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Fabrication and Characterization of a Wrist Wearable Cuffless Pulsimeter by Using the Hall Effect Device

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A wrist wearable cuffless pulsimeter with a portable and small size apparatus using Hall effect is fabricated. The analysis of the pulse wave measured by the testing product of pulsimeter is done to measure the pulse rate and blood pressure. The blood pressure obtained by the puslimeter is compared with the practical values measured by electronic or mercury liquid blood pressure meters. The detail analysis of a pulse wave measured by a wrist wearable cuffless pulsimeter detecting the changes of the magnetic field can be used to develop a new diagnostic algorithm of blood pressure applying for oriental medical apparatus.

Keywords : blood pressure meter, cuffless pulsimeter, Hall effect, clinical testing product

1. Introduction

According to Ubiquitous-health industry, the new medical paradigm, a medical service will be provided not only at hospital but also in real life. As the market of its continuous growth is expected, the main technologies, accuracy and convenience of sensing and a medical information that needs for care of individual's health, are necessary to standardize for developing products. To see on spatial side of it in real life, developing a sensing technology which cares individual's health and measures blood pressure and pulse of patient is necessary factor to enlarge the range of medical service. This makes it possible that the chronically ill, the old and the infirm can measure and monitor blood pressure or pulse repeatedly, also can manage optimized service that prevents form diseases.

Traditional technology using a radially arterial pulsimeter is a conceptually materialized measuring device of pressure and pulse to portable device as watch or ring [1, 2]. Also, it is difficult to measure data accurately to use a traditional taking pulse method when it moves, because it is difficult to hold its sensor and it makes static even though the traditional taking pulse method can measure blood pressure and pulse by holding its pulse wave sensor at aorta radialis. There is optical, electrocardiogram and presser sensor for the traditional pulse wave measuring sensor which difficult measuring method brings about hardship of industrialization problem causing by flaw of oversized device [3, 4]. To solve these problems, it is necessary to develop wrist holding measuring instrument of checking blood pressure and pulse which is held its sensor on perimeter of radius of wrist to analyze blood pressure or pulse and monitor effectively to take pulse of aorta radialis using Hall element [5-7].

Therefore in this research, the first product is produced by using Hall device which is able to measure minute change of magnetic field by pulsatory motion and permanent magnet. Also an algorithm of estimation of blood pressure is developed to analyze a pulse wave from data of testing on patients.

2. Waveform Analysis of Radially Artery Pulse

Principal elements of measuring the pulse by human in

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traditional pulse method are force of pulsatory motion, period of pulsatory motion, expansion of pulse, speed of contraction, palpation depth, width and length of pulse [8, 9]. The wrist wearable cuffless pulsimeter of our research has important technological meaning to analyze and monitor blood pressure and pulse by holding it on perimeter of radius of wrist and perimeter of ulna to measure pulse wave of aorta radialis effectively [4].

To make a wrist wearable cuffless pulsimeter, we analyzed experiment data that received to demand the shape of spatial pulse by reading the type of wave which ranged Hall device with constant arrangement. Effect of Hall element used for the main material of magnetic converted element which is composing with general Indium antimonide (InSb), Indium antimonide (InAs), Germanium (Ge), and Silicone (Si) [10]. Since the size of electromotive force by magnetic field can measure magnetic force, there is an advantage that is able to measure the magnetic field of micro portion or magnetic field. In addition, when the alteration of magnetic field results from the position, measuring their position is possible.

Schematic of the basic structure of wrist wearable cuffless pulsimeter is Fig. 1 as follows. Alteration of voltage, using the magnetic Hall device, gained as electrical signal followed by position change of a permanent magnet situated on radial artery. Electrical signal means waveform of pulse. Through the hardware of circuit, electrical signal get only the signal that is differentiated signal of magnetic change. The signal process module shows the shape that offered picture of pulse by the magnetic change of position change through software. The size of Hall multiplex device and magnetic field sensitive rate from using radial artery position to pulse wave sensor based on its semiconductor is real shape of PCB (Print Circuit Board) with Hall multiplex device and property of curve which is 3×4 mm^2 and 1.2 mV/Oe, respectively.

Entered electrical signal through three multiplex (MUX) in Hall device array qualifies a minute parallel condition through the wheatstone bridge circuit. It also saves to memory device through amplifier circuit and bandwidth filter circuit. The data of 30 frames per second processes rapidly. Output signals of processed hardware deliver to the circuit part of software which is connected to RS232C and the signal at the moment converts to Math-Lab program through matrix so that shows the image to monitor.

Fig. 2 is an example waveform that applied to estimation and measurement of blood pressure and it shows that righteousness of the main correlation factor about the regression analysis for the estimated algorithm of blood pressure. We signify necessary main correlation factors to deduction of the regression analysis equation for the estimated algorithm of blood pressure which are the time of systolic period, the reflective time, the notch time, the acceleration of pulse wave, the ratio of area (systolic period area/diastolic period area), and the increasing pressure index (reflective wave peak/systolic wave peak).

3. Clinical Data of a Wrist Wearable Cuffless Pulsimeter

The imaging circuit diagram of system by computer, read 36 hall devices of three sets according to the fact that Hall device is a set. Generally, through hardware, signal of hall device delivers to software by converting into

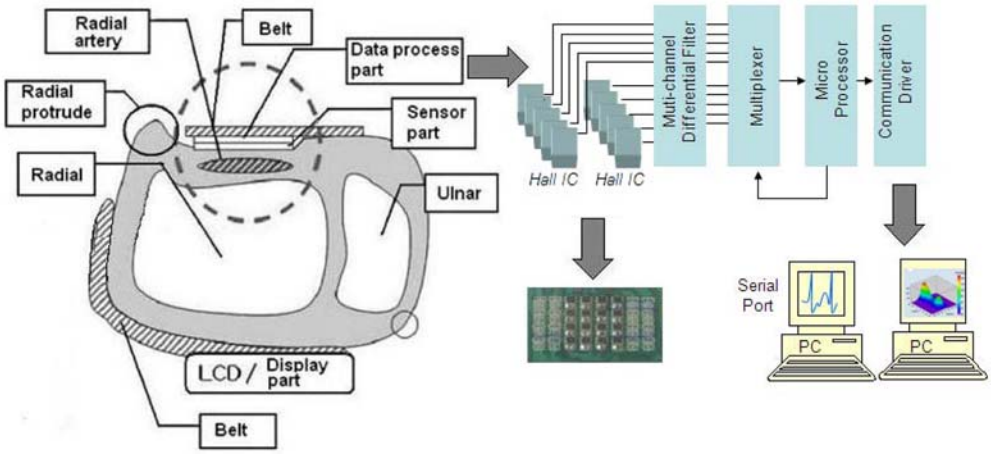

Fig. 1. (Color online) Schematic of the basic structure of wrist wearable cuffless pulsimeter. A cross-section of one form of the radial artery pulsimeter's pulse-sensing and skin-contacting parts by using multiple Hall devices and permanent magnets, respectively. The pressure chamber between the skin-contacting and pulse-sensing parts is full of air. A functional block diagram showing a detected signal treatment hardware which is built in a radial artery 3-dimensional and spatial pulse sensing part.

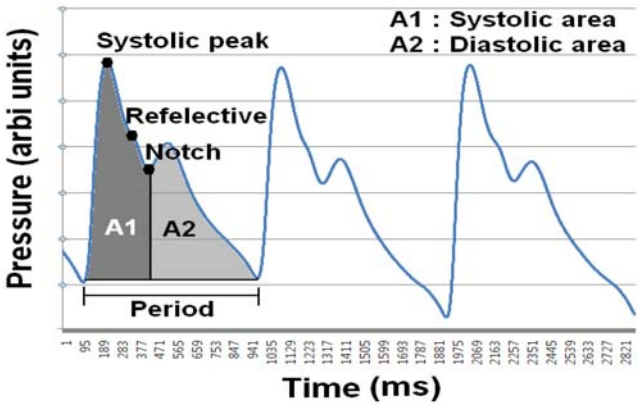

Fig. 2. (Color online) A typical pulse waveform to analyze a pulse signal carried out by using the pulsimeter. The regression analysis for the estimated algorithm of blood pressure needs to the following six major correlative factors; ① the period of pulse wave, ② the time of systolic period, ③ the reflective time, ④ the notch time, ⑤ the ratio of area (systolic period area/diastolic period area), and ⑥ the increasing pressure index (reflective wave peak/systolic wave peak).

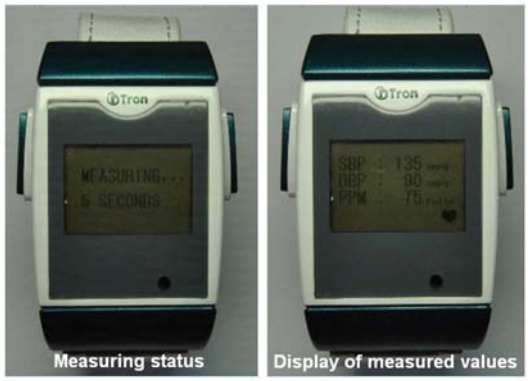

Fig. 3. (Color online) Photographs of the clinical product testing of the pulsimeter using Hall device. Here the weight and consuming power of the wrist wearable pulsimeter are 80 g and 1.65 W, respectively. The product testing of the proposed radial pulsimeter and the measuring feature, which are a wrist watch or bracelet, transfer the increased pressure to the skin-contacting part intact when the pressure of the constant pressure chamber is increased.

waveform and combines all those waveforms of peak value to change to video signal so that consists of monitoring structure.

The clinical product of a wrist wearable cuffless pulsimeter looks like Fig. 3 which uses Hall device to get data. A permanent magnet and Hall device that placed inside of air bladder are arranged safely to contact with the biggest pulse spot in radial artery. The pulsimeter is reduced its weight to about 80 g including battery. It showed that amount of electrical power of lithium battery is less than 1.65 W (Output current 500 mA, 3.4 V) after wear the pulsimeter. It is able to save the value of high/low blood pressure measurement for one day, if the battery is 100% recharged. We distinguish normal person and high blood pressure patient to the relation of pulse between blood pressure of systolic and regular arteriotony which is able to divide by the shape of pulse wave [11]. The diastole is justified to start point of the representative pulse wave and the systolic period is appointed to the first zero point of the first differential wave. The systolic peak (or augmentation point) is appointed to sixth differentiation's second or third zero point of normal blood pressure's pulse wave and the notch point is appointed to zero point of third or fourth of sixth differentiation and pulse wave of high blood pressure.

Table 1. Comparison of the measured and estimated values of BP obtained from the clinical data.

BP Classification	Systolic blood pressure (SBP)			Diastolic blood pressure (DBP)		
Clinical patient number	Estimated value	Measured value	Error	Estimated value	Measured value	Error
1	123.0	145	22.0	69.0	63	–6.0
2	121.6	140	18.4	70.0	63	–7.0
3	125.1	142	16.9	69.3	81	11.7
4	125.4	140	14.6	68.8	77	8.2
5	122.9	142	19.1	68.6	78	9.4
6	122.8	135	12.2	68.5	81	12.5
7	125.0	137	12.0	67.6	73	5.4
8	123.6	135	11.4	67.1	74	6.9
9	123.3	136	12.7	67.1	74	6.9
10	122.9	133	10.1	65.5	58	–7.5
11	118.3	130	11.7	68.0	61	–7.0
12	123.1	135	11.9	67.3	54	–12.3
13	119.6	105	–14.6	64.7	50	–14.7
Standard deviation			12.1			5.9

The clinical trials participants about the algorithms of blood pressure estimation are composed of various age groups in Sangji University's Oriental Medical Industry Development Center (7 males, 6 females). The experimental method is to measure pulse wave with no pressurization method pulsimeter about five seconds to get output of pulse wave. The measured and estimated values of the BP of 13 participants were compared, as shown in Table 1. Right after getting the pulse wave, estimating blood pressure with electrical sphygmomanometer on right arm and left arm. If patients always wear the wrist wearable pulsimeter, a frequency of diagnosis will increase rapidly and early detection of diseases rate will be higher. Furthermore, patients possibly get new information about looking after one's health and health problems at home, if they always wear the wrist wearable pulsimeter.

4. Conclusion

The clinical product of portable pulsimeter to make it miniature for deriving an accurate measurement of data of blood pressure and pulsation are fabricated. It can be commercialized as non-pressurization blood pressure and pulsimeter. Therefore, through the analysis of non-pressurization pulse wave using a Hall device that perceived a minute magnetic field change of permanent magnet, we proposed the new estimated blood pressure diagnostic algorism of oriental medicine.

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