Translational Motion Compensation and Center Frequency Estimation

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1. Introduction

We have developed a phase-sensitive correlation method, namely, *phased-tracking method*, for estimating the displacement distribution in the arterial wall for strain imaging [1]. In such methods, ultrasonic pulses with finite frequency bandwidths are used. Therefore, the apparent change in center frequency occurs due to the interference of echoes from scatterers in the wall. Under such a condition, the displacement estimates are biased because it is obtained using the phase change and center frequency of received RF echo. An autocorrelation-based method was proposed to compensate for this apparent change in center frequency [2]. However, the performance of this method is limited because the autocorrelation technique prefers the narrow band signals [3]. To reduce the influences of the change in center frequency, the large translational motion of the arterial wall should be compensated because the error due to the change in center freqeucy depends on the magnitude of the displacement (= phase change) and the translational motion of the arterial wall is much larger than strain. In this study, the displacement distribution of a phantom mimicking an artery was estimated using the autocorrelation technique with the translational motion compensation and center frequency estimation.

2. Methods and Materials

2.1. Displacement estimation using conventional autocorrelation methods including phased-tracking method

The phases of echoes from a moving target, which is located at depth d in the initial frame, are different in two consecutive n-th and (n+1)-th frames. This phase shift, $\Delta\theta_d(n)$, depends on the displacement of the target. Therefore, the instantaneous displacement, $\Delta x_d(n)$, between these two consecutive frames is estimated as follows:

$$\Delta x_d(n) = \frac{c_0 \Delta\theta_d(n)}{4\pi f_0}, \tag{1}$$

where c_0 and f_0 are the speed of sound and center frequency of RF echo, respectively. The accumulated displacement is obtained by integrating the instantaneous displacement with respect to time, and the displacement distribution is obtained by estimating the accumulated displacement at each depth d which corresponds to the arterial radial direction. Finally, strain distribution is obtained by the spatial differentiation of displacements with respect to the arterial radial direction.

2.2. Center frequency estimation based on autocorrelation

As shown by Eq. (1), in conventional phase-sensitive autocorrelation method, the knowledge of center frequency is required to obtain the unbiased displacement estimates. Rabben, *et al.* introduced the center frequency estimation based on autocorrelation technique to obtain the unbiased displacement estimates [2].

2.3. Displacement estimation with translational motion compensation

To further reduce the influence of the change in center frequency, the translational motion of the arterial wall should be compensated. Figures 1(a) and 1(b) shows the RF echoes from the phantom used in this study before and after the increase in the internal pressure, respectively. The translational motion of the wall is compensated by tracking the echo from the luminal interface because it is dominant and is less influenced by the interference from other echoes from scatterers in the wall. After compensating for the translational motion (Figs. 1(c) and 1(d)), the phase shift of echoes before and after the increase of internal pressure is estimated at each depth *d* along the radial direction of the phantom. In this case, the estimated phase shift contains only the phase shift due to strain. Therefore, the error due to the translational motion can be reduced.

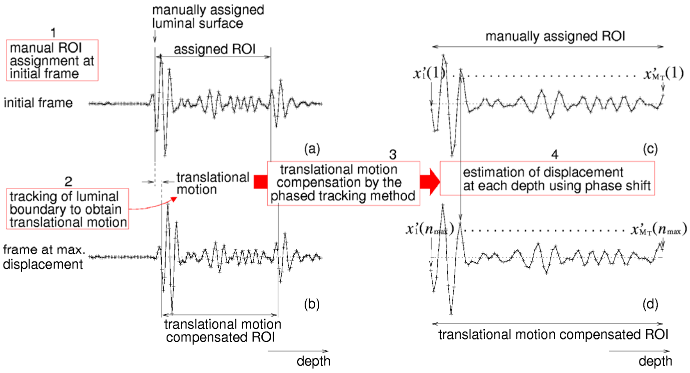

Fig. 1 Translational motion compensation.

3. Basic Experiments Using a Phantom

In this study, the phantom was scanned in its longitudinal direction with a 10-MHz linear array probe. RF echoes were sampled at 40 MHz. Figure 2(a) shows the strain distribution along the ultrasonic beam estimated by the conventional autocorrelation method. Plots and vertical bars show means and standard deviations of 46 ultrasonic beams. Mean values follow the theoretical strain profile, which obtained by the measured internal pressure and elastic modulus (749 kPa) of wall. However, standard deviations are large. In Fig. 2(b), the center frequency estimation was applied to the conventional method. However, the strain estimates are not improved so much. Figure 2(c) shows the strain distribution obtained by the proposed method. Strain estimates were improved significantly by translational motion compensation and center frequency estimation.

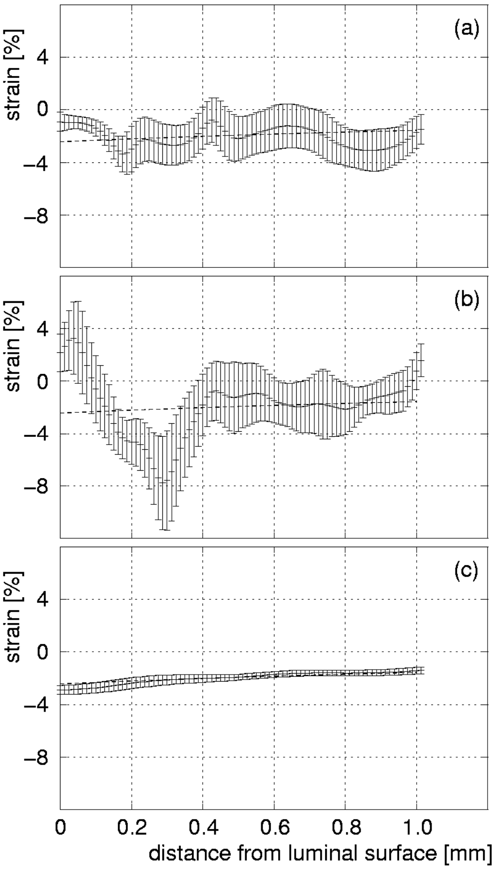

Fig. 2 Estimated strain distribution. (a) Conventional method. (b) Conventional method with center frequency estimation. (c) Proposed method with translational motion compensation and center frequency estimation.

4. Conclusions

This study addressed that the apparent change in center frequency leads significant error in strain estimation. The proposed method with translational motion compensation and center frequency estimation reduces this error significantly.

References

1. H. Kanai, M. Sato, N. Chubachi, and Y. Koiwa: IEEE Trans. Ultrason. Ferroelect. Freq. Contr. **43** (1996) 791.
2. S. I. Rabben, S. Bjærum, V. Sørhus, and H. Torp: Ultrasound Med. Biol. **28** (2002) 507.
3. H. Hasegawa and H. Kanai: IEEE Trans. Ultrason. Ferroelect. Freq. Contr. **53** (2006) 52.