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Measurement of local change in myocardial thickness caused by electrical excitation in heart wall

心臓壁における電気的興奮の伝導に伴う局所厚み変化の計測

Yu Obara[1 ‡], Shohei Mori[2], Mototaka Arakawa[1,2], and Hiroshi Kanai[2,1]
([1]Grad. School of Biomed. Eng., Tohoku Univ.; [2] Grad. School of Eng., Tohoku Univ.)
小原 優[1‡]，森 翔平[2]，荒川 元孝[1,2]，金井 浩[2,1]（[1]東北大院 医工，[2]東北大院 工）

1. Introduction

It is well known that cardiac contraction is caused by the conduction of electrical excitation. However, the detailed mechanism of the transition process in the myocardium from diastole to systole during the pre-ejection period has been unclear.

In our previous study, the propagation of myocardial contraction caused by the conduction of electrical excitation was measured using the velocity waveforms at the multiple points on the heart wall.[1)] Since the velocity waveforms contain the whole motion of the heart wall, it is difficult to measure only the minute contraction response caused by electrical excitation. Though in several studies the changes in thickness were measured for removing the effect of the whole motion of the heart wall,[2)] it is difficult to measure the local and minute changes in thickness by using the conventional velocity estimation method.

In the present study, the local and minute changes in thickness caused by electrical excitation were measured using the multiple-frequency phased-tracking method for the velocity estimation.

2. Methods

2.1 Measurement of Strain Rate

For estimating the velocities at multiple points on the heart wall, the multiple-frequency phased-tracking method[3)] was applied to the RF data acquired by the ultrasound measurement. Using the multiple-frequency phased-tracking method, the local and minute velocity was successfully measured.

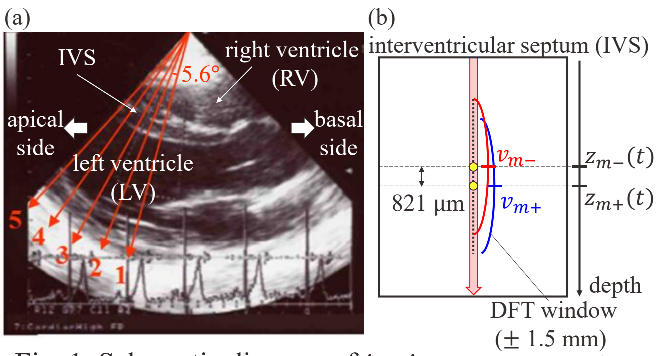

Fig. 1. Schematic diagram of *in vivo* measurement; (a) B-mode image, (b) calculation of the m-th layer of SR.

The strain rate (SR) is calculated using the velocities in two positions. The m-th layer of SR at time t is calculated as

$$SR_m(t) = \frac{v_{m+}(t) - v_{m-}(t)}{|z_{m+}(t) - z_{m-}(t)|}, \quad (1)$$

where $z_m(t)$ is the depth of the m-th layer and $v_m(t)$ is the velocity in the beam direction at the depth $z_m(t)$. The positive (negative) SR indicates the increase (decrease) in thickness, i.e. myocardial contraction (relaxation).

2.2 Measurement Environment

In vivo measurement was applied to the interventricular septum (IVS) of a 20's healthy male using an ultrasound diagnostic equipment (SSD-6500, Aloka) with a sector probe of the 3.75-MHz center frequency. **Figure 1** shows the schematic diagram of the *in vivo* measurement. The sampling frequency was 15 MHz and the frame rate was 630 Hz.

3. Results and Discussion

Figure 2 shows the estimated velocity distributions mapped on the M-mode image during the pre-ejection period. As well as the result in the previous study,[1)] the velocity toward the left ventricular (LV), which is shown as blue in Fig. 2, propagated from the basal side (beam 1) to the apical side (beam 5) during the period of the electrocardiogram (ECG) QRS-complex.

Figure 3 shows the SR distributions mapped on the M-mode image during the pre-ejection period. As shown in Fig. 3, we confirmed that not all the myocardial layers moving toward the LV contracted (cold color) during the period of the ECG QRS-complex.

For the discussion, the estimated velocity and SR waveforms at the m-th layer of SR in beam 3 are shown in **Fig. 4**. In the previous study[1)], the contraction response caused by electrical excitation was identified as the velocity toward the LV during -40 ~ 0 ms, however, the SR did not change, i.e. the myocardium did not contract or relax,

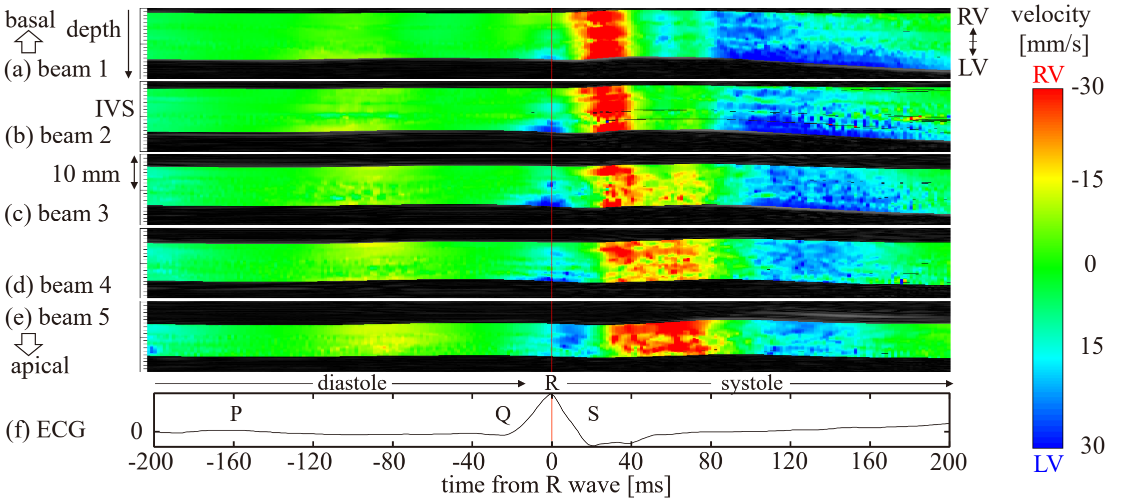

Fig. 2. (a) - (e) Velocity distribution mapped on the M-mode image, (f) ECG waveform.

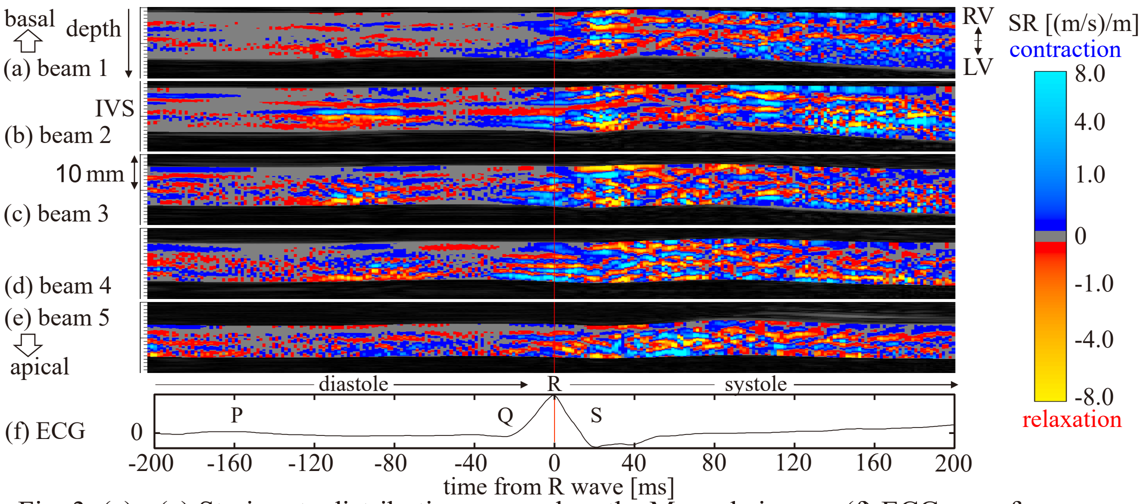

Fig. 3. (a) - (e) Strain rate distribution mapped on the M-mode image, (f) ECG waveform.

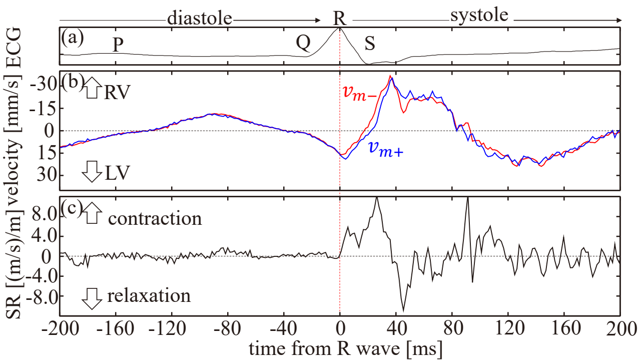

Fig. 4. (a) ECG waveform, (b) velocity waveform at the m-th layer of SR at beam 3, (c) SR wave-form at the m-th layer of SR at beam 3.

in this period as shown in Fig. 4. These results show that the whole motion of the heart wall is dominant than the contraction response caused by electrical excitation in this time period. Therefore, in the previous study, the propagation of the whole motion of the heart wall would be measured as the contraction response. Thus, it is necessary to use the SR waveform to measure the minute contraction response with the whole motion removed.

Moreover, the contraction layer and the relaxation layer alternately appeared in the depth direction in the local SR distributions estimated by the multiple-frequency phased-tracking method as shown in Fig. 3, which was not acquired in the previous study.[2)] From the result, it is expected to measure the local propagation of the minute contraction response from layer to layer.

4. Conclusion

In the present study, the local and minute thickness changes were measured by using the multiple-frequency phased-tracking method. It was considered that the local SR in the myocardial layers was useful to measure the minute contraction responses caused by electrical excitation.

References

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