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Analysis of Both Hands' Two Pulse Waveforms using a Clip-type Pulsimeter Equipped with Magnetic Sensing Hall Device

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Two concurrent signals of the pulse wave measured from both hands' radial artery in un-pressurization condition using the prototype model of two clip-type pulsimeters with a permanent magnet and Hall device are investigated. The phase differences of two pulse waves from 22 subjects have some distinct points according to the handedness. Thus, the propagation of the pulse wave calculated from phase difference is both fast and slow to each other. It is confirmed that this phenomenon comes from the difference of blood vessel hardness between right- and left- hand of each subject rather than a quantity of muscle.

Keywords : both hands, clip-type pulsimeter, pulse waveforms, Hall device, permanent magnet

1. Introduction

Highly reproducible diagnostic measurements of bio-signals from patients are demanded to improve quality of medical services for human well-beings. Additionally, convenient and daily diagnosis of representative bio-signals such as the pulse frequency, the heart rate and the blood pressure by using new house-hold gauge equipment with innovatively wrist- and forearm- wearable form factor has been proposed to supply reliable judgment to ensure one's health status [1, 2]. Therefore, development of a novel measurement method to check the pulse frequency, the heart rate, and the blood pressure with high fidelity using a convenient wearable monitor is a required pre-condition for the upcoming ubiquitous industry [3, 4].

The oriental diagnostic appliances with reproducibility and reliability are demanded as objective clinical references. To facilitate the process of finding the pulse wave, a portable pulsimeter to diagnose organization and development of the forceps shaped pulsimeter using a Hall device need to be provided [5, 6]. The oriental medicine which developed since the ancient times can be modernized to provide more reliability and enhanced clinical services. For example, a pulsation, one important diagnostic method in oriental medicine, judges the condition of patient's internal organs by the "Chon", "Chwan", and "Chuck" of radial artery.

The pulsation is undertaken according to the oriental doctor's subjective decision; it has been argued frequently "whether the oriental medicine is scientific or not". Thus, accurate decisions through scientific approaches are necessary. Various ways of pulsimetering have been developed recently on the basis of these arguments. Despite the efforts to renovate the oriental medicine, non-objective errors in pulsimeter still exist. The oriental six pulses: the "Chon", "Chwan", and "Chuck" of both the left and right hand have to be carefully considered as they imply different meanings. Most of existing pulsimeters developed so far have a very critical limitation, they can only diagnose pulses from one spot [7, 8].

Usually, oriental doctors examine their patients by diagnosing both hands simultaneously, after gaining left hand's pulse wave, the right one is performed with the time difference between left and right. However, comparing each of the pulse waves according to time differences is not objective. Moreover, the heart is leaning towards the left in the human body. We designed some experiments for verifying this hypothesis; pulse flow from the heart could reach left hands' radial artery and then the

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right one due to time differences. Such an analysis of pulse wave patterns from both sides is important for clinical applications. Comparative analysis of both hands' pulse wave condition may suggest a novel technique to develop a fundamental element for the pulsimeter.

This research is focused on developing a new diagnosis by measuring the pulse wave from both hands' radial artery simultaneously using clip-type pulsimeter equipped with Hall device and non-invasive pulse sensor. Based on the idea that the phase difference of two pulse waves obtained by fixed Hall device at center of radial artery could reflect a difference in pulse wave's velocity of propagation, we could interpret and adopt this as the characteristics of both hands' arterial tube.

2. Experimental Method

A proto-type pulsimeter with a clip used in this research is composed of: a permanent magnet, Hall sensor, partial measurement, LED, display, USB port, and switch parts. Nevertheless, the elastic latex rubber is used for bringing comfort during skin contacts without pressurization. The cylindrical shaped apparatus is 2 mm in diameter and 1 mm in height. The permanent magnet has magnetic field of 300 Oe approximately on the surface, and was glued with an epoxy at the center of elastic rubber [9, 10]. In other words, the center of circular tube is located on "Chwan" of radial artery and a stretched Latex rubber surrounds the contact surface of wrist's skin. The cylindrical permanent magnet in contact with the skin of radial artery can move its location easily with the pulse vibration.

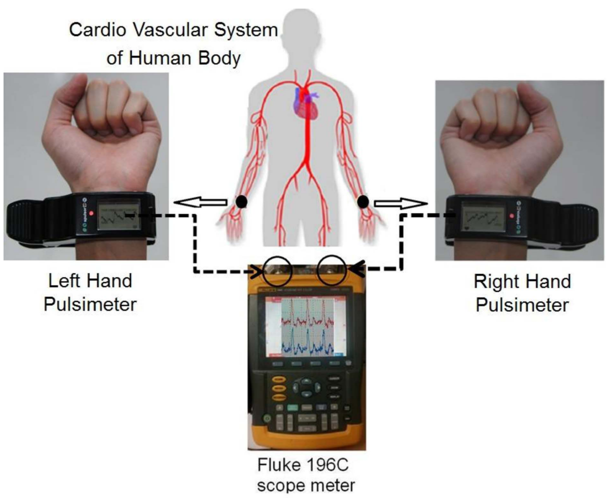

Fig. 1. (Color online) The cardiovascular circulatory system for the arteries and the diagram of a clip-type pulsimeter to measure pulses from both hands simultaneously is illustrated. The digital oscilloscope to observe two pulse waveforms (Fluke 196C scope meter) is equipped to integrate signals from both hands.

The displacement between Hall device modulator which is a key component for both hands' measurable pulsimeter used in this research and the magnet is 2.5 mm. A permanent magnet within 1 mm is moving upwards and downwards by artery's pulse with high and low vibrations. An outline is depicted in Fig. 1 for pulse wave signal measurements, as for both hands. As indicated in Fig. 1, an oscilloscope displaying two pulse waves and power supply is needed to acquire the pulse waves using 196C scope meter from Fluke Company. The pulse from both hands is detected by two clip-type pulsimeters with DC constant voltage supply, permanent magnet, and Hall device magnetic field sensor which provides necessary voltage and analyzes pulse waves on both hands' comparatively.

3. Experimental Results and Discussions

Through using the permanent magnet and Hall device equipped with clip-type pulsimeter, an experiment targeting at healthy 22 male subjects was accomplished. For more reliable results, they were forbid to smoke and eat for an hour at least, and had no alcohol intakes for one day. The signal analysis from typical time of a pulse wave point is acquired by the placement of tiny permanent magnet which is measured in seconds. The starting pulse wave from the left wrist's radial artery is compared simultaneously with the following pulse wave from the right wrist's radial artery by the clip-type pulsimeter. All data from both hands' pulse waveforms uses a wrist clip-type pulsimeter equipped with magnetic sensing Hall device are refined to reduce rough noises through a filtering process as shown in Fig. 2(a).

Through four stages of selecting the typical pulse signals from 22 clinical participants, as marked in Fig. 2(b), peak value differences were clearly indicated. To investigate whether this phenomenon is due to mechanical error, we used two channels' intersections composed of a pulsimeter and an oscilloscope for measuring both hands. Thus, the phase difference of two pulse waves is a phenomenon which appeared due to the motion of the blood vessels depending on the characteristics.

For computerized analysis of the Visual C++ program, all incoming signals of pulse waves were set to 0 automatically, then noises were eliminated and the output data of 1000 points/s was calculated. In the other words, after collecting the spot where a striking point is emerged along the pulse wave in accordance with time, serial process was used for computing the raw data with a self-developed consumer manual to decide whether to choose the repetitive process than five detected pulse wave

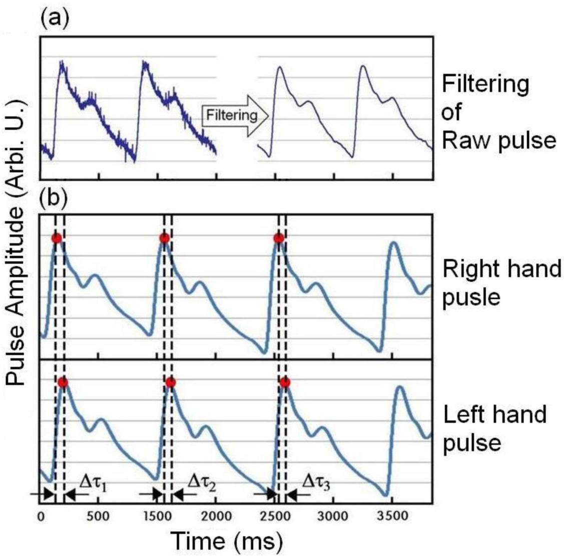

Fig. 2. (Color online) (a) Filtering process for all data of both hands' two pulse waveforms using a wrist clip-type pulsimeter equipped with magnetic sensing Hall device to smooth the rough noises. (b) Two different arterial pulse signals obtained by simultaneous measurements of both hands' clip-type pulsimeter. Here, Δτ is a time interval measured from a phase difference of two pulse waveforms.

signals. In other words, after collecting the striking point where the pulse wave emerges with time, a serial process was used for computing raw data with a self-developed manual to select either the repetitive process or the five detected pulse wave signals. Four basic steps are as follows: (1) Showing the pulse wave based on the measured data from the clip-type pulsimeter; (2) Calculating the particular data with measured basic data; (3) Saving the measured data; (4) Loading the measured data and displaying it. The shape of pulse wave is measured at the both hands' radial artery simultaneously and time difference (Δτ) of main peak value are indicated in Fig. 2(b) through data filtering process on computer. When selecting the five lowest noises from the eight phases, differences appeared between both hands' pulse waves from 22 participants, the time values of x-axis used is indicated at Table 1. The produced time difference Δτ of phase differences in ms unit from all of the clinical participants' data of both hands' pulse wave was determined as the marginal error within ± 5% of accuracy.

This research framed a hypothesis: the distance from heart to left radial artery is shorter than the distance of from heart to right radial artery, thus, it reaches the left radial artery earlier. However, the result of an experimental value that showed the time differences Δτ of negative (−) reaching the pulse wave at right hand's radial artery first is observed from the values from 6 experimenters among 22 experimenters in Table 1. However, experimental values showing negative time differences Δτ reaching the right hand's radial artery first is found from 6 out of 22 experimenters in Table 1. Going back to the beginning of the experiment, we checked the problems implied and found that the initial formulated hypothesis could be wrong.

Table 1. The average time interval (ms) and the estimated pulse wave velocity (EPWV) (m/s) between two main peaks and the pulse wave velocity are calculated and estimated by two different simultaneous measurements from dual-handed clip-type pulsimeter mounted with left hand and right hand. Here, the standard deviation and the mean value for $\Delta\tau_{ave}$ (ms) and (EPWV) (m/s) are noticed.

Clinical Participant Number	Age	Average Time $\Delta\tau_{ave}$ (ms)	Estimated Pulse Wave Velocity (EPWV) (m/s)
1(R)*	20	11.0	4.50
2(R)	20	28.5	1.75
3(R)	20	8.0	6.25
4(R)	20	8.0	6.25
5(R)	20	10.5	4.75
6(R)	20	4.0	12.50
7(R)	20	5.4	9.25
8(R)	20	13.0	3.80
9(R)	20	10.0	5.00
10(R)	21	15.5	3.20
11(R)	23	17.0	2.95
12(R)	23	15.5	3.20
13(R)	23	17.0	2.95
14(R)	23	15.0	3.30
15(R)	27	15.5	3.20
16(B)*	28	12.0	4.15
17(L)*	20	-4.5	-11.10
18(L)	20	-11.5	-4.30
19(B)	26	-8.5	-5.90
20(B)	28	-13.0	-3.85
21(L)	29	-8.0	-6.25
22(L)	30	-15.5	-3.20
Standard Deviation	3.53	11.7	5.52
Mean Value	22.7	6.5	1.92

*Here, (R), (L), and (B) are right hander, left hander, and both hander, respectively.

Based on the mimetic diagram of main blood vessels in human body (Fig. 1), an assumption for the length of blood vessel is impossible for constructing a hypothesis [11, 12]. The pressure wave occurs to the aorta at the time of heart contraction and this pressure wave delivers radial artery along an aorta. The pressure pulse wave reaching the radial artery has differences in arrival time depending on the distance from heart to radial artery, thus the denotative method for the distance delivering the pressure pulse wave need to be divided over a difference of arrival

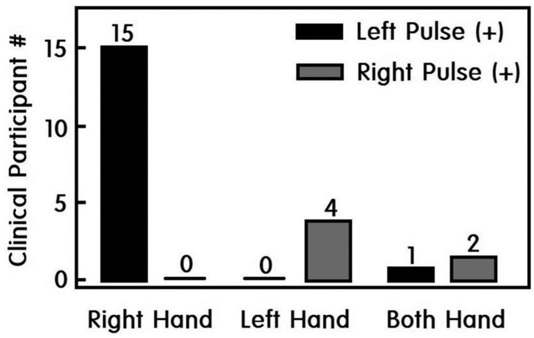

Fig. 3. Analysis histogram for the pulse signals of left hand and right hand measured from Table 1. The right pulse (+) and the left pulse (+) show earlier pulses for more left pulse than the right pulse, respectively.

time. This is used to calculate pulse wave velocity [13].

The distance from aortic valve to wrist is 0.8 m in principle. If it took about 0.25 second to reach the pulse wave, the pulse wave velocity (PWV) would be 3.2 m/s. If the radial artery distance from both sides of the heart is different, only about 5 cm of differences can be considered generally. Therefore, the difference of left and right blood vessel's length can be ignored with the heart being the central figure in quickening the blood flow and the PWV by a decreasing degree of elasticity for artery and an increasing degree of stability when a widely known hardening of the artery has proceeded clinically.

We investigated 15 people with positive values of phase difference where the pulse wave of left radial artery arrives earlier than the right; and, 6 people had right hand arrivals earlier. There is something in common of being left-hander or ambidextrous whose right radial artery beats earlier. After dividing the experimental group on right-hander, left-hander, and ambidextrous basis, the difference is distinct in Fig. 3. All 15 right-handers' left radial artery was beating earlier; and 4 left-handers' right radial artery was earlier.

And in the case of 3 ambidextrous, there was 1 person for earlier left radial artery and 2 people for earlier right artery. Thus, a large quantity of muscle could be a hassle when assuming the pulse wave. Fig. 3 is the analyzed clinical result from 22 people which measures pulse waves from both hands' radial artery. As indicated, the length and structure of artery from the heart in cardiovascular circulating system is symmetrical to the heart of the central body while the thickness of blood vessel is connected in the same shape. We can deduce that the elasticity of blood vessel through the muscle influences both hands when working out.

When we look at the bar graph of Fig. 3 that summarizes clinical data of Table 1, the right-hander's left pulse signal is arriving earlier from the heart to radial artery. Left-hander has right pulse wave signals arriving more quickly from the heart. Since the pulse wave's velocity of propagation is shown to be influenced by the blood vessel hardness of individuals, the propagation of the pulse wave calculated from phase difference is both fast and slow upon each other [14].

4. Conclusion

In the conclusion, using the prototype model of two clip-type pulsimeters with a permanent magnet and Hall device, we compared and analyzed two signals from the pulse wave of both hands' radial artery without pressure. We confirmed phase differences that have clear distinction of two pulse waves for right-handers and left-handers targeting male subjects of 20 years of age. The shape of two pulse waves from the phase difference predicts that the propagation of pulse wave can be affected to be fast and slow for each other. And, thus, blood vessel hardness differences of both left and right hand of each subject is observed as a potential reason for such results instead of the muscle quantity.

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