# 2P5-13

# Noninvasive assessment of vascular elastography using 2D phase-sensitive motion estimator

## 2 次元位相追跡法による血管壁の非侵襲的ストレイン計測

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### 1. Introduction

Vascular stiffness changes with the progress of arteriosclerosis, and a strain is one of the important factors for earlier diagnosis. Therefore, a more precise estimation method is needed. In the previous researches on vascular elastography, only 1D motion was focused on in a phase-sensitive method. Generally, because the arterial wall is pulled or extruded by the heartbeat, the motion of the artery is not one-dimensional, which means that the artery moves not only the radial direction but also the longitudinal direction. In this situation, the phase shifts in ultrasonic echoes occur along both the lateral and axial directions simultaneously. The accuracy is expected to be improved by taking into consideration the 2-D phase shift in the phase-sensitive method.

In this study, we compared the accuracies of the 1D and 2D phase-sensitive methods[1,2] by a simulation phantom with known strain distributions. Furthermore, both phase-sensitive methods were applied to a common carotid artery (CCA) to compare a difference in the estimated axial strains.

### 2. Materials and Methods

The phantom simulating a CCA with a homogenous wall was generated for the evaluation of the motion estimator using Field II, an ultrasound simulation package [2,3]. Point scatterers were arranged randomly at 10 scatterers per an ultrasonic resolution in order to generate fully developed speckle. In this study, an elevation direction of the phantom was not considered. Let us define the lateral and axial displacement within the anterior and posterior walls by $V_x(t)/FR$ [mm] and $V_z(t) \cdot r/d(t)/FR$ [mm], respectively, where and $V_x$ and $V_z$ are the lateral and axial velocities, which were velocities at anterior wall estimated from *in vivo* data using the 2D phase-sensitive method, respectively, internal radius $r$ was set to 2.5 mm, $d(t)$ was a distance from the center axial of the blood vessel, and $FR$ is a frame rate. Let us define the lateral and axial displacements of perivascular tissue by 0 and $V_z(t) \cdot r/d(t)^2/FR$ [mm].

Ultrasonic echoes from the simulation phantom and *in vivo* CCA was measured by using plane-wave high-frame-rate imaging. In each plane-wave transmission, 24 focused receiving beams were created at intervals of 0.2 mm. One image frame consisting of $24 \times 4 = 96$ focused receiving beams was obtained by 4 emissions of plane waves. The frame rate was 1302 Hz. Echoes were received by a linear array probe with a center frequency of 7.5 MHz at a sampling frequency of 31.25 MHz. The number of elements was 192.

**Figure 1** shows a B-mode image of the simulation phantom. Red points shown in Fig. 1 were placed in the anterior and posterior walls as tracking points, at which the lateral and axial velocities were estimated. The size of the correlation window was set at ±4 mm (lateral) × ±0.2464 mm (axial).

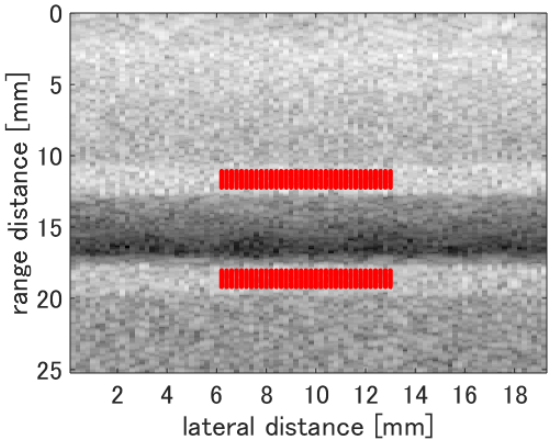


Fig. 1. B-mode image of the simulation phantom. Red points correspond to tracking points.

### 3. Experimental Results

In the phantom experiment, one result on the axial velocities at the anterior and posterior walls estimated by using the 1D and 2D phase-sensitive methods are shown in **Figs. 2 and 3**, respectively. The values of bias errors and standard deviations in the axial velocities in the anterior and posterior walls using 1D phase-sensitive method were $0.6\% \pm 16.4\%$ and $0.3\% \pm 11.5\%$, respectively.

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Meanwhile, those by the 2D phase-sensitive method were 0%±8.3% and 0.2%±12.4%, respectively, and the lateral velocities were 0.6% ± 14.9% and 0.3%±12.9%, respectively.

**Figure 4** shows the axial strain distribution using the 2D phase-sensitive method. The strains decay for a homogeneous wall, which was larger at the inner region and smaller at the outer region, can be seen. Since a difference in the axial velocities was larger at the boundary between the outer region and the tissue, strains in such a region were very large.

**Figure 5** shows the axial shear strain distribution of a healthy subject using the 2D phase-sensitive method. The estimated axial shear strain was the extremely small for a healthy subject. The estimated strain in **Figs. 4 and 5** were computed by applying the least-square method to the distribution of displacements.

## 4. Conclusion

Through the phantom experiments, the 2D phase-sensitive method had shown better performance in the anterior wall in terms of bias errors and standard deviations than the 1D phase-sensitive method. This result indicates the potential of the 2D phase-sensitive method. In the *in vivo* experiment, the extremely small axial shear strain was observed for a healthy subject without plaque.

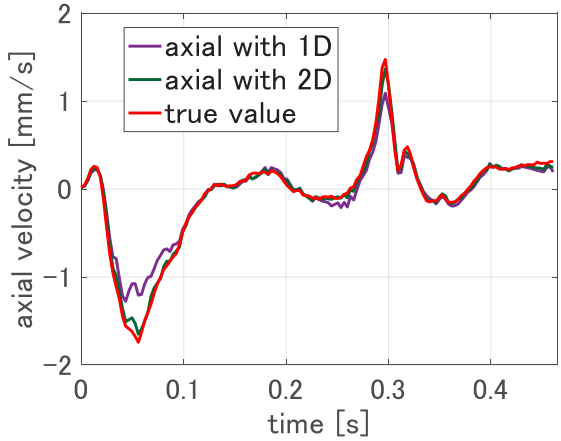


Fig. 2. Estimated axial motion velocities at red points in the anterior wall in Fig. 1.

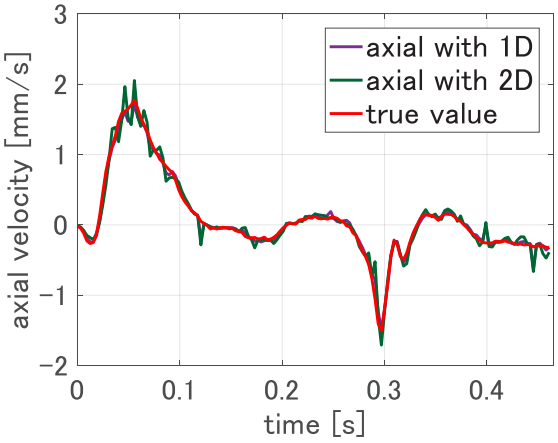


Fig. 3. Estimated axial motion velocities at red points in the posterior wall in Fig. 1.

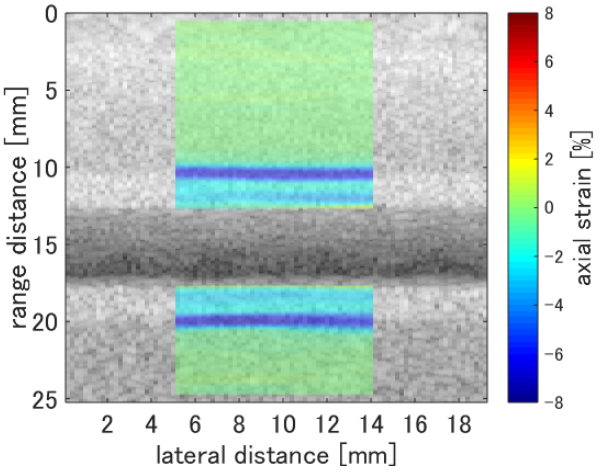


Fig. 4. B-mode image of the simulation phantom and the axial strain distribution using the 2D phase-sensitive method.

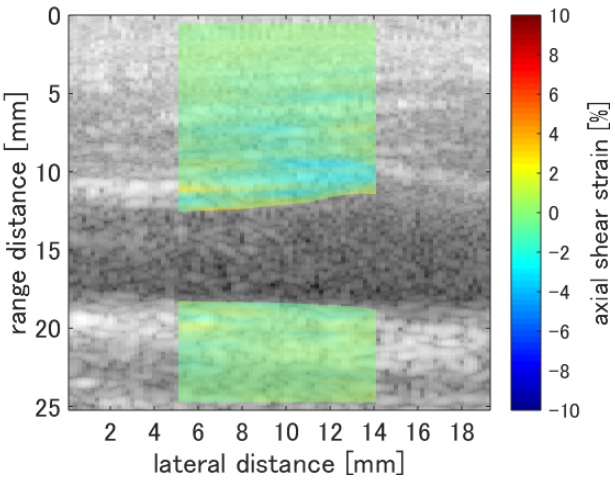


Fig. 5. B-mode image of the carotid and the axial shear strain distribution using the 2D phase-sensitive method.

## References

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