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Comparative assessment of circulatory autonomic regulation in the patients with coronary artery bypass graft or valvular heart disease correction

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Abstract:
The objective of our study was to investigate the features of circulatory autonomic regulation in the patients with a coronary artery bypass graft surgery (CABG) or correction of a valvular heart disease (CVHD).
Material and Methods. Our study enrolled 42 patients (including 12 women) aged 63 (57; 67), who underwent CABG; and 36 patients (including 16 women) aged 58 (47; 65), who underwent CVHD. Simultaneous 15-minute recordings of electrocardiograms and photoplethysmograms (PPG) were performed on all patients before and after the surgery. We assessed and analyzed statistical and frequency-related measures of heart rate variability (HRV) and index of synchronization (S) among low-frequency (LF) oscillations in HRV and PPG.
Results. The values of most autonomic regulation indices in our study did not have statistically significant differences among the patients with CABG and CVHD at all stages of research. The exception was represented by the heart rate, which was higher before CVHD (p=0.013).
Conclusion. In all patients with CABG, the values of HRV and S did not depend on the differences in their clinical statuses or performed cardiac surgical interventions.

Keywords: cardiovascular autonomic control, coronary artery bypass graft surgery, valvular heart disease, heart rate variability.

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Introduction

Heart rate variability (HRV) has recently become a conventional study object in cardiac surgery patients [1]. Available clinical evidence regarding prognostic significance of HRV indices in such patients is somewhat contradictory. While some study results indicated an increased risk of lethal outcomes of coronary artery bypass surgery (CABG) in the patients with reduced HRV [2], other data implied no connection between the indices of vegetative dysfunction and the prognosis in cardiac surgery patients [3]. Besides HRV, the researchers' attention was attracted by blood pressure variability (BPV), characterizing autonomic regulation processes in the cardiovascular system [4]. In our earlier publications, we used the evaluation of synchronization of low-frequency (LF) oscillations in HRV and the photoplethysmogram (PPG) signal to study an interaction between baroreceptor reflex mechanisms of circulatory autonomic regulation [5]. It was established that cardioplegia, widely used for various cardiac surgeries, was increasing the risk of postoperative complications [6]. At the same time, the effect of cardioplegia and other cardiac operative procedures on the autonomic regulation of the cardiovascular system remained virtually unexplored.

The objective of our study was to investigate the features of circulatory autonomic regulation in the patients who underwent coronary artery bypass graft surgery (CABG) or correction of valvular heart disease (CVHD).

Material and methods

Our study included 42 patients (29% of those women) aged 63 (57; 67) years old (the data are presented as medians and interquartile range – Me), who underwent CABG surgery and 36 patients (44% of those women) aged 58 (47; 65), who underwent CVHD. All patients were subjected to full clinical examination, medicated treatment and cardiac surgery (CABG or CVHD) in conditions of artificial blood circulation (ABC). CABG was performed on working hearts, while cardioplegia was used for CVH.

Table 1. Clinical and anamnestic characteristics of the patients in the study groups

Indicators	Groups of patients		p
	CABG (n=42)	CVHD (n=36)	
Age, years, median and interquartile range (25%; 75%)	63 (57; 67)	58 (47; 65)	0,086
Females, %	29	44	0,152
BMI, kg/m², median and interquartile range (25%; 75%)	29,2 (27,3; 32,9)	25,6 (23,2; 29,0)	0,001
HA in the anamnesis, %	71,4	0	<0,001
Stroke in the anamnesis, %	4,8	5,6	0,874
AH, %	95,2	50,0	<0,001
Smoking, %	35,7	16,7	0,063
Diabetes, %	16,7	0	0,012
COPD, %	7,1	0	0,107
PCI in the anamnesis, %	19,0	0	0,007
LVEF, %, median and interquartile range (25%; 75%)	60 (55; 62)	66 (60; 67)	0,001
Blood creatinine (before surgery), mg/dl, median and interquartile range (25%; 75%)	84 (74; 105)	69 (61; 88)	0,044
Blood glucose (before surgery), mmol/l, median and interquartile range (25%; 75%)	5,4 (4,9; 6,2)	5,0 (4,7; 5,2)	0,051
Hematocrit (before surgery), %, median and interquartile range (25%; 75%)	41 (38; 44)	40 (37; 42)	0,779
ACEI (before surgery), %	81,0	27,8	<0,001
Beta blockers (before surgery), %	81,0	22,2	<0,001
Statins (before surgery), %	71,4	22,2	<0,001
Diuretics (before surgery), %	35,7	44,4	0,436
CCB (before surgery), %	23,8	5,6	0,029
Cardioplegia, %	0	100	<0,001
Duration of ABC, minutes, median and interquartile range (25%; 75%)	73 (56; 98)	124 (102; 145)	<0,001
Duration of postoperative ALV, hours, median and interquartile range (25%; 75%)	13,5 (9,0; 21,5)	20,0 (13,0; 25,0)	0,099
Length of stay in a hospital, days, median and interquartile range (25%; 75%)	7,5 (7,0; 8,0)	8,0 (7,0; 11,0)	0,085
Nosocomial complications, %	16,7	38,9	0,039

M±SD – mean and standard deviation; median and interquartile range range (25%; 75%) – median and interquartile range range ; BMI – body mass index; HA – heart attack (myocardial infarction); AH – Arterial Hypertension; COPD – chronic obstructive pulmonary disease; PCI – percutaneous coronary intervention; LVEF – left ventricular ejection fraction; ACEI –of angiotensin-converting-enzyme inhibitors; CCB – calcium channel blockers; ABC – artificial blood circulation; ALV – artificial lungs ventilation.

All patients gave their voluntary informed consent to participate in the study. The design of the study was approved by the ethical committee of A.N. Bakoulev National Medical Research Center for Cardiovascular Surgery, Russian Federation Ministry of Healthcare

The exclusion criteria encompassed heart rhythm disturbances impeding HRV analysis, severe heart failure, cardiomyopathy, endocrine diseases (except for compensated diabetes), cancer, stroke, mental illness, microcirculation disorders, and secondary arterial hypertension.

General clinical characteristics of the patients in the study groups are presented in *Table 1*. Patients with CABG had a higher level of body mass index, diastolic pressure, blood creatinine, as well as much higher frequency of previous myocardial infarction, diabetes mellitus and arterial hypertension. Patients after CVHD were characterized by higher left ventricular ejection fraction, longer duration of intraoperative use of the cardiopulmonary bypass and a slightly increased frequency of nosocomial complications. We also detected some differences in patient groups under examination in terms of frequencies of certain types of medication prescriptions.

We conducted simultaneous 15-minute electrocardiogram (ECG) and FPG recordings with 250 Hz frequency of discretization from the index finger of all patients before and 5-7 days after a surgery. The patients were in a supine position and breathed spontaneously. Recordings containing significant breath holding, extrasystoles, and a prominent linear trend were not included in the subsequent analysis.

We evaluated statistical and frequency-related indicators of heart rate variability (HRV) and the synchronization index of low-frequency (LF) oscillations in HRV and PPG (S-index). The S index (proportion of time expressed as a percentage of the total recording of biological signals, during which the low-frequency oscillations were synchronous among themselves) was computed in accordance with the previously proposed original method [5].

Besides, the following HRV indicators were calculated [7]: average heart rate (HR, bpm); SDNN (ms); total spectrum power of HRV in the frequency range 0 – 0.50 Hz (TP, ms2); the ratio of the low-frequency power range (0.04-0.15 Hz) to the total spectrum power of HRV, expressed as a percentage (LF%); the ratio of the high-frequency (HF) power range (0.15-0.40 Hz) to the total spectrum power of HRV, expressed as a percentage (HF%); power ratio of LF to HF ranges of HRV spectrum (LF / HF).

Statistical analysis was conducted with Statistica 6.1 (StatSoft, USA) software package. Quantitative data were presented in the form of a median and interquartile range - Me (25%; 75%), qualitative data were presented in the form of ratios (frequencies), expressed as percentages. We used non-parametric statistical methods. The comparison of the groups, due to the fact that significant part of the indicators did not comply with a normal distribution, was conducted with a Mann-Whitney criterion. Comparison of frequencies was made using the t-test. Statistical significance of evaluations and comparisons was taken at the level above 95%.

Results

Among the indicators of circulatory autonomic regulation (both initially and 5-7 days after surgery) in the two groups, the difference was revealed only at the level of average HR before surgery, that was higher in patients undergoing surgical CVHD, than in the CABG group (p = 0.013) (*Table 2*). At that, there was a marked intra-group variability of values of the majority of vegetative indicators under study in both groups of patients, which manifests itself in a rather wide range between the minimum and maximum values of

the indicators, as well as the size of the interquartile range (*Table 2*). After cardiac surgery operations there was a significant (p <0.05) decline in a number of vegetative regulation indicators: SDNN, TP and LF / HF.

Discussion

CABG surgery is associated with a HRV decrease at early post-operative stage, which lowers the significance of using HRV indicators for evaluating a long-term risk of developing cardiovascular complications [3, 9]. However, some scientists have previously reported high predictive power of non-linear HRV assessment for postoperative risk in the patients who underwent this type of cardiac surgery [10, 11].

The total reduction of HRV in the patients with CVHD is due to baroreceptor reflex dysfunction in conjunction with a hemodynamic failure of the venous heart [12, 13], which can be corrected via surgery.

We observed total HRV decrease in postoperative period for most patients after the surgery under artificial circulation condition (CABG or CVHD), which supported the results of other studies [12-15]. Such decrease in HRV was probably due multiple factors: artificial circulation and the features of a cardiac surgery (anesthesia, duration of postoperative artificial lung ventilation, cardioplegia and others) [14, 16, and 17].

However, the mechanisms of these impacts on the autonomic regulation of the cardiovascular system are still poorly studied [18–20]. However, the differences in clinical status among the groups of cardiac surgery patients in our study (*Table 1*) did not cause group differences in circulatory autonomic regulation vegetative indicators (*Table 2*), which is remarkable because the influence of many clinical characteristics on HRV (in particular, age, body mass index, heart attack rate, systolic function condition of the left ventricle, beta-blocker therapy, etc.) has been previously proved [7]. Additional assessment of the mechanisms of systemic circulatory autonomic regulation can be completed on the basis of synchronization evaluation of the low-frequency fluctuations in HRV and PPG [5]. This approach has previously demonstrated good predictive power for personalized cardiovascular risk assessment [5]. The present study did not discover significant differences in the values of this indicator before and after the surgery in both groups of the patients under study (see *Table 2*; p> 0.05).

Conclusion

Save for average HR levels, no differences among the patients after CABG vs. CVHD surgery were found in synchronization index values of the LF oscillations in their cardiovascular system and in most HRV-related indicators of our study (SDNN, TP, LF%, HF%, LF/HF).

Conflict of interest

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Table 2. Indicator values of circulatory autonomic regulation in the patients of the study groups before and after cardiac surgery

Indicators	Groups of patients		p
	CABG (n=42)	CVHD (n=36)	
Before surgery			
S, %	24,7 (18,3; 35,2)	22,5 (13,4; 27,4)	0,400
Heart rate, bpm	67 (60; 72)	69 (65; 80)	0,013
SDNN, ms	34,9 (24,9; 52,3)	37,7 (28,4; 53,1)	0,903
TP, ms ^{2}	493 (311; 1247)	425 (246; 969)	0,696
LF%	24,4 (16,5; 34,6)	29,4 (17,1; 36,9)	0,653
HF%	21,6 (9,5; 47,0)	20,2 (11,1; 29,7)	0,422
LF/HF	1,2 (0,6; 2,7)	1,4 (0,6; 2,9)	0,546
5-7 days after surgery			
S, %	20,3 (10,2; 27,5)	20,2 (15,5; 28,1)	0,529
Heart rate, bpm	78 (73; 87)	74 (66; 90)	0,439
SDNN, ms	15,6 (11,3; 41,0)	18,0 (11,1; 71,9)	0,479
TP, ms ^{2}	84 (26; 496)	125 (36; 2735)	0,326
LF%	26,6 (18,1; 36,4)	30,8 (21,8; 39,8)	0,526
HF%	26,3 (10,8; 46,4)	23,7 (9,7; 43,4)	0,637
LF/HF	0,8 (0,5; 3,4)	1,2 (0,6; 2,9)	0,586

Data is presented in the form of the median and interquartile range (25%; 75%).

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