Measurement of Spatial Pulse Wave Velocity by using Clip-type Pulsimeter Equipped with Hall Sensor and Photoplethysmography

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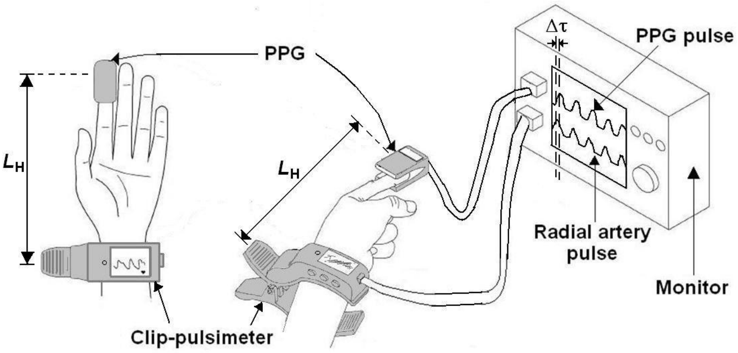
1. Introduction

The development of medical devices for bio-signal monitoring of pulse frequency, heart rate, the blood velocity, PWV(pulse wave velocity), SPWV(spatial pulse wave velocity), and blood pressure is a prerequisite for the U-health-care industry. Through periodic research on the radial artery, the Hall device was developed to sense magnetic field changes generated by periodic movement. A permanent magnet has been fixed at the radial arterial side. Based on the same operating principles, researchers advanced the existing technology to develop a wrist-wearable clip-type pulsimeter. Therefore, the present research aimed to develop a medical device with the combined capabilities of a photoplethysmography (PPG) and clip-type pulsimeter. Then goal was to measure two respective pulse waves simultaneously and to determine the properties and the potential applications of SPWV studies by analyzing the data obtained from the two measurements.



$$\text{SPWV (Spatial Pulse Wave Velocity)} = \frac{L_H\text{(Hand length)}}{\Delta\tau\text{(Time interval)}}$$

Figure 1.

2. Acquisition of the Pulse Wave by using the Clip-type Pulsimeter

PPG, which measures the degree of light absorption in a tissue based on the change in peripheral blood flow rate, is used in the optical method of measuring pulse waves. If we measure the intensity of the light transmitted to the skin by attaching a luminescent sensor and photo detector to the pulsimeter, the output of the photo detector will indicate that the signals are moving in accordance with every heartbeat. In contrast, other medical devices for relaxation pulse detection indicate an increase in the signals detected with a decrease in blood flow rate. A PPG usually displays a low-frequency band; however, a high-frequency band can occur relative to the origin of the PPG signal, depending on individual pulse frequency. Therefore, the PPG was designed to detect frequency bands ranging from 0.05 Hz to 20 Hz. A direct constant-current source is used to activate the red light of the

LEDsensor. The light sensor of the photo detector displays two outputs(+, −) with opposite current flow directions by converting the outputs into currents after detecting the incoming light. To convert the currents into voltage, a current-voltage converter circuit is used, connecting the output to a difference amplifier.

3. Measurement and Analysis of SPWV

When the heart contracts, a pressure wave will occur at the aorta and is delivered to the radial artery. Given that the distance of 0.8 m from the muscle to the peripheral parts will take the pulse wave approximately 0.23 s to travel to the radial artery, the PWV would be 3.2 m/s.

Using the clip-type pulsimeter, equipped with a Hall device,the differences between the two respective waveforms obtained from the PPG, which uses SpO_2 to indicate the pulse waveform, and the radial artery pulsimeter, which indicates the oxygen saturation level, are simultaneously measured (Fig. 2). We were able to measure SPWV by dividing the time difference of the two waveforms by the distance of the wrist to the fingertip. The interrelation of the estimated blood pressure can be determined by performing a statistical analysis of the experimental clinical data. In effect, $\Delta\tau$ indicated an approximately three-fold difference in the two peak values.

The differences of SPWV and PWV between males and females are shown in Table 1. The significance level was set at *p*-values less than 0.05. The SPWV of males were significantly faster than that of females. And there was nearly significant difference between male and female. In order to investigate the cause of the gender difference, we analyzed the interrelation of SPWV to PWV, distances, blood pressure and pulse rate. The relationships are presented in Table 2.

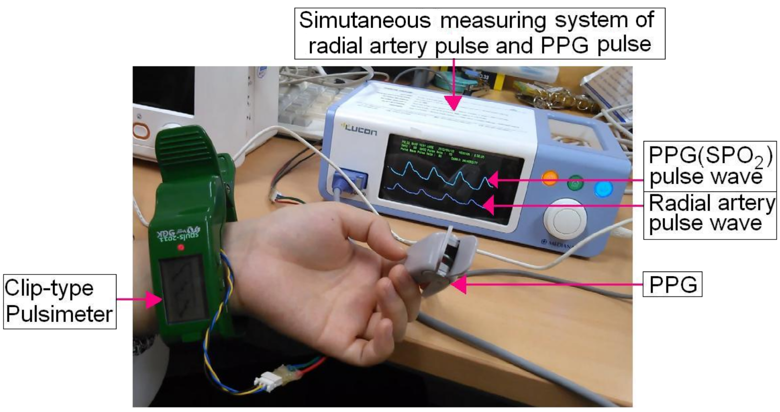


Figure 2.

Table 1. Correlation Coefficients between SPWV and the Other Parameters. (n=39)

Parameters	SPWV	PWV
Distance from sternal angle to wrist	0.455**	0.253
Distance from wrist to fingertip	0.352*	0.203
Systolic blood pressure	0.039	0.374*
Diastolic blood pressure	0.020	0.368*
Pulse rate	-0.025	0.411**
PWV	0.106	-

* $p < 0.05$, ** $p < 0.01$.

There was no significant correlation between SPWV and PWV. It implies that clinical characteristics of SPWV are different from that of PWV. In this study PWV was, as it is well known, in significant relation to blood pressure and pulse rate. On the other hand, SPWV was not in significant relation to blood pressure and pulse rate, but to arm and hand length. The reason of this result seems like that the blood pressure inside of the arterial vessel will be closed to 0 mmHg around of peripheral blood vessel. PWV is mainly determined by collagenization of elastin fiber located in the large artery wall and vascular smooth muscle tone controlled by sympathetic nerve activity. Therefore an increase in sympathetic nerve activity causes an increase in the pulse rate, blood pressure and PWV. But in case of vascular walls located between wrist and fingertip, especially in terminus of the blood vessels such as capillaries, there are only a few elastin fibers and vascular smooth muscles. Generally blood vessels in men are better developed than in women because men are bigger than women and need more blood supplied to the terminal tissue in body. Therefore we estimated that the reason the men's SPWV was faster than women's SPWV could be vascularity is better developed in men's terminal tissue.

5. Conclusions

In this study, we placed a clip-type pulsimeter, affixed with a permanent magnet on the radial artery protrusion of the wrist to detect the pulse waves (through a Hall device) that were emitted from the magnetic field by generated the work of the radial artery. In other words, a hardware based voltage detection system was applied through equipping the Hall device right upper side after placing a permanent magnet in the center of the radial artery (the "Chawn" area of wrist). We developed a system that used a clip-type pulsimeter and PPG equipment. The SPWV gained by simultaneous measurement, using both the clip-type pulsimeter and PPG was not in relation to PWV.

Male SPWV was significantly faster than that of the female. The difference between that of the male and the female was nearly significant. We believe the reason for the higher SPWV in males is due to the larger vascularity of male terminal tissue when compared to that of a female. We suggest these results are the basis for a new bio-signal that can be monitored using a clip-type pulsimeter and PPG and then displayed using a dual screen apparatus for patient to principal clinical parameter. The findings of the present study indicate that SPWV measurements can be useful for obtaining continuous blood pressure and pulse measurement data, using an unpressurized type of PPG for application in a U-health-care bio-monitoring system. However, further analysis of the pulse wave algorithm is necessary to verify the accuracy of our device.

Acknowledgements

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