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Characteristics of the pulse wave in patients with chronic gastritis and the healthy in Korean Medicine*

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Abstract—**Chronic gastritis is a disease that occurs in one in every 10 persons in Korea. Endoscopic examination is needed to diagnose chronic gastritis in western medicine, but it causes patients pain, long period of examinations and financial burden. In KM (Korean Medicine), on the other hand, it can be known whether stomach is abnormal or not through a pulse diagnosis. The 'Guan' position of the right wrist is related to a stomach in KM. Thus, the pulse wave of the right-hand "Guan" of patients with chronic gastritis and the healthy were measured. Then, the diagnostic parameter and features to distinguish between the patients with chronic gastritis and the healthy were discovered. Through P-H curve, consequently, it can be concluded that the pulse waves of patients with chronic gastritis appear as a floating pulse, whereas the pulse waves of the healthy appear as a normal pulse.**

I. Introduction

Four examinations (observation, listening/smelling, asking and palpation) are used in KM to diagnose a disease, especially, pulse diagnosis, which belongs to palpation, is the most representative diagnostic method [1]. The doctor of oriental medicine classifies 28 different pulse qualities through a pulse diagnosis [2]. However, it is not easy for any human being to judge pulse quality. Therefore only trained experts are able to classify pulse qualities. Furthermore, the judgment of pulse quality sometimes can be different, according to the condition of a doctor. Hence the main contents of existing studies were to judge the pulse qualities, such as floating pulse, sunken pulse, slow pulse, rapid pulse and so on, through a pulse diagnosis [3]. Various studies, such as artificial neural network, fuzzy theory, decision tree and so on, were attempted to judge these pulse qualities [4, 5, 6]. However, there is not direct association between the pulse qualities through a pulse diagnosis and diseases in clinical practice. A lot of the studies to diagnose a disease, based on bio-signals, were conducted in western medicine. In this paper, therefore, it is studied to discover a diagnostic parameter, which can classify diseases through pulse diagnosis.

Chronic gastritis, which occurs in one in every 10 persons in Korea, is easy to neglect because there is not a noticeable subjective symptom. However, the chronic gastritis should be diagnosed early and supervised, consistently. This is because it increases the incidence of gastric adenocarcinoma [7]. In order to diagnose chronic gastritis with medical imaging an endoscope is being used in western medicine. This causes patients pain, long period of inspection and financial burden. On the other hand, pulse diagnosis in KM is based on basic theory that there are organs corresponding to three pulse positions ('Cun', 'Guan' and 'Chi') of the left and the right wrist. Of these, the 'Guan' position of the right wrist is related to a stomach. In this study, therefore, the pulse wave of right-hand "Guan" of patients with chronic gastritis and the healthy are measured. Therefore, the purpose of this study is to discover primary parameters and features that are able to distinguish patients with gastritis from the healthy.

II. Collection of Pulse Waves and Pre-Processing

The pulse waves are collected from 46 patients, with chronic gastritis (Male: 19, Female: 27) and 46 healthy people (Male: 15, Female: 31) in an Oriental Hospital of Daejeon University. Note that all subjects agree with gathering their own pulse wave. The average age of subjects is 67.1(±4.6) and the features of subjects are shown in Table I.

TABLE I. The features of subjects

	The healthy			**Patients with chronic gastritis**		
	Height	*Weight*	*Age*	*Height*	*Weight*	*Age*
Male	166.6	70.3	67.6	165.7	63.7	69.7
Female	152.1	57.4	66.5	152.9	57.4	65.7

In traditional pulse diagnosis, the practitioners usually use three fingertips (Index, Middle and Ring fingers) to feel the pulse fluctuation on three positions, named 'Cun', 'Guan' and "Chi', in a patient's wrist [1]. It is well-known that the right-hand 'Guan' is related to the stomach. Therefore, in this study, pulse waves are measured at the right-hand 'Guan' position of patients under five different pressures from 30mmHg to 230mmHg, which are exerted on the wrist. For simplicity, the exerted pressures on the wrist are called the

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pressing force, and 5 different pressures are designated as step 1, step 2, through step 5. In order to extract a feature point of each step of the pressing force pulse waves are measured for 5 seconds, to collect at least 5 cycles. Pulse-taking device is shown in Fig. 1, which is used to measure pulse waves in this study.

Figure 1. Pulse-taking device (Mac-01, HuBDIC, Korea)

High-pass filter is employed, as pre-processing of the measured pulse waves, so that the measured pulse wave of each step of pressing force starts at the same point. Moreover several cycles of the pulse waves to extract a feature point are divided into one cycle of pulse wave.

III. EXTRACTION AND SELECTION OF A FEATURE POINT

There are two methods to extract a feature point. One is to extract a peak and a valley point of each pulse wave and the corresponding time, as a feature point [8]. Another one is to extract a feature point by using the Gaussian model [9, 10]. In the former method, a feature point is not clear, as BVT (Blood Vessel Tension) is decreased. Therefore, the Gaussian model is used to extract a feature point, in this study. The pulse wave can be modeled as Eq. (1), including two Gaussian functions and offset.

$$f(x|A_1,\tau_1,\sigma_1,A_2,\tau_2,\sigma_2,d) = A_1 e^{-(\frac{x-\tau_1}{\sigma_1})^2} + A_2 e^{-(\frac{x-\tau_2}{\sigma_2})^2} + d \quad (1)$$

where, $A_1 e^{-(\frac{x-\tau_1}{\sigma_1})^2}$ is the primary wave and $A_2 e^{-(\frac{x-\tau_2}{\sigma_2})^2}$ is the secondary wave. The Gaussian model in Eq. (1) can be expressed with 7 parameters of $A_1, A_2, \tau_1, \tau_2, \sigma_1, \sigma_2$ and d. As shown in Fig. 2 each parameter denotes as follows:

- A_1 and A_2 are the amplitudes of two waves
- τ_1 and τ_2 are phases of the two waves
- σ_1 and σ_2 are width of two bell-shaped waves
- d is offset.

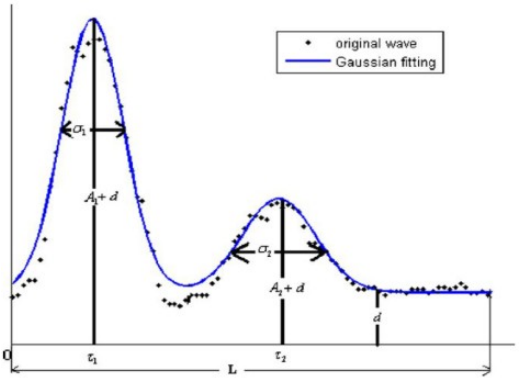

Figure 2. Gaussian model fitting parameters for a typical single-period waveform [10]

It is well-known that relative values between the two waves provide more reliable information. Therefore another 7 parameters, such as $\frac{A_2}{A_1}, \frac{\tau_2}{\tau_1}, \frac{\sigma_2}{\sigma_1}, \frac{\tau_1}{L}, \frac{\tau_2}{L}, \frac{\sigma_1}{L}$ and $\frac{\sigma_2}{L}$ are added [10]. T-test for 14 parameters in total is executed with the level of significance of 0.01 and 0.05, so as to choose a feature parameter that can distinguish between the patients with chronic gastritis and the healthy. As shown in Eq. (2), then, statistical difference is calculated to extract the most significant parameter, statistically, among the selected parameters through a t-test.

$$\text{statistical difference of } \alpha = \frac{|\overline{\{\alpha\}_H} - \overline{\{\alpha\}_P}|}{S_{\overline{\{\alpha\}_H},\overline{\{\alpha\}_P}}} \quad (2)$$

where, $\overline{\{\alpha\}_H}$ and $\overline{\{\alpha\}_P}$ denote the means of $\{\alpha\}_H$ and $\{\alpha\}_P$ respectively. $S_{\overline{\{\alpha\}_H},\overline{\{\alpha\}_P}}$ is defined as follows:

TABLE II. The data of feature points of patients and normal people for each step of pressing force

		A_1	τ_1	σ_1	A_2	τ_2	σ_2	L
Normal	Step 1	7.908 (5.763)	35.717 (11.621)	23.014 (8.493)	4.418 (2.809)	73.135 (13.930)	48.774 (12.364)	167.210 (26.383)
	Step 2	19.538 (6.523)	34.056 (7.481)	21.769 (5.029)	10.812 (4.494)	73.254 (11.574)	47.557 (10.526)	166.000 (25.474)
	Step 3	24.642 (10.475)	37.937 (16.639)	24.073 (12.969)	14.609 (10.700)	67.014 (13.852)	41.558 (9.719)	165.971 (25.286)
	Step 4	20.123 (12.679)	32.560 (12.301)	19.222 (8.859)	11.397 (8.086)	59.054 (18.875)	36.990 (15.856)	158.493 (31.059)
Patient	Step 1	13.376 (10.700)	36.857 (13.989)	23.397 (9.739)	7.173 (5.085)	73.265 (12.575)	48.923 (10.750)	169.493 (23.461)
	Step 2	20.686 (11.718)	36.528 (13.378)	22.926 (9.132)	12.604 (14.040)	72.158 (15.205)	47.289 (14.271)	168.434 (24.329)
	Step 3	20.582 (9.654)	38.686 (17.146)	23.220 (11.647)	14.054 (11.837)	63.589 (19.209)	40.421 (14.966)	166.702 (24.525)
	Step 4	15.208 (10.562)	37.106 (17.091)	22.239 (24.219)	10.361 (8.353)	62.336 (21.266)	38.541 (16.004)	156.434 (29.266)

$$S_{\overline{\{\alpha\}_H},\overline{\{\alpha\}_P}} = \sqrt{\frac{S_1^2}{N_1} + \frac{S_2^2}{N_2}} \quad (3)$$

where, S_1^2 and S_2^2 are the variances of $\{\alpha\}_H$ and $\{\alpha\}_P$ respectively. One parameter among 14 parameters to distinguish between the patients with chronic gastritis and the healthy is determined through the calculated statistical differences.

IV. Experimental Results

By using Eq. (1) with a feature point of each step of the pressing force, pulse waves can be generated using A_1 of Table II, as shown in Fig. 3. There is no feature point extracted in the step 5 where the highest pressure is applied. Therefore, the results from step 1 to step 4 are compared, in this study. With comparison of the pulse waves of the patients and the healthy, the amplitude of patients' pulse wave is high in the low pressing force (step 1, step 2) whereas the amplitude of the pulse wave of the healthy appears high in the high pressing force (step 3, step 4).

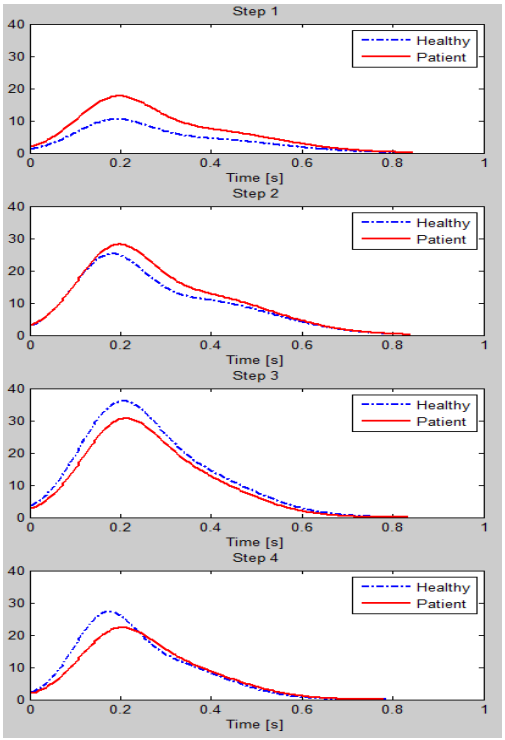

Figure 3. Comparison of the pulse wave of patients and the healthy

Fig. 4 shows the Pressing force on wrist against pulse Height, called P-H curve. The pressing force of step 5 is estimated by Gaussian model, because only the pressing forces of step 1 to step 4 are measured. In the case of the healthy, the highest value of pulse height is shown in step 3. In case of the patients, on the other hand, the biggest value of pulse height is displayed from step 2 and step 3. In addition, the value of pulse height is 24.642 and 20.686 for the healthy and patients, respectively. From these results, it can be known that pulse height of the patients is 84% of one of the healthy and pulse wave of the patients appears as a floating pulse.

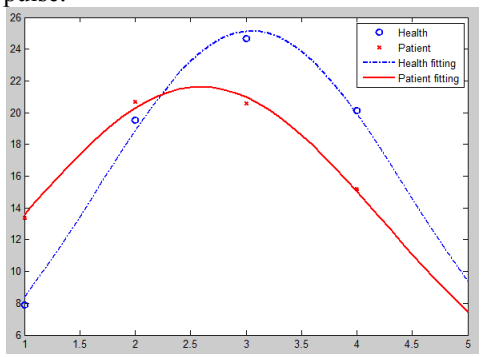

Fig. 4. P-H curve of patients and the healthy
(x-axis mean pressing force steps)

This implies that the results of this study agree with the content of literature that right-hand 'Guan' at the superficial level of depth is connected with the stomach. Note that the right-hand 'Guan' at the deep and superficial level of depth is related to the spleen and the stomach, respectively, as shown in Table III [11].

TABLE III. The pulse positions and their relationship to the 6 main acupuncture channels as noted in the nan jing

Position (right wrist)	Deep	Superficial
Cun	Lung	Large intestine
Guan	Spleen	Stomach
Chi	Pericardium	Triple Heater

Table IV and V show the results of t-test and the value of statistical differences. At the level of significance of 0.05, primary parameters to distinguish the patients and the healthy are extracted as follows:

- step 1: A_1, A_2
- step 2: τ_1
- step 3: $A_1, \tau_2, \tau_2/\mathrm{L}$
- step 4: $A_1, \tau_1, \tau_1/\mathrm{L}$

At the level of significance of 0.01, a total of 6 parameters are statistically significant. Of these, A_2 at step 1 has the biggest values of statistical differences. After taking all the parameters of the patients with chronic gastritis and the healthy, it can be concluded that p value of A_1 at step 1, step 3 and step 4 is less than 0.01. Moreover the value of statistical difference of A_1 parameter (6.44, 4.08 and 4.27) is greater than other parameters.

TABLE IV. The statistical differences of basic parameters for the two groups

	A_1	τ_1	σ_1	A_2	τ_2	σ_2	L
Step 1	**6.44****	0.90	0.42	**6.79****	0.10	0.13	0.93
Step 2	1.23	**2.32***	1.59	1.74	0.82	0.22	0.99
Step 3	**4.08****	0.45	0.70	0.50	**2.07***	0.91	0.30

Step 4	**4.27****	**3.09****	1.67	1.28	1.65	0.99	0.69

*p < 0.05, **p < 0.01,

TABLE V. The statistical differences of ratio parameters for the two groups

	A_2/A_1	τ_2/τ_2	σ_2/σ_1	τ_1/L	τ_2/L	σ_1/L	σ_2/L
Step 1	0.91	0.71	0.12	0.31	0.60	0.12	0.37
Step 2	1.78	1.89	0.06	1.72	1.48	0.93	0.68
Step 3	1.23	1.33	1.06	0.78	**2.12***	0.78	1.35
Step 4	1.77	0.34	0.17	**3.71****	1.61	1.67	0.85

*p < 0.05, **p < 0.01,

V. CONCLUSION

In KM theory, the right-hand 'Guan' at the deep and superficial level of depth is related to the spleen and the stomach, respectively. According to this theory, there should be a difference between the patients and the healthy, when measuring the pulse waves of the right-hand "Guan" at the superficial level of the depth. In this study, the pulse waves were measured from 41 patients with chronic gastritis and 41 health people. The elderly at the average age of 67.1 were chosen as the subjects for this study. A total of 14 feature points were extracted for each step of the pressing force by using Gaussian model. A_1 among the 14 feature points, is the most significant parameter to distinguish the patients with chronic gastritis and the healthy. The value of A_1 parameter, at each step of pressing force, can express P-H curve and the floating/sunken pulse can be judged through a P-H curve. Thus, it can be concluded that A_1 is the primary parameter to discriminate the patients with chronic gastritis. Then it can be diagnosed as chronic gastritis, through P-H curve that is generated by the value of A_1.

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