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Influence of Breathing Pattern on Heart Rate Spectral Power in Supine Position and Consistency in Two Different Divisions of the Total Frequency Area in Heart Rate Spectral Analysis

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Abstract The aim of the present study was to find the reference values for autonomic nervous function tests and to find out whether breathing pattern has influences on heart rate variation.

Ten male healthy subjects with mean (standard deviation) of age 58.8 (4.2) years were studied. The heart rate variation was measured by electrocardiograph measurement during both spontaneous and deep breathing for two minutes in supine position. For heart rate spectral analysis, a Fast Fourier Transformation program was used. We used two divisions of the total frequency area. In the I-division, the total frequency area was divided into low frequency band with the area from 0.04 to 0.15Hz and high frequency band with the area from 0.15 to 0.40Hz and in the II-division, into low frequency band with the area from 0.04 to 0.12Hz and high frequency band with the area from 0.20 to 0.28Hz. Frequency related power of the bands was calculated.

Frequency related power significantly increased during deep breathing. During both spontaneous and deep breathing there were strong gatherings of power between the frequencies 0.15 and 0.20Hz and between the frequencies 0.29 and 0.40Hz, which were not calculated in the II-division.

Our results suggest that breathing pattern has an influence on heart rate variation in supine position which must be considered in the evaluation of autonomic neuropathy based on heart rate variation. We assume that the I-division of the total frequency area is more informative in the evaluation of cardiac autonomic function during different autonomic contexts.

Key words : Autonomic nervous activity, Heart rate variation, Breathing pattern, Fast Fourier Transformation.

Introduction

The factors causing variation in heart rate are complex[1], but there is a clear relationship between heart rate variation and breathing pattern, particularly in regular breathing, which is well known as respiratory sinus arrhythmia[2]. In some reports[2-6], a correlation between autonomic integrity and the heart rate-respiration relationship was suggested. In others[7,8], attempt has been made to study the association between heart rate variation and breathing pattern, rather than R-R variability alone. Heart rate variations during deep breathing, as a test for autonomic neuropathy, have been used to evaluate autonomic nervous function of patients with hand-arm vibration syndrome[9-15].

Cardiac autonomic activity can be estimated using heart rate variation by heart rate spectral analysis. Usually, during different autonomic contexts, power in the high frequency (HF) band of the heart rate power spectrum is widely recognized as a measure of vagal modulation of heart rate, and the ratio of power in the low frequency (LF) band to HF is used as a measure of cardiac sympathovagal balance. It has been generally accepted that power in the LF band is a measure of sympathetic modulation of heart rate during different autonomic contexts, although the autonomic significance of LF power is not so clear. However, in supine position, frequency related power of the both LF and HF bands has linkage with the parasympathetic nervous system at metronome respiratory frequency[16]. Investigators varied to divide the total frequency area into LF (0.04-0.12 Hz[16,17], 0.04-0.15Hz[18-20]) and HF (0.20~0.30 Hz[16,17], 0.15~0.40Hz[18-20]) bands.

In this study, we examined heart rate variability using heart rate spectral analysis in healthy individuals during both spontaneous and deep breathing in supine position. We also assessed the degree of consistency of the heart rate variation due to breathing pattern in two different divisions of the total frequency area in supine position. An adequate reference material is required to evaluate autonomic neuropathy. The aim of the present study was to find the reference values for autonomic nervous function tests and to find out whether breathing pattern has influences on heart rate variation.

Materials and methods

We studied 10 male subjects with age-range 51 to 64 (58.8±4.2) years. All subjects were healthy with no history of cardiac, respiratory, or vascular disease. The subjects refrained from caffeine, tobacco, alcohol consumption and abstained from any medication for at least 24 hours before and during the experimental session.

After discussion about the experimental session, informed consent paper was signed by every subject. After setting of electrodes for electrocardiograph (ECG) measurement, the subjects were instructed to begin a 40-minute resting baseline period in supine position. The heart rate was measured by ECG during spontaneous breathing for two minutes in supine position and during deep breathing (five seconds in and five seconds out, 6 cycles a minute) for two minutes also in supine position. The ECG signal was recorded and stored on FM tape by a data recorder Teac R-61 and was played back and fed into a microcomputer (NEC PC-9801DX) with an analog to digital converter with the frequency of sampling 250Hz and then processed on a microcomputer (NEC PC-9821 V12). For heart rate spectral analysis, a Fast Fourier Transformation program was used. We used two divisions of the total frequency area. In the I-division, the total frequency area was divided into LF band with the area from 0.04 to 0.15Hz and HF band with the area from 0.15 to 0.40Hz and in the II-division, into LF band with the area from 0.04 to 0.12Hz and HF band with the area from 0.20 to 0.28Hz and frequency related power of these bands was calculated. As in supine position, frequency related power of the both LF and HF bands is a measure of parasympathetic[16] modulation of heart rate at metronome respiratory frequency, power of the combined frequency band (LF+HF) was also calculated. All data were expressed in log values. The experiment room temperature was maintained at 25±1℃.

Comparison of parameter measures during spontaneous and deep breathing was performed by paired t-test. Pearson correlation

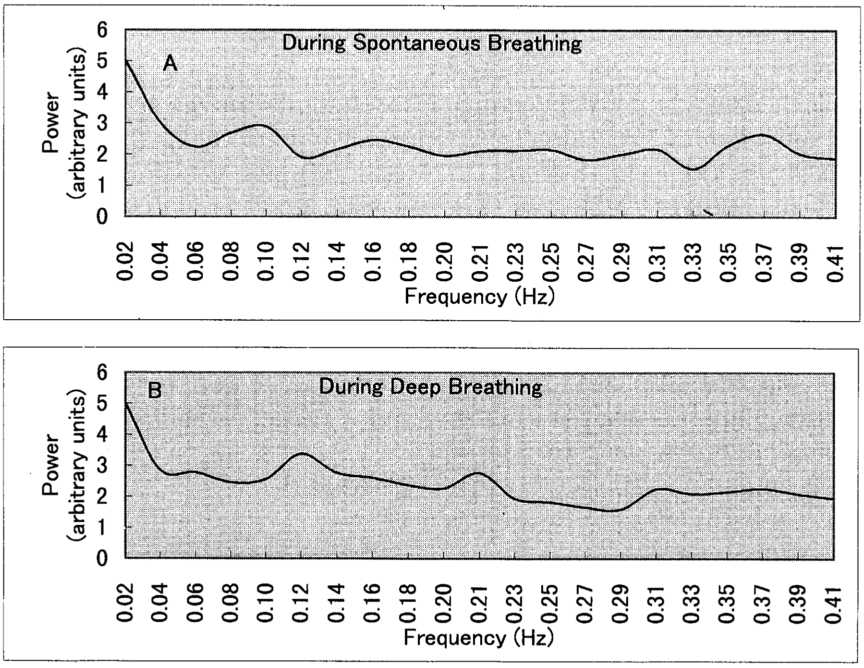

Fig. 1. Heart rate spectral components of a 54 year old healthy subject using a Fast Fourier Transformation program on the R-R interval data obtained during spontaneous breathing (panel A) and during deep breathing (six respiratory cycles a minute, panel B).

coefficients were used to evaluate consistency of the heart rate variation due to breathing pattern in the two different divisions of the total frequency area in heart rate spectral analysis in supine position. $P < 0.05$ was considered to indicate a significant difference.

Results

The heart rate spectral analysis using the Fast Fourier Transformation program was carried out on the R-R interval data obtained during spontaneous and deep breathing tests, enabling the various spectral components of the heart rate variation to be visualized (fig. 1). During both spontaneous and deep breathing in supine position there were strong gatherings of power between the frequencies 0.15 and 0.20Hz and between the frequencies 0.29 and 0.40Hz, which were not calculated in the II-division.

Table 1. Power spectral estimates in heart rate variation during spontaneous and deep breathing in supine position calcuated according to I-division (LF, 0.04-0.15Hz and HF, 0.15-0.14Hz) of the total frequency area in heart rate spectral analysis

Variables	Spontaneous breathing	Deep breathing
LF	16.1±1.5	17.8±1.2**
HF	30.1±3.2	31.4±3.5*
LF+HF	46.2±4.3	49.2±4.2*
LF/HF	0.5±0.1	0.6±0.1

All date were expressed as mean±SD. * : $p < 0.05$, ** : $p < 0.01$, significant as compared with spontaneous breathing value by using paired *t*-test. LF, low frequency and HF, high frequency.

Table 1 shows power spectral estimates in heart rate variation during spontaneous and deep breathing in supine position calculated according to I-division (LF, 0.04-0.15Hz and HF, 0.15-0.40Hz) of the total frequency area. Frequency related power of the high, low and combined (LF+HF) frequency bands significantly increased during deep breathing ($p<0.05$, $p<0.01$). The difference in ratio of power in the LF band to HF (LF/HF) was not significant between the two types of breathing.

Table 2. Power spectral estimates in heart rate variation during spontaneous and deep breathing in supine position calculated according to II-division (LF, 0.04-0.12Hz and HF, 0.20-0.28Hz) of the total frequency area in heart rate spectral analysis

Variables	Spontaneous breathing	Deep breathing
LF	13.7±1.3	14.9±1.0**
HF	11.6±1.7	12.4±1.3
LF+HF	25.3±2.4	27.3±1.9**
LF/HF	1.2±0.2	1.2±0.1

All data were expressed as mean±SD. **: $p<0.01$, significant as compared with spontaneous breathing value by using paired t-test. LF, low frequency and HF, high frequency.

Table 3. Pearson correlation coefficients for I versus II divisions of the total frequency area in heart rate spectral analysis

Variables	Spontaneous breathing	Deep breathing
LF	0.993***	0.980***
HF	0.887***	0.904***
LF+HF	0.960***	0.915***
LF/HF	0.935***	0.887***

***$p<0.001$. LF, low frequency and HF, high frequency.

Table 2 shows power spectral estimates in heart rate variation during spontaneous and deep breathing in supine position, as calculated according to II-division (LF, 0.04-0.12Hz and HF, 0.20-0.28Hz) of the total frequency area. Frequency related power of the low and combined frequency bands increased during deep breathing ($p<0.01$). Frequency related power of HF band tended to increase during deep breathing. The difference in LF/HF was not significant between the two types of breathing.

Table 3 contains the Pearson correlation coefficients for the spontaneous-spontaneous breathing and deep-deep breathing comparisons in supine position for I and II divisions of the total frequency area in heart rate spectral analysis. Within each breathing pattern, there was substantial consistency across the two divisions of the total frequency area in heart rate spectral analysis, with HRV correlation coefficcests being greater than 0.88 and significant at $p<0.001$ for all variables.

Discussion

The variability in heart rate has been widely used to evaluate the function of the autonomic nervous system in diabetic patients[21-23]. Despite the widespread use of the method for the diagnosis of cardiac autonomic dysfunction based on heart rate variation, little attention has been devoted to the fact that a large proportion of this heart rate changes is related to breathing pattern. It is well known that the respiratory sinus arrhythmia is strictly under neurovegetative control[23], therefore, any change of the relationship between heart rate and respiration could be related to a change of the neurovegetative tone.

Cardiac autonomic nervous system activity may be estimated by heart rate spectral analysis. Investigators used various divisions of the total frequency area into LF and HF bands. In this study, we used two divisions of the total frequency area. In I-division, the total frequency area was divided into LF band with the area from 0.04 to 0.15Hz and HF band with the area from 0.15 to 0.40Hz and in II-division, into LF band with the area from 0.04 to 0.12Hz and HF band with the area from 0.20 to 0.28Hz. Pomeranz, et al.[16] showed that in supine position, atropine produced substantial reductions in frequency related power of the both LF and HF bands in heart rate spectral analysis at metronome respiratory frequency, demonstrating the parasympathetic contribution to these frequency bands.

Spectrally defined heart rate variability is recognized to be influenced by respiratory rates[24]. For deep breathing we used six cycles a minute (five seconds in and five seconds out), which are considered to be most suitable[25], because deep breathing or breathing at slow rates (6/min) in the supine position increases variation due to respiratory parasympathetic input. On the other hand, respiratory rate changes somewhat from cycle to cycle during spontaneous breathing. During respiration the heart rate rises during inspiration and begins to fall at the end of it and during expiration[26], as being dependent on the afferent information from the stretch receptors in the lung and the mechanoreceptors in the right atrium[27].

In I-division, frequency related power of the LF, HF and combined frequency bands significantly increased during deep breathing, while in II-division, frequency related power of the low and combined frequency bands significantly increased during deep breathing and frequency related power of the HF band tended to increase. Pearson correlation coefficients for the spontaneous-spontaneous breathing and deep-deep breathing comparisons in supine position for I and II divisions of the total frequency area in heart rate spectral analysis indicated greater consistency of the result. On the other hand, there were strong gatherings of power between the frequencies 0.15 and 0.20Hz and between the frequencies 0.29 and 0.40Hz, which were not calculated in the II-division of the total frequency area in heart rate spectral analysis. This was the reason why the increase of the frequency related power of the HF band in the II-division did not reach the level of significance. There is no need to divide the total frequency area into LF and HF bands when electrocardiograph measurement is done in supine position without any stress manipulation and frequency related power of the total frequency area (as in the present study combined frequency band, LF+HF) can be used as a variable of heart rate variation.

The present results therefore suggest that frequency related power increases during deep breathing in supine position, indicating an influence of breathing pattern on heart rate variation. Breathing pattern must be considered in the evaluation of autonomic neuropathy based on heart rate variation. Although it was shown that almost the same results were provided by the two divisions of the total frequency area in heart rate spectral analysis, we consider that the I-division of the total frequency area in heart rate spectral analysis used in this study is more informative and should be taken in mind in the evaluation of cardiac autonomic function during different autonomic contexts.

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