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Factors associated with the increase in spatial and frontal QRS-T angles in patients with inferior myocardial infarction

Aim To identify clinical, echocardiographic, and angiographic factors related with an increase in the frontal QRS-T angle (fQRS-T) and the spatial QRS-T angle (sQRS-T) in patients with inferior myocardial infarction.

Material and methods The study included 128 patients aged (median [25th percentile; 75th percentile]) 59.5 [51.5; 67.0] years diagnosed with inferior wall acute myocardial infarction. fQRS-T was calculated as a module of difference between the QRS axis and the T axis in the frontal plane. sQRS-T was calculated by a synthesized vectorcardiogram as a spatial angle between the QRS and T integral vectors.

Results The fQRS-T for the group was 54.0 [18; 80] and sQRS-T was 80.1 [53; 110]. The correlation coefficient for fQRS-T and sQRS-T values was 0.42 (p<0.001). Both fQRS-T >80° and sQRS-T >110° compared to their lower values were associated with a higher frequency of history of post-infarction cardiosclerosis (44% and 12%, respectively; p<0.05), a lower left ventricular ejection fraction (51 [47; 60] % at fQRS-T >80° and 55 [50; 60] % at fQRS-T <80° (p<0,05); 49 [44; 57] % at sQRS-T >110° and 57 [51; 60] % at sQRS-T <110° (p<0.01); more frequent development of acute heart failure (16 and 2%, respectively; p<0.05); and early postinfarction angina (13 and 2%, respectively; p<0.05). The increased fQRS-T was associated with a higher incidence of damage to the circumflex artery (45 and 20%, respectively; p<0.05). The increased sQRS-T was associated with a history of arterial hypertension (97 and 76%, respectively; p<0.05), chronic heart failure (22 and 3%, respectively; p<0.05), chronic kidney disease (19 and 4%, respectively; p<0.05), and a larger myocardial lesion (mean number of damaged segments by echocardiography was 3.8 [2; 6] at sQRS-T >110° and 2.6 [1; 4] at sQRS-T <110°; p<0.01). sQRS-T was significantly greater in multivascular damage (87° [68; 121] than in one- or two-vascular damage (72° [51; 100]; p<0.05). sQRS-T values were significantly lower with spontaneous reperfusion (66 [29; 79] than without spontaneous reperfusion (77° [55; 115]; p<0.05).

Conclusion In patients after inferior wall acute myocardial infarction, increases in fQRS-T and sQRS-T were associated with more severe damage of coronary vasculature, decreased left ventricular ejection fraction, and more severe course of disease.

Keywords Frontal QRS-T angle; spatial QRS-T angle; myocardial infarction; synthesized vectorcardiogram

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Risk stratification is a critical element in treating patients with coronary artery disease, including acute coronary syndrome (ACS). In this regard, researchers have recently become more interested in electrocardiographic indicators, which characterize the relationship between the processes of ventricular depolarization and repolarization. The prognostic value of these indicators has been demonstrated multiple times in both the general population and groups of patients with different pathologies [1].

Twenty years ago, it was shown that larger spatial discrepancies between the vectors of ventricular depolarization and repolarization had an independent prognostic value for sudden cardiac death (SCD) in patients with a history of myocardial infarction (MI) [2, 3]. The spatial QRS-T angle (sQRS-T) was subsequently used to describe the relative positions of the ventricular depolarization and repolarization vectors. The prognostic and diagnostic capabilities of this indicator have been explored in many studies, although it is calculated using special software.

Lastly, the frontal QRS-T (fQRS-T) angle has recently been suggested. It is easily calculated as the difference between the QRS- and T-axes, which are automatically calculated using the most up-to-date electrocardiographs.

Several studies have shown that fQRS-T can be used as a diagnostic criterion when MI is suspected. This is an independent prognostic criterion for early and long-term cardiac and overall mortality in patients with acute ST-elevation myocardial infarction (STEMI) and non-ST-elevation myocardial infarction (NSTEMI), and has so far has aroused interest in fQRS-T and sQRS-T [4 to 8].

In the fatal outcome group, patients with acute MI who underwent primary percutaneous coronary intervention (PCI) or thrombolytic therapy had significantly higher values of fQRS-T in both the first electrocardiogram (ECG) at the time of hospitalization, and the ECG after PCI or 90 minutes after the beginning of thrombolytic therapy. Moreover, fQRS-T in the ECG 90 minutes after the beginning of thrombolytic therapy was significantly lower in patients with effective thrombolysis than those with failed thrombolysis. This allows fQRS-T to be considered as a possible criterion for myocardial reperfusion. Multivariate analysis showed that fQRS-T ≥90° in the ECG following PCI or 90 minutes after the beginning of thrombolytic therapy was an independent predictor of in-hospital death [4].

In patients with STEMI who underwent PCI or coronary artery bypass grafting (CABG), fQRS-T was an independent predictor of death within 12 months and was also associated with longer hospital stays [5].

In the prospective study, fQRS-T was registered by ECG in 2,705 patients with suspected STEMI upon hospital admission. There were significantly more patients with confirmed STEMI than those with ruled-out STEMI ($p<0.001$). The combined use of standard electrocardiographic criteria of ischemia and fQRS-T increased ECG sensitivity for the diagnosis of STEMI from 45% to 78% and specificity from 86% to 91% ($p<0.001$ for both comparisons). fQRS-T also was shown to be an independent predictor of all-cause death within 2 years of follow-up [6].

In patients with a history of MI and left ventricular ejection fraction (LVEF) ≤40%, fQRS-T was an independent predictor of overall and cardiovascular mortality. The independent prognostic value of fQRS-T remained after bundle branch blocks, STEMI, and its locations were taken into account [7].

The findings of two multicenter prospective observational studies in patients with ACS were used to develop and evaluate a 30-day and 2-year mortality risk stratification score – Frontal QRS-T Angle and Age Risk (FAAR) score. An increase in the FAAR score was associated with an increase in 30 day and 2-year mortality (for 2-year mortality: 0–3.7%, 4–57%, $p<0.001$). The high prognostic value of the score was the same in the validation cohort, in the male and female groups, in STEMI and NSTEMI, and exceeded the GRACE score [8].

It should be noted that the increase in both fQRS-T and sQRS-T is associated with the increased risk of adverse outcomes in patients with MI and the increased risk of developing MI.

Among the 9,498 subjects of the ARIC prospective study who had no baseline cardiovascular diseases, when other risk factors were taken into account, the pathological (>95th percentile) values of both fQRS-T and sQRS-T were associated with more than a two-fold risk of MI within a 10-year follow-up period [9]. In the 2-year follow-up period, fQRS-T >90° was an independent predictor of developing MI in patients with diabetes mellitus (DM) [10].

The factors which affect fQRS-T in patients with MI have not been adequately studied. When assessing the effects of the myocardial perfusion defect, (assessed by single-photon emission computed tomography) on fQRS-T in 71 patients with a history of anterior wall MI and 71 controls without myocardial perfusion defects, this indicator was significantly higher in patients with MI (82±49°) than in controls (30±26°; $p<0.001$). Multivariate analysis showed that age and the presence of myocardial perfusion defect were independent determinants of fQRS-T [11].

However, in a similar study of 42 patients with inferior MI, fQRS-T was much lower (27±22°) and did not differ statistically significantly from that in the control group. Patients with inferior MI had no correlations between fQRS-T and myocardial perfusion defect, according to SPECT [12].

In 1,000 patients with history of MI (82% male, mean age 59±10 years), fQRS-T was negatively correlated with LVEF ($r=-0{,}4$; $p<0.01$), and this correlation was stronger with LVEF <50% ($r=-0.5$; $p<0.01$). It was virtually absent with LVEF >50%. fQRS-T >90° allowed a decrease in LVEF to be detected with a 76% sensitivity and 74% specificity [13].

In 340 patients with STEMI, fQRS-T predicted coronary atherosclerotic load, since both pre- and post-PCI values were significantly higher in the middle and high SYNTAX-score group [14]. However, it should be noted that in this study, the average and high SYNTAX score group also differed from the group with low scores in terms of age, infarct-related artery (IRA), LVEF, and hemoglobin levels. Thus, the contribution of all these factors on increased fQRS-T, in addition to coronary artery disease severity, was not clear.

In 269 patients with STEMI, fQRS-T SYNTAX ≥23 also predicted the severity of atherosclerotic coronary artery disease with 77% sensitivity and 63% specificity, being an independent predictor of the SYNTAX score in the multivariate analysis [15].

Objective

To determine clinical, echocardiographic, and coronarographic factors associated with increased sQRS-T and fQRS-T in patients with inferior MI.

Material and methods

Medical records of patients treated in A. L. Myasnikov Institute of Clinical Cardiology, and diagnosed with acute inferior MI in 2016–2017, were selected from the Interin medical information system. The study included patients who underwent a 12-lead digital ECG and had echocardiogram and coronary angiography (CA) data stored in the Interin system. The study did not include patients with paced ventricular rhythm and left bundle branch block. The study included 128 patients: 97 (76%) males and 31 (24%) females, age 59.5 [51.5; 67.0] years.

Electrocardiogram

Digital 12-lead ECGs were recorded on an Easy ECG computer electrocardiograph prior to hospital discharge, i.e., on day 8 [6; 10] from the onset of MI, and processed using Easy ECG software (ATES MEDICA, Russia). fQRS-T was calculated as an absolute difference between the QRS- and T-axes (frontal plane). When the difference was more than 180°, the angle value was reduced to the minimum by subtracting from 360°. sQRS-T was calculated using a synthesized vectorcardiogram as a spatial angle between the QRS and T integral vectors.

Echocardiogram

Transthoracic Echo was performed on a Vivid 9 (GE, USA) ultrasound device following the recommendations for cardiac chamber quantification in adults [16]. The B-mode biplane method of disks (modified Simpson's rule) was used to measure left ventricular (LV) volumes. In order to assess the local myocardial contractility disorders, a 16-segment LV model was used.

Coronary angiography:

CA was performed on an Allura Xper FD 10 angiographic complex (Philips, Netherlands) via radial access. A more than 70% narrowing of the main epicardial artery or primary branches was considered hemodynamically significant stenosis.

Statistical analysis

The statistical analysis of data was performed using MedCalc version 12.7.8. Continuous variables are represented as the median and interquartile range [25th percentile; 75th percentile], and qualitative variables as the absolute number and percentage (%). The Mann – Whitney test was used to estimate the differences between two independent quantitative variables, and the chi-square method was used for qualitative variables. The Spearman rank correlation coefficient was applied to determine the relationship between variables. The differences were considered statistically significant at $p<0.05$.

Results

The correlation coefficient between fQRS-T and sQRS-T was 0.35 ($p<0.0001$). The within-group mean fQRS-T was 40° [18; 80]. There were weak but significant correlations between fQRS-T and patient's age ($r=0.19$; $p=0.03$), heart rate ($r=0.20$; $p=0.025$), and LVEF ($r=-0.23$; $p=0.009$).

The within-group median age was 76 [53; 110] years. There were weak but significant correlations between sQRS-T and a patient's age ($r=0.22$; $p=0.01$), time from the onset of symptoms to hospital admission ($r=0.23$; $p=0.01$), LVEF ($r=-0.25$; $p=0.004$), and the number of involved segments detected by echocardiogram ($r=0.20$; $p=0.02$).

Clinical characteristics, echocardiogram and CA findings in patients with fQRS-T and sQRS-T in the upper quartile versus three lower quartiles, and the significance of the corresponding differences are shown in Tables 1, 2, 3.

In multiple vessel coronary artery disease, sQRS-T was significantly higher (87° [68; 121]) than in single and two-vessel disease (72° [51; 100]; $p=0.018$). In spontaneous reperfusion, sQRS-T was significantly lower (66° [29; 79]) than without spontaneous reperfusion (77° [55; 115]; $p=0.04$).

The following case studies demonstrate that such indicators as sQRS-T and fQRS-T can reflect the severity of myocardial and coronary bed damage more clearly than standard ECG.

Case study #1

Patient with high fQRS-T and sQRS-T.

Figure 1 represents an ECG of a 77-year-old patient recorded on day 10 of acute MI Diagnosis: Coronary artery disease. Inferior posterior MI dated 13.03.16. Alveolar pulmonary edema dated 13.03.16. Primary PCI: angioplasty with stenting of the anterior descending artery and the left circumflex artery dated 13.03.16. Subtotal ostial stenosis of the right coronary artery. Arterial hypertension, grade 3, risk 4. Diabetes mellitus, type 2

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Table 1. Clinical characteristics of patients with different fQRS-T and sQRS-T

Indicator	fQRS-T>80° (n=32)	fQRS-T<80° (n=96)	p	sQRS-T>110° (n=32)	sQRS-T<110° (n=96)	p
Female	11 (34%)	20 (21%)	0.21	13 (41%)	18 (19%)	0.02
Age, years	66 [52; 69]	58 [51; 63]	0.03	62 [54; 69]	58 [51; 66]	0.05
BMI, kg/m^2	30 [27; 33]	28 [26; 32]	0.11	30 [26; 33]	28 [26; 32]	0.75
AH	26 (81%)	78 (81%)	0.79	31 (97%)	73 (76%)	0.02
CHF	4 (13%)	6 (6%)	0.37	7 (22%)	3 (3%)	0.003
DM	10 (31%)	24 (25%)	0.66	11 (34%)	23 (24%)	0.38
PICS	14 (44%)	12 (12%)	<0.005	14 (44%)	12 (12%)	<0.005
CKD	5 (16%)	5 (5%)	0.10	6 (19%)	4 (4%)	0.02
Time to hospitalization, hours	4 [2; 9]	2.5 [2; 6]	0.11	3.6 [2; 9]	3.0 [2; 6]	0.09
Pulmonary edema	5 (16%)	2 (2%)	0.01	5 (16%)	2 (2%)	0.01
Early post-infarction angina	4 (13%)	2 (2%)	0.04	4 (13%)	2 (2%)	0.04

BMI, body mass index; AH, arterial hypertension; CHF, chronic heart failure;
DM, diabetes mellitus; PICS, post-infarction cardiosclerosis; CKD, chronic kidney disease.

Table 2. Echocardiogram findings in patients with different fQRS-T and sQRS-T

Indicator	fQRS-T >80° (n=32)	fQRS-T<80° (n=96)	p	sQRS-T>110° (n=32)	sQRS-T<110° (n=96)	p
LVEDD, cm	5.25 [4.9; 5.6]	5.15 [4.8; 5.5]	0.59	5.35 [4.8; 5.8]	5.10 [4.8; 5.4]	0.15
IVST, cm	1.05 [1.0; 1.18]	1.1 [1.0; 1.1]	1.0	1.05 [1.0; 1.2]	1.1 [1.0; 1.1]	0.22
LVPWT, cm	1.05 [0.9; 1.1]	1.0 [1.0; 1.1]	0.96	1.1 [1.0; 1.1]	1.0 [1.0; 1.1]	0.17
LVEF, %	51 [47; 60]	55 [50; 60]	0.048	49 [44; 57]	57 [51; 60]	0.001
Number of LV segments involved, including PICS	2.5 [2; 5]	2.0 [1; 4]	0.16	4.0 [2; 6]	2.0 [1; 4]	0.04
Involvement of the lateral LV wall	11 (34%)	11 (11%)	0.006	9 (28%)	13 (13%)	0.09
Involvement of RV	1 (3%)	11 (12%)	0.25	3 (9%)	9 (9%)	0.72

LVEDD, left ventricular end-diastolic dimension; IVST, interventricular septal thickness; LVPWT, left ventricular posterior wall thickness; LVEF, left ventricular ejection fraction; PICS, post-infarction cardiosclerosis; RV, right ventricle.

Table 3. Coronary angiography findings in patients with different fQRS-T and sQRS-T

Indicator		fQRS-T >80° (n=29)	fQRS-T <80° (n=96)	p	sQRS-T >110° (n=30)	sQRS-T <110° (n=95)	p
IRA	RCA	15 (52%)	74 (77%)	0.02	18 (60%)	71 (75%)	0.18
	LCX	13 (45%)	19 (20%)	0.02	11 (37%)	21 (22%)	0.17
	Other vessels	1 (3%)	3 (3%)	0.54	1 (3%)	3 (3%)	0.54
Spontaneous reperfusion		2 (7%)	7 (7%)	0.68	0	9 (9%)	0.19
Number of vessels involved	1	12 (41%)	37 (39%)	0.98	12 (40%)	37 (39%)	0.91
	2	8 (28%)	30 (31%)	0.94	6 (20%)	32 (34%)	0.22
	>2	9 (31%)	29 (30%)	0.90	12 (40%)	26 (27%)	0.26

IRA, infarct-related artery; RCA, right coronary artery; LCX, left circumflex artery.

CA: 70% proximal stenosis of LAD, several to 95–99% medium stenoses. 60% proximal stenosis of the diagonal branch followed by subtotal stenosis. Left circumflex artery (LCX): 40% ostial stenosis, medium occlusion, post-occlusion segment is fed by internal collateral vessels. Subtotal ostial stenosis of the obtuse marginal (OM) artery. RCA: subtotal ostial stenosis.

Echocardiogram: LV dilation (LV end-diastolic dimension 5.8 cm), hypokinesis of the basal and medium segments of the inferior, posterior LV wall, medium segment of the lateral wall of LV. Reduced global contractility of LV (LVEF 36%). LV hypertrophy LV diastolic dysfunction type 2. Signs of pulmonary hypertension.

Case study #2

Patient with relatively low fQRS-T and sQRS-T.

Figure 2 represents an ECG of an 83-year-old patient recorded on day 7 of acute MI Diagnosis: CAD, inferior STEMI dated 16.05.17. Angioplasty with RCA stenting

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dated 16.05.17. Arterial hypertension, grade 3, risk 4. Nephrolithiasis. Chronic kidney disease, stage 4.

CA: 70% ostial stenosis of LAD, several 30–40% medium stenoses. 70% ostial stenosis and 40% medium stenosis of LCX. RCA: medium occlusion (thrombosis).

Echocardiogram: cardiac chambers are not dilated, walls are not thickened. Myocardial hypokinesis in the basal, medium segments of the inferoposterior LV wall. Adequate global contractility of LV (LVEF 60%).

Case study #3

Patient with high fQRS-T and sQRS-T.

Figure 3 represents an ECG of a 50-year-old patient recorded on day 10 of acute MI Diagnosis: CAD, acute inferoposterior, lateral MI dated 06.02.16. State after angioplasty with RCA stenting dated 06.02.16. Angioplasty with LAD stenting; angioplasty of OM, LCX dated 11.04.11. Arterial hypertension, grade 3, risk 4.

More than 6-year history of arterial hypertension (AH), with a maximum increase in blood pressure (BP) up to 180/100 mmHg. In January 2011, the patient began to experience a pressing pain in the left half of the chest irradiating to the left arm when exerting a little physical activity. In March 2011, he was examined and treated with a diagnosis of acute non-Q wave MI. One month before the current hospitalization, exercise tolerance decreased sharply. The patient experienced anginal pain when exerting a little physical activity.

In the morning on 06.02.16, he felt pressing pain in the left half of his chest with irradiation behind his sternum and into his left arm. The patient was delivered to the intensive care unit with the diagnosis of acute inferior MI 3 hours after onset of the pain.

Figure 2. ECG of an 83-year-old female patient on day 7 of acute MI. fQRS-T 75°, sQRS-T 56°

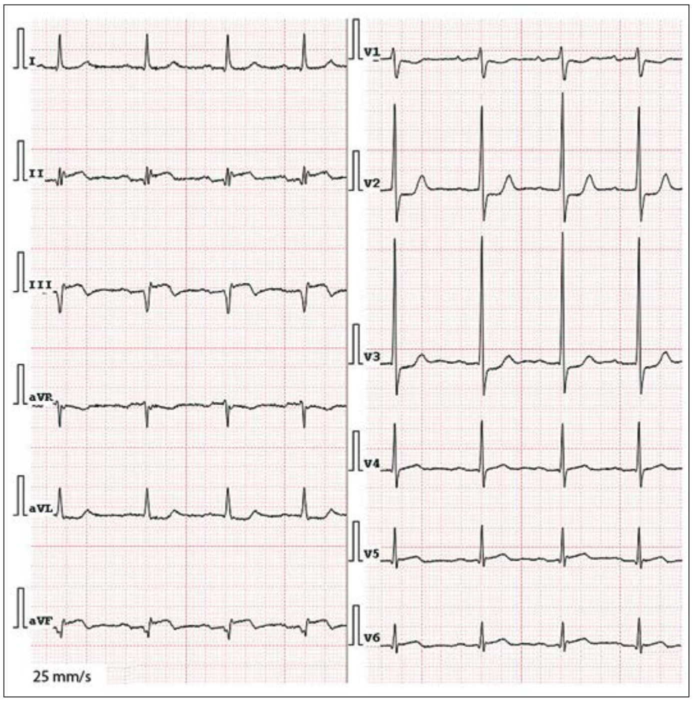
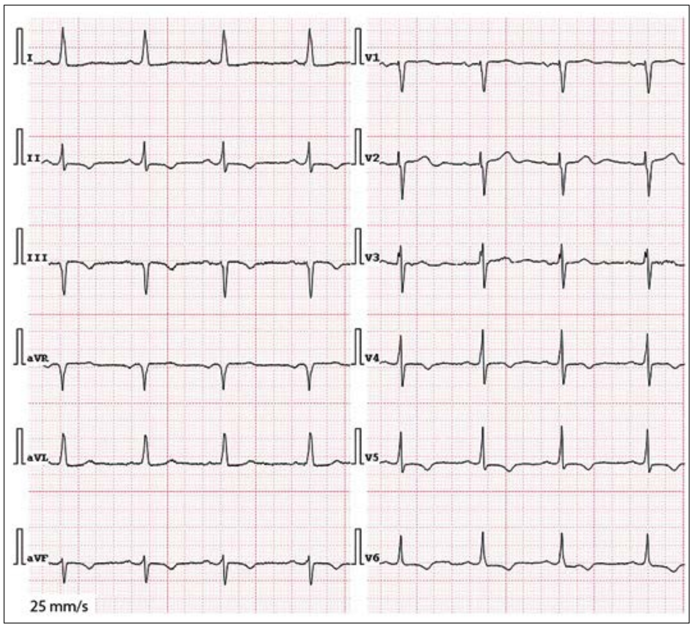


Figure 1. ECG of a 77 year-old female patient on day 10 of acute MI. fQRS-T 106°, sQRS-T 146°



CA: 50% proximal stenosis of LAD, a previously installed stent at the proximal and medium segment boundary without signs of hemodynamically significant restenosis. LCS: continuous 80% medium stenosis. 50% proximal stenosis of OM, several up to 70–80% medium stenoses. RCA: subtotal distal stenosis.

Echocardiogram: interventricular septal thickness 1.3 cm; LV posterior wall thickness 1.1 cm; LV is dilated; anteroseptal hypokinesis.

Stress echocardiogram: positive test for latent coronary insufficiency. The initial echocardiogram showed a zone of anteroseptal, anterior hypokinesis (apical, medium segments), and a zone of hypokinesis of the LV posterolateral wall (basal, medium segments). At maximum exercise, the initial disturbance of the local LV anterior contractility became aggravated and extended (to the LV anterolateral wall). Average exercise tolerance.

Case study #4

Patient with low fQRS-T and sQRS-T. Figure 4 represents an ECG of a 52-year-old patient recorded on day 10 of acute MI Diagnosis: CAD. Acute inferior MI dated 04.02.17. Angioplasty with RCA stenting dated 02.02.17. Arterial hypertension, grade 2, risk 4.

On 04.02.17, the patient experienced intense pressing pain behind the sternum for the first time. He called for an ambulance and was delivered to the intensive care unit with the diagnosis of acute inferior MI 2 hours later.

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Figure 3. ECG of a 50-year-old male patient on day 10 of acute MI. fQRS-T 149°, sQRS-T 134°

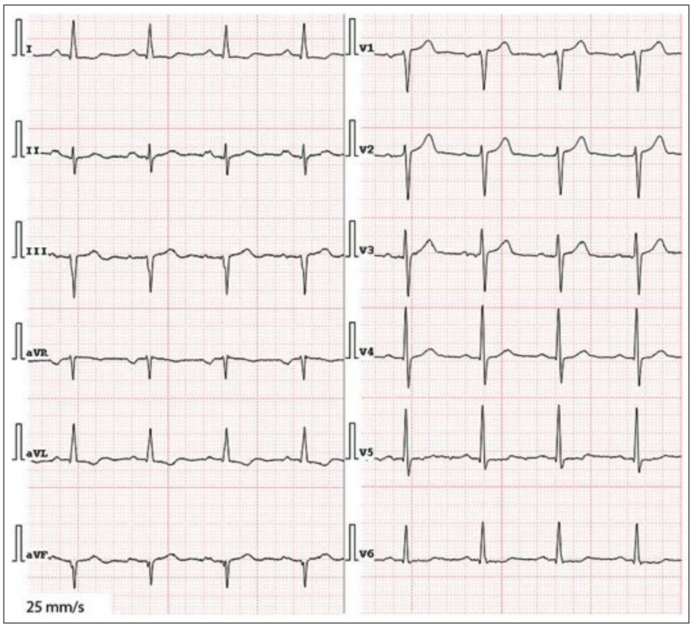
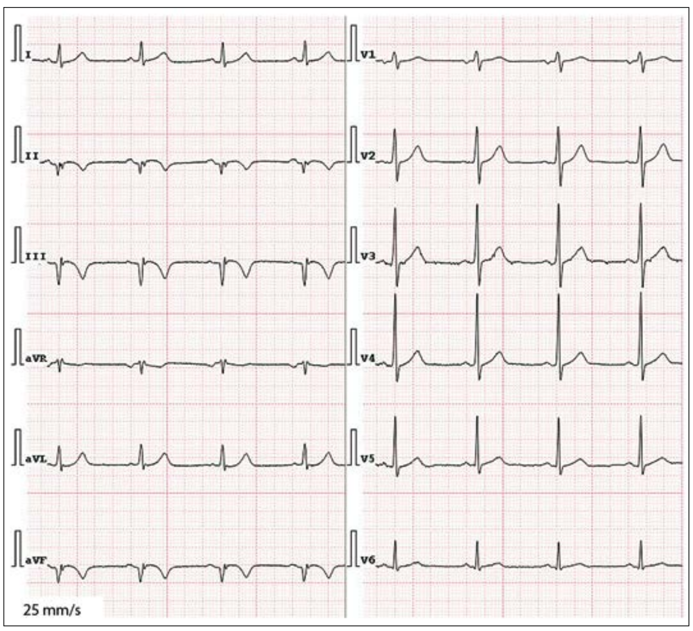


Figure 4. ECG of a 52-year-old male patient on day 10 of acute MI. fQRS-T 11°, sQRS-T 10°



CA: Proximal occlusion of RCA, the post-occlusion segment is fed by internal collateral arteries.

Echocardiogram: cardiac chambers are not dilated, walls are not thickened. Small hypokinesis of inferoposterior wall of LV. LVEF 60%.

Discussion

The QRS-T spatial angle is determined between the main ventricular depolarization and repolarization vectors. In healthy individuals, QRS and T are oriented in the same direction, and both the spatial and frontal QRS-T angles are small.

When a pathology develops, multiple small ventricular repolarization irregularities appear. This leads to the extension of both spatial and frontal QRS-T angles. A wider frontal QRS-T angle was shown to be a marker of ventricular arrhythmia risk [7].

In patients with a history of MI, fQRS-T is also predictive of all-cause death. Some authors suggest that patients with increased fQRS-T may have limited compensatory capabilities of the cardiovascular system in the development of other pathologies, such as infectious diseases and cancer [7].

In our group of patients with acute inferior MI, both increased fQRS-T and sQRS-T were associated with a more severe course of illness – history of postinfarction cardiosclerosis, more extensive myocardial involvement, and, as a consequence, lower LVEF, heart failure, and early postinfarction angina.

According to other authors, patients with ACS or MI with increased fQRS-T, compared to smaller fQRS-T, were older [5–8], had a more frequent history of MI [5, 6, 8], heart failure [5, 7, 8], and decreased LVEF [4, 7]. A more frequent presence of multiple vessel coronary artery disease [5] and left coronary artery involvement [7] was observed. Moreover, patients with increased fQRS-T had NSTEMI more often than STEMI [7, 8].

In our group, fQRS-T and sQRS-T were correlated significantly yet not very strongly, i.e., these indicators overlapped only partially, as seen in our tables of study results.

Increased fQRS-T, rather than sQRS-T, was associated with the more frequent involvement of the left circumflex artery (LCX) and, thus, more frequent MI extension to the LV lateral wall. Patients with increased fQRS-T were older than those without increased fQRS-T.

However, increased sQRS-T, compared to the increased fQRS-T, was more consistently associated with the degree of myocardial damage: more segments involved; and the presence of chronic heart failure. Increased sQRS-T, rather than fQRS-T, was associated with a history of AH, chronic kidney disease.

The mechanisms of increasing fQRS-T and sQRS-T are not yet well known. In patients with AH, the wider spatial separation of QRS and ST-T vectors (so-called tension syndrome) is associated with increased LV mass, effects of the autonomic nervous system, shifts in the electrolyte and acid-base balance, and the processes of electric myocardial remodeling, as manifest in changes in ion channels and intercellular interactions [17]. Moreover, it has been shown that patients with AH and ST-T changes, when compared to those without such changes and healthy individuals with comparable LVEF, had significantly reduced longitudinal deformation, endomyocardial radial deformation, and early systolic clockwise rotation [18, 19]. The mechanisms of changes in sQRS-T and fQRS-T in patients with MI are not yet known.

It should be noted that, according to the literature, there are no generally accepted normal thresholds for sQRS-T or fQRS-T. Statistical methods were used in several studies to select fQRS-T thresholds. This enabled prediction of the presence of low LVEF [13], high SYNTAX scores [14, 15], all-cause death [7], and in-hospital death [4] with the greatest accuracy. In these studies, the optimal fQRS-T thresholds ranged from 73.5° to 91°. In several studies, the upper tertiles of this indicator were used as the fQRS-T threshold: 42° in patients with suspected STEMI [6] and 104° patients with ACS [8]. In the population study [9], values higher than the 95th percentile (114° for sQRS-T and 63° for fQRS-T) were considered pathological, and values higher than the 75th percentile (83° for sQRS-T and 31° for fQRS-T) were considered borderline.

When selecting thresholds in our work, we tried to strike a balance between two requirements:

1) the fQRS-T and sQRS-T values are large enough to identify an association with adverse factors;
2) the sizes of groups are sufficient for statistical analysis.

The association of these indicators with the severity of coronary artery lesions might be more pronounced at lower thresholds. The association with myocardial contractility disturbances might be more pronounced at higher thresholds. This requires further research in larger groups.

Conclusion

Electrocardiographic indicators characterizing the relationship between the processes of ventricular depolarization and repolarization have been the focus of much attention in recent years among foreign researchers.

However, this issue remains insufficiently addressed in Russian literature. Our study is an attempt to draw the attention of the Russian cardiologists to this topic.

In our study, we highlighted inferior myocardial infarction since its electrocardiographic diagnosis often remains a challenge [20]. In the analysis group, increased fQRS-T and sQRS-T was associated with more severe coronary artery disease, decreased left ventricular ejection fraction, and, thus, the more severe clinical course of myocardial infarction. The above case studies show that conventional ECG cannot fully represent the picture of the severity of myocardial damage in these patients.

There are still many unresolved issues regarding the use of fQRS-T and sQRS-T in patients with myocardial infarction. The optimal thresholds of these indicators are not yet known. Their changes in patients with acute myocardial infarction have not been studied.

Thus, it is not clear how soon after the onset of myocardial infarction they should be estimated. Moreover, it is unclear what treatment aspects should be most addressed in patients with increased fQRS-T and sQRS-T, in order to improve their prognosis. The introduction of sQRS-T in practice is still challenging since special software is required to calculate it. However, it may provide more complete information than fQRS-T. All of these questions require further investigation.

No conflict of interest is reported.

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