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COMPARISON OF THE INTEGRAL INDICES OF THE VECTORCARDIOGRAM WITH CLINICAL DATA IN PATIENTS WITH CHRONIC CORONARY HEART DISEASE

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SUMMARY

The aim of the work was to compare the integral parameters of the vectorcardiogram (VCG) – spatial QRS-T angle and electrocardiographic ventricular gradient (VG) – with clinical data in patients with chronic coronary heart disease (CHD).

The study included 213 patients with CHD (165 men and 48 women, mean age 62.1±9.8 years) who underwent a comprehensive clinical and instrumental examination. The control group consisted of 50 practically healthy persons (30 women and 20 men, mean age 56.5±8.8 years). The QRS-T angle and VG were calculated on the VCG, derived from the 12-lead digital ECG.

In patients with CHD, the VG module and VG-X, VG-Y, VG-Z components were significantly smaller, and the QRS-T angle was significantly higher than in healthy individuals of the same sex. The presence of arterial hypertension, hyperlipidemia, diabetes mellitus, chronic heart failure and obesity was associated with increased QRS-T angle. In patients who had a history of anterior myocardial infarction, compared to patients without myocardial infarctions, the VG module and its components VG-X and VG-Z were significantly decreased and the QRS-T angle was increased. In patients who had a history of inferior-posterior myocardial infarction, the VG-Y component was significantly decreased and the VG-Z component was increased. The threshold value VG-Y≤10 ms allowed to detect the old inferior-posterior myocardial infarction with a sensitivity of 63% and a specificity of 75%; threshold values of VG-X≤14 ms and VG-Z<10 ms allowed to diagnose old anterior myocardial infarction with a sensitivity of 67-77% and specificity of 85-79%, respectively.

In CHD patients, higher QRS-T angle values were associated with the presence of traditional risk factors – arterial hypertension, hyperlipidemia, diabetes and obesity. Changes in VG in myocardial infarctions of different localizations were different.

Keywords: *synthesized vectorcardiogram, QRS-T spatial angle, ventricular gradient, chronic ischemic heart disease.*

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INTRODUCTION

Coronary heart disease (CHD) has remained one of the most important cardiology problems for decades. Despite the fact that in recent years there has been a tendency in Russia to reduce the mortality from Coronary heart disease (CHD), this indicator remains high. At the same time, the number of patients with CHD is increasing, both due to newly diagnosed cases, and due to improved diagnosis and treatment. According to the epidemiological study [1], the prevalence of CHD among individuals of 55 y.o. and older was 34% in men and 36% in women.

In patients with stable Coronary heart disease (CHD), the prognosis may vary significantly depending on the initial clinical data. As mentioned in the European recommendations for the treatment of stable CHD [2], assessment of the prognosis is an important component in the treatment of patients with CHD. Given the high prevalence of chronic coronary artery disease, the issue of non-invasive risk stratification remains relevant on the basis of data from routine, widely available methods of instrumental research, in particular ECG.

In recent years, with the introduction of the digital ECG, there has been an increase in interest in integrated vector cartographic indicators – the QRS-T spatial angle and the electrocardiographic ventricular gradient (VG), which, according to several studies, have predictive value for cardiovascular complications and mortality in different groups of subjects [3].

The exact mechanisms underlying the increase in the QRS-T angle are not clear yet. The aim of our work was to compare the spatial angle of QRS-T and VG with clinical data in patients with chronic coronary heart disease (CHD).

MATERIAL AND METHODS

The study included 213 patients with CHD who were on treatment at the Myasnikov Institute of Clinical Cardiology of Federal state budget organization "Scientific Medical Research Center of Cardiology" of the Ministry of Health of the Russian Federation. The diagnosis was established according to current recommendations based on a comprehensive clinical and instrumental examination. All patients had a digital ECG in 12 leads. The control group consisted of 50 practically healthy individuals (30 women and 20 men, 56.5±8.8 y.o.) without clinical and electrocardiographic signs of cardiovascular diseases.

Electrocardiography

Digital electrocardiograms in 12 leads were recorded using the Easy ECG computer electrocardiograph (Ates Medica, Russia) and processed using Easy ECG software (Ates Medica, Russia). A 10-second ECG record was produced; similar cardiocomplexes were averaged, after which automatic marking was performed (if necessary with manual correction). Vector cardiography of the leads X, Y, and Z were calculated from an electrocardiogram in 12 leads using special linear transformations [4]. The QRS-T angle was calculated as the spatial angle between the integral vector QRS and T. To obtain the VG, the integrals (the areas under the curve) over the QRST period in the leads X, Y, and Z were calculated, which were considered components of the X, Y, and Z electrocardiographic ventricular gradient (VG). VG was normalized to the maximum vector of the QRS complex. The VG module and its components VG-X, VG-Y and VG-Z were analyzed. The x axis was directed from right to left, the y axis from top to bottom, and the z axis from behind in front.

Statistical analysis

Data was analyzed using statistical software MedCalc, version 12.7.8 (MedCalc Software BVBA, Ostend, Belgium). Continuous variables depending on the type of distribution are represented as the mean±SD (with normal distribution) or in the form of a median and interquartile range (25th and 75th percentile); qualitative variables – in percent. To estimate the differences between the two independent quantitative variables, we used the unpaired t-test or the Mann-Whitney test, for qualitative variables-the exact Fisher test. To determine the relationship between the variables, the Pearson or Spearman correlation analysis was performed. Characteristic curves (ROC curves) were used to describe the informativeness of the indicators. The level of statistical significance was assumed to be $p<0.05$. The sensitivity and specificity of the criteria were calculated using the following formulas: sensitivity = TPR / (TPR + FNR) × 100%, specificity = TNR / (TNR + FPR) × 100%, where TPR is truly positive results; FNR – false-negative results; TNR – truly negative results; FPR – false positive results.

RESULTS

Characteristics of patients at the time of examination are presented in Table 1.

Angina of tension of II FC was present in 63 (30%) patients, III FC in 114 (54%) patients, IV FC in 9 (4%) patients; 7 (3%) patients had atypical angina pectoris; in 13 (6%) patients – unstable angina; In 6 (3%) patients, the ECG was recorded less than 1 month after the acute coronary syndrome.

Overweight (BMI more than 25 kg/m^2) was observed in 93 (44%) patients, obesity (BMI more than 30 kg/m^2) – in 81 (38%) patients.

Therapy taken: antiplatelet agents – 190 (90%) patients, beta-blockers – 169 (80%) patients, angiotensin converting enzyme inhibitors and / or angiotensin II receptor antagonists II-148 (70%), statins – 176 (83%), calcium channels blockers – 52 (25%) patients, nitrates – 64 (30%) patients, diuretics – 36 (17%) patients, anticoagulants - 14 (7%) patients, antiarrhythmics – 9 (4%) patients.

Indicator values of Vector cardiography in patients with CHD and healthy individuals of different sex are presented in Table 2.

In patients with CHD, the VG module and VG-X, VG-Y, VG-Z components were significantly smaller, and the QRS-T angle was significantly higher than in healthy individuals of the same sex. In patients with CHD, there was no difference in Vector cardiography indicator depending on the sex of patients. At the same time, in

Table 1. Characteristics of patients at the time of examination

Characteristic	Value
Age, years	62,12±9,81
Male	165 (77,8%)
Arterial hypertension	188 (88,7%)
Hyperlipidemia	112 (52,8%)
Diabetes	35 (16,5%)
chronic heart failure	21 (9,9%)
Myocardial infarction in anamnesis	128 (60%)
percutaneous coronary intervention (PCI) in anamnesis	64 (30%)
Aortocoronary bypass surgery/ Mammarocoronary bypass surgery in anamnesis	11 (5%)
Heart rate, beats per minute	64 [58; 70]
Current smoking	48 (22,7%)
Smoking in the anamnesis	72 (34,1%)
Body mass index (BMI), kg / m^2	29 [26; 31]

Table 2. Indicator values of Vector cardiography in patients with CHD and healthy individuals of different sex

	Norm		CHD	
	Male	Female	Male	Female
VG, ms	*86,1±24,9*	*76,6±13,3*	*62,5±29,5**	*58,0±22,8**
VG-X, ms	*47,3±16,3*	*42,3±8,8*	*26,4±21,0**	*25,4±20,3**
VG-Y, ms	*28,0±9,3*	*29,0±10,7*	*13,4±16,9**	*16,9±14,7**
VG-Z, ms	*35,0±12,9*	*25,1±11,8#*	*20,5±28,6**	*15,4±23,2**
QRS-T angle, degrees	*52,6±24,2*	*49,0±19,9*	*76,8±41,5**	*69,3±42,7**

** p <0.05 compared with the norm group*
 # p <0.05 compared to healthy men

Table 3. QRS-T angle (in degrees) in patients with CHD with the presence and absence of concomitant diseases

	arterial hypertension	hyperlipidemia	diabetes mellitus	chronic heart failure
Yes	*77,0 [46,0; 106,5]*	*79,9±42,8*	*90,1±47,0*	*92,4±50,1*
No	*60,0±45,5**	*69,8 [42,0; 93,0]**	*72,1±40,1**	*73,2±40,4**

** p<0,05*

healthy women, the VG-Z component was significantly less than in healthy men.

In patients with CHD, weak but significant negative correlations of the VG module with age of patients were found (r = -0.17, p = 0.01) as well as VG-Y with age of the patients (r = -0.16, p = 0, 02) and VG module with heart rate (r = -0.19, p = 0.01), also VG-X with heart rate (r = -0.16, p = 0.02) and a weak positive correlation of the QRS-T angle with heart rate (r = 0.21, p <0.01). In healthy individuals, significant negative correlations of VG module with HR (r=-0.55; p<0.01), VG-X with HR (r=-0.54; p<0.01) and VG-Z with HR (r=-0.40; p<0.01) were revealed.

The presence of arterial hypertension, hyperlipidemia, diabetes mellitus and CHD was associated with large values of the QRS-T angle compared to patients without the indicated forms of pathology (Table 3).

The presence of concomitant diabetes was associated with a significant decrease in the VG and VG-X module: the VG module in patients with CHD with diabetes mellitus 47.4±25.4 ms, without diabetes 64.3±27.9 ms, p <0.01; VG-X in patients with CHD with diabetes 20,2±16,9 ms, without diabetes 27,3 [14,0; 42.0] ms, p<0.05. The presence of chronic heart failure was associated with a significant decrease in VG-X: in patients with CHD with chronic heart failure 14.6±24.3 ms; in patients with CHD without CHF 27.4±20.1 ms, p<0.01.

There were no statistically significant differences in Vector cardiography indicator depending on the presence or absence of a history of aortocoronary bypass surgery/ mammarocoronary bypass surgery in anamnesis and percutaneous intervention, and also depending on smoking.

Of the 128 patients who had a history of myocardial infarction, 62 (48.4%) had myocardial infarction of the inferior localization, 48 (37.5%) had anterior localization; 18 (14.1%) patients had a history of myocardial infarction without a Q wave.

Values of Vector cardiography indicator in patients with CHD, depending on the presence in the anamnesis of myocardial infarction are given in Table 4.

Thus, in patients who had a history of myocardial infarction with anterior location, compared with patients without myocardial infarction, the VG module and its components VG-X and VG-Z were significantly decreased and the QRS-T angle was increased. In patients who had a history of myocardial infarction of the inferior-posterior localization, compared with patients without myocardial infarction, the VG-Y component was significantly decreased and the VG-Z component was increased.

Figure 1 shows synthesized orthogonal ECG, vectorcadograms and decartograms of repolarization acceleration (dipolar maps of the ventricular gradient) of a practically healthy man and patients who underwent myocardial infarction of the inferior and anterior localization.

The results of the ROC analysis of the separation of patient groups with the presence and absence of Q-forming myocardial infarctions in anamnesis are presented in Table 5.

A significant decrease in the VG module in patients with angina pectoris of the III FC was found in comparison with the II FC: 58.9±27.0 ms and 70.9±27.7 ms, respectively; p<0.01. There were no other statistically significant differences in Vector cardiography indicator in patients with stress angina II, III, and IV FC and patients with unstable (first-ever) angina pectoris.

Values of Vector cardiography indicator in patients with CHD in relation to body mass index (BMI) are presented in Table 6.

DISCUSSION

Estimation of the prognosis and, accordingly, risk stratification is an important task in the treatment of patients with CHD. On the one hand, it is important to identify patients with more severe forms of the disease in time, who need more intensive examination and treatment, including myocardial revascularization. On the other hand, it is also important to identify patients with milder forms of the disease in order to avoid excessive invasive and non-invasive tests and revascularization procedures.

Table 4. The values of Vector cardiography indicator in patients with CHD, depending on the presence in the anamnesis of myocardial infarction

	VG, ms	VG-X, ms	VG-Y, ms	VG-Z, ms	QRS-T angle, degree
without MI	60,8±23,8	32,2±16,8	17,2±11,7	22,6±16,5	69,6±36,7
MI without Q wave	64,8±24,0	27,7±16,1	18,8±14,4	22,2±28,6	84,7±44,1
MI of lower back localization	71,5±31,6	30,7±21,6	5,7±15,4[1,2]	33,2±29,3[1]	68,8±42,0
MI of front localization	48,6±27,5[1,3]	9,2±18,9[1,2,3]	17,9±21,3[3]	-5,2±24,9[1,2,3]	89,2±46,0[1]

[1] – p<0.05 compared to the group without MI
[2] – p<0.05 compared to the group without Q wave
[3] – p<0.05 in comparison with the MI group of the inferior-posterior localization

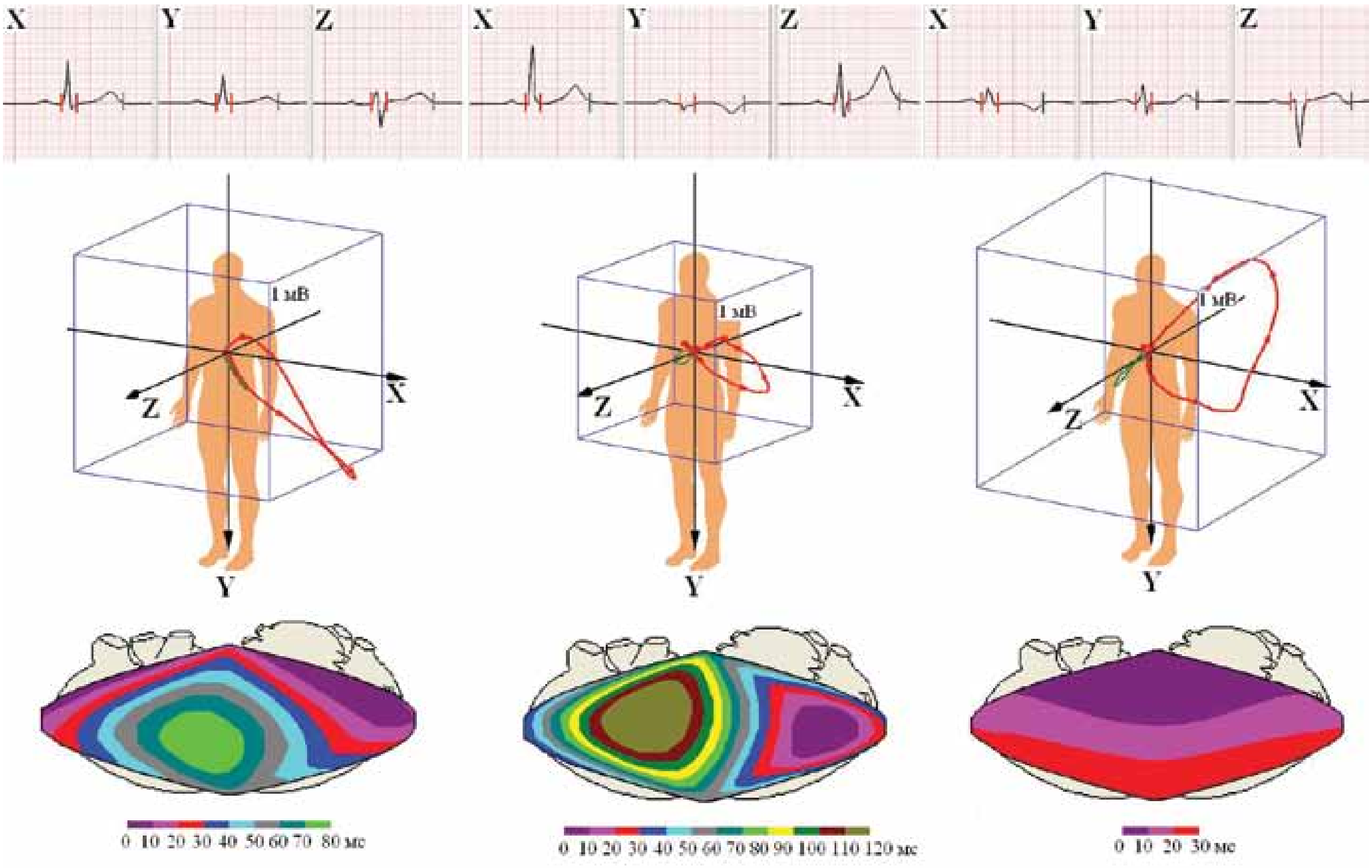

Figure 1. Synthesized orthogonal ECG, vectorcadograms and decartograms of repolarization acceleration (dipole map of the ventricular gradient) of a practically healthy male of 60 y.o.; a patient of 45 y.o., who underwent a myocardial infarction of the inferior-posterior localization and a patient of 48 y.o. who underwent a myocardial infarction of anterior localization

In recent years, a number of studies have demonstrated the prognostic value of the QRS-T spatial angle for cardiovascular complications and mortality in different groups.

Table 5. Results of ROC-analysis of the separation of patient groups with the presence and absence of Q-forming myocardial infarctions in the anamnesis

	MI of inferior-posterior localization	MI of anterior localization	
Threshold value, ms	VG-Y≤10	VG-X≤14	*VG-Z<10*
Sensitivity, %	63	67	*77*
Specificity, % (CHD without MI)	75	85	*79*
Specificity,% (norm)	74	96	*96*
AUC (CHD without MI)	0,72±0,04	0,81±0,04	*0,83±0,04*
AUC (norm)	*0,90±0,03*	*0,94±0,03*	*0,90±0,03*

AUC is the area under the ROC curve

The increased QRS-T angle was an independent predictor of cardiovascular mortality and all-cause mortality in patients referred for stress echocardiography with confirmed or suspected CHD [5]. Taking into account the QRS-T angle, the assessment of the risk of sudden cardiac death in patients with acute coronary syndrome was made more accurate than using standard risk factors [6].

It is believed that the angle QRS-T and VG are indicators of the global electrical heterogeneity of the myocardium and depend on the difference in duration and form of action potentials in different areas of the ventricular myocardium. Normally, the main contribution to their formation is made by the difference in the duration of action potentials in the subepicardial, subendocardial and middle layers of the ventricular myocardium [7]. In conditions of pathology, a change in the form and duration of the action potential in the ischemia zone, as well as the processes of electrical remodeling, which are caused by changes in the ion channels and intercellular connections, may have a significant effect on the change in VG [8].

The values of vector cardiography indicators in healthy individuals, obtained in this study, were very close to those described earlier using the real system of orthogonal leads of McFee-Parungao [9].

Table 6. Values of Vector cardiography indicator in patients with CHD in relation to BMI

	VG, ms	VG-X, ms	VG-Y, ms	VG-Z, ms	QRS-T angle, degree
BMI <25 kg/m²	72,7±25,5	33,1± 18,6	19,7±18,7	25,3± 27,1	55,7±31,0
BMI 25-30 kg/m²	64,8±27,6	27,7±19,3	16,4±14,9	19,2± 31,1	70,1±35,6
BMI >30 kg/m²	52,9±27,1[1,2]	21,9±22,5[1]	8,7±15,3[1,2]	16,7± 23,1	87,7±47,5[1,2]

[1] - p <0.05 compared with the BMI group <25 kg/m²

[2] - p <0.05 as compared to the BMI group of 25-30 kg/m²

In this case, the differences in the VG-Z component in patients of different sex and the dependence of the modulus and components of VG on heart rate were confirmed [10]. In our previous work, differences in the values of the VG-Y component in healthy individuals older and younger than 40 years were demonstrated [11]. In healthy adults of a more mature age, the dependence of vector cardiography indicators on age was not revealed. In patients with coronary heart disease, the correlations between the vector cardiography and heart rate values were significantly weaker than in healthy individuals. Apparently, other factors have a stronger effect on these indicators in CHD patients.

In this study, in patients with CHD, higher values of the QRS-T angle were associated with the presence of concomitant arterial hypertension, hyperlipidemia, diabetes mellitus, chronic heart failure, and obesity. This is consistent with the data of other studies on the relationship between the increase in the QRS-T angle with high blood pressure values [12, 13], the level of glycosylated hemoglobin and low-density lipoprotein cholesterol [14, 15]. The relationship between the QRS-T angle and the body mass index in patients with metabolic syndrome was also described [15]. It is known that in individuals with established diagnosis of CHD, the traditional risk factors for the development of CHD – hypertension, hypercholesterolemia, diabetes, obesity – have an adverse effect on the prognosis, presumably because of their effect on the progression of atherosclerosis. Changes in vector cardiography indicators in such individuals may be associated with other hemodynamic conditions of heart function in conditions of high arterial stiffness, but this issue requires further study.

When comparing vector cardiography indicators with magnetic resonance imaging of the heart in patients aimed at cardioverter-defibrillator implantation [16], the QRS-T angle was increased in patients with postinfarction cardiosclerosis, and also correlated with increased left ventricular mass, its dilatation, and reduction of the ejection fraction. The same authors found an increase in VG azimuth in patients with postinfarction cardiosclerosis, but they did not take into account the localization of postinfarction cardiosclerosis. In our group, a significant increase in the QRS-T angle was observed in the presence of anterior myocardial infarction in the anamnesis, but not in the inferior-posterior localization. Changes in the orientation of VG in myocardial infarctions of different locations were different: in the presence of anterior myocardial infarction in the anterior history, VG-X and VG-Z components were reliably reduced; and with inferior localization, the component VG-Y is reduced and the VG-Z component is increased. These changes may be due to changes in the shape and duration of action potentials in the zones of chronic myocardial ischemia.

Comparison of vector cardiography indicators in patients with chronic coronary artery disease with data from instrumental survey methods will be the subject of our further research.

CONCLUSION

Recently, more attention has been paid to the search for early predictors of adverse outcomes of cardiovascular diseases. One of them, along with other electrocardiographic indicators, include spatial QRS-T angle and VG. Although these indicators have been proposed for a long time, and their prognostic significance has been proved in a number of studies, the exact mechanisms underlying their changes remain insufficiently clear.

In our work, the QRS-T angle and VG are compared with the clinical data in patients with chronic coronary artery disease. It turned out that in these patients, the pathological values of the QRS-T angle are associated with the presence of traditional risk factors such as arterial hypertension, hyperlipidemia, diabetes, obesity, as well as concomitant CHF and myocardial infarction of anterior localization.

Changes in VG were different depending on the localization of myocardial infarction and allowed with a sufficiently high sensitivity and specificity to diagnose myocardial infarctions of anterior and inferior-posterior localization.

Apparently, in patients with chronic coronary artery disease, the presence of pathological changes in the QRS-T angle and VG indicates a more severe clinical condition of the patient. The precise mechanisms of these changes and, in particular, their comparison with the data of instrumental survey methods, require further study.

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