3P5-19

Two-dimensional Blood Flow Vector obtained by Bidirectional Doppler Ultrasound with Parallel Beamforming

平行波を用いた二方向のステアリングによる二次元血流ベクトル測定

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1. Introduction

Ultrasonography has widely spread as a simple and useful tool in the clinical settings. Although the blood flow can be estimated with Doppler ultrasound, only one-dimensional blood flow component along the ultrasound beam is measured by conventional ultrasound systems. The method is not enogh to measure the complex flow in the biological systems. The blood flow with a complex structure, e. g. stenosis or bifurcation, would be correctly visualized if the two-dimensional blood flow vector is estimated at real time. The method of estimating the true blood flow leads to early diagnosis of the diseases originated from the blood vessels. This paper describes the technique of estimating a two-dimensional blood flow vector by compounding two different one-dimensional components of blood flow vector obtained by bidirectional Doppler ultrasound with parallel beamforming.

2. Methods

The specifications of the ultrasound system used in the present study are shown in Table 1. The linear array probe with a central frequency of 7.5 MHz was used and the pulse repetition frequency was 5 kHz. The Doppler signal was acquired by insonifying a scanned region with a parallel beamforming. Velocity component of the one-directional blood flow was estimated by averaging 12 ultrasound pulses in one-directional steering. Total number of 24 transmits with each +15 and -15 degree steering was considered as one set of the measurement. For pulsed Doppler method, the repetition frequency was 2.5 kHz at each direction. An animation was created by repeating the acquisitions at 40 Hz.

As shown in Fig. 2, phase difference produced the reflected wave from scattering blood cells which moved in the first transmission and the second transmission. The wave drawn with the red line is a wave which transmitted first, and the wave drawn with the green line is a wave which transmitted to the next. Moving distance was found by detecting the phase difference of these two waves, and flow vector was estimated by dividing the difference by pulse intervals. Fig. 1 shows the schematic illustration of calculating two-dimensional blood flow. Each one-directional blood flow vector was obtained in the black or red area, two-dimensional blood flow vector in the blue area was calculated by compounding the two components. When the time lag of steering two-directions is shortened, blood low vector would be obtained more precisely. Moreover, when the two or more lines are scanned at once by using a parallel beamforming, temporal resolution would be improved. Because the simultaneous acquisition of the 128 lines was carried out in the present study, the frame rate was 128 times faster compared with conventional focused beamforming.

The carotid artery of a 24 years-old healthy young male was scanned for 1.0 sec. Signal and image processing were performed by the original software written in the C language.

Table.1 Specifications of the ultrasound system

Parameters	Value
Transducer	Linear array
Number of active elements	128
Pitch	0.2 mm
Kerf	0.02 mm
Center frequency	7.5 MHz
Number of cycles pr. Pulse	3
f_{prf} of pulse	5 kHz
Number of transmit events at one set	24
f_{prf} of set	40 Hz
Sampling frequency	30 MHz
Apodization in receive	Tukey
Focal point	Parallel

3. Results

Fig. 3 (a) and (b) show the picture produced from the data acquired with the ±15-degree steering. The centdal part of the picture colored in red or blue is a carotid artery and the information of the blood flow vector is represented. The vectors shown in the blue arrows are the blood flow away from the transducer in +15-degree steering, and those sith the red arrows are away from the transducer in -15-degree steering. Two-dimensional blood flow vector can be estimated by compounding these one-dimensional vectors.

Fig. 4 shows the B-mode image of a scanned region, and the vector image which combined two pictures. The ultrasound probe was located in a top edge and the depth direction was 42.7 mm and a lateral direction was 25.6 mm in size. The carotid artery is shown in the upper part of the picture. Two-dimensional blood flow vector was estimated in the area enclosed by the red line. Outside of the area, only the blood flow vector of one direction was obtained and a two-dimensional blood flow vector cannot be estimated.

4. Conclusion

This paper showed that the two-dimensional blood-flow vector could be estimated in real time by bidirmethod with parallel beamforming. The algorithm was confirmed by the two-dimensional blood flow in the carotid artery. The improvement of signal/noise ratio is required in the signal processing because the sensitivity was altered in the parallel beamforming. It also requires the extension of the measured region by making a steering angle small.

5. References

1) J. Udesen, F. Gran, K. L. Hansen, J. A. Jensen, C. Thomsen, and M. B. Nielsen; IEEE Trans. Ultrason. Ferroelectr. Freq. Control. 55 (2008) 1729.

2) G. Montaldo, M. Tanter, J. Bercoff, N. Benech, and M. Fink; IEEE Trans. Ultrason. Ferroelectr. Freq. Control. 56 (2009) 489.

3) J. A. Jensen and S. I. Nikolov; IEEE Trans. Ultrason. Ferroelectr. Freq. Control. 51 (2004) 1107.

4) C. Kasai, K. Namekawa, A. Koyano, and R. Omoto; IEEE Trans. Sonics and Ultrason. SU-32, No.3. (1985) 458.

5) J. Udesen, M. B. Nielsen, K. R. Nielsen, and J. A. Jensen; Ultrasound in Med. & Biol., Vol. 33, No. 4 (2007) 541

6) J. A. Jensen, S. I. Nikolov, K. L. Gammelmark, M. H. Pedersen; Ultrasonics 44 (2006) e5

7) L Thomas and A Hall; IEEE Ultrason. Symposium (1994) 1701
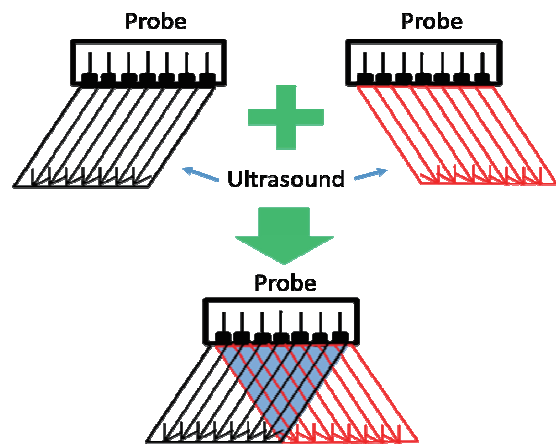
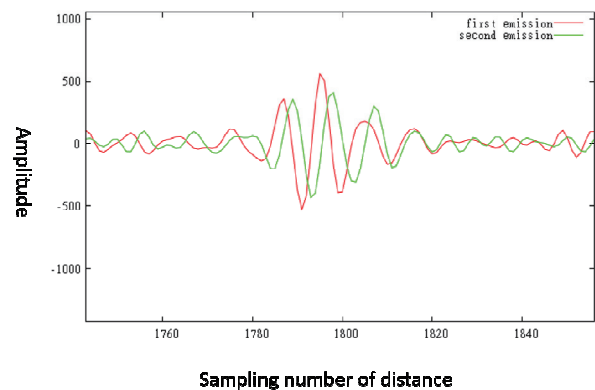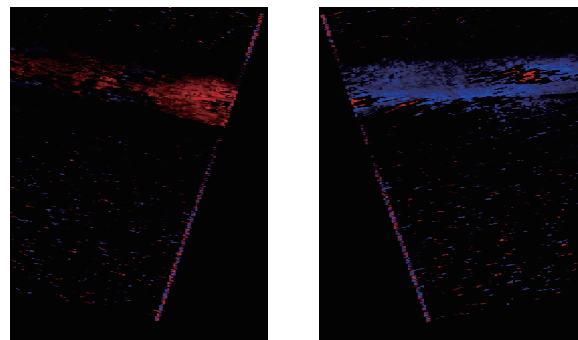Fig.1 Compounding of bidirectional ultrasound beam

Fig.2 Phase difference of two transmitted pulses

(a) 15 degree steering   (b) -15 degree steering

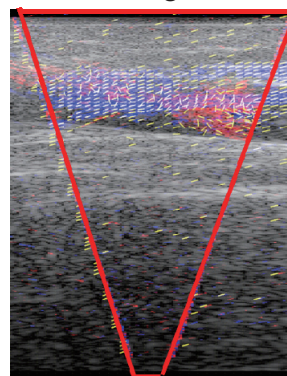Fig.3 The one-dimensional blood-flow vector in a ±15 degree steering

Fig.4 B-mode image of a scanned region and the vector image which combined two pictures