# 3P5-1

## Local Two-Dimensional Distribution of Propagation Velocity of Myocardial Contraction for Ultrasonic Visualization of Propagation Path of Contraction

心筋収縮伝播路の超音波による可視化を目指した
収縮伝播速度の局所２次元分布

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### 1. Introduction

When medical diagnosis and treatment are applied for myocardial ischemic regions that is the early stage of ischemic heart disease, fatal necrosis of the myocardium can be avoided by prompt reperfusion. Therefore, rapid identification of ischemic regions is essential.

In previous studies, we focused on the response of myocardial contraction associated with the propagation of electrical excitation in the heart, and confirmed the propagation of myocardial contraction along the propagation path of electrical excitation using ultrasound.[1)] Furthermore, we measured the ischemic interventricular septum (IVS) of the swine heart, and compared the propagation velocity of myocardial contraction in the normal and ischemic myocardium.[2)] The estimated propagation velocity was 2.7 m/s in the normal myocardium and 1.4 m/s in the ischemic myocardium, and we confirmed that the propagation velocity of myocardial contraction decreased by about 50% due to ischemia. However, it was assumed that the myocardial contraction propagates parallel to wall in the heart wall, and the propagation velocity is constant within the measurement range.

In the present study, the local and two-dimensional propagation velocities of myocardial contraction were estimated using ultrasound for the detailed visualization of the propagation path of myocardial contraction.

### 2. Methods

#### 2.1 Delay Time Measurement of Myocardial Contraction Response[1,2)]

By applying the phased-tracking method[3)] to the RF signals acquired by ultrasonic measurement, velocity waveforms with minute vibration were simultaneously obtained at several thousands of points in the myocardium. The cross-correlation method was applied to the resultant velocity waveforms, and the delay time $\tau_p$ of the contraction response at each measurement point from that at the reference point was determined. Finally, $\tau_p$ was converted into the delay time $\tau_{ij}$ [s] ($i$: beam position, $j$: depth) from the electrocardiographic R wave representing the onset of the ventricular contraction.

#### 2.2 Propagation Velocity Estimation of Myocardial Contraction Response[4)]

In Cartesian coordinates, the delay time distribution $\{\tau_{ij}\}$ of the myocardial contraction response was expressed as $(x, y, \tau_{xy})$ in the coordinates of positions $(x, y)$ and delay times $\{\tau_{xy}\}$. The quadratic surface $T(x, y)$ was fitted by the method of the least squares in the region of interest (ROI) centered at $(x_0, y_0)$. The two-dimensional propagation velocity of myocardial contraction was then calculated using the gradient of the surface $T(x, y)$. The gradient vector was expressed as $\nabla T = [\partial T/\partial x, \partial T/\partial y]^T$, and the propagation velocity $\boldsymbol{v}_e(x_0, y_0)$ was estimated by

$$\boldsymbol{v}_e(x_0, y_0) = \begin{bmatrix} \frac{dx}{dT} \\ \frac{dy}{dT} \end{bmatrix} = \begin{bmatrix} \frac{T_x}{T_x^2 + T_y^2} \\ \frac{T_y}{T_x^2 + T_y^2} \end{bmatrix}, \quad (1)$$

where $T_x = \partial T/\partial x$ and $T_y = \partial T/\partial y$.

### 3. *In Vivo* Experiment

#### 3.1 Experiment Environment

*In vivo* measurement was applied to the IVS of a 23 years old healthy male using an ultrasound diagnostic equipment (SSD-6500, Aloka) with a sector probe of 5-MHz center frequency. The pulse repetition frequency was 6,510 Hz, and the high frame rate measurement of 434 Hz was realized by reducing the number of beams to 15. The sampling frequency was 20 MHz and the angle between successive beams was 5.6°. **Figure 1** shows the B-mode image and the RF acquisition area. The basal side in the heart was beam 0, and the apical side was beam 14.

#### 3.2 Results and Discussion

As in the previous studies[1,2)], the contraction response in the time phase just before the beginning of main contraction was focused, and the propagation of myocardial contraction in the IVS was visualized. **Figure 2** shows the estimated result of the propagation velocity vectors $\{\boldsymbol{v}_e(x_0, y_0)\}$. The direction and magnitude of propagation velocities ware indicated by the direction and color of arrows, respectively. The size of ROI for $T(x, y)$ was 7.7 mm in the beam direction, 5 beams in the lateral direction, and 15 ms in the delay time. The propagation velocity was represented as the velocity vector in each ROI so that local and two-dimensional estimation became possible.

For physiological discussion, the results of the estimated propagation velocities $\{\boldsymbol{v}_e(x_0, y_0)\}$ were decomposed to the lateral and beam directions at each position. The result is shown in **Fig. 3**. The propagation to the apical side (beam 14) was defined as positive in the lateral direction, and the propagation to the probe was defined as positive in the beam direction. Focusing on the propagation in

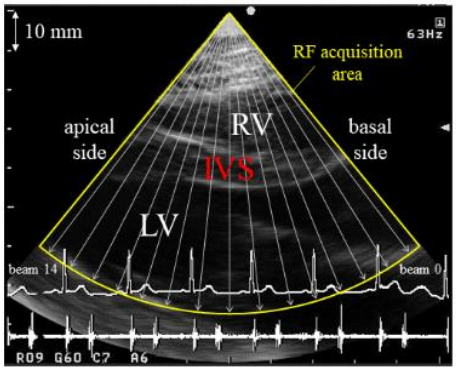


Fig. 1. B-mode image of healthy male. (IVS: interventricular septum, RV: right ventricle, LV: left ventricle)

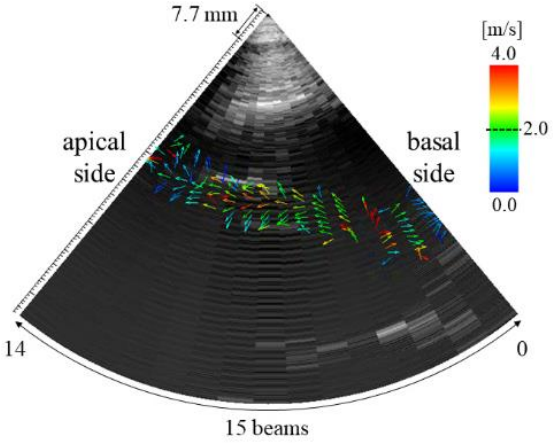


Fig. 2. Propagation velocities $\{\boldsymbol{v}_e(x_0, y_0)\}$ of myocardial contraction.

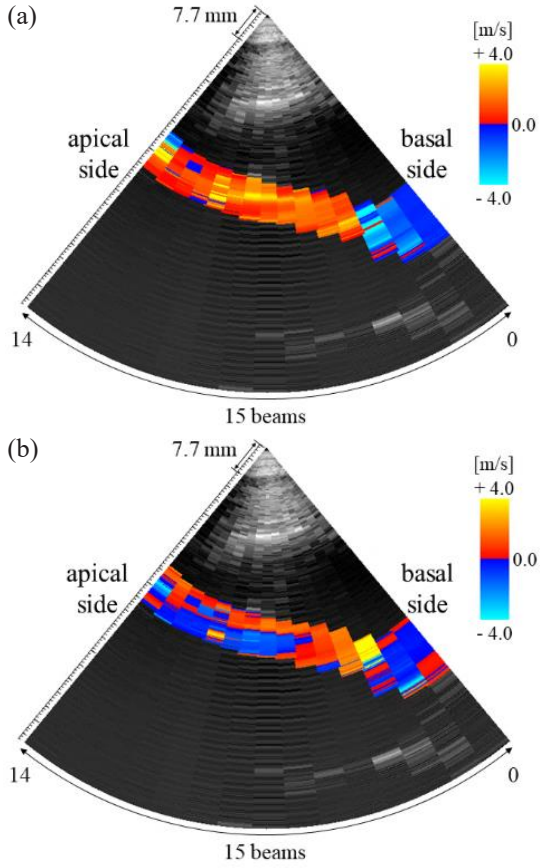


Fig. 3. Propagation velocity of myocardial contraction in (a) lateral direction (positive: apical side) and (b) beam direction (positive: probe side).

the lateral direction, the contraction propagated from the basal to the apical sides in the beams 3–14, and from the apical to the basal sides in the beams 0–2. In the beams 3–14, the propagation direction of the contraction coincided with that of electrical excitation because the conducting system runs through the myocardium in these regions. On the other hand, in the beams 0–2, the contraction propagated away from the beginning point of electrical excitation in the IVS (near beams 2 and 3) because the conducting system does not run through the myocardium in these regions. Focusing on the propagation in the beam direction, the contraction propagated upward and downward in the beams 5–14. It seems that the contraction propagated away from the conducting system running inside the IVS, although further investigations such as increasing subjects are needed.

Moreover, the absolute values of the propagation velocity were averaged within the measurement range. They were 1.5 m/s in the lateral direction and 1.1 m/s in the beam direction. In the lateral direction, the conducting system whose propagation velocity is about 2–4 m/s[5] runs through the myocardium, and myocardial contraction propagates at the faster velocity than ordinary myocardium. Therefore, it is considered that the propagation velocity in the lateral direction was estimated faster than that in the beam direction.

## 4. Conclusion

In this study, the local and two-dimensional propagation velocities of myocardial contraction were estimated by ultrasound. The propagation of myocardial contraction reflects that of the electrical excitation. Therefore, if the propagation of myocardial contraction can be visualized in detail by the proposed method, the identification of region of myocardial ischemia and the detection of arrhythmia can be expected. Not only the abnormality of the conducting system but also the propagation path of myocardial contraction when the abnormality occurs could be visualized.

## References

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