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Accurate Estimation Method of Arterial Wall Movement in Longitudinal Direction

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***Abstract*—For early diagnosis of arteriosclerosis, we have developed methods of measuring arterial wall characteristics such as local elastic modulus and luminal surface roughness by measuring the arterial wall movement. Since the carotid artery moves not only in the radial direction but also in the longitudinal direction due to the contraction of the heart, the movement in the longitudinal direction has to be estimated and introduced into measurement methods of arterial wall characteristics. However, the estimation of the longitudinal movement of the intima-media complex (IMC) is difficult because the acoustic property of IMC is homogeneous in the longitudinal direction, especially in the very early-stage of arteriosclerosis. Therefore, the objective of the present study is to examine an accurate estimation method of the arterial wall movement in the longitudinal direction. The longitudinal displacement of IMC was measured by the block matching method. As the conventional method, the block matching method was applied to the envelope of radio-frequency (RF) signals in IMC. In the present paper, it was also applied to the difference signals of the envelope of RF signals between the neighboring beams to amplify the change of subjects in the longitudinal direction. The block matching methods were applied to the signals in IMC acquired in the right common carotid artery of healthy subjects in the twenties, and the estimated results were compared with the trajectory of the longitudinal movement of IMC which was the change of maximum amplitudes of echo envelope in IMC. In the conventional method, several estimated displacements did not correspond with the trajectory of the longitudinal movement of IMC. By subtracting echo envelope signals in the longitudinal direction, the change of signals was amplified; therefore, the estimated displacements well corresponded with the trajectory of the longitudinal movement of IMC.**

Keywords—arteriosclerosis, arterial wall movement, block matching

I. Introduction

For early diagnosis of arteriosclerosis, the measurement of arterial wall characteristics is important. The ultrasonic measurement of the arterial wall movement is effective for measuring arterial wall characteristics such as elastic modulus [1, 2], pulse wave velocity [3-5], and luminal surface roughness [6-8]. The dominant movement which is focused to measure such characteristics is the movement in the radial direction; however, the carotid artery also moves in the longitudinal direction due to the contraction of the heart. Therefore, the movement in the longitudinal direction has to be estimated and introduced into measurement methods of arterial wall characteristics. However, the estimation of the longitudinal movement of the intima-media complex (IMC) is difficult because the acoustic property of IMC is homogeneous in the longitudinal direction, especially in the very early-stage of arteriosclerosis. Thus, the objective of the present study is to examine an accurate estimation method of the arterial wall movement in the longitudinal direction.

In the present study, we focused on the block matching method to estimate the arterial wall movement in the longitudinal direction [8]. We examined the case where the block matching method was applied to the envelope of radio-frequency (RF) signals in IMC and the case where the block matching method was applied to the difference signals of the envelope of RF signals between the neighboring beams.

In the present paper, the block matching methods were applied to the healthy young subjects in the twenties, The estimation accuracy of the arterial wall movement in the longitudinal direction was evaluated by comparing with the trajectory of maximum amplitudes of echo envelope in IMC.

II. Methods

RF signals were acquired in the right common carotid artery of healthy subjects in the twenties. We used a 7.5 MHz linear type probe of ultrasonic equipment (Aloka SSD-6500), with a sampling frequency of 40 MHz, a frame rate of 286 Hz, lateral beam intervals of 150 μm. Figure 1(a) shows the measured B mode image of the right common carotid artery.

First, the region of IMC in the posterior wall was determined as the red lines in Fig. 1(a). Then, the region of interest (ROI) with widths of 2.4 mm was set in the region of IMC and the movement of the ROI was tracked by the block matching method [8-10]. In the block matching method, the normalized correlation function was interpolated using the reconstructive interpolation to track the micron-order movement between frames [8, 9, 11].

As the conventional method, the block matching method was applied to the envelope of RF signals. Since the acoustic property of IMC is homogeneous in the longitudinal direction especially in the very early-stage of arteriosclerosis, it is difficult to accurately track the longitudinal movement of the IMC. Therefore, in the present paper, the block matching method was also applied to the difference signals of the envelope of RF

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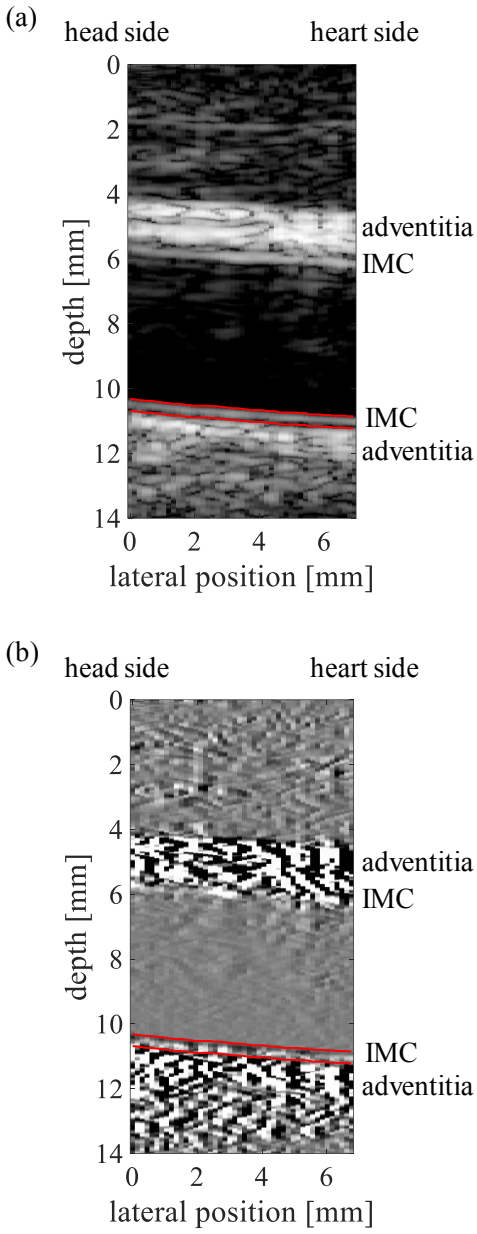

Fig. 1. (a) Ultrasound B mode image of the right common carotid artery of the healyth subject in twenties. (b) Image of difference signals of envelope of RF signlas between neighboring beams in the longitudinal direction. The red lines show the region of IMC.

signals between the neighboring beams in to amplify the change of subjects in the longitudinal direction.

III. Results and Discussion

Figure 1(b) shows the image of difference signals of the envelope of RF signals between the neighboring beams. The envelope of RF signals in the IMC region in Fig. 1(a) shows the homogeneous brightness in the longitudinal direction. On the other hand, the image of difference signals between the

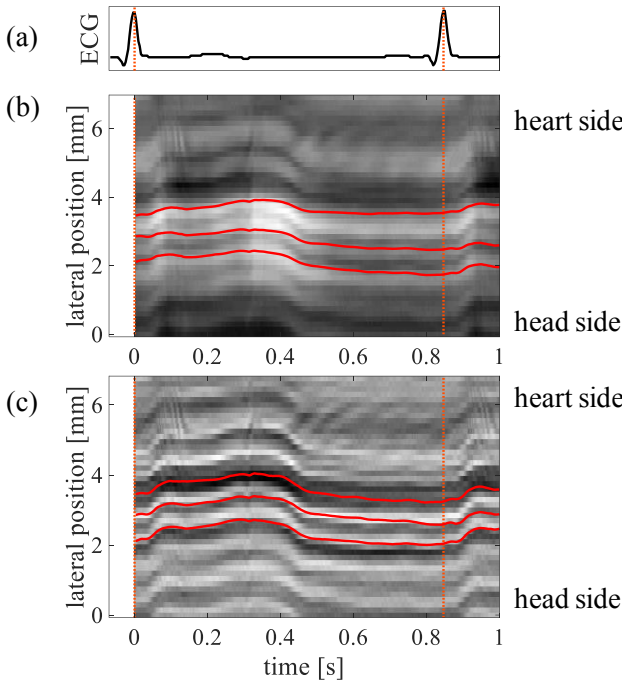

Fig. 2. (a) ECG. (b) Estimated displacements by the block mathing method for the envelope of RF signals. (c) Estimated displacements by the block mathing method for the difference signals of the enveloep of RF signals between neighboring beams in the longitudinal direction. Change of maximum amplitudes of echo envelope and that of substracted image in the longitudinal direction are shown in (b) and (c), respectively.

neighboring beams in Fig. 1(b) shows the brightness change in the longitudinal direction in the IMC region.

Figure 2 shows the tracking results by the block matching method. Figure 2(a) shows the electrocardiogram (ECG). The estimated displacements of center positions of ROIs are plotted by red lines in Figs. 2(b) and 2(c). Figure 2(b) shows the result estimated from the envelope of RF signals shown in Fig. 1(a). Figure 2(c) shows the result estimated from the difference signals between neighboring beams in the longitudinal direction shown in Fig. 1(b). The change of maximum amplitudes of echo envelope in IMC is also shown in Fig. 2(b) and that of the subtracted image of Fig. 2(b) in the longitudinal direction is shown in Fig. 2(c), respectively. These brightness changes in Figs. 2(b) and 2(c) show the trajectory of the longitudinal movement of IMC.

In Figure 2(b) which is the estimated result using the envelope of RF signals, several estimated displacements did not correspond with the change of brightness in Fig. 2(b). On the other hand, in Fig. 2(c), by subtracting echo envelope signals in the longitudinal direction, the change of signals was amplified; therefore, the longitudinal movement of IMC was accurately tracked. The estimated displacements well corresponded with the brightness change in Fig. 2(c) which shows the trajectory of the longitudinal movement of IMC. Thus, in order to accurately track the longitudinal movement of IMC, it is effective to apply the block matching method for the difference signals of the envelope of RF signals in the longitudinal direction.

IV. Conclusion

In the present study, we examined the accurate estimation method of the arterial wall movement in the longitudinal direction by the block matching method. Since the acoustic property of IMC is homogeneous in the longitudinal direction, it was effective to apply the block matching method to the difference signals of the envelope of RF signals in the longitudinal direction to accurately estimate the longitudinal movement of IMC. It is expected that the accurate estimation of the longitudinal movement of IMC improves the estimation accuracy of the arterial wall characteristics such as the elastic modulus and the luminal surface roughness.

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