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Measurement of Transitional Change of Myocardial Expansion and Contraction Using Two-Dimensional Speckle Tracking
2次元スペックルトラッキングによる
心筋伸縮の時間的遷移の計測

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1. Introduction

Ultrasonic diagnosis is useful for a quantitative assessment of regional myocardial function[1)]. However, the investigation of the myocardial change from a contracted state to a relaxed state is still challenging.

In this study, we evaluate transitional change of myocardium during a single heart beat by calculating the differential of the distance between two measurement points on a myocardium tracked using a two-dimensional speckle tracking method and a signal processing algorithm with graphical processing units (GPUs).

2. Methods

2. 1. Calculation of Change in Distance between the Two Points

Figure 1 shows the process of tracking measurement points used in the proposed method. First, the measurement points are set in the ventricular septum along a scan line. Second, the displacement of each point is calculated using two dimensional speckle tracking at every frame. The differential of the *i*-th distance between two measurement points is given by

$$S_i(n) = \Delta d_i(n) - \Delta d_i(0), \qquad (1)$$

$$\Delta d_i(n) = \left|\boldsymbol{d}_{i+k}(n) - \boldsymbol{d}_{i-k}(n)\right|, \qquad (2)$$

where n is the frame number, $\boldsymbol{d}_i(n)$ is the position vector of the *i*-th measurement point. In this study, we improve the estimation accuracy of the differential of distance by temporal averaging:

$$\overline{S}_i(n) = \frac{1}{N_C}\sum_{k=-(N_C-1)/2}^{(N_C-1)/2} S_i(n+k), \qquad (2)$$

where N_C is the number of frames used for the temporal averaging. In addition, we employ a two-step tracking method[2)] to calculate the displacement of the left ventricular posterior wall because the tracking method can suppress the effects of deformation and high-brightness sites on tracking. To begin with, a coarse displacement is estimated using a correlation window that is divided into a plurality. Next, the minute displacement is estimated using a small width correlation window.

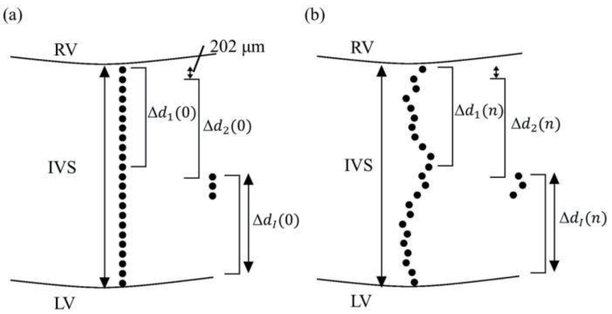

Fig. 1: (a) The tracking measurement points at the first frame. (b) The tracking measurement points at the *n*-th frame.

2.2. Suppression of the Analysis Time Using the GPUs

Since the two-dimensional speckle tracking is required a massive analysis time, we employ a parallel signal processing algorithm using the GPUs. The computational load per one frame using a two-dimensional speckle tracking is defined by

$$O_{\mathrm{CPU}}(N_b \times N_d \times N_{Sl} \times N_{Sd} \times N_{wl} \times N_{wd}), \qquad (3)$$

where $N_b \times N_d$ is the total number of points of interest, $N_{Sl} \times N_{Sd}$ is the number of points in search area, and $N_{wl} \times N_{wd}$ is the number of points in correlation window width.

Each block is assigned to the respective measurement point and each thread is assigned to the respective point in the search area in GPUs using the compute unified device architecture (CUDA). By performing parallel processing in this way, the calculation amount of the theoretical per thread is given by:

$$O_{\mathrm{GPU}}(N_{wl} \times N_{wd}). \qquad (4)$$

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3. *In Vivo* Experimental Result

We obtained RF signals of the heart of a 23-year-old healthy male using parallel beam forming (PBF)[3]. B-mode image of a left long axis cross-section of a heart is shown in Fig. 3. In this experiment, the frame rate was 860 Hz and the sampling interval in the axial direction was 51.3 μm. The number of scanning lines was 112 and angle between succeeding beams was 0.375° .

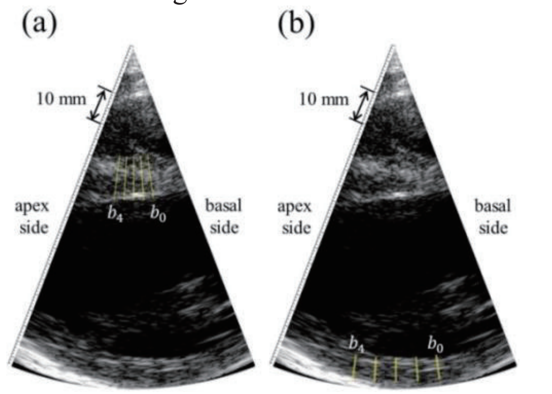

Fig. 2: B-mode image in the heart wall of the 23-year-old healthy male. (a) The analysis object in the ventricular septum. (b) The analysis object in the left ventricular posterior wall.

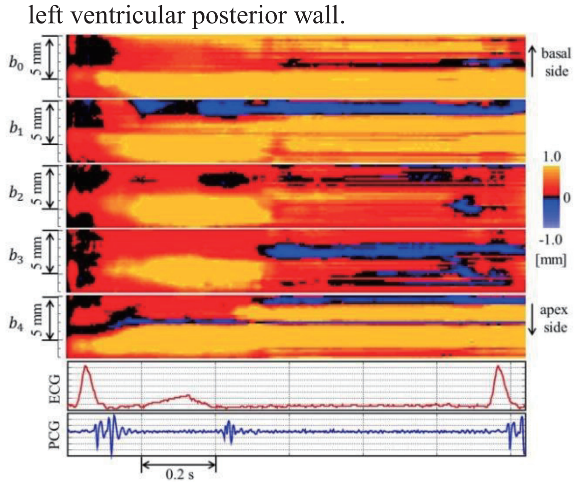

Fig. 3: Change in distance between the two points in the ventricular septum.

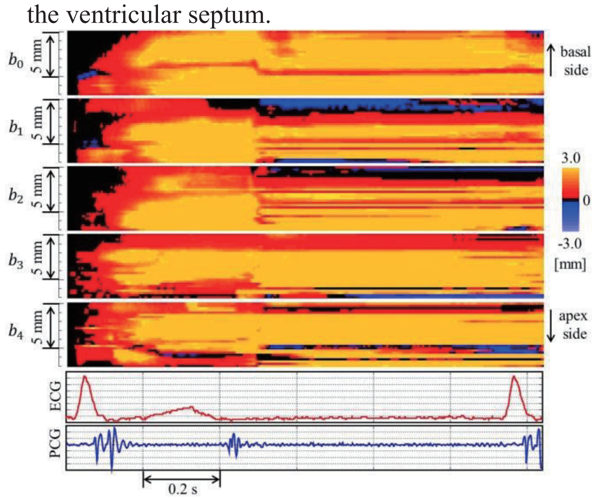

Fig. 4: Change in distance between the two points in the left ventricular posterior wall.

Figures 3 and 4 show the differential of the distance along a scan line in the ventricular septum and in the left ventricular posterior wall, respectively. As shown in Fig. 3, myocardial contraction of the apex side followed by that of the basal side in the ventricular septum. As shown in Fig. 4, the myocardial contraction in the left ventricular posterior wall has a similar trend to that in the ventricular septum. This result is consistent with a previous study[4].

Furthermore, as shown in Fig.3, the differential of distance in the left ventricle of the heart muscle at the ventricular septum was significantly larger than that in the right ventricle. This phenomenon may originate from the large pulse pressure to eject blood into the aorta. On the other hand, in the left ventricular posterior wall, there were no significant differences between the left ventricle side and the epicardial side, as shown in Fig. 4.

In the beams of b_2 and b_3 in the ventricular septum, the decrease in the differential of the distance was observed at the rapid inflow phase, as shown in Fig. 3. This phenomenon may originate from the thinned ventricular septum caused by the inflow of blood into the left ventricle. However, in the other beams except the above-mentioned two beams, including the beams in the left ventricular posterior wall, this phenomenon did not appear. These results may be caused by the employment of parallel beamforming that has a low S/N ratio and an average spatial resolution. Future work should include the optimization of the transmit beamforming.

4. Conclusion

In this study, we proposed a new method that estimates the transitional change of myocardium in a single heartbeat by calculating the change in distance between two measurement points in myocardium. We have investigated the RF data of a healthy male, and myocardial contraction of the apex side followed by that of the basal side both in the ventricular septum and left ventricular posterior wall. This result shows the potential of the proposed method for cardiac physiology elucidation of myocardial expansion and contraction.

References

1. J. D'hooge, et al.: IEEE Trans. UFFC. **49** (2002) p. 281
2. D. Asari, *et al.*: Jpn. J. Appl. Phys. **53** (2014) p. 07KF21
3. H. Hasegawa, et al.: IEEE Trans. UFFC. **55** (2008) p. 2626
4. M. Tanaka, *et al.*: J Cardiol. **63** (2014) p. 313