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홀소자가 구비된 요골동맥 집게형맥진기와 심전도로 측정된 맥파전달속도

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자성센싱 홀소자가 구비된 집게형 맥진기와 대중적인 생체신호를 측정하는 심전도를 이용하여 맥파전달속도(PWV)를 조사하였다. 동시 측정된 심전도파의 피크치와 요골동맥파의 시작점의 시간차 그리고 심장과 손목간의 거리차를 가지고 맥파전달속도를 계산하였다. 임상데이터로부터 분석된 PWV값은 5~7 m/s의 범위 안에 평균 6 m/s이었다. 맥파전달속도 분석을 통한 혈관탄성도를 예측함으로써, 미래의 한양방 협진용 건강관리 의료기기에서 제시하는 주요 지수로 응용할 수 있는 가능성을 확인하였다.

주제어 : 자성센싱, 홀소자, 맥파전달속도(PWV), 심전도(EEG), 요골동맥파, 집게형 맥진기

Pulse Wave Velocity Measured by Radial Artery Clip-type Pulsimeter Equipped with a Hall Device and Electrocardiogram

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The clip-type pulsimeter equipped with a magnetic sensing Hall device and the most popular body sign of the electrocardiogram (ECG) were investigated in order to analyze the pulse wave velocity (PWV). The PWV simultaneously calculated by means of time difference between the maximum peak of ECG pulse wave and the starting point of radial artery pulse wave, and distance difference between the heart position and the radial wrist position. The PWV analyzed from the clinical data was a wider scope of 5~7 m/s with an average value of 6 m/s. By the prediction of blood vessel's elasticity from the analysis of PWV, it may be useful for developing an oriental-western diagnostic medical signal device for a U-health-care system in the future.

Keywords : magnetic sensing, Hall device, pulse wave velocity (PWV), electrocardiogram (ECG), radial artery pulse, clip-type pulsimeter

I. Introduction

Sensing technology to measure bio-signals such as blood pressure, pulse, blood velocity, and pulse wave velocity is an important means for continuous management of human diseases. The medical remote service through the on-line network after measuring these signals outside the hospital and the other medical service for the promotion of health or effective management of the athletes' exercise and physical condition will be needed in the research field of future medical system [1, 2]. The sensors currently developed are somewhat less accurate and inconvenient with the limitations of measuring time and space in case of outdoor activity. In particular, they cannot measure blood pressure and pulse without causing inconvenience to the patient, and have remarkably a low accuracy because of noise by body's movement [3].

Unless biometric accuracy is reliable, nothing can be used as decision data for medical practices. So, accurate measurements are an essential precondition for the

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settlement of Ubiquitous-Health (U-Health) [4]. Currently, medical factors measured through arteries are indices established in the western medical system where objective experiments and studies have been carried out using medical devices, which do not cover the measurement factors in the oriental pulse diagnostic method. Therefore, the major research that can increase the objectivity of the data measured by integration with existing western medical devices is necessary, so that experiments and studies in the oriental pulse diagnostic method can be carried out. There have been many studies on a guarantee of portable medical devices, which should be mobile and made smaller as a vital element, but they are still at an early stage for usage of U-Health.

In addition, the development of a system that measures bio-signals such as the blood pressure and pulse of the elderly infirm and the chronically ill provides treatments and services for the users who have any abnormalities. The necessity of treatments through the analysis of the measured data is at the stage of establishing a new concept and a tool. Pulsimeters using sensors for the pressure are commercialized, but they have a demerit that they are difficult to industrialize for U-Health as they cannot guarantee smaller size and mobility. Most pulsimeters currently industrialized use one sensor contacting the tube part or three sensors contacting three points of radial artery wrist, so they cannot get optimum signals unless placed in exact position. Moreover, existing blood pressure gauges and pulsimeters mostly use sensors made of a rigid body, so they put considerable pressure to a certain point on the skin during the pulse measurement, which may cause pain and fear. Therefore, the technological supplementation is necessary to develop the new pulsimeter.

This study used a prototype analyzing the pulse wave of radial artery measured using a wrist wearable clip-type pulsimeter in which a small permanent magnet is fixed to radial perimeter and a magnetic sensing semiconductor Hall device is installed at the top. A device to measure the electrocardiogram (ECG) simultaneously by linking to its device was developed. In other words, ECG wave and radial artery pulse wave were simultaneously measured using a patient monitor established ECG, and a cuff less clip-type pulsimeter equipped with a Hall device as a pulse measuring sensor for non-invasive medical treatment. The characteristics of pulse wave velocity (PWV) in analyzing the pulse wave and ECG were studied.

II. Experimental Methods

The prototype of clip-type pulsimeter used in this study is composed several parts of permanent magnet, Hall

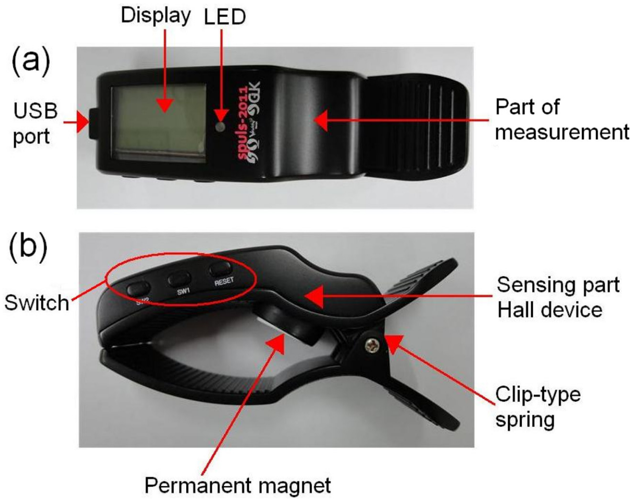

Fig. 1. (Color online) (a) The upper view and (b) the side view of real measuring feature of side view for a clip-type pulsimeter equipped with a magnetic sensing Hall effect device passed signals through the voltage detecting hard ware system. All the arrows indicate main parts composed of permanent magnet, Hall sensor, part of measurement, LED, display, USB port, and switch.

sensor, part of measurement, LED display, USB port, and an on switch (Fig. 1). Especially, the elastic Latex rubber was used for surface texture of contact skin part to avoid pressing the skin locally. The permanent magnet, cylinder shape of 2 mm for diameter and 1 mm for height, of approximately 300 Oe of surface magnetic field, is placed at the center of elastic rubber and fastened as an epoxy. In other words, the central circular disk of permanent magnet is placed at the part "Chawn of radial artery and is evenly stretched. Latex rubber surrounds the contact skin surface of the wrist. Contacted cylinder permanent magnet with skin of radial artery is able to move easily by vibration of pulse [1, 3].

Used in this experiment, key component of clip-type pulsimeter and the displacement between the Hall effect device and the magnet is 2.5 mm [4, 5]. The permanent magnet inside (1 mm), is moving up and down by high and low vibration, when placed at artery pulse. An incoming signal of pulse wave acquired from the clip-type pulsimeter sets to 0 automatically, removing noise and acquiring the output data of 1000 points/s. The analyzable visual C++ program at PC is equipped inside of the measurement part. It can calculate more than five pulse-wave signals, which is detected through the clip-type pulsimeter after selecting where remarkable point is at the pulse wave form by the time.

To get pulse wave of radial artery, the permanent magnet is put close to the skin surface. It changes the position of magnet from radial artery with the vertical displacement. The variation in position of the magnet changes the strength of the magnetic field. Hall sensor detects certain field intensity and follows the magnetic displacement. The output detected by Hall sensor represents the change in magnetic field with respect to the voltage signal. At this time there is also a change in the noise signal. So filtering the changed signal with analog filter, and then make the signal analog to digital by A/D Converter is built in processor, it accumulate the digitized signal. Sampling the pulse signal to digital signal suggests the feature point of pulse frequency and computing time after differentiating of each signal. Magnetic sensor of Hall device is used A1395 type by Allegro Company that has highly sensitive and linear characteristic in strength of magnetic field. Within V_{CC} input voltage has 10 mV/G sensitivity and let 0.1~3.2 V in the linear characteristic strength of magnetic field when apply to $V_{CC}/2$ V of polarity [3, 4].

This research used 3.3 V so calculate substitution V_{CC} available to sensing until 155 Oe. The distance between the magnets to the sensor has to make the strength of the magnetic field below 155 Oe. We get the data from A/D Converter through analog filter but still have a noise. So design the digital filter of processor for remove the noise [5]. That digital filter is used low pass filter by moving average filter to remove noise. Moving average filter recalculates with adjacent 50 data. To minimize the noise should increase filtering area but that makes intensify distortion of data. Therefore, we decide of suitable filtering area. Each divided section of cycle from pulse signal has been done filtering and first derivation.

ECG is recorded on curve of potential difference and heartbeat depending on heart contract [6]. Heart has self-moving and rhythmic, so heart is unique and different kind of muscle than other muscles. Heart contract is like a generator supplying electricity. In other words it is minute electric that dynamics of heart contract occur from sinus node of atrium. This minute electric flow through the heart muscle than current is flow all of the body, and it can record the current from body surface. This recording device called ECG that ECG wave recorded electrocardiogram [7].

The pulse transfer time (PTT), part of the pulse wave velocity (PWV) method of measurement, which is measuring the compliance, or the tension level of blood vessel for the circulatory system. It is the method using widely to the study of circulatory system. The PTT is the time of transiting pressure from aortic valve to peripheral part. The elasticity is a proportional to contrary concept of compliance and depends on blood vessel's distance and structural characteristics of arterial wall. Furthermore, PTT is decreasing caused arterial stiffness by vascular system disease, diabetes, senility, and others.

First select two points of what you want to measure, and then use two points of pressure sensor or pressure element or use the pole points and measure the transition of impedance or light sensor or ECG method. Distance between the cardiac output's start point and final point divided by PTT gives PWV. PTT and PWV are inversely proportional to each other. The elastic blood vessel is soft and elastic so it can absorb the pulse wave and makes PTT slower [8]. It cannot absorb pulse wave and make PTT faster because hard and small blood vessel is going stiffening and smaller by cholesterol [9].

In this research, we want to measure both the PPT and the PWV, so we used ECG pulse wave and radial artery pulse wave together as you see Fig. 1, and used Hall device in the pulsimeter for measure the radial artery. In Fig. 2, we detect R_P point in ECG pulse wave, and detect H_P point in radial artery pulse wave with the pulsimeter. The time difference between R_P and H_P is defined by the PTT. Also, Fig. 2 shows configuration of ECG and radial artery pulsimeter for the measurement of PWV. Here H_P and H_D are a distance of heart position, starting point of radial artery pulse wave and a distance of radial wrist position, respectively.

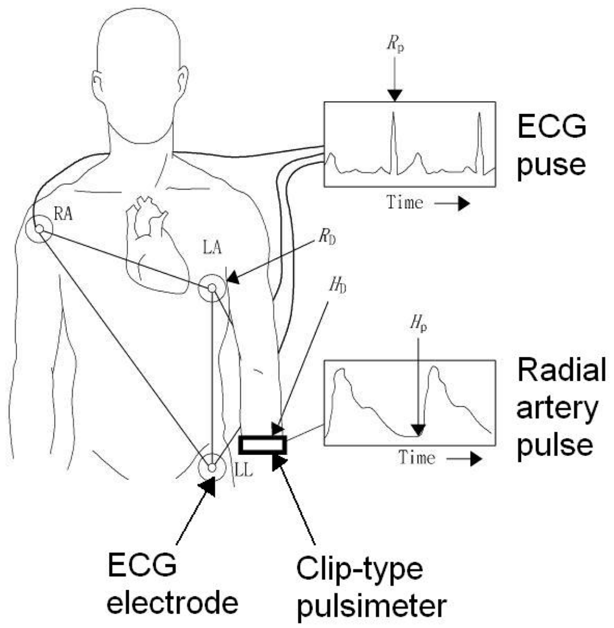

Fig. 2. Configuration of ECG and radial artery pulsimeter for the measurement of PWV. Here R_P, R_D, H_P, and H_D are maximum peak of ECG pulse wave, distance of heart position, starting point of radial artery pulse wave, and distance of radial wrist position, respectively.

III. Results and Discussion

When the heart contract occur pressure wave, this pressure wave through aorta sends to radial artery. But, this reaching time is distinction by the length of heart to radial artery, PWV is divide the pressure wave and the reaching time. In principle, length of heart to radial artery is 0.8 m and reaching time is 0.25 s that makes 3.2 m/s of PWV. Widely known clinically hardening of arteries goes along, it decrease the grade of elasticity of artery and increases the grade of stiffness [10]. It is reasonable to disregard the distinction length of left blood vessel and right blood vessel because normal heart of left-right radial artery can consider 5 cm. Meanwhile it can change the blood flow rate according to blood vessel diameter size. News from nowhere the blood flow rate at the artery is 50 cm/s, at the capillary 0.5 mm/s, at the vena cava 25 cm/s. The capillary is slower and slower because it separate in various parts that makes total section area widely. On stability, cardiac output is 5 *l*/min and it takes 50 s to 60 s to cycle the whole body [11, 12]. It always changes depending on heart contractile force, heart rate, blood viscosity, blood volume, etc., and depending on sex, body position, outside temperature etc. Fig. 3 shows measuring system of this research. ECG pulse and radial artery pulse measured with EEG and clip-type pulsimeter equipped hall device shows up to two different wave time difference of peak value.

PWV can measured the time difference EEG pulse and radial artery pulse on Fig. 3 divided by the distance from the heart to the wrist of the test subject. Result of clinical trial lead correlation of blood pressure estimation. The software patient monitor-based sand to the hardware that data of experiment with RS-232 communication port about 115,200 bps transmission speed and mark at monitor then save the sanded experiment data. Real time display of the transmitted data from hardware can be used to check the status of the data, designed the wave analysis in a form of the excel file for save at any moment. These kind waves of using patient monitor software are shown in Fig. 3.

The person directly involved of clinical test about measured pulse wave velocity are 40 people, which includes students, graduate students, and school personnel approximately 20 years of age, belong to the Department of Oriental Biomedical Engineering in Sangji University. The method of experiment is to take a comfortable seated position and get the ECG wave with the attached induce I, induce II, induce III of standard limb leads, at the same time put clip-type pulsimeter magnet on the wrist radial artery for appear the main pulse signal. The time measured the difference between the heart and the wrist of measuring point to get PTT and PWV of equations of (1) and (2) show Fig. 4.

$$PTT = (R_P - H_P) \tag{1}$$

$$PWV = (R_D - H_D)/PTT \tag{2}$$

PTT is the time difference of peak point of ECG wave and start value of radial artery. Actually, PTT of eq. (1) and eq. (2) is an average vaule of 5 different time intervals, as shown in Fig. 4.

Fig. 5 shows through analytical researches size order of

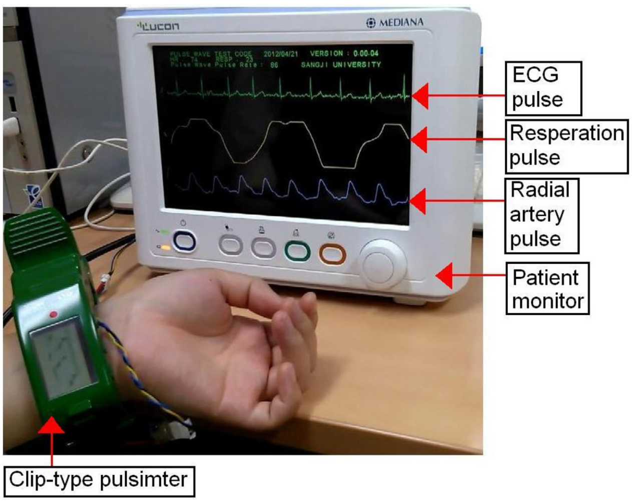

Fig. 3. (Color online) Real picture of simultaneous measurement for ECG pulse and respiration pulse by using patient monitor made by Mediana Co., Ltd. (Wonju, Korea), and radial artery pulse by using the clip-type pulsimeter equipped with a magnetic sensing Hall device.

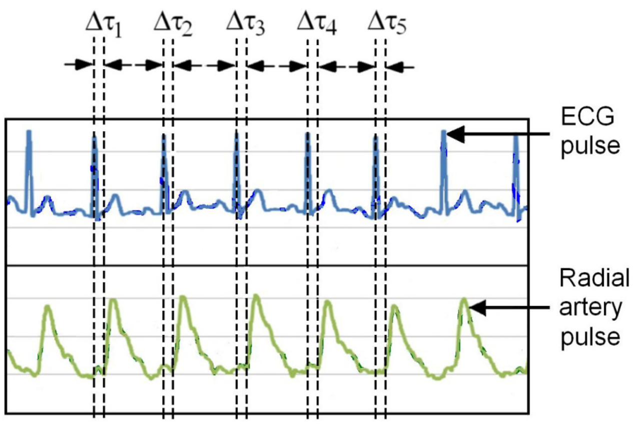

Fig. 4. (Color online) ECG and radial artery pulses obtained by the simultaneous measurements from ECG meter and clip-type pulsimeter mounted with the attached induce I, II, and III and axis for the standard (anode) limb lead and a left hand wrist, respectively. Here $\Delta\tau_i$ is time interval measured from i^{th} phase difference of two pulse waveforms.

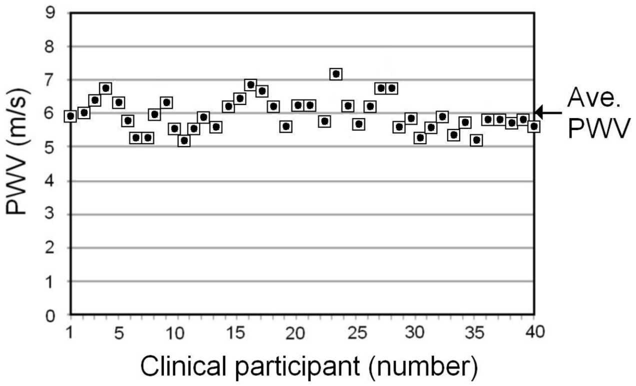

Fig. 5. The analysis of PWV from 40 clinical participants having 20 ages according to the increasing order of maximum blood pressure. The average value of PWV is about 6 m/s.

maximum and minimum blood pressure in blood flow about 40 people having 20 ages. Every clinical participant PWV is same as Fig. 5, which minimizes the error with extraction 4/1000 s smallest data of PWV, which compares ECG pulse and radial artery pulse. In the eyes of the Fig. 5, PWV that gave third data which measuring system both of clip-type pulsimeter is distributed in 5~7 m/s, an average value of PWV is 6 m/s that shows approximate the existing value. Both of PWV and blood flow is important body sign measuring instrument, it is significance of helping normal people to know their body sign and take care of health themselves. That is, by the prediction of blood vessel's elasticity from the analysis of PWV, it may be useful for developing an oriental-western diagnostic medical signal device for a U-health-care system in the future.

IV. Conclusions

In the this research, two simultaneous peaks of radial artery pulse wave and electrocardiograph pulse wave were measured by using the clip-type pulsimeter equipped with a Hall device, and the electrocardiogram (ECG) were investigated in order to analyze pulse wave velocity. The measured value of pulse wave velocity was about 5~7 m/s, and it was proved that the new method could provide more precise value of pulse wave velocity than the conventional biomedical signal monitoring system. This result implies that the data measured by the oriental medical diagnosis apparatus (pulsimeter) is clinically useful in the future.

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