SHORT RESEARCH ARTICLE

Dynamics of low-frequency oscillations in heart rate in chronic heart failure patients during load tests under 0.1 Hz controlled breathing

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Abstract

Background. Low-frequency (LF) oscillations in heart rate (HR) are largely an index of baroreflex gain. Controlled 0.1 Hz breathing maybe used as input stimuli for study of this resonance phenomenon in LF oscillations in HR. The aim of this study was the investigation of the dynamic characteristics of LF oscillations in the heart rate (HR) of chronic heart failure (CHF) patients during bicycle exercise (BE) tests, under 0.1 Hz controlled breathing.

Methods. Forty five male patients aged 50±3 years with left ventricle ejection fraction (EF) <50% and 35 male patients aged 52±6 years with EF>50% participated in the study. BE tests were performed for all participants. Five-minute recording of R-R intervals was performed first in sedentary posture and in 25 W load stage of BE test. The frequency estimates of heart rate variability in LF spectrum bands were obtained.

Results. Under the load rising till 25 W in CHF patients with EF<50%, consequent depression of LF band power was observed 2-3 times in comparison with the relaxed condition. There was no similar significant expressed dynamic in the group with EF>50%.

Conclusions. The stability of LF oscillations in HR to low-intensity loads depends from the severity of myocardial contractility damage. The power dynamic of 0.1 Hz component of the heart rate variability spectrum may be considered an independent index of dynamic stability of the heart autonomic control in CHF patients.

Keywords: Heart rate variability, chronic heart failure, 0.1 Hz oscilation, load test

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Introduction

At present, there are several points of view on the nature of low-frequency (LF) oscillations in heart rate (HR) in humans. According to one hypothesis, these LF oscillations in HR are largely an index of baroreflex gain.[1,2] The existence of a resonance frequency in the 0.1 Hz range in the cardiovascular control is well known.[3-5] Controlled 0.1 Hz breathing maybe used as input stimuli for study of this resonance phenomenon in LF oscillations in HR. Presence of 0.1 Hz resonance phenomenon in HR in chronic heart failure (CHF) patients testifies about the functional status of baroreflex gain and its dysfunction. Implementation of controlled breathing allows a decrease in the influence of additional unregistered factors on the autonomic heart control system, that is impossible during spontaneous breathing.[6,7]

It is especially interesting to study dynamics of LF oscillations in HR during load tests. For example, LF oscillations in HR are used to increase reliability of load test results, for the diagnosis of coronary atherosclerotic stenosis in patients with coronary heart disease.[8] Nevertheless, diagnostic opportunities of load test in CHF patients are not disclosed until now.

Heart rate variability (HRV) is a well-known marker of autonomic dysfunction in CHF patients.[9] However, dynamics of LF oscillations in HR are not investigated in these patients during load tests.

The aim of this paper was to study the dynamic characteristics of LF oscillations in HR in CHF patients, during bicycle exercise (BE) tests, under 0.1 Hz controlled breathing.

Methods

Subjects

Forty five male CHF patients aged 50±3 years (left ventricle ejection fraction < 50%) and 35 male patients aged 52±6 years without CHF (left ventricle ejection fraction >50%) participated in the study. An informed consent from all volunteers was obtained. The study protocol conformed to the ethical guidelines of 1975 Helsinki Declaration, reflected by a priori approval of the local Ethics Committee.

Baseline characteristics of both groups are shown in table 1. Thirty four patients (75,6%) with ejection fraction (EF) <50% had a history of myocardial infarction (MI), while in the group with normal EF, only 10 patients (33,3%) had a history of MI.

Measurements and protocol

Extracting from the electrocardiography signal a sequence of R-R intervals, i.e., a series of time intervals between the two successive R peaks, we obtained information about the HRV. To obtain equidistant time series from not equidistant sequence of R-R intervals, we approximated it with cubic splines and resample with a frequency of 5 Hz.

A tachogram (R-R interval series) recording was performed in the course of BE tests with loads of 25 W, under 0.1 Hz controlled breathing, for 5 min at each stage of a test. A registration of R-R interval series was performed in sedentary posture and 90 seconds after the beginning of 25 W load stage of BE test. This allowed us to exclude an influence of transients of cardiac function adaptation on the results. The preparation of patients for BE tests included antianginal drugs cessation: for nitrates 24 hours before testing and for beta adrenergic blockers 3-7 days before testing.

The depth and the phase's ratio of controlled breathing did not differ from those under the spontaneous breathing. The beginning of each inhalation was indicated by the computer-generated sound of duration 0.5 seconds. The subject was asked to inhale when the sound signal appeared. All the subjects were instructed to

inhale according to the computer-generated sound and expire spontaneously. No attempts were made to regulate the inhalation/exhalation ratio; the only instruction to the subjects was to maintain their normal breathing depth. There were no other requirements on the character of breathing. Each subject was suggested to choose himself the most comfortable duration of inhale and exhale and the amplitude of breathing. Before starting the protocol all of individuals were trained to breath synchronized with the electronic metronome.

The next day all CHF patients had BE tests with loads of 25 W, under spontaneous breathing. A tachogram (R-R interval series) recording was performed also.

Data analysis
In order to obtain HRV frequency estimates, the parametric method for constructing the spectrum of the temporal R-R series based on the autoregressive model up to the 14th order was used. For further analysis, low-frequency (LF, 0.04–0.15 Hz) bands were used,[9] in which the HRV spectrum frequency power was calculated (in ms^2).

R-R interval series free of noise, extra systoles, a noticeable linear trend were selected for spectral analysis.

Statistical analysis
The statistical analysis of the results included the following. To compare the variables between patients' groups we used the Mann–Whitney test. To compare the variables within one patients' group we used the Wilcoxon rank test. Continuous variables are reported as medians (Me) with inter-quartile ranges (Q_1, Q_3) and minimum-maximum range values [min-max] for non-parametric data or mean (M) with standard deviation (sd) for normally distributed data. Categorical data are presented as frequencies and percentages. The obtained estimations were considered statistically significant if $p<0.05$. For the statistical analysis the software package Statistica 6.1 was used.

Results and discussion
The comparison of average R-R intervals duration (index inverse to HR) under BE test was performed in both of patients' groups. This is necessary to evaluate the adequacy of study of autonomic influences on HR. It was shown, that in the same conditions of cardiovascular system functioning (relaxed condition and 25 W load) there were no significant differences of average R-R intervals duration in patients with EF<50% and EF>50% (table 2). The balance between sympathetic and parasympathetic departments of the autonomic nervous system in these groups of patients could be interpreted as constant in stipulated conditions of the autonomic heart control system, functioning independently of the severity of a myocardium lesion. In this connection there appeared a necessity of studying of the heart rate variability frequency spectral components, which were independent from prevalence of activity degree of one or the other autonomic nervous system department but characterize a central link of heart rhythm control. In accordance with the concepts of autonomic heart control system functioning listed above, it provoked a direct interest, in particular, to the study of a dynamic of LF component of the HRV spectrum parameters in subjects with different EF.

In the process of studying LF band of the HRV spectrum in patients with EF<50% and EF>50% in rest under 0.1 Hz controlled breathing, there were no significant differences in its spectral power (table 3). Consequently, the power of LF band did not display adequately myocardial contractility in the relaxed patients´ condition. It is necessary to take this fact into consideration while interpreting heart rate variability characteristics. But under the load rising till 25 W in patients with myocardial contractility damage, consequent depression of LF component spectral power in 2-3 times in comparison with the relaxed condition was observed under 0.1 Hz controlled breathing (table

3). At the same time, there was no similar reliable expressed dynamic in the group with normal EF.

It possible to say that the status of LF oscillations in HR, under 0.1 Hz controlled breathing, in CHF patients with EF>50% is characterized by relative tolerance to low-intensive loads, while in patients with EF<50% these LF oscillations is very unstable to the same loads. Thus, tolerance of LF oscillations in HR to low-intensity loads under 0.1 Hz controlled breathing may be considered to be an independent criterion of dynamic tolerance evaluation of the autonomic heart control in CHF patients.

In most patients low EF was associated with prior MI. Although we have not studied the influence of prior MI on the autonomic heart control in CHF patients. It is known that combination of prior MI and impaired systolic function associated with impaired autonomic heart regulation (estimated by SDNN – standard deviation of beat-to-beats or NN intervals).[10] These three risk-factors determine a greater risk of all-cause and cardiac death within a 5-year period.[10] Also autonomic indexes estimated by HRV have predictive value on long-term outcome in patients with low EF.[11] Perhaps, the study of functional status of baroreflex gain estimated by 0.1 Hz resonance phenomenon in HR will receive more prognostic information in CHF patients with prior MI. However, this hypothesis requires further research.

It is also known that the baroreflex sensitivity have clinical significance in CHF patients.[12] Some authors suggest that 0.1 Hz breathing influences on baroreflex sensitivity.[13-15] Y.C. Tzeng et al.,[16] concludes that slow breathing does not influence globally the baroreflex sensitivity. We suppose that 0.1 Hz controlled breathing lowers the impact of other factors (internal and external) on LF band of HRV spectrum. This may be due to the resonance phenomenon in LF oscillations in HR. In our study it was shown that there are no differences between the patients with EF<50% and EF>50% in rest and in 25 W load under spontaneous breathing (table 4). Thus, 0.1 Hz controlled breathing is potentially a main external factor for the study of baroreflex gain and its dysfunction in CHF patients.

Conclusions

The stability of LF oscillations in HR to low-intensity loads under 0.1 Hz controlled breathing depends on the severity of myocardial contractility damage. The dynamic of LF band of HRV spectrum may be considered an independent index of dynamic stability of the heart autonomic control in CHD patients

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ANNEX

Table 1: Baseline characteristics of the patients with EF <50% and EF >50%

Parameters	Patients with EF <50% (n=45)	Patients with EF >50% (n=35)	p-level
Age, years, m±sd	50±3	52±6	0.06
Prior MI, %	75.6	33.3	<0.001
History of stable angina pectoris, %	73.3	74.3	0.92
Family history of premature heart disease, %	31.1	25.7	0.60
Prior percutaneous coronary intervention, %	0	0	-
Prior stroke, %	0	0	-
History of arterial hypertension, %	88.9	85.7	0.67
Smoking, %	33.3	34.3	0.93
Left ventricle EF, %, Me (Q_1, Q_3) [min-max]	39 (32, 45) [24-49]	58 (54, 62) [51-68]	<0.001

Table 2: Value of average R-R intervals (ms) of patients with EF <50% and EF >50% during rest and 25 Wt loading under 0.1 Hz controlled breathing

Groups	Rest	25 Wt	p-level
EF >50%	0.72 (0.64, 0.85) [0.54-0.91]	0.63 (0.58, 0.7) [0.51-0.79]	0.002
EF <50%	0.72 (0.65, 0.81) [0.56-0.98]	0.63 (0.56, 0.69) [0.50-0.84]	0.008
p-level	0.64	0.26	

The data are submitted as Me (Q_1, Q_3) [min-max]; EF - ejection fraction.

Table 3: Value of spectral power of the LF band of HRV of patients with EF<50% and EF>50% during rest and 25 Wt loading under 0.1 Hz controlled breathing

Groups	Rest	25 Wt	p-level
EF >50%	407 (150, 819) [110-961]	334 (164, 639) [120-788]	0.19
EF <50%	454 (96, 719) [68-844]	130 (60, 265) [32-391]	<0.001
p-level	0.59	<0.001	

The data are submitted as Me (Q_1, Q_3) [min-max]; EF - ejection fraction.

Table 4: Value of spectral power of the LF band of HRV of patients with EF<50% and EF>50% during rest and 25 Wt loading under spontaneous breathing

Groups	Rest	25 Wt	p-level
EF >50%	204 (84, 544) [56-720]	125 (54, 202) [40-312]	0.03
EF <50%	192 (88, 463) [46-714]	112 (67, 181) [37-296]	0.02
p-level	0.24	0.52	

The data are submitted as Me (Q_1, Q_3) [min-max]; EF - ejection fraction.