Measurement of Heart Rate Variability as an Interactive Determinant of the Autonomic Nervous System: Correlation With Chinese Medical Constitution

Yung-Hsien Chang, Chuang-Chien Chiu[1], Yan-Hong Chen[1]

Department of Acupuncture, China Medical College Hospital;

[1]Department of Automatic Control Engineering, Feng Chia University, Taichung, Taiwan, R.O.C.

Background. The autonomic nervous system (ANS) is the major system controlling the visceral activities. ANS contains both sympathetic and parasympathetic function and coordinates the activity of a specific organ. In this study, we measured heart rate variability (HRV) as an interactive determinant of ANS, and correlated ANS functions with Chinese medical constitution.

Methods. In this study we measured the patients' pulse rates and electrocardiography signals and then transformed the data into HRV ratios and spectral energy ratios to represent ANS functions. Three groups were studied in order to correlate HRV findings with the Chinese medical constitution. Healthy subjects were used as the control group (Yin-yang balance); patients in a vegetate state were categorized as being Yin-yang vacuity. Persons who were categorized as Yang vacuity in Chinese medical constitution.

Results. In the control group, the sympathetic HRV (LF) was 44.34 ± 26.64, and the parasympathetic HRV (HF) was 50.36 ± 25.38. The ratio (LF/HF) was 0.92 ± 0.35. That is, LF was balanced with HF, and the patient was considered to be in a homeostatic state. On the other hand, patients in a vegetate state had LF readings of 5.35 ± 1.12, and HF readings of 6.11 ± 2.53. Persons who were categorized as being Yang vacuity, had an average LF reading of 14.74 ± 1.01. Although HF was within the normal range (60.46 ± 40.32), the ratio between LF and HF was only 0.36 ± 0.18.

Conclusions. Our results provide useful information for the relationship between Chinese medical constitution and ANS activity. The procedure is non-invasive, and it could help physicians to make a reliable clinical diagnosis in the Chinese medicine constitution. **(Mid Taiwan J Med 2000;5:167-72)**

Key words

autonomic nervous system, Chinese medical constitution, heart rate variability

INTRODUCTION

Traditional Chinese medicine is a unique system that utilizes five diagnostic procedures: inspection, listening, smelling, inquiry, and palpation. The patient's condition is then categorized as being vacuity or repletion. Among these characters, the theory of Yin-yang balance is the most important, and that Yin-yang imbalance in a patient would appear as a particular symptom requiring immediate medical attention. [1-3]. Interestingly, the symptom of Yin-yang imbalance is quite similar to the described effect of autonomic

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Address reprint requests to : Yung-Hsien Chang, Department of Acupuncture, China Medical College Hospital, No 2, Yuh-Der Road, Taichung 404, Taiwan, R.O.C.

nervous system (ANS) activity [3]. Physiologically, the main function of ANS is to coordinate the activities of internal organs, such as adjusting body temperature, blood pressure, heart rate, and endocrine output. The corresponding relationship between the ANS activity and Chinese medical constitution therefore deserves more attention.

In this study, we will determine heart rate variability (HRV) and electrocardiograph (ECG) signals as an interactive determinant of ANS, and then correlate ANS functions with Chinese medical constitution [4-11]. The purpose of this study is to provide an objective measure for characterizing the state of vacuity or repletion by using modern techniques to analyze ANS activities. Moreover, the practice of traditional Chinese medicine could be coupled with modern medical diagnoses.

METHODS

Measurement and Analysis

Thirty healthy subjects without evident disease were used as a control group. Patients with obvious Chinese medical Yin-yang constitution were then placed into experimental groups. In addition to the normal control group (Yin-yang balance), two groups were further studied to correlate HRV findings with the Chinese medical constitution. Data collected from patients in vegetate states was used as Yin-yang vacuity (n = 30). Persons who are frequently cold-extremities and lack of energy were categorized as Yang vacuity in Chinese medical constitution (n = 30). The other three types of Chinese medical Yin-yang constitution, Yin-yang repletion, Yang repletion and Yin repletion, were categorized according to the measured ratio of sympathetic and parasympathetic HRV. Nonetheless, because the number of cases in each category was below five patients, the data for the accurate prediction are under evaluation in an ongoing study. The electrocardiogram signal was continuously captured by a computer, and the stability response of autonomic function was obtained by a resting test method. Before testing, subjects were examined by two respective physicians for the detailed Chinese medical Yin-yang constitution. Subjects were then laid quietly for 5 minutes while maintaining spontaneous breathing before the ECG. The subjects were not under the influence of alcohol, caffein or medicine. The test was performed in the morning between 9:00 A.M. and 12:00 a.m. with controlled ambient temperatures of 24 °C.

Physiological data were recorded by an ECG recorder (Model FCP-2201, Fukuda Denshi), and the signal was digitized by a 12-bits A/D converter (Model Lab-PC-1200, National Instrument). The data acquisition and analysis programs were analyzed under the LabVIEW. Off-line analysis was performed on a personal computer [6]. The ECG signals were collected at 300 samples/sec. Each data file contained nearly 350 points of R-R interval variability, and the QRS segment (ECG signal between QRS wave) [7] was used to characterize the QRS wave, from which the R wave can be located at the time axis by selecting the suitable threshold. The standard deviation of the R-R interval variability was calculated by time-domain analysis and power spectrum density (PSD) analysis [10]. The spectrum range was restricted to within 0.04 to 0.5 Hz in order to measure the autonomic function accurately [4-6, 8]. The low frequency (LF) was determined to be between 0.04 Hz and 0.15 Hz, and high frequency (HF) was determined to be between 0.15 Hz and 0.5 Hz.

RESULTS

Through the power spectrum density method in frequency domain of heartbeat (Fig. 1A), the difference in HRV could be visualized (Figs. 1B and C). The normal range of LF power in a person at a state of Yin-yang balance was 44.34 ± 26.64, while the HF power was 50.36 ± 25.38. The LF/HF ratio was 0.92 ± 0.35. The result indicated a balance between sympathetic and parasympathetic functions as depicted by PSD analysis (Fig. 2A).

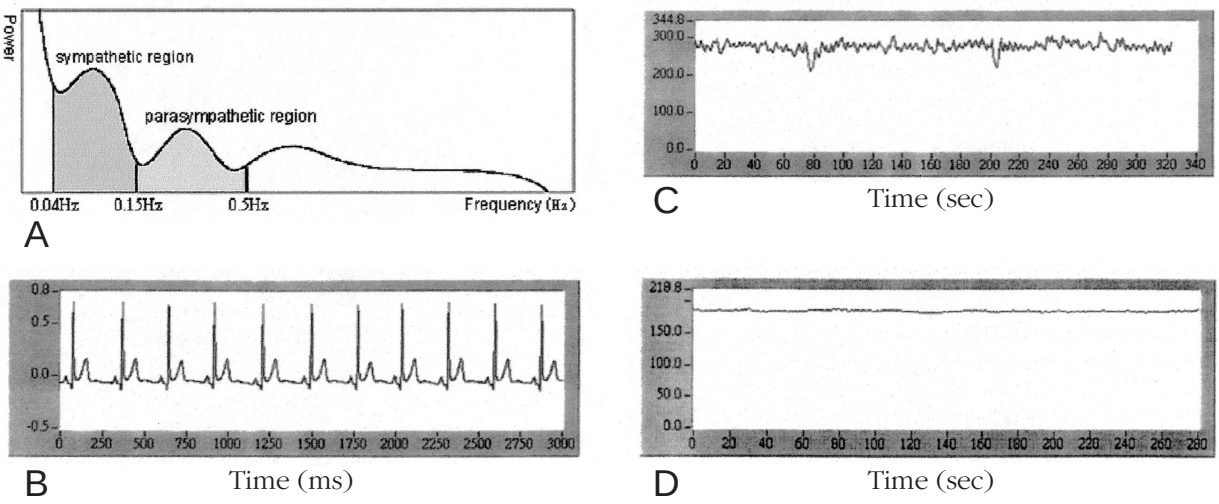

Fig. 1 Definition of power spectrum density regions, ECG spectrum and HRV profile. A: The regions of sympathetic and parasympathetic activities in PSD. B: Normal ECG spectrum. C: HRV profile of a normal person that represents Yin-yang balance. D: HRV profile of a patient at vegetate state that represents the extreme of Yin-yang vacuity.

Table 1. Comparison between parameters of Yin-yang balance and those of Yin-yang vacuity on mean of LF, HF, HRV and SD of HRV

Parameter	Yin-yang balance (n = 30)	Yin-yang vacuity (n = 30)	*p* value
LF	44.34 ± 26.64	5.35 ± 1.12	< 0.001
HF	50.36 ± 25.38	6.11 ± 2.53	< 0.001
SD of HRV (ms)	44.01 ± 10.64	20.52 ± 3.27	< 0.05

LF = low frequency power; HF = high frequency power; SD = standard deviation; HRV = heart rate variability.

Interestingly, LF/HF ratio in patients with Yin-yang vacuity was 1.13 ± 0.64. Nonetheless, LF was only 5.35 ± 1.12, and HF was also low, at 6.11 ± 2.53 (Fig. 2B). Moreover, the standard deviation of the R-R interval variability in the time domain could demonstrate a significant difference between Yin-yang balance and Yin-yang vacuity (Yin-yang balance: 44.01 ± 10.64 ms, Yin-yang vacuity: 16.66 ± 3.36 ms) (Table 1). The HRV standard deviation of person with Yang vacuity was 43.89 ± 11.03 ms, where the LF reading was 14.74 ± 1.01, and the HF was 60.46 ± 40.32. The ratio of LF/HF was 0.36 ± 0.18. Such data correlated well with our hypothesis (Fig. 2C).

Besides these three conditions, other examples of Yin-yang repletion, Yang repletion and Yin repletion were respectively shown in Figs. 2D to 2F. However, since the case number in each category was less than five, the data are being evaluated in an ongoing study. In terms of clinical parameters, no significant differences were found among groups that were divided by Chinese medical Yin-yang constitutions. In the Yin-yang balance group, the age was 24.0 ± 3.4 years, the height was 167.0 ± 7.3 cm, the weight was 62.6 ± 8.0 kg, blood pressure was 109 ± 12/69 ± 9 mmHg, hear rate 71.5 ± 9.6 beats/min, and body temperature was 36.6 ± 0.4 °C. In Yin-yang vacuity group, the age was 65.0 ± 19.1 years, the blood pressure was 112 ± 21/74 ± 14

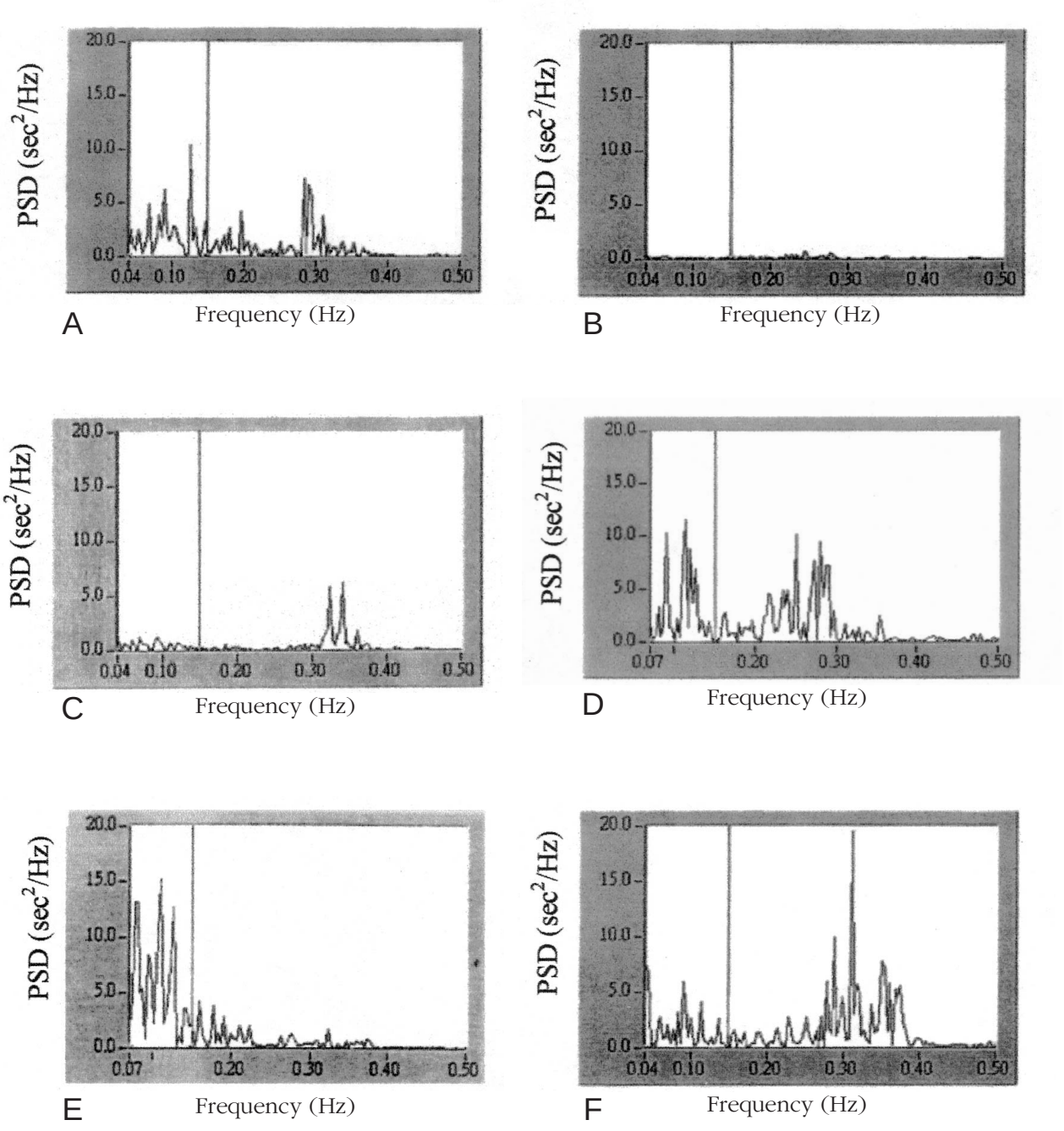

Fig. 2 Power spectrum density analysis shows the significant difference among persons at various conditions of Chinese medical constitution. A: Normal control that represents Yin-yang balance. B: patient at vegetate state that represents the extreme of Yin-yang vacuity. C: PSD profile of a person with Yang vacuity. D: PSD profile of a person with Yin-yang repletion. E: PSD profile of a person with Yang repletion. F: PSD profile of a person with Yin repletion.

mmHg, hear rate 63.6 ± 6.9 beats/min, and body temperature was 36.3 ± 0.7 °C. In Yang vacuity group, the age was 23.5 ± 2.6 years, the height was 161.0 ± 5.5 cm, the weight was 50.5 ± 4.3 kg, blood pressure was 112 ± 8/71 ± 6 mmHg, hear rate 66.0 ± 9.7 beats/min, and body temperature was 36.1 ± 0.3 °C. In Yang repletion group (n = 5), blood pressure was

102 ± 12/64 ± 9 mmHg, hear rate 73.9 ± 3.8 beats/min, and body temperature was 36.5 ± 0.2 ℃. In Yin repletion group (n = 4), blood pressure was 101 ± 9/65 ± 5 mmHg, hear rate 61.25 ± 9.8 beats/min, and body temperature was 36.3 ± 0.2 ℃. In Yin-yang repletion group (n = 4), blood pressure was 112 ± 7/75 ± 6.0 mmHg, hear rate 65.4 ± 11.0 beats/min, and body temperature was 36.5 ± 0.8 ℃.

DISCUSSION

We used a non-invasive method to evaluate the correlation of the autonomic nervous function with Chinese medicine Yin-yang constitution. Our results showed that by measuring R-R interval variability from ECG, the PSD analysis could differentiate Yin-symptom from Yang-symptom easily. The difference is quite significant ($p < 0.05$). Such results also suggest that utilizing a PSD analytic method to monitor the Yin-yang modulation or to follow the regulation of physiological activity is feasible. Our findings provide useful information confirming the relationship between autonomic nervous activity and Chinese medicine constitution. The principle could be applied clinically not only to make a reliable diagnosis in Chinese medicine constitution, but also to replenish the adequate remedy for patients in need.

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自律神經的功能與中醫陰陽體質的穩態相關性：以心率變異分析作為交感神經和副交感神經交互作用測定值並探討中醫體質之研究

張永賢　邱創乾[1]　陳彥宏[1]

中國醫藥學院附設醫院　針灸科　逢甲大學　自動控制工程學系[1]

背景　自律神經是調節內臟活動的主要神經系統。分析心率變異因此可以提供自律神經功能的資料。本研究是以心率變異分析作爲交感神經和副交感神經交互作用之測定值並探討其與中醫體質平衡穩態相關性之研究。

方法　本研究以測量健康人、植物人及陽虛病患的自律神經之交感及副交感神經時域與頻域分佈情形及振幅狀況，並由均衡比值探討其頻率能量比，同時探討陽證與陰證的臨床分析。

結果　正常人的自律神經活性，交感神經頻譜能量爲44.34±26.64，而副交感神經頻譜能量爲50.36±25.38，兩者間的比值爲0.92±0.35。長期臥床的植物人，其LF是5.35±1.12，HF是6.11±2.53，屬陰陽俱虛的病理變化。陽虛者，其LF爲14.74±1.01，能量較正常低，而HF在正常範圍，爲60.46±40.32，兩者間的比值只有0.36±0.18。

結論　心博間頻率變異可測出自律神經的變化調節，而頻域分析可反映自律神經活性。本研究探討自律神經活性與中醫體質學陰陽平衡，正常人的交感與副交感神經頻譜能量相互平衡，但植物人則自律神經活性低，屬中醫的陰陽俱虛，至於陽虛者則只有較低的交感神經頻譜，至於自律神經活性與中醫體質的相關，則要大量資訊測量及臨床體質去分析，才能得到肯定的答案。（中台灣醫誌 **2000;5:167-72**）

關鍵詞

自律神經，中醫體質，心率變異分析

聯絡作者：張永賢

地　　址：404 台中市北區育德路2號

中國醫藥學院附設醫院　中醫部

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