

Study on the Selection of Representative Pulse Wave

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Objectives : The purpose of this study is to develop the method of selecting representative pulse wave.

Methods : The pulse waves were acquired at the right and the left Guan point(關部) with 1420 people who were apparently healthy. The shape agreement of right and left pulse wave and the floating-sinking ratio were compared with three cases, which were the pulse height based method, the pulse area based method, and the pulse time based method.

Results : In the point of the shape accordance, the pulse time based method was the best, and the pulse area based method was the worst. In the point of the floating-sinking ratio, the pulse height based method was the worst, and the pulse time based method was the best.

Conclusions : So, the pulse time based method was recommended for selecting the representative pulse wave. This study compared the selection methods of representative pulse using the physiological characteristics of pulse wave. Further studies are required, because the representative pulse wave is the main factor of determining the shape and the floating-sinking characteristic of the pulse wave.

Key Words : representative pulse wave, shape accordance, floating-sinking ratio, pulse height, pulse time

Introduction

Pulse diagnosis, which uses the senses of the doctor's finger in order to observe the pulsation, therefore examining the condition of the patient's inner organs and meridian pathways, is an important method of assessment in Oriental medicine. With the Pulse Diagnosis Apparatus, the pulse diagnosis have made a great progress in providing a objective definition of the characteristics of the pulses, which had been characterized in terms of natural phenomenon or poetic expressions. Furthermore, there are several attempts to standardize the doctors' subjective diagnosis with the Pulse Diagnosis Simulator¹⁾.

Researches on the objectification of pulse diagnosis can be broadly divided into 4 parts; pulse formation

mechanism, objective description of the pulse waves, objective measurement and examination of the pulse waves, and objective analysis of pulse waves²⁾. Some research has made efforts to interpret the formation mechanism of the pulse waves by analyzing the hemodynamic analysis of the cardiovascular system³⁾ and also by analyzing the motion of radial artery in an anatomical point of view⁴⁾. Some research has discussed an objective standard for pulses⁵⁾, and classified the 28 traditional pulses systematically⁶⁾. To objectify the description of pulse, several studies have been made on the measurement parameters except blood pressure, such as the palpation sound of the artery⁷⁾ and the hemodynamic parameters by the supersonic waves⁸⁾. Some studies have focused on the automation of pulse recognition and assess-

• Received : 26 September 2008 • Revised : 10 November 2008 • Accepted : 11 November 2008

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ment with computer⁹⁾.

To develop a pulse diagnosis apparatus combinable to the traditional pulse diagnosis principles, measurement signals that have a significant meaning to oriental medicine theories are required. The representative pulse wave, selected among several pulse wave signals, is an essential element in determining the pulses' status (floating pulse or sinking pulse) and figure. This research critically analyzed the problems of the existing method used to select representative pulse waves, and then suggested a new method by considering the physiological characteristics of the artery.

Materials and Methods

1. Research subjects.

Pulse waves were acquired from 1420 apparently healthy people who visited the Medical Center in order to take a medical check up. Excluding 427

data with errors, this research used data of 993 subjects. Table 1 shows the reason of excluding.

The following table is the gender and age distribution of the subjects.

2. Selection of representative pulse wave

To distinguish the method of pulse diagnosis, the following terms were used. Hemodynamic pulse wave is the blood pressure wave of the artery excluding the palpating pressure. On the other hand, hemodynamic pulse wave with the palpating pressure are called the pulse wave.

1) measurement of pulse wave

Pulse wave signals were measured at the Guan point(關部) with the Pulse Diagnosis Apparatus (3-D Mac, Daeyo Medi, Korea). When the sensor approximately positioned near the subject's Guan point, the 3-D Mac compared signals from the 5 sensors and automatically located the center measuring sensor on the Guan point. The 3-D Mac adjusted the pressure

Table 1. The reason of data excluding

reason	number of data
missing Guan(關部) data	48
missing constitution data	50
missing data file	2
missing excel file	34
measurement error	190
pulse shape detection error	84
T1 detection error	19
total	427

Table 2. The distribution of participants by age and sex

		Age (years)							Total
		10-19	20-29	30-39	40-49	50-59	60-69	70-	
male	N	7	20	109	166	185	56	14	557
	%	1.3	3.6	19.6	29.8	33.2	10.1	2.5	
female	N	2	28	84	166	109	28	19	436
	%	0.5	6.4	19.3	38.1	25.0	6.4	4.4	
Total	N	9	48	193	332	294	84	33	993
	%	0.9	4.8	19.4	33.4	29.6	8.5	3.3	

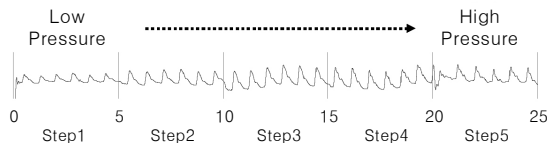


Fig. 1. The measured pulse waves

range into 5 stages, and pressed the measuring point with constant pressure for 5 seconds, according to each stage. Fig.1 shows the measured pulse wave signals.

2) The characteristics of the pulse wave signals.

Fig.2 shows the typical pulse wave signal. We could observe three peaks from a pulse wave. The first peak is caused by the contraction of the heart, the superposition of the reflected wave effect the shape of the second and the third peak. The first peak is a critical index of the contraction features of the heart. In this study, H1 represents the pressure of the first peak and T1 represents the time of the first peak. A represents the area of the pulse wave. Physically, A means the energy of the pulse wave.

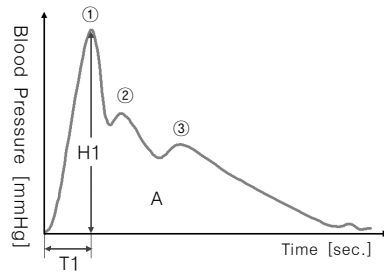


Fig. 2. Parameters of the pulse shape

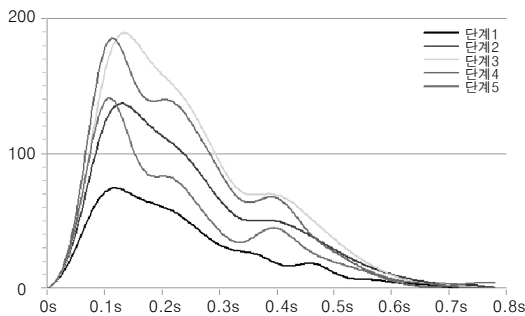
3) The conventional method of selecting representative pulse waves.

The conventional method selects the representative pulse wave with the basis of H1. Among the representative pulse waves of each steps, the pulse wave with the highest H1 is selected as the representative pulse wave for 5 steps. Fig.3(a) shows the representative pulse waves for each step of the measured signals in Fig.1, and Fig.3(b) is the representative pulse wave of all steps.

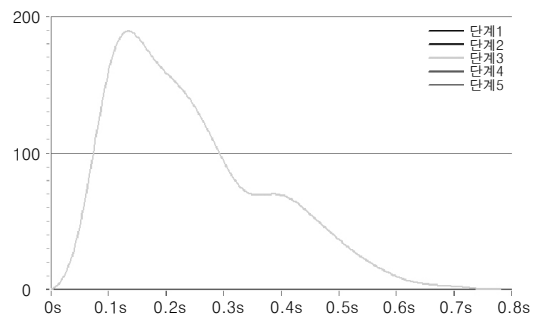
3. Problems of the conventional method.

By analyzing the representative pulse waves that were acquired by the conventional selection method, the following problems were found.

1) The decrease of pulse wave area (A) was not reflected.



(A) for each step



(B) for all steps

Fig. 3. Representative pulse wave

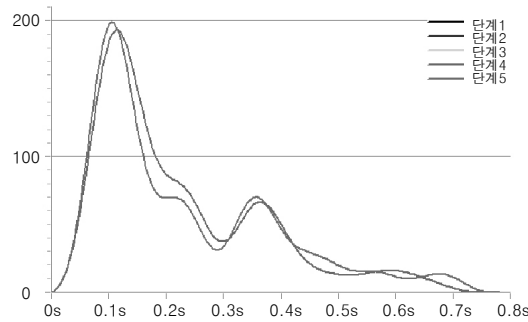


Fig. 4. Example of pulse area problem

There were cases in which even if the H1 was the highest, the A was not the maximum. In Fig.4, the 5th step becomes the representative pulse wave with the highest H1 standard. However, the A of 5th step is smaller than that of 4th step. The Physical meaning of the A is the energy of pulse wave, it must be carefully considered.

2) The shape of the left and right representative pulse waves was not in accordance.

Fig.5 shows the left and right pulse wave of an identical subject. Both the 3rd stage of each hand was selected as the representative pulse wave. However, the shape of each wave did not match. To determine the shape accordance of the two pulse shapes, the shapes of three pulse peak was used.

Although the pulse wave is a hemodynamic pulse wave with the palpating pressure, the main factor for the shape of wave is the physiological characteristics of the artery.

Symmetry is the basic rule of the human body, the left and right representative pulse wave should not be in severe discordance. With the H1 based selecting method, the shape accordance ratio of the representative pulse waves for both hands was 62%.

3) The ratio of the sinking-pulse was too high

In this study, the floating pulse is defined as the pulse which has the representative pulse in the 1st or 2nd step. The middle pulse has the representative pulse in the 3rd step. The sinking pulse has the representative pulse in the 4th or 5th step. The ratio

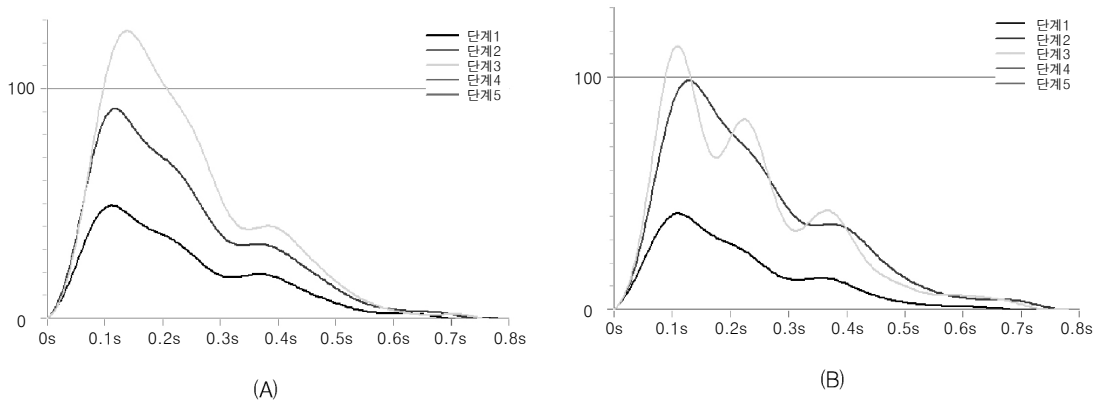


Fig. 5. Example of pulse shape discordance problem

of floating/middle/sinking pulse with the H1 based method was, 19%/33%/48% in the left hand, 7%/20%/73% in the right hand. The deviations among the ratios were considerable, and especially the ratio of the sinking pulse was too high. Also the discordance of the left and right ratio of floating/middle/sinking was serious.

4. Comparison of the selecting methods for the representative pulse wave

The three methods for selecting the representative pulse wave were compared. With qualitative analysis of clinical data, T1, H1, A were selected as the evaluation parameter for selecting the representative pulse wave. The H1 based method, which is the conventional method, selects the waveform with the highest H1 as the representative pulse wave. The T1 based method selects the waveform with the longest T1 as the representative pulse wave. Similarly, A based method selects the waveform with the largest A as the representative pulse wave.

Results and Discussion

The three methods for the selecting representative pulse wave were compared with 993 subjects.

1. The shape accordance of the left and right representative pulse waves

Table 3 shows the result of the shape accordance of the representative pulse wave with 993 subjects. T1 based method showed the maximum accordance. The A based method showed the minimum accordance.

According to the cardiovascular physiology, the pressure wave is produced by the ejection of blood by left ventricle. The wave is transmitted to the upper limb and the lower limb along the artery. And the hemodynamical pulse wave is formed with the superposition of the reflected wave and the forwarding wave¹⁰⁾. Therefore the main factor for the shape of the pulse wave is the physical characteristics of the artery. Since the physical characteristics of the left and right arteries are generally identical, there should be little difference in the shape of the pulse waves measured at the radial artery of the

Table 3. Comparison of shape accordance

		A	T1	H1
accordance	n	594	696	611
	%	60	70	62
discordance	n	399	297	382
	%	40	30	38
total	n	993	993	993

Table 4. Comparison of floating and sinking ratio

		A		T1		H1	
		left	right	left	right	left	right
floating	n	265	104	415	289	186	70
	%	26.7	10.5	41.8	29.1	18.7	7.0
middle	n	281	227	214	219	329	203
	%	28.3	22.9	21.6	22.1	33.1	20.4
sinking	n	447	662	364	485	478	720
	%	45.0	66.7	36.7	48.8	48.1	72.5
total	n	993	993	993	993	993	993

both wrist. Although the pulse wave is a hemodynamic pulse wave with the palpating pressure, the main factor for the shape of wave is the physiological characteristics of the artery. The characteristics of the skin of both hands don't differ significantly, the shape of the pulse waves at both hands should be identical. With qualitative analysis of clinical data, we found that T1 is closely related to the representative pulse wave. In other words, the shape of the pulse wave was changed after the maximum step of T1. T1 based method increased the shape accordance of pulse waves than the H1 based method.

2. The ratio of the floating pulse and the sinking pulse

Table 4 shows the floating and sinking ratio of the three methods. The imbalance of the floating and sinking ratio of the right hand was more serious than that of the left hand. And the ratio of sinking pulse was high. H1 based method showed the worst case at the both hands. For example, in the H1 based method of the right hand, the floating pulse ratio was 7%, whereas that of the sinking pulse was 72.5%. The T1 based method showed a fairly reasonable proportion between the floating pulse and the sinking pulse.

The floating-sinking status of the pulse is the pulse location where the most apparent pulse beat is measured. It can be said that the floating pulse is observed at the low pressure compared to the sinking pulse. Although the scientific mechanism of the floating-sinking pulse is still unknown, the excessive rate of sink pulse seems not natural. So we selected the method in the point of minimizing the imbalance. Shin¹¹⁾ proposed a mathematical model considering the characteristics of the skin, and reported that the thickness of the skin increases the tendency of sinking pulse. Presuming that a person normally uses his/her right hand, the thickness of the right hand is larger than that of the left hand. So it is reasonable that the ratio of the sinking pulse of the right hand is larger than that of the left

hand. According to Table 4, in all cases the ratio of the sinking pulse of the right hand is larger than that of the left hand. Nevertheless, the excessive imbalance of the sinking pulse is hard to see as a normal physiological characteristic.

Till this point, there has been almost no researches regarding representative pulse waves. In western medicine the inner pressure of the blood vessels are emphasized, so there is no such concept like pulse diagnosis as in oriental medicine, which observes the pulse waves according to the added pressure on the skin. Even in Korea, researches on Pulse Diagnosis Apparatuses have been the majority, with no gold standard on how to select a representative pulse wave.

I carefully assume that this research is the first to present a standard on representative pulse waves. By adopting the symmetry theory which is the most fundamental characteristic of the human body, this research selected the left and right accordance and the symmetry of the sinking/floating pulse ratio as the standard for representative pulse waves. Not having been able to supply a quantitative parameter for the comparison of the left/right pulse shapes is the limitation of this paper, but this remains as a matter to be presented through further investigation in the near future.

Conclusion

Pulse waves were acquired from 1420 people who visited the Medical Center in order to take a medical check up. Pulse wave signals were measured at the Guan point(關部) with the Pulse Diagnosis Apparatus (3-D Mac, Daeyo Medi, Korea). Excluding data with errors, the three methods for selecting the representative pulse waves were compared with the data of 993 subjects.

The three methods for the selecting representative pulse wave were compared. With qualitative analysis of clinical data, T1, H1, A were selected as the evaluation parameter for selecting the representative

pulse wave. The H1 based method, which is the conventional method, selects the waveform with the highest H1 as the representative pulse wave. The T1 based method selects the waveform with the longest T1 as the representative pulse wave. Similarly, A based method selects the waveform with the largest A as the representative pulse wave.

1. The shape accordance of pulse waves at both hands was maximum in the T1 based method. The A based method showed the minimum accordance.
2. The imbalance of the floating and sinking ratio of the right hand was more serious than that of the left hand. The ratio of sinking pulse of the right hand was larger than that of the left hand. The T1 based method showed a fairly reasonable proportion between the floating pulse and the sinking pulse.

T1 based method was more reasonable than conventional H1 based method in the point of the shape accordance of pulse waves at both hand and the balance of the floating and sinking ratio.

Acknowledgement

This research was supported by a grant from the Next Generation New Technology Development Program (10028438) funded by the Ministry of Knowledge Economy of the Korean Government.

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