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Breathing rates and heart rate spectrograms regarding body position in normal subjects

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Abstract

The right lateral body position has been proposed as an effective vagal enhancer. However, the possibility of breathing affecting heart rate power spectra in different body positions has not been assessed. The level of vagal modulation in various body positions in normal subjects was estimated by calculating heart rate power spectra. The results suggest that the levels of vagal modulation do not necessarily reflect a change due to assuming different body position, but might be the consequence of changed breathing patterns. Before adopting the right lateral body position as vagal enhancing, the contribution of varying breathing pattern should be eliminated.

Keywords: Heart rate variability; Body position; Breathing pattern; Vagal modulation; Power spectral analysis

1. Introduction

Heart rate variability (HRV) and its assessment using power spectral analysis raised the possibility of quantifying the characteristics of the autonomic nervous system in a non-invasive way [1,2]. Reduced cardiac vagal activity has been reported in patients with coronary artery disease (CAD) and associated with higher mortality and morbidity [3]. The spectral power in the high-frequency range of the heart rate power spectrum has been proposed as a probe for quantifying the level of vagal modulation [4]. Pharmacological and postural measures have been tried in order to increase the level of vagal modulation in normal subjects and CAD patients [5,6]. Among postural manoeuvres,

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the right lateral decubitus position has been proposed to increase the level of vagal modulation in normal subjects [7]. Lately, it has been reported that this position improves the HRV indexes associated with high mortality in CAD, acute myocardial infarction (AMI) and chronic heart failure (CHF) patients [3,8,9]. This led to the proposal that body position is an effective vagal enhancer.

Our study using the same methodology [10] failed to confirm the previously reported observations on normal subjects [7]. Additionally, the high frequency spectral power component, providing an estimate of vagal modulation, has been shown to be strongly dependent on breathing frequency and tidal volume [11]. As the influence of either controlled or spontaneous breathing on the power spectra in the positions assumed has not been investigated in other related studies, we decided to account for the possible effects of breathing on the estimated level of vagal modulation in right lateral decubitus and supine position.

2. Materials and methods

Twelve healthy volunteers, five females and seven males aged 20–31 years were enrolled in the study. The protocol has been designed following the guidelines of the Slovenian National Ethics Committee. Informed consent was obtained from each subject prior to measurement.

Experimental protocol: The measurements were made in two morning sessions, the second following the first at an average of 29 days, and the intervals between sessions ranging from 2 to 95 days. To avoid the effect of diurnal variation [12] on HRV measures, all measurements were taken between 8:30 and 11:30 AM and were started at least 1 h hour after subject had woken up. All subjects were instructed not to drink caffeinated or alcoholic beverages at least 24 h, nor to eat anything 2 h prior to the recording session. None of the subjects took any medicament. A subject assumed two positions each time, namely the supine and right lateral decubitus position. After a 10-min rest in each position, bipolar surface electrocardiogram (electrodes on the position of V_1 and V_5) and respiratory waveform (nose-tip thermistor) were recorded for 10 min using a two channel digital recorder. The electrocardiogram and respiratory waveform were digitized at a sampling rate of 450 Hz by a 12-bit analog-digital converter.

RR interval detection: Off-line analysis was performed subsequently on the data using custom designed DEKG software package. RR intervals were determined by an R wave peak detection algorithm. Time series comprising 500-s consecutive RR intervals of sinus rhythm were selected for further analysis. The intervals were manually checked to exclude any missing or ectopic beats.

Breath interval detection: Respiratory waveform has been analyzed to detect the time when each inspiration began, and the length of breathing cycles was determined again using DEKG software package. The results of automatic procedures were checked and corrected in cases where irregular breathing patterns occurred. Finally, the time series from the same 500-s interval as in RR analysis was used in further processing.

Spectral power analysis: The 500-s RR intervals were interpolated by cubic-spline and resampled at 4 Hz to obtain 2000-point equidistant data samples. Hann window and linear detrend of data were applied before computing the power spectrum by Fourier transform. Total power (TP) of spectra was defined in the range of 0.01–0.40 Hz, high frequency (HF) power within 0.15–0.40 Hz, and low frequency (LF) power within 0.04–0.15 Hz. Normalized power (n) was defined as the ratio of power in each band to total power. The nHF power indicated cardiac vagal modulation;

the nLF power indexed sympathetic baroreflex modulated activity. The LF/HF ratio represented sympathovagal balance.

Statistical analysis: To ascertain normal distribution of data, logarithmic transforms of originally skewed values of power spectra were calculated. The results of power spectral measurements in supine and right recumbent positions were further analysed using paired t-test; a value of $p < 0.05$ was considered significant.

To assess the repeatability of measurements we computed difference-to-mean ratios (R) of values obtained from the measurement of the first and the second session:

$$R = \frac{|p1 - p2|}{0.5(p1 + p2)},$$

where $p1$ and $p2$ are parameters computed from the measurements of the first and the second session respectively.

3. Results

Breath interval and results of HRV analysis are summarized in Table 1. As shown, no important differences in HRV measures were observed regarding supine and right recumbent position. The same result was obtained in both the recording sessions. The average breath interval and RR interval did not change appreciably on acquiring different positions in either measuring session. The trend

Table 1
Breathing, RR interval and spectral indices of subjects in lateral and supine positions (two sessions)

	Lateral	Supine	*P* value
Session 1			
Breath interval (s)	4.22 ± 1.06	4.22 ± 1.02	0.987
RR interval (ms)	1033 ± 114	1046 ± 135	0.468
TP (ms^2)	4152 ± 3253	5804 ± 4760	0.003
HF (ms^2)	1852 ± 1469	2924 ± 2800	0.002
LF (ms^2)	1715 ± 1712	2146 ± 2158	0.427
nHF	0.43 ± 0.14	0.48 ± 0.18	0.148
nLF	0.41 ± 0.16	0.36 ± 0.18	0.082
LF/HF	1.17 ± 0.83	1.04 ± 0.99	0.077
Session 2			
Breath interval (s)	4.07 ± 0.56	4.01 ± 0.61	0.607
RR interval (ms)	993 ± 95	1002 ± 108	0.464
TP (ms^2)	3513 ± 1815	4571 ± 3354	0.192
HF (ms^2)	1817 ± 1303	2289 ± 1812	0.389
LF (ms^2)	1158 ± 573	1645 ± 1394	0.274
nHF	0.46 ± 0.17	0.46 ± 0.17	0.863
nLF	0.35 ± 0.11	0.36 ± 0.13	0.504
LF/HF	0.98 ± 0.76	1.16 ± 1.36	0.804

Data are expressed as mean ± SD.

Table 2
Difference-to-mean ratio (R) of parameters listed in Table 1 as estimates of day-to-day stability of data

	Lateral	Supine
Breath interval	0.15 ± 0.27	0.17 ± 0.32
RR interval	0.13 ± 0.21	0.16 ± 0.21
TP	0.40 ± 0.26	0.43 ± 0.29
HF	0.51 ± 0.25	0.48 ± 0.42
LF	0.51 ± 0.33	0.51 ± 0.39
nHF	0.30 ± 0.34	0.37 ± 0.33
nLF	0.25 ± 0.36	0.42 ± 0.30
LF/HF	0.34 ± 0.43	0.64 ± 0.37

Lower value of respective parameter denotes higher stability. Data are expressed as mean ± SD.

towards longer RR interval, higher TP, HF, nHF and lower LF/HF ratio in the supine position could be observed, however the differences were not statistically significant. Moreover, there was an important difference in the magnitude of total and high frequency power in favour of the supine position in the first recording period.

To illustrate the day-to-day stability of the results we present the means of the differences between the first and second sessions for all the variables from Table 1, together with their standard deviations (Table 2). Breath interval and RR interval were most stable in both positions as denoted by the lowest values of difference-to-mean ratio R in Table 2.

4. Discussion

This study confirms the different responses of the autonomous nervous system to adopting right recumbent and lying supine positions reported previously [10] and proposed in healthy subjects [7], patients with severely diseased coronary arteries [3] and patients after AMI [8]. As many factors could affect the acquisition of HRV spectra, special attention was paid to comparing the methodological approaches employed in our and corresponding studies [7,8,10]. The equilibration time to reach a stable haemodynamic state after adopting the desired body position has been extended in our study by an additional 5 min before each recording period. We believe that the latter allowed for better haemodynamic recovery after the perturbation observed as a minor, transient frequency drop when the right recumbent position was assumed. We have not made any major modification of data collection, processing and calculation from those in the studies compared [7,8,10].

Among other factors that may cause different levels of vagal modulation in the respective positions, respiratory rate could have markedly influenced HRV power spectra. A major reduction in the HRV power spectra occurs between 7.5 and 15 breaths/min for HF power and between 6 and 10 breaths/min for LF power, indicating a significantly low gain breathing frequency response for both LF and HF power between 15 and 24 breaths/min [11]. Although the average breathing rate did not differ remarkably between the two positions, implying the lack of significant overall effect on the power spectra in each the position, the respective breathing frequencies in some of our

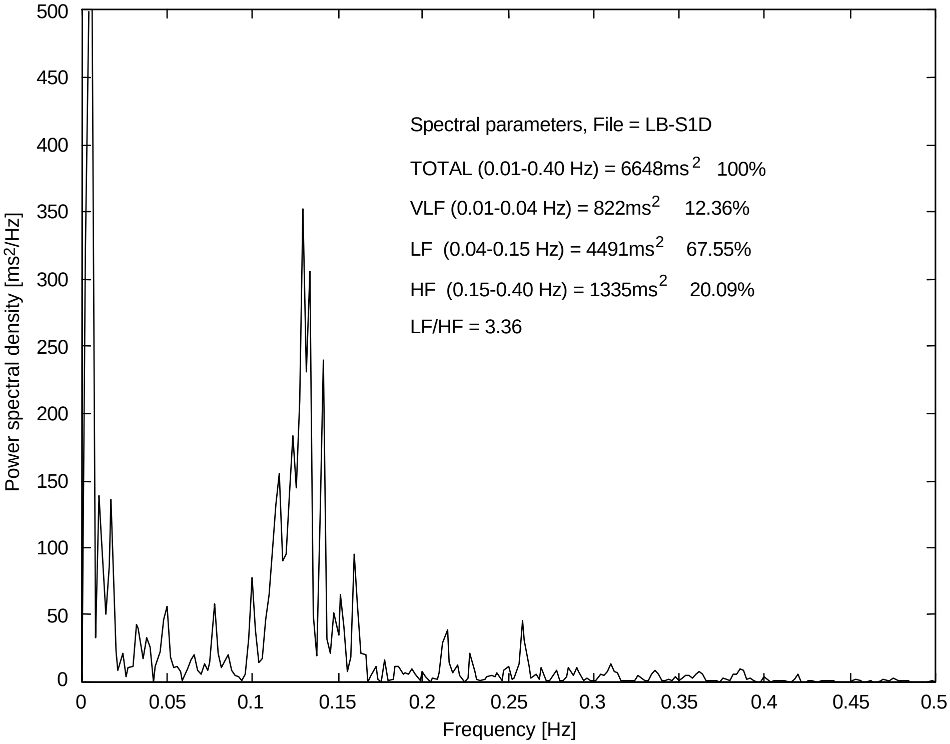

Fig. 1. Power spectrum of RR intervals in the supine position of a volunteer. Low breathing rate (8.5 breaths/minute corresponding to 0.14 Hz) moved the majority of spectral power below 0.15 Hz causing a substantial change in HF, LF and especially in LF/HF parameters.

subjects during measurements did differ considerably. Breathing rates spanned from 8 to 20 breaths per minute, sharply augmenting low-frequency power at lower breathing rates, and causing substantial reduction of spectral power, particularly in the high-frequency range at the highest breathing rates. Further, following the recommendations for power spectra calculation [13] in the prescribed frequency ranges in those selected cases might contribute to additional bias in measurements during spontaneous breathing, seen as a remarkable power shift into the low-frequency region of the *R–R* power spectrum (demonstrated in Fig. 1).

Kuo et al. [7] did not account for the possible confounding factor of altered breathing frequency and pattern before proposing the right lateral decubitus position as the most effective vagal enhancer. As shown previously, changing the respiratory frequency might result in varying the magnitude of high-frequency power by up to ten-fold [11]. Additionally, we showed in our study that the effects of changed breathing and day-to-day variability prevail over the effect of assuming different body positions on HRV power spectra (Tables 1 and 2).

In spontaneously breathing subjects, where breathing rates agreed closely in each respective position within 14–15 breaths per minute, we assumed the effect of breathing to be equally expressed in both supine and right lateral position. Even then, the normalized high frequency (nHF), an indicator of cardiac vagal activity [3,7,14], was not significantly higher when the right recumbent position was adopted. On the contrary, nHF showed the opposite trend towards higher vagal modulation in the supine position.

Extended information on time-stability regarding posture induced responses was provided by repetitive measurements in our study. Kuo et al. on the other hand, draw their conclusions from single HRV measurements in each respective subject [7]. As to the constancy of the proposed response, a trend pointing to the higher vagal modulation when lying supine was observed in our study in both measurements, provided the breathing period remained constant. Similarly to previous studies [3,15], the HRV indices showed intersubject variation as well as variation among successive day measurements as shown in Table 2. The TP and HF were significantly different in one but not in the other measurement. This could be explained by the fact that the level of day-to-day variation in HRV measures exceeds the level of autonomous modulation when adopting a different body position within one measurement. In another study, we observed a significant change in breathing pattern after coronary artery bypass grafting [16].

One of the limitations of the present study is that it refers to a small population sample only. Further, breathing was observed rather than controlled. However, we regard that as a necessary precondition, since controlled breathing may alter the respiratory component of power spectra [14].

5. Summary

Heart rate variability and its assessment using power spectral analysis raised the possibility of quantifying characteristics of the autonomic nervous system in a non-invasive way. This study was designed to assess the level of vagal modulation in the supine and right recumbent positions in normal healthy subjects as many manoeuvres that might increase vagal tone have been sought, both in normal subjects and in patients with heart disease. To account for the possible posture-respiratory interaction affecting the level of vagal modulation, breathing analysis has been performed simultaneously.

Twelve subjects, five males and seven females, aged 20–31 years were enrolled in the study. To evaluate the day-to-day stability of short-term ECG recordings and the constancy of posture-induced autonomic response, every subject participated in two morning recording sessions. ECG and respiratory signals were obtained to calculate heart and breathing rate intervals. Heart rate power spectra were obtained by off-line Fourier transform analysis. The frequency domain measures, namely very low frequency power (VLF), low frequency power (LF), high frequency power (HF) and total power (TP) were determined, and their normalized correlates used in the comparison between supine and right recumbent position. Normalized high frequency (nHF) indicated cardiac vagal activity, normalized LF power indexed sympathetic modulated activity, *low frequency power/high frequency power* ratio (LF/HF) provided a measure of sympathovagal balance. Logarithmic transforms of originally skewed values of power spectra were calculated. Breathing rates and log transforms of power spectral measurements in supine and right recumbent position were further analysed using paired t-test; a value of $p < 0.05$ was considered significant.

The results showed remarkable variation between measurements on successive day as well as among study subjects. No important differences in HRV measures were observed regarding supine and right recumbent position in the first or second recording session. The average breath interval and RR interval did not change appreciably on acquiring different positions in either measuring session. However, a tendency toward higher vagal modulation in the supine position, which was significant in the first recording session, has been observed in both measurements. Together with results of the breathing analysis, our results do not suggest higher vagal modulation when lying in the right recumbent position.

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