Validity of Frequency Domain Method in Assessment of Cardiac Autonomic Function During Controlled Breathing in Healthy Subjects

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Abstract

The clinical utility of spectral analysis of heart rate variability is currently under research. We studied the correlation between heart rate variability measures derived from frequency domain and maximum-minimum method during one minute deep breathing at 6 respiratory cycles per minute. Ten healthy volunteers aged between 20-22 years of either sex took part in the study. Heart rate response to deep breathing was recorded with the subject in supine position connected to the limb lead II. Simultaneously the ECG signals were picked up by the digital data acquisition system and fed in to a computer. Heart rate variability measures from maximum-minimum and frequency domain method were estimated by computer assisted method. The heart rate variability measures calculated for evaluation from frequency domain method was high and low frequency absolute power spectra. The values derived from maximum-minimum method were maximum R-R interval, minimum R-R interval and its ratio during deep berating. Pearson correlation test was employed to find the correlation between heart rate variability measures. High and low frequency power spectra and ratio of maximum to minimum R-R interval during deep breathing were significantly correlating (P<0.0001). High and low frequency was significantly correlating with longest R-R interval during deep breathing (P<0.0001). Low and high frequency did not correlate with minimum R-R interval. The results of the present study suggests that either low or high frequency power spectra could be used to assess cardiac parasympathetic activity by employing deep breathing test.

Key Words: *frequency domain, heart rate variability, parasympathetic function*

The beat of the healthy heart is not absolutely regular. This fluctuation in heart beat is known as heart rate variability. Indices of heart rate variability provide a window onto autonomic modulation of the heart.[1] In population studies, decreased heart rate variability has predictive value for mortality among healthy adults.[2, 3] It is a well-established risk factor for arrhythmic events and mortality among post-myocardial patients.[4,5] Reduced heart rate variability identifies diabetic patients with autonomic neuropathy.[6] Heart rate variability in combination with other risk stratifiers, e.g. ejection fraction, can identify cardiac patients at especially high risk of mortality.[1] In the intact heart parasympathetic fibers are inhibitory and sympathetic are excitatory. Inhibitory actions of cardiac parasympathetic nerves are reported to provide electrical stability to the heart and thus preventing ventricular tachycardia in humans.[7]

There are two approaches to measurement of heart rate variability: analysis in the time or in the frequency domain. Some workers consider frequency domain method is superior to time-domain analysis of heart rate variability because former approaches exclude random fluctuations and may provide quantitative information on the level of sympathetic – as well as vagal – cardiac neural outflow.[8] However validity of clinical utilization of heart rate variability analysis by frequency domain method is still under extensive research. Currently based on the recommendations of task force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology,[9] short term measurements of 5 minute electrocardiogram during spontaneous breathing are processed by frequency domain method. ECG data obtained for heart rate variability analysis in this condition is largely influenced by respiratory rate and tidal volume.[10,11] Consequently, quantifying parasympathetic activity during spontaneous breathing may not accurately measure neural outflow. Hence we investigated the validity of spectral analysis of heart rate variability in quantifying parasympathetic activity during one minute controlled deep breathing.

Methods

This study was carried out in the autonomic research laboratory attached to department of physiology, Kasturba Medical College, Mangalore. This study was undertaken after obtaining the consent from the study subjects.

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Subjects

There were 10 normal, healthy volunteers of either sex in the age range of 20-22 years who were trained to perform deep breathing maneuver accurately.

Design of the study

Recordings were made in the morning after subjects were completely relaxed. The parasympathetic test employed in this study was heart rate response to deep breathing at 6 respiratory cycles per minute.[12] The reproducibility of heart rate variability during deep breathing maneuver was investigated in 5 subjects by measuring heart rate variability 3 times on different occasions in 15-20 days time.

Parameters measured

The measures of heart rate variability were considered from two methods of analysis of heart rate variability: (1) One of the main time domain methods namely maximum-minimum method. (2) Frequency domain method. The heart rate variability parameters measured from these two methods were: (1) Maximum-Minimum method: Longest R-R interval, shortest R-R interval and ratio of longest R-R interval to shortest R-R interval during deep breathing maneuver. (2) Frequency domain method: High frequency, Low frequency (in absolute power) spectral components.

Deep breathing test procedure

Test was performed after the subjects sufficiently relaxed. After giving proper instructions and sufficient training, the subjects were made to lie in supine position and through verbal signal they were asked to breathe maximally allowing five seconds for inspiration and five seconds for expiration for one minute.

Data acquisition

The ECG was recorded continuously at a speed of 25 mm/second connected to the limb lead II throughout the deep breathing maneuver. Simultaneously the ECG signals were picked up by the digital acquisition system (ADC box-6008 USB) and fed into a computer.

Frequency domain analysis

The heart rate variability power spectrum was obtained using fast Fourier transform analysis. The energy in heart rate variability series of the following specific frequency bands was studied, namely the low frequency (0.040-0.015 Hz) and high frequency component (0.015-0.400 Hz). The low frequency and high frequency values were expressed in absolute power (ms^2).

Time domain analysis

The heart rate variability measures quantified by computer assisted method was maximum R-R interval, minimum R-R interval and ratio of maximum R-R interval to minimum R-R interval expressed in milliseconds. The accuracy of these values, as measures of longest R-R interval in expiration and shortest R-R interval in inspiration during deep breathing maneuver was confirmed by comparing them with the longest R-R interval in expiration and shortest R-R interval in inspiration measured from conventional ECG strip.

Statistics

Pearson correlation coefficient test was used to find the correlation between heart rate variability parameters obtained from frequency domain and time domain methods. *P* value less than 0.05 was considered as significant.

Results

High and low frequency were the two major spectral components selected for correlation with E:I ratio, maximum and minimum R-R interval during deep breathing. High and low frequency spectral components were found to be highly correlating with E:I ratio (r=0.980, *P*<0.0001, Figure 1; r=0.976, *P*<0.0001, Figure 2 respectively). High and low frequency were also significantly correlating with maximum R-R intervals obtained during expiration (r=0.990, *P*<0.0001, Figure 3 and Figure 4). Non-significant correlation was observed between minimum R-R interval obtained during deep breathing and high and low frequency in absolute power (r=0.330).

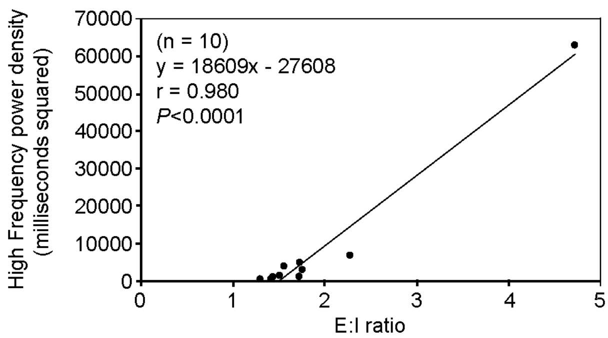

Figure 1. Correlation between high frequency power density and E:I ratio during deep breathing. n = sample size; Y = 18609X -27608; r=0.980; *P*<0.0001, where Y = high frequency power density (milliseconds squared) and X = E:I ratio

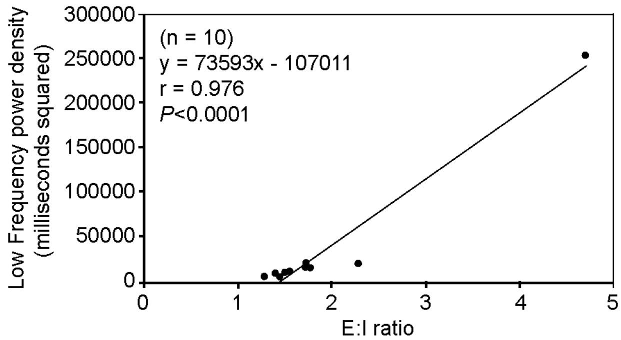

Figure 2. Correlation between low frequency power density and E:I ratio during deep breathing. n = sample size; Y = 73593X -107011, r=0.976; *P*<0.0001, where Y = low frequency power density (milliseconds squared) and X = E:I ratio

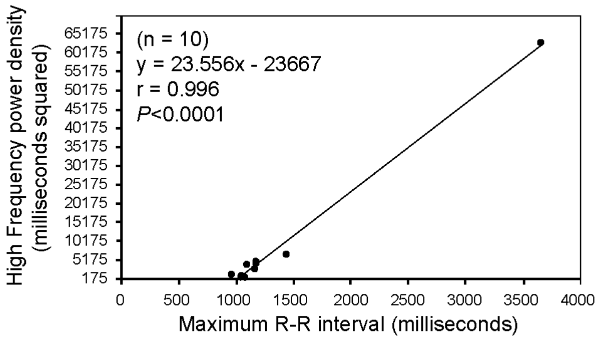

Figure 3. Correlation between high frequency power density and maximum R-R interval during deep breathing. n = sample size; Y = 23.556X -23667, r=0.996; *P*<0.0001, where Y = high frequency power density (milliseconds squared) and X = maximum R-R interval in milliseconds

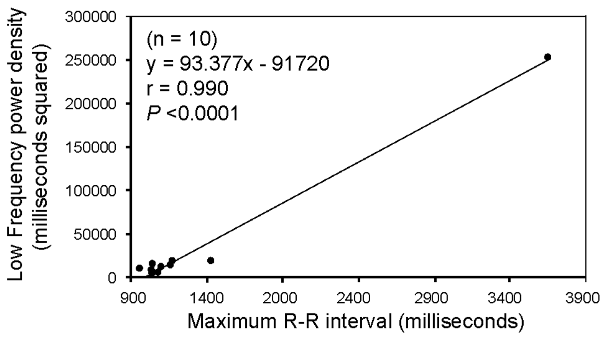

Figure 4. Correlation between low frequency power density and maximum R-R interval during deep breathing. n = sample size; Y = 93.377X -91720, r=0.990; p<0.0001, where Y = low frequency power density (milliseconds squared) and X = maximum R-R interval in milliseconds

Discussion

The easy means of recording of heart rate response to respiration has led to a series of methods in quantifying it. This in turn has made it difficult to select an appropriate heart rate variability parameter in routine clinical practice. As, heart rate variability analysis in various methods employees the data obtained from the ECG tracing, finding correlation between the heart rate variability parameters derived from these methods might ease the job of a clinician in selecting an appropriate heart rate variability parameter for assessment of cardiac autonomic function . Thus this study looked into the correlation between heart rate variability measures obtained from maximum-minimum method and frequency domain method during controlled breathing.

In the present study high and low frequency spectral components did not correlate with minimum R-R interval in inspiration but showed significant correlation with maximum R-R interval in expiration. There are important effects of respiration on the heart and circulatory system. In the central nervous system there are interactions between pacemakers and efferent autonomic tone which directly affect heart rate and blood pressure. There are also variations in vagal tone that centrally mediated and related to respiration. These result in decreased vagal activity occurring during inspiration and an increased vagal activity during expiration.[13] Thus it could be suggested that low and high frequency spectral components quantify respiration induced cardiac parasympathetic activity.

Measures of heart rate variability in response to cyclic deep breathing are among the simplest to record and the most sensitive indicators of parasympathetic function. Both afferent and efferent pathways are vagally mediated.[14] Respiratory sinus arrhythmia increases when respiratory frequency approaches the frequency of the intrinsic baroreflex-related heart fluctuations. Therefore, respiratory sinus arrhythmia in adults is maximal at a breathing rate of 6 per minute.[15] Numerous methods of analyzing the magnitude of the resultant enhanced sinus arrhythmia have been described.[16, 17] The simplest and widely performed measure is the E:I ratio – a ratio of the longest R-R interval in expiration to the shortest R-R interval in inspiration.[18] In the present study high and low frequency spectral components were found to be highly correlating with E:I ratio. This finding suggests that both high and low frequency components obtained during deep breathing at 6 respiratory cycles per minute quantify cardiac parasympathetic activity.

Thus our study finding demonstrates that quantifying either high or low frequency spectral component by Fourier transform spectral analysis method during one minute controlled breathing could be used for the assessment of cardiac parasympathetic activity in routine clinical practice. This method is less time consuming compared to spectral analysis done from 5 minute electrocardiogram data obtained during spontaneous respiration.

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