Relationship Between Power Spectral Densities of P-P and R-R Intervals

Yoshiaki TAKEI

Department of Health and Physical Education, Kobe University

To investigate the role of the peripheral effector for the generation of heart rate variability, the relationship among the P-P, R-R, P-R, and R-P intervals were compared on five healthy male subject in the supine position. During supine rest, electrocardiogram was monitored, and P-P, R-R, P-R, and R-P intervals were measured. Power spectral densities (PSD) were estimated by using direct method for successive 256 intervals. PSDs were integrated at the low (PSD_{LF}; 0.05-0.15 cycle/beat) and high (PSD_{HF}; 0.20-0.40 cycle/beat) frequency bands. Mean interval times of P-P, R-R, R-P, and P-R intervals were 827±40, 827±40, 657±34, 170±19 msec, respectively. PSD_{LF}s of P-P, R-R, R-P, and P-R intervals were 15677±2771, 15566±2815, 15345±2767, 1491±255 msec²/c/b, respectively. PSD_{HF}s of P-P, R-R, R-P, and P-R intervals were 13289±3602, 12918±3897, 12558±3630, 2758±517 msec²/c/b, respectively. The PSD of P-R intervals showed white noise. These results might suggest that the periodic fluctuation would be formed at or above the sinoatrial node.


Key words: Heart rate variability, Spectral analysis, Autonomic nervous system activity

It is well known that a healthy subject has periodic fluctuation of heart rate variability (HRV). This fluctuation was considered to be a biological error for a long time. Cardiac transplant recipients have no fluctuation of HRV (Sands et al., 1989). Heart rate control by cardiac autonomic nervous activities was accompanied with the HRV. Two peak power spectral densities in the low (PSD_{LF}) and high (PSD_{HF}) frequency bands were detected by using the spectral analysis. PSD_{LF} reflects sympathetic nervous activity and PSDHF vagal nervous activity (Pagani et al., 1986).

The indices reported previously were peak PSD (Hayano et al., 1990), integration of PSD (Ichimaru & Yanaga, 1989), ratio of peak PSDS (Pagani et al., 1986), and the ratio of integration of PSDS (Yamamoto et al., 1991).

Iwase et al. (1991) reported the muscle sympathetic nervous activities during tilting in the young and elder normal subjects with microneurogram. Elderly subjects enhanced the muscle sympathetic nervous activities than younger. The reflect of arterial baroreceptor influences the PSD_{LF}. The increase of the muscle sympathetic nervous activity would rise up the PSD_{LF}. However Simpson & Wicks (1988) described the smaller amplitude of PSD_{LF} in the elderly subjects than in the young ones in the supine and standing position.

The validity as indices of autonomic nervous activity for the ratio of peak PSD or integration of PSD need the linear relationship between the indices and the cardiac autonomic nervous activity. There was no report concerning about it.

The mechanism of the origin of the HRV was needed to validate the quantitative assessment for the autonomic nervous system activity by using the
spectral analysis of HRV. Lately, some researchers tried to calculate the fractal dimension from the time series data of HRV (Yamamoto et al., 1991). In these studies, almost researchers consider the fractal dimension to mean the complexity of upper brains stem. These discussion suggested that the fluctuation was formed in the upper brain stems. The purpose of this study is the comparison of the PSD of P-P, R-R, P-R, and R-P intervals on the electrocardiogram in order to investigate the role of peripheral effector for the origin of HRV.

METHODS

Five healthy male subjects were studied. The mean and standard deviation of their age, height, and weight were 30.2±6.0yrs, 168.3±4.8 cm, and 70.8±15.6 kg, respectively.

Each subject maintained rest for 10 min in supine position. At rest, analogue output from electrocardiogram with 1V/1mV were monitored from CMs or II- lead and stored to the video cassette data recorder. The stored data was digitized with A/D converter (Canopus Co.Ltd. JAPAN; Analog Pro I) whose sampling rate was 1KHz and transferred to the micro-computer (Epson Co. Ltd. JAPAN; PC386LS) for 300 Kword. The 2 Kbyte test signal was extract from the top of data. The prototype of one cardiac cycle was determined, and pre-P wave position, pre-S wave position, and post-T wave position were detected on the CRT. The amplitudes of P wave and Q wave were calculated automatically. The summation of the amplitude of Q wave and the difference between P and Q waves divided by 5.0 was stored to the memory 1. The summation of 100 msec and the time between R and T waves was stored to the memory 2. The data was read from the top of RAM disk data every one word sequentially, compared with the memory 1, and stored to the buffer array. When read data was greater than the memory 1, the difference was calculated between the present and the previous data. If the difference is less than 0, the previous data was determined as R wave automatically and memory 3 was incremented by 1. The peak value of buffer array was searched by using the smoothing first derivative method. The peak value was detected as peak P wave and buffer was cleared. The summation of the time to the peak P wave and memory 2 was stored to the array 1, and the time from P wave to R wave to the array 2. These operation was repeated 260 times. R-R interval was calculated by the summation of nth data of array 1 and array 2, and P-P interval by the summation of n+1th data of array 1 and nth data of array 2. These data was restored to the micro floppy disk.

The mean interval time of successive 256 R-R, P-P, P-R, and R-P intervals was calculated. PSD was estimated by direct method. The integration was performed at the low (0.05-0.15cycle/beat) and high (0.20-0.40cycle/beat) frequency bands.

One-way ANOVA was performed to the data. Significant level was 5%.

| Table 1 | Mean interval times and power spectral densities at the low and high frequency bands of P-P, R-R, R-P, and P-R intervals. |
|---------|-----------------|-----------------|-----------------|-----------------|
|         | time (msec)     | PSD_{LF} (msec^2/c/b) | PSD_{HF} (msec^2/c/b) |
| P-P interval | 827±40          | 15677±2771       | 13289±3602        |
| R-R interval  | 327±40          | 15566±2815       | 12918±3897        |
| R-P interval  | 657±34          | 15345±2767       | 12558±3630        |
| R-P interval  | 170±19          | 1491±255         | 2758±517          |

PSD_{LF}; Power spectral density at the low frequency band
PSD_{HF}; Power spectral density at the high frequency band
Fig. 1  Time series data and estimated PSD of P-P interval
Fig. 2  Time series data and estimated PSD of R-R interval
Fig. 3  Time series data and estimated PSD of R-P interval
Fig. 4 Time series data and estimated PSD of P-R interval
RESULTS

Table 1 showed mean interval times and estimated PSD_{LF} and PSD_{HF} of P-P, R-R, P-R, and R-P intervals. There was significant difference in mean interval times and estimated PSD_{LF} and PSD_{HF} among P-P, R-R, P-R, and R-P intervals (p < 0.01). There was no significant difference in estimated PSD_{LF} and PSD_{HF} among P-P, R-R, and R-P intervals (p < 0.01).

Fig. s 1-4 showed the example of time series data and its estimated PSD in a subject. The shapes of PSDs in P-P, R-R, and R-P intervals were same. The PSD of P-R intervals was white noise.

DISCUSSION

P-P, P-R, and R-P intervals should be measured with the onset of the P wave. In the present study, these interval were determined with the peak P wave. During measurement of interval times, P wave form was scarcely changed.

At rest, heart rate is controlled by the flex regulation via arterial baroreceptor (Ninomiya et al., 1971). The cardiac signals from the circulatory central nervous system spread over sino-atrial node (SA node), atrium, atrial-ventricular node, and ventricle, sequentially. On the electrocardiogram, P wave is the onset of the electrical excitation of atrium, and R wave the onset of the electrical excitation of left ventricle. The variability of P-R intervals presented white noise. The results suggested that the periodic fluctuation of heart rate was formed in the SA node or in the upper circulatory central nervous system.

HRV of normal subject has the 1/f fluctuation. Generally, 1/f fluctuation have the robustness for white noise. This is why there was the same shape and value of P-P and R-R intervals.

At rest, vagal nervous system was dominant in a healthy subjects. Cardiac vagal nervous system have two tracts. Right vagal tracts lengthen the excitation cycle, and left vagal tracts extend the atrio-ventricular conduction time. If HRV were formed in the upper central nervous system, the periodic fluctuation of P-R interval would be observed. Glass et al. (1983) found three phase-locking (2 : 1, 1 : 1, 2 : 3), periodic-double bifurcation, and chaos of the coupling interval and interval time when spontaneously beating aggregates of cells obtained from embryonic chick heart was stimulated periodically. In this report, it was not cleared whether the periodic fluctuation of interval times. The observation of white noise on the fluctuation of P-R interval might suggest the periodic fluctuation would be formed at or above the SA node.

REFERENCES


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Yoshiaki TAKEI

Department of Health & Physical Education, College of Liberal Arts & Sciences, Kobe University, 1-2-1 Tsurukabuto, Nada, Kobe 657 JAPAN

武 井 義 明

〒653 神戸市灘区鶴甲1-2-1 神戸大学教養部体育学研究室