International Heart and Vascular Disease Journal. Volume 12, № 42, June 2024
ISSN: 2311-1623 (Print)
ISSN: 2311-1631 (Online)
http://www.heart-vdj.com

High-resolution electrocardiography for chronic heart failure in the elderly

Grachev D.S., Petrov V.S.

Ryazan State Medical University, Ryazan, Russia.

AUTHORS:

Dmitry S. Grachev, PhD student of the Department of Hospital Therapy with Medical-Social Expertise course, Ryazan State Medical University, Ryazan, Russia. ORCID: 0009-0002-5972-5631

Vadim S. Petrov, MD, PhD, Associate Professor, Professor of the Department of Hospital Therapy with Medical-Social Expertise course, Ryazan State Medical University, Ryazan, Russia. ORCID: 0000-0001-8631-8826

The aim of the study was to investigate the main parameters of high-resolution electrocardiography (HRECG) in elderly patients suffering from chronic heart failure (CHF).

Methods. The study included 120 patients (87 women (72.5%) and 33 men (27.5%)) of elderly age (mean age 81.32±4.2 years) with CHF. Patients with postinfarction cardiosclerosis (PICS) were divided into groups: 38 patients with CHF IIA and CHF IIB stages; 50 patients with complete bundle branch block (CBBB) with CHF IIA and CHF IIB stages; 32 patients with atrial fibrillation (AF) with CHF I and CHF IIA stages. Patients underwent ECG, Holter monitoring, HRECG.

Statistical processing of the study results was performed using the Stat Soft 13.0 software package.

Results. The highest values in the group of patients with CHF + PICS were recorded for QTc (452.52±3.55 ms), QTp (87.83±1.21 ms) and TotQRSF (103.25±2.97 ms). The highest values in the group of patients with AF were recorded for QTc, TotQRSF and LAS40 (452.65±2.69 ms; 100.04±2.36 ms and 51.64±2.85 μV, respectively). In patients with complete bundle branch block (CBBB), the highest values were recorded for QTc, TotQRSF, LAS40 and PTotal (463.25±3.98 ms; 115.44±3.45 ms; 67.44±4.63 μV and 128.83±8.65 ms, respectively). The highest QTc and TotQRSF values were observed in patients with CHF IIB stage + PICS and CHF IIB stage + CBBB. Linear regression analysis revealed a correlation between ventricular late potential indices (TotQRSF, RMS40, LAS40) and cardiac ECHO parameters such as end diastolic diameter (EDD), end systolic diameter (ESD), interventricular septal thickness (IVST), left ventricle posterior wall thickness (LVPWT).

Conclusion. HRECG analysis can assess myocardial electrical instability and remodeling in CHF. In our study, HRECG indices such as TotQRSF, RMS40, and LAS40, which reflect myocardial electrical heterogeneity, were impaired in elderly patients with severe CHF. This suggests the presence of fragmented electrical activity, which may be associated with structural and functional myocardial changes. HRECG analysis can be used for a comprehensive assessment of the cardiovascular system in this group of patients.

* Corresponding author. Tel. +7 (927) 640-2658. E-mail: dmitrygrachev@internet.ru

Keywords: chronic heart failure, high-resolution electrocardiography, postinfarction cardiosclerosis, atrial fibrillation, myocardium.

Conflict of interests: none declared.

Recieved: 27.03.2024
Accepted: 15.05.2024

For citation: Grachev D.S., Petrov V.S. High-resolution electrocardiography for chronic heart failure in the elderly. International Journal of Heart and Vascular Diseases. 2024. 42 (12): 27–32. DOI: 10.24412/2311-1623-2024-42-27-32

Introduction

Chronic heart failure (CHF) is a complex clinical syndrome resulting from functional or structural heart disease that impairs ventricular filling or ejection of blood into the systemic circulation. CHF remains a common disease with high morbidity and mortality [1, 2]. Experts estimate the current prevalence of CHF worldwide to be 64.34 million cases according to the Global Health Data Exchange registry [3].

The most common causes of CHF in the Ryazan region are arterial hypertension — 89.6%, atrial fibrillation (AF) — 63.3%, and coronary heart disease — 64.9% [4]. In the process of aging, the probability of these diseases increases, which emphasizes the need for a comprehensive approach to diagnosis and treatment, and raises questions about individual prevention of this disease from an early age [5]. In older age, the problem of senile asthenia syndrome and the presence of multiple comorbidities worsen prognosis, increase the number and duration of hospitalizations, and reduce the survival rate of patients with CHF [6]. Cardiac remodeling alters the electrical activity of the heart, which can be detected by electrocardiogram recording.

In recent years, the method of high-resolution electrocardiography (HRECG) has become more widespread. The basis of this method is computer amplification, averaging and filtering of different parts of the electrocardiogram with their subsequent mathematical processing [7]. Thus, this method allows the selection and analysis of low amplitude signals, which are inaccessible for analysis by traditional methods of ECG recording and containing important diagnostic information [8].

For example, when comparing deceased and surviving patients with chronic rheumatic heart disease, which is a model of slowly progressing CHF, a deterioration in the dynamics of ventricular late potentials detected by HRECG is noted [9]. In this regard, obtaining the most complete information about the electrical potential of the heart in this cohort of patients is an important diagnostic problem.

The study of the main parameters of HRECG in patients with CHF allows a more detailed assessment of myocardial electrophysiological properties, which in turn may influence the management tactics of these patients.

The aim of the study was to investigate the main parameters of high-resolution electrocardiography (HRECG) in elderly patients suffering from chronic heart failure (CHF).

Methods

The study included 120 patients (87 women (72.5%) and 33 men (27.5%)) of advanced age (mean age 81.32±4.2 years) with CHF who signed an informed consent. Inclusion criteria for the study were: presence of CHF diagnosis in medical records and the life expectancy greater than one year. Exclusion criteria: presence of cancer, signs of acute infection including SARS-CoV-2, severe mental illness, and inability to complete the questionnaires required by the study.

The main clinical characteristics of the study subjects are summarized in Table 1.

While evaluating the physical development, the mean height of the study subjects was 163.09±7.86 cm, the mean body weight was 75.18±13.36 kg, the mean BMI was 28.26±4.76 kg/m^2, and the mean waist circumference was 99.80±11.51 cm.

Patients with postinfarction cardiosclerosis (PICS) were divided into the following groups: 38 patients with CHF IIA and CHF IIB stages; 50 patients with complete bundle branch block (CBBB) with CHF IIA and CHF IIB stages, and 32 CHF I/ IIA stages patients with AF. Patients underwent a comprehensive clinical and instrumental evaluation: 12-channel HRECG

Table 1. **Clinical characteristics of patients in the study groups**

Parameters	Studied patients, (n = 120)	
	Abs.	% of group
Hypertension	113	94%
Obesity	40	33
Type 2 diabetes mellitus	22	18
AF (permanent or paroxysmal)	62	52
History of myocardial infarction	29	24
History of stroke	17	14
Senile asthenia syndrome	40	33
CHF, I stage	12	10
CHF, IIA stage	68	73
CHF, IIB stage	20	17
Reduced ejection fraction (EF)	8	7%
Moderately reduced EF	20	17%
Preserved EF	92	76%

with polyfunctional Holter monitor (Cardiotekhnika-07-AD-3/12P, Incart, Russia); echocardiography on Philips Affiniti 70 device with evaluation of end-diastolic diameter (EDD), end-systolic diameter (ESD), interventricular septal thickness in diastole (IVST), left ventricular posterior wall thickness in diastole (LVPWT).

The following HRECG parameters were evaluated: TO (turbulence onset, %), TS (turbulence slope, ms/RR) QTc (corrected QT interval, ms) QTdis (dispersion of QT interval, ms), QTp (value in absolute units to T-wave peak, ms), JTc (corrected JT interval, ms), JTdis (dispersion of JT interval, ms), $MTWA_{max}$ (maximum microvolt alternation of T-wave, μV), $MTWA_{mean}$ (mean microvolt alternation of T-wave, μV), TotQRSF (duration of the filtered QRS complex, ms), RMS40 (root-mean-square amplitude of the last 40 ms of the QRS complex, μV), LAS40 (duration of the low-amplitude portion of the signal at the end of the QRS, μV), PTotal (duration of the filtered P-wave, ms), RMS20 (root-mean-square amplitude of the last 20 ms of the P-peak, μV).

The study was conducted in accordance with Good Clinical Practice and the tenets of the Declaration of Helsinki. The study was approved by the local ethics committee of the Ryazan State Medical University in October 2021. Voluntary informed consent was obtained from all participants prior to enrollment.

Statistical analysis

Statistical processing of the results of the study was performed using the Stat Soft 13.0 software. The arithmetic mean and standard deviation were calculated for quantitative variables. In the absence of normal distribution, non-parametric Wilcoxon and Mann-Whitney tests were used. One-way analysis of variance was used to compare means, and linear regression analysis was used to assess the possible associations between variables.

Differences between groups were considered statistically significant at $p \leq 0.05$.

Results

The main parameters of HRECG in groups of CHF patients depending on the presence of PICS were compared. The parameters data are shown in Table 2. The presented data show statistically significant differences between groups for such parameters as QTc (p=0.034), QTp (p=0.001), TotQRSF (p=0.005) with the highest values in the group of patients with PICS (452.52±3.55 ms; 87.83±1.21 ms and 103.25±2.97 ms, respectively) and RMS40 (p=0.032) with the lowest value in the group of patients with PICS — 21.22±2.14. Other parameters such as TS, QTdis, JTc, JTdis, $MTWA_{max}$, $MTWA_{mean}$, LAS40, PTotal, RMS20 did not show statistically significant differences between groups.

We analyzed the main HRECG parameters in groups of CHF patients depending on the presence of AF. Detailed results are shown in Table 3. The

Table 2. **Comparative characterization of key HRECG parameters in patients with and without PICS**

HRECG parameters	CHF without PICS (M±m)	CHF + PICS (M±m)	p
TO, %	0.83±0.74	−0.16±0.22	0.488
TS, ms/RR	8.03±1.25	4.55±0.71	0.154
QTc, ms	443.21±2.33	452.52±3.55	0.034*
QTdis, ms	18.25±1.00	21.11±1.74	0.146
QTp, ms	83.32±0.68	87.83±1.21	0.001*
JTc, ms	330.12±3.09	334.14±2.92	0.449
JTdis, ms	18.26±1.01	21.26±1.75	0.128
MTWA max, μV	111.24±47.6	32.33±6.92	0.379
MTWA mean, μV	41.35±21.69	8.67±0.76	0.424
TotQRSF, ms	93.82±1.70	103.25±2.97	0.005*
RMS40, μV	27.24±1.46	21.22±2.14	0.032*
LAS40, μV	45.91±2.04	53.04±3.60	0.079
PTotal, ms	114.45±2.79	115.07±3.85	0.909
RMS20, μV	3.65±0.07	3.49±0.13	0.288

Note. *p<0.05 — statistically significant differences between groups.

Table 3. **Comparative characterization of key HRECG parameters in patients with and without AF**

Parameters	CHF without AF (M±m)	CHF + AF (M±m)	p
TO, %	0.66±0.73	0.44±0.51	0.875
TS, ms/RR	8.69±1.14	2.15±1.52	0.006*
QTc, ms	438.42±2.71	452.65±2.69	0.001*
QTdis, ms	22.33±1.22	15.84±1.17	0.001*
QTp, ms	84.54±0.83	84.61±0.90	0.954
JTc, ms	328.92±4.27	333.39±2.29	0.348
JTdis, ms	22.35±1.22	15.92±1.18	0.001*
MTWA max, μV	24.62±4.15	141.2±62.10	0.124
MTWA mean, μV	7.98±0.50	52.03±28.38	0.202
TotQRSF, ms	92.62±1.73	100.04±2.36	0.010*
RMS40, μV	26.24±1.87	25.20±1.62	0.673
LAS40, μV	43.48±1.98	51.64±2.85	0.022*
PTotal, ms	112.12±2.98	121.73±2.12	0.067
RMS20, μV	3.72±0.07	3.30±0.12	0.005*

Note. *p<0.05 — statistically significant differences between groups.

Table 4. **Comparative characterization of key HRECG parameters in patients with and without CBBB**

Parameters	CHF without CBBB (M±m)	CHF + CBBB (M±m)	p
TO, %	0.57±0.70	0.81±0.82	0.869
TS, ms/RR	7.8±1.21	4.97±0.72	0.269
QTc, ms	439.38±2.03	463.25±3.98	0.001*
QTdis, ms	18.24±0.98	21.36±1.86	0.122
QTp, ms	84.34±0.71	85.21±1.22	0.530
JTc, ms	333.41±2.97	325.36±3.45	0.132
JTdis, ms	18.28±0.98	21.44±1.86	0.118
MTWA max, μV	101.77±51.04	72.73±17.62	0.728
MTWA mean, μV	42.31±23.37	12.70±6.12	0.435
TotQRSF, ms	89.72±1.27	115.44±3.45	0.001*
RMS40, μV	28.86±1.43	16.08±1.87	0.001*
LAS40, μV	41.08±1.47	67.44±4.63	0.001*
PTotal, ms	110.89±1.67	128.83±8.65	0.001*
RMS20, μV	3.68±0.07	3.38±0.14	0.062

Note. *p<0.05 — statistically significant differences between groups.

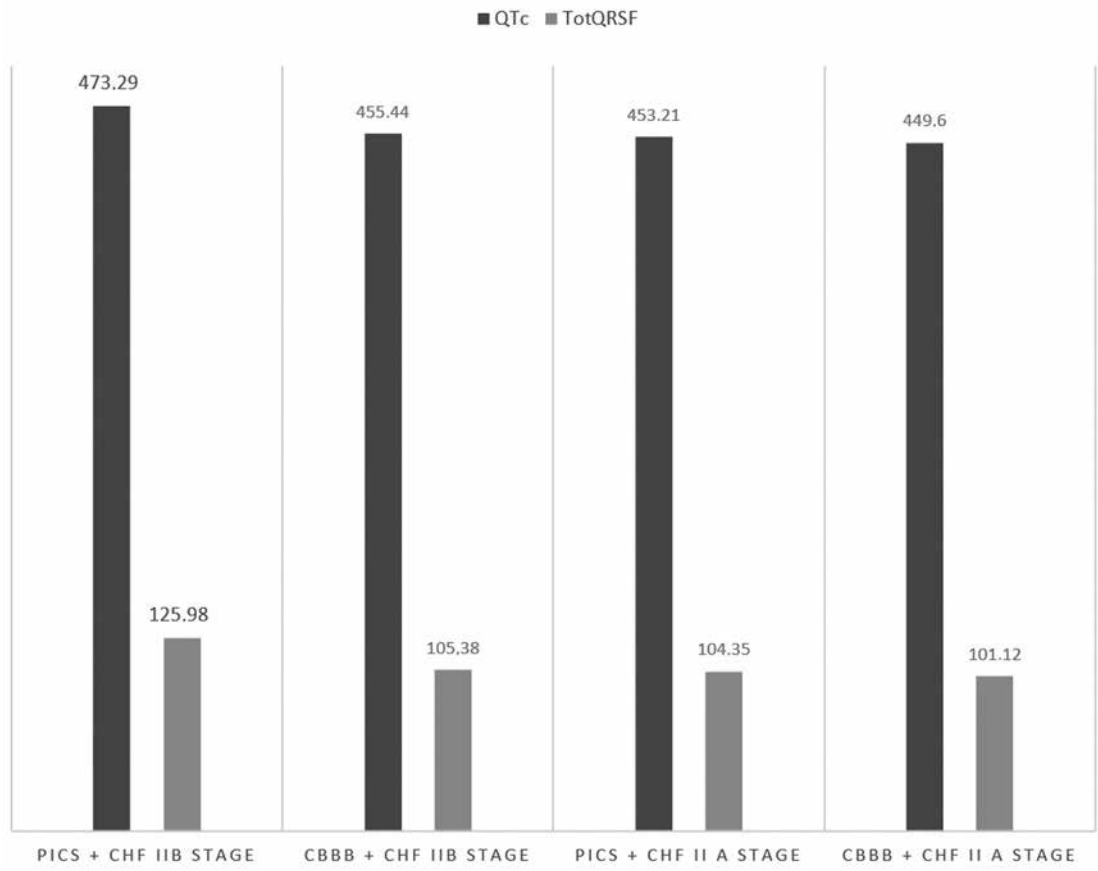

Fig. 1. Comparative characterization of QTc and TotQRSF in patients with CHF + PICS, CHF + CBBB

groups were statistically significantly different in the following parameters: TS (p=0.006), QTc (p=0.001), QTdis (p=0.001), JTdis (p=0.001), TotQRSF (p=0.010), LAS40 (p=0.022) and RMS20 (p=0.005). The highest values for TS, QTdis, JTdis and RMS20 were observed in the group of patients without AF (8.69±1.14%; 22.33±1.22 ms; 22.35±1.22 ms; 22.35±1.22 ms and 3.72±0.07 μV, respectively). The highest values of QTc, TotQRSF and LAS40 were recorded in the group of patients with AF (452.65±2.69 ms; 100.04±2.36 ms

Table 5. **Relationship between cardiac ultrasound parameters (EDD, ESD, IVST, LVPWT) and ventricular late potentials (TotQRSF, RMS40, LAS40)**

Parameters	B	R2	p
EDD and TotQRSF	12.1 (7.95; 16.25)	0.165	0.001*
EDD and RMS40	–6.92 (–10.54; –3.31)	0.079	0.001*
EDD and LAS40	9.93 (4.56;15.30)	0.074	0.001*
ESD and TotQRSF	13.73 (10.07;17.39)	0.248	0.001*
ESD and RMS40	–7.06 (–10.39; –3.73)	0.095	0.001*
ESD and LAS40	11.98 (7.14;16.83)	0.125	0.001*
IVST and TotQRSF	31.80 (11.16; 52.44)	0.053	0.003*
IVST and RMS40	0.94 (–16.64; 18.52)	0.001	0.916
IVST and LAS40	14.07 (–11.87; 40.00)	0.007	0.286
LVPWT and TotQRSF	33.13 (7.67; 58.59)	0.038	0.011*
LVPWT and RMS40	21.20 (–0.08; 42.48)	0.023	0.051
LVPWT and LAS40	2.46 (–29.39; 34.32)	0.001	0.879

Note. *p<0.05 — statistically significant differences between groups.

and 51.64±2.85 μV, respectively). Parameters such as $MTWA_{max}$, $MTWA_{mean}$, RMS40, PTotal, LAS40 showed no statistically significant differences between the groups.

The main characteristics of HRECG in CHF groups depending on the presence of CBBB were evaluated (Table 4). The parameters QTc (p=0.001), TotQRSF (p=0.001), LAS40 (p=0.001), and PTotal (p=0.001) showed statistically significant differences between CHF without CBBB and CHF with CBBB groups, with their highest values in the group of patients with CBBB (463.25±3.98 ms; 115.44±3.45 ms; 67.44±4.63 μV; 128.83±8.65 ms, respectively). The following parameters including TO, TS, QTdis, QTp, JTc, JTdis, $MTWA_{max}$, $MTWA_{mean}$, and RMS20 showed no statistically significant differences between groups.

Linear regression analysis was performed to identify the possible relationship of ventricular late potentials represented by the indices (TotQRSF, RMS40, LAS40) with cardiac ultrasound. The analysis showed that there was indeed a statistically significant relationship between different parameters of the ECG and the cardiac ultrasound. Specifically, the EDD and ESD showed a correlation with the following parameters: TotQRSF, RMS40, LAS40. IVST and LVPWT seemed to correlate with TotQRSF. However, IVST and LVPWT parameters did not show statistically significant relationship with LAS40, RMS40.

The highest values of QTc and TotQRSF were observed in patients with CHF stage IIB + PICS and CHF stage IIB + CBBB (Figure 1).

Tables 2, 3, 4, 5 summarize the results of HRECG.

Discussion

The HRECG method is becoming more and more widespread in clinical practice. The method itself and its individual parameters, which characterize the temporal and amplitude properties of the QRS complex and the P-wave, can be used to assess myocardial electrical instability and the processes of electrophysiological cardiac remodeling observed in patients with CHF and associated with poor long-term prognosis [7]. Thus, more pronounced values of QRS fragmentation (TotQRSF) are observed in deceased patients with chronic rheumatic heart disease, and the increase of this parameter increases the risk of death, as well as the deterioration of ventricular late potentials (TotQRSF, RMS40 and LAS40) at 10-year follow-up [9].

In our study, this parameter was statistically higher in the group of patients with PICS (103.25±2.97 ms), AF (100.04±2.36 ms), and CBBB (115.44±3.45 ms). Increased TotQRSF interval, shortened RMS40 interval in CHF + PICS patients (103.25±2.97 ms and 21.22±2.14 μV, respectively), CHF+CBBB patients (115.44±3.45 ms and 16.08±1.87 μV, respectively), and increased LAS40 in AF and CBBB groups (51, 64±2.85 μV and 67.44±4.63 μV, respectively) may indicate the presence of myocardial zones with inhomogeneous conduction, which represent an anatomic-physiological substrate for the development of arrhythmias.

In the linear regression analysis, TotQRSF, RMS40 and LAS40 correlated with cardiac ultrasound parameters such as EDD, ESD, IVST, LVPWT. This may indicate that these parameters may reflect structural changes in the myocardium. These results show the importance of assessing QRS fragmentation to identify a more "severe" cohort of CHF patients in order to optimize the treatment strategy and evaluate the prognosis of the disease. Thus, the addition of SGLT2 receptor inhibitors leads to a significant improvement in ventricular late potential indices after 6 months [10]. On the other hand, the use of antiarrhythmic drugs from the IC group can lead to a worsening of these parameters [10].

Changes in QT interval duration are associated with a number of cardiovascular diseases. At the same time, the prognostic significance of the parameters and their thresholds are not well understood. A

number of studies have found a reliable association between prolongation of the QT interval and the severity of myocardial damage [11].

In our study, an increased QTc interval was found in patients with CHF + PICS, patients with CHF + AF and patients with CHF + CBBB (452.52±3.55 ms; 452.65±2.69 ms; 463.25±3.98 ms, respectively). The highest values were found in patients with CHF stage IIB + PICS and CHF stage IIB + CBBB. The prolongation of the QT interval in patients with CHF + PICS, as well as in patients with CHF + CBBB, indicates the presence of myocardial electrical instability, which is unfavorable in terms of the development of life-threatening arrhythmias.

Thus, these results highlight not only the relationship of electrocardiographic parameters in the assessment of cardiac function, but also their potential application in clinical practice to improve the diagnosis and management of patients with cardiovascular diseases.

Conclusion

The HRECG method is becoming more and more widespread in clinical practice, allowing to assess myocardial electrical instability and processes of electrophysiological remodeling of the heart in patients with CHF. Our study demonstrated a worsening of the parameters such as TotQRSF, RMS40 and LAS40, reflecting electrical heterogeneity in the myocardium in more severe patients. This suggests the presence of fragmented myocardial electrical activity in elderly patients with CHF, which may be a substrate for the development of life-threatening complications. Changes in these parameters may correlate with anatomic and functional characteristics of the heart determined by ultrasound. These parameters, together with changes in QT interval duration, are associated with structural changes in the myocardium and may serve as indicators of myocardial electrical instability. Thus, this method is useful and promising for a comprehensive assessment of the cardiovascular system and clinical decision making in this group of patients.

Conflict of interests: none declared.

References

1. Malik A., Brito D., Vaqar S., et al. Congestive Heart Failure. In: StatPearls. Treasure Island (FL): StatPearls Publishing; 2023.
2. Lind L., Ingelsson M., Sundstrom J., et al. Impact of risk factors for major cardiovascular diseases: a comparison of life-time observational and Mendelian randomisation findings. Open Heart. 2021;8(2):e001735. DOI: 10.1136/openhrt-2021-001735
3. Virani S.S., Alonso A., Benjamin E.J., et al. Heart Disease and Stroke Statistics-2020 Update: A Report From the American Heart Association. Circulation. 2020;141(9):e139-e596. DOI: 10.1161/CIR.0000000000000757
4. Smirnova E.A., Sedykh E.V., Gorbova A.V., Zheronkina V.V., Kurtikova O.V. Assessment of the Clinical Profile and Approaches to the Diagnosis and Treatment of Patients Hospitalized with Acute Decompensation of Heart Failure; I.P. Pavlov Russian Medical Biological Herald. 2022;30(2):183–192. Russian. DOI: 10.17816/PAVLOVJ81552
5. Mamedov M.N., Mitchenko E.I., Serpitis P., et al. Updated european guidelines for the prevention of cardiovascular diseases. Analytic review. International Heart and Vascular Disease Journal. 2022;10(33):6–12. Russian. DOI: 10.24412/2311-1623-2022-33-6-12
6. Smirnova E.A., Sedykh E.V. Acute decompensation of heart failure: current issues of epidemiology, diagnostics, therapy. Science of the young (Eruditio Juvenium). 2021;9(2):289–300. Russian. DOI: 10.23888/HMJ202192289-300
7. Dumpis Ya.Yu., Weinstein A.B., Yashin S.M. Registration of late ventricular potentials using signal-averaged ECG: fundamentals of the method, existing practical recommendations, diagnostic value. Clinical arrhythmology. 2022;1:354. Russian.
8. Oslopov V.N., Kushcheva A.V., Khairullin A.R., et al. High-resolution electrocardiography in clinical practice. Bulletin of Modern Clinical Medicine. 2023;16(6):110–122. Russian. DOI: 10.20969/VSKM.2023.16(6).110–122
9. Petrov V.S. Ventricular late potentials in patients with rheumatic heart disease. International Heart and Vascular Disease Journal. 2021;9(29):4–10. Russian.
10. Razin V.A., Tsareva A.A. Empagliflozin in the treatment of patients with chronic heart failure, its effect on ventricular arrhythmias. Bulletin of SurGU. Medicine. 2023;16(2):59–62. Russian. DOI 10.35266/2304-9448-2023-2-59-62
11. Mominov A.A., Mominov A.T. Sudden Cardiac Death, Significance, Definition, Qt Intervals. Central Asian Journal of Medical and Natural Science. 2022;3(6):133–137. Russian.