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Measurement of carotid artery pulse wave by piezoelectric sensor ~ Examination of left / right difference ~

圧電センサによる頸動脈波測定～左右差の検討～

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1. Introduction

The cerebrovascular disease accounts for the top proportion of deaths worldwide, and more than 110,000 people died in 2015 in Japan. The causes of cerebrovascular is considered to be arteriosclerosis and hypertension etc., which are asymptomatic diseases.

In case of ischemic vascular diseases, ex. cerebrovascular disease, the blood flow becomes worse and causes the lack of oxygen in brain cells due to the stenosis and obstruction of carotid artery vessels. It indicates the strong necessity of a quick and convenient evaluation system for the occlusion of a blood vessel in the emergency medicine.

In this study, we have tried to develop a simple method to judge occlusion of blood vessels in the cerebrum, focusing on the pulse wave. A pulse wave is a composite wave constituted by an incident wave and a reflected wave and we can measure easily from the surface skin. The incident wave is a displacement wave of the surface skin caused by a pressure wave generated by blood ejected from the heart (forward wave). The reflected wave is a displacement wave caused by a pressure wave reflected at the vascular bed (backward wave) [1]. The advantages of the pulse wave measurement are non invasive, inexpensive and the use of a simple system.

From the pulse waves measured at the carotid artery, we can evaluate the hardness of blood vessel in brain[2]. Using artificially vessel mimicking tubes, we have actually reported that the pressure wave reflections can be observed from the intravascular stenosis[3]. We have also reported the strong reflected wave in the eldery prople from the analysis of the observed pulse waves. In this study, then, the pulse wave measurement was applied to check the carotid artery occlusion. Comparing the pulse velocity waves measured at left and right acrotid arteries, the difference of the data is discussed.

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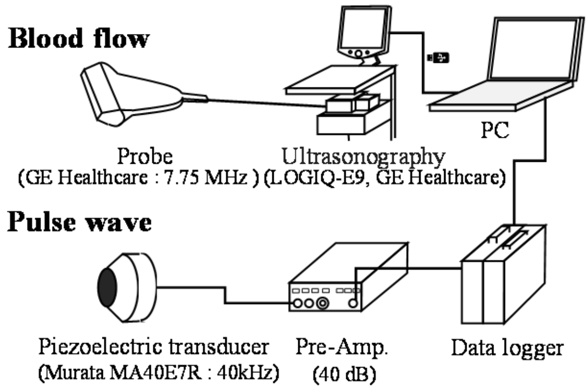

Fig. 1 Experimental system for the pulse wave and blood flow measurements.

2. Experiments

2.1 Subjects

Healthy subjects were 11 men and women in their twenties who had no history of cardiovascular disease and had not taken hypertension drugs. One subject in his 50's is suffering chronic carotid artery occlusion. Before measurement, the subject laid down in the supine position for 5 minutes in a quiet room. The procedures were approved by the medical ethics committee of Doshisha University.

2.2 Data Collection

The pulse velocity waves were measured at the common carotid arteries using a piezoelectric transducer (MA40 E7R, Murata Manufacturing). The observed signal was amplified by 40 dB by a preamplifier (NF5307; NF Corporation) and digitalized using a 14 bit analog to digital converter (NR-500; NR-HA08, Keyence) at a sampling frequency of 10 kHz. We also used ultrasonic Doppler system (LOGIQ e, GE Healthcare). The center frequency of the ultrasonic probe (12L RS, GE Healthcare) was 7.75 MHz.

3. Result and discussion

Figure 2 shows the left and right carotid artery pulse velocity and blood flow velocity waveforms of a healthy subject. The amplitudes are normalized. The cross-correlation of the left and right waveforms was then evaluated. In case of the pulse velocity waves of healthy subjects, the maximum values of the cross-correlation function were in the range from 0.85 to 0.99 with the standard deviation of 0.04. This suggests that there is little difference between the data obtained in the left and right artery. The blood flow wave velocity waveforms also showed similar tendency and the cross-correlation function were in the range from 0.90 to 0.98 with the standard deviation of 0.02. As can be seen, the waveforms were very similar, telling that the condition of blood vessels in the left and right arteries were almost same.

In case of the carotid artery occlusion patient, Fig. 3 shows the waveforms of observed pulse velocity and blood flow velocity waveforms. The patient had the occlusion in the right artery. It seems interesting because the difference was small in the blood flow velocity whereas the waveform was dramatically different in the pulse velocity. The maximum value of the cross-correlation function of the blood flow velocity waveform was 0.94, and that of the pulse wave was 0.34. All cross-correlation data are summarized in Fig.4.

The big difference between the pulse velocity and blood flow velocity seems to come from the effects of the reflected wave. The short period of the pulse velocity may come from the multiple reflection between the occlusion and the heart or the collateral circulation. More detailed discussion should be needed with additional data.

4. Conclusion

The left and right carotid artery pulse velocities of healthy subjects and carotid artery occlusion patient were measured and compared. As a result, the carotid artery occlusion patient showed big difference in the pulse velocity measured at left and right carotid arteries. These data implies the possible evaluation of the stenosis and occlusion of the carotid artery by the pulse wave. The measurement of pulse wave is simple and non-invasive, which may be used in the emergency medicine in the future.

References
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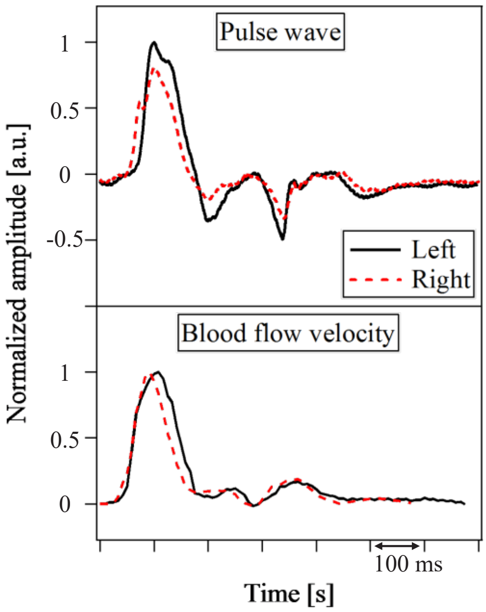

Fig. 2 Pulse velocity and blood flow velocity waveforms of a healthy subject.

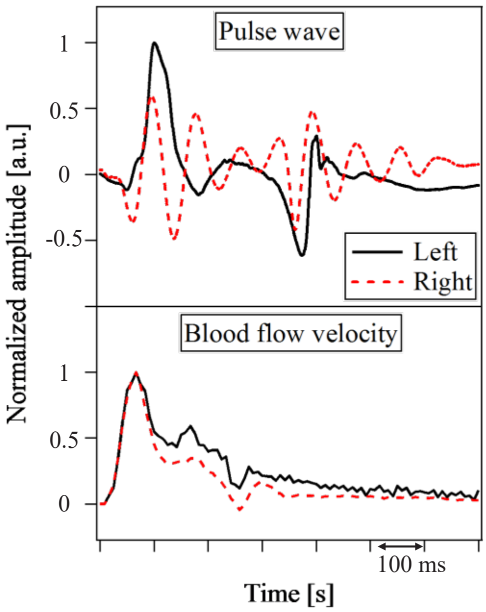

Fig. 3 Pulse velocity and blood flow velocity waveforms of a carotid artery occlusion patient.

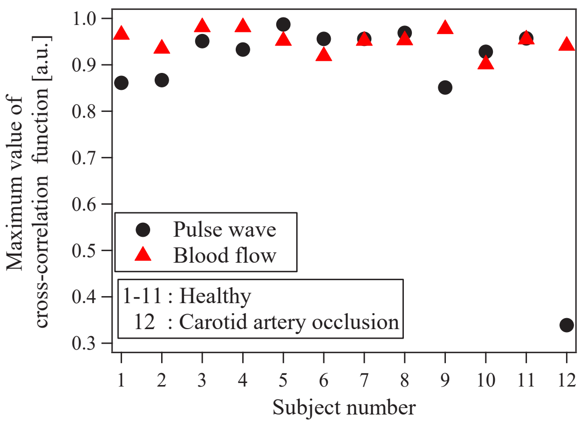

Fig.4 Correlation function of left and right artery data.