ELECTRONICS AND ELECTRICAL ENGINEERING
ISSN 1392-1215 2006. Nr. 3(67)
ELEKTRONIKA IR ELEKTROTECHNIKA

MEDICINE TECHNOLOGY
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MEDICINOS TECHNOLOGIJA

Complex Informative ECG Parameters for Suspicion Coronary Artery Lesions

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Introduction

Despite the rise and spread of new diagnostic methods in cardiology the electrocardiogram (ECG) still is the main diagnostic tool which is non-invasive, easily performed and cheap. Because the ECG is so widely used it is believed that a better understanding of its results and being able to analyze them better would be beneficial for detecting ischemic heart disease (IHD) at its early stages. Recognition of coronary artery stenosis from resting ECG in case of non acute ischemia is limited. However further new characteristics and their combinations are developing in computer analysis of rest ECG. In this paper we present ECG analysis data (QT, JT, T morphology) and our attempts to find the best complex of ECG parameters for coronary artery stenosis prediction.

Methods

Patients: 199 patients with stable and unstable angina pectoris were investigated (140 men and 59 women). Coronary angiography was performed for all the patients for evaluating coronary artery stenosis. Age, gender, diagnosis of stable and unstable angina, ischemic ECG changes (negative T waves, ST segment changes), hypertension were evaluated. It was considered that stenosis of coronary artery lumen $\geq$ 50 % is haemodynamically significant, stenosis of coronary artery lumen $\leq$ 30% - haemodynamically non significant. The patients with arrhythmias, bundle branch blocks were excluded from the research. Myocardial mass index (MMI), left ventricular systolic function were evaluated from echocardiography; left ventricular hypertrophy was diagnosed if MMI $\geq$116 gr/m² in men and MMI $\geq$104 gr/m² in women.

The patients were divided into two main groups according to coronary artery stenosis degree: 1st group (stenosis of coronary artery lumen $\leq$ 30%) and 2nd group (stenosis of coronary artery lumen $\geq$ 50 %). The second group according to the numbers of stenotic vessels was divided into three subgroups: 2a – one vessel disease, 2b – two vessel disease and 2c – three vessel disease.

An additional study population for QT dispersion evaluation (Kantonsspital St.Gallen) consisted of 94 unselected patients consecutively referred for coronary angiography due to chest pain, dyspnea or abnormal exercise test. A luminal narrowing $\geq$ 50% of the crosssection of coronary arteries was considered as hemodynamically significant, < 50% - as hemodinamically unsignificant.

Heart rate variability: heart rate variability (HRV) analysis was performed after adaptation period of 10–15 min in lying down position. The HRV analysis software was created by the workers of Institute of Cardiology of Kaunas University of Medicine. Following parameters of HRV were estimated: standard deviation of RR interval (SDNN), mean duration of RR interval (RRNN), coefficient of variation. Spectrum of HRV was divided into three frequencies: VLF – very low frequency component (from 0,003 to 0,04 Hz); LF – low frequency component (from 0,04 to 0,15 Hz) and HF – high frequency component (from 0,15 to 0,4 Hz). Total power (TP) and value of LF into TP in absolute values were evaluated. HRV characteristics were assessed from rhythmograms, which were analysed using computer system.

QT interval: variables were measured automatically employing appropriate computer software. 12 lead rest ECG were recorded into a computer simultaneously. Noises from electrical network, muscles and breathing waves were eliminated by using low and high frequencies filters, isoelectric line was restored. 12 lead ECG after dividing into 10 s intervals was averaged every 60 s and 10s. QT and JT intervals were measured from standard (I, II, III, AVR, AVL, AVF) leads and from thoracic (V1-6) leads. QT dispersion (QTd) and JT dispersion (JTd) were calculated as follows: from the longest QT or JT interval subtracted the shortest QT or JT intervals. Rate corrected QT interval (QTc) and rate corrected JT interval (JTc) were calculated using Bazett formula.

In additional study population QT intervals were prospectively assessed from ECG recordings (12 leads, paper speed 100 mm/s), the QT interval for each lead was assessed by two experienced cardiologists unaware of the results of coronary angiography. QT duration was measured from the beginning of the QRS complex to the visual return of the T wave to the baseline. When a T wave was interrupted by a U wave, the end of the T wave was defined as the nadir between the T and the U waves. Whenever such distinction was not possible, the lead was discharged from the analysis. QTd was calculated as the difference between the maximum and the minimum QT intervals in any of the 12 leads and corrected QT dispersion (QTcd) as the difference between the maximum and the minimum QTc intervals according to Bazett`s formula.

T loop morphology: parameters were assessed from vectorcardiography X, Y, Z orthogonal Frank leads, using Dower matrix. Noises were diminishing using 21 point triangle (10 s) scrolling window filter. Vectorcardiographic T loop was projected onto plane. Further the loop on the plane was inscribed into square. The square was divided into 400 pieces. Three parameters of T loop morphology were evaluated as follows: T loop area, T loop index (proportion of T loop area and T loop length) and the angle (αQRS-T) between QRS and T vectors in frontal plane (from I and III leads).

Computer ECG analysis method for the prediction of coronary artery stenosis is based on singular value decomposition (SVD), which first components are derived from synthesized X, Y, Z leads [1]. Three ECG bases were used to find the most accurate classification for the patients without previous MI. 1st base contained 240 patients with angina pectoris (240 patients), 2nd base (1st base+ECGs of healthy people=270 ECGs) and 3rd base (2nd base+ECGs of patients with acute MI=460 ECGs) SVD was used for all 460 12 lead ECG. According to dipol model of electric heart activity, electrical potential registered in any lead, can be expressed as three-dimensional electrical vector (X, Y, Z) project onto appropriate lead. 5 min ECG was averaged inside of one RR interval that way noises were minimized and calculations were disencumbered. Then the averaged ECG was divided into three phases, which tally with P, QRS waves and ST segment. Hereby orthogonal systems of coordinates have been found, that way biases of approximation of registered ECG signal were diminishing by synthesized orthogonal leads. Every three ECG phases were equalized by length to estimate shapes of ECG waves and to obtain standardized length of base vector components. Classification of ECG was performed using the nearest neighbour method. The information of 5 nearest neighbours was used.

Digital ECG was recorded for all patients (discretisation parameters 12 bit, 2 kHz, recording interval of 10 s, 12 standard leads). Later these ECGs were processed by computer software, created by the workers of Institute of Cardiology of Kaunas University of medicine Eight leads of ECGs were recorded using computer analysis system − I, II, V1−V6, and another four leads − III, aVR, aVL ir aVF are reconstituted from I and II leads. ECGs were filtered by means of high and low frequencies filters, eliminating drift of isoelectric line. At the next stage the recognition of P, Q, R, S, T waves were produced, durations and amplitudes of the waves were measured, then these parameters were averaged during 10 s interval recordings. αQRS, αP, αT and αQRS-T angles describing projections of vectors in the frontal plane were determined from I and III leads, they were calculated by the formula:

$$y_i = arctg\left(1{,}15\frac{\Delta y_i^{III}}{\Delta y_i^{I}} + 0{,}575\right), \qquad (1)$$

Where Δy_i^{III} − is the sum of QRS, P and T wave amplitudes from III lead, Δy_i^{I} − from I lead. 1,15 ir 0,575 coefficients are presented in this formula because lead I and III are not perpendicular to each other. Measurements of angles in cardiology are not conventional, they are measured not in the 0…360° interval, but 0…+180° ir 0…-180° intervals, tgα value is negative in I and II quadrants and positive − in II and IV quadrants, therefore it was necessary to apply reduction formulae of these angles.

Statistical analysis: was performed using SPSS 9,0 and STATISTICA 5,0 for Windows. Mean values of the variables and mean standard deviation were calculated. Mean values were compared using Student t-test. Categorical values were compared using χ2 test. Rank correlation was evaluated by Spearman coefficient. The difference was significant if p<0,05, tendency – if 0,05<p<0,15. Logistic regression model was used to predict coronary artery stenosis ≥ 50 %, applying the formula: $p(x) = e^g / \left(1 + e^g\right)$, $g(x)=\beta_0+\beta_1 x_1+\beta_2 x_2+...+ \beta_k x_k$,o $\beta_0, \beta_1, \beta_2,...,\beta_k$ – the parameters of logistic model.

Results

The clinical, coronary angiographic, echocardiography data were analysed. These parameters were evaluated for first (stenosis of coronary artery lumen ≤ 30%) and for the second (stenosis of coronary artery lumen ≥ 50 %) patient groups.

Clinical electrocardiographic, echocardiographic and coronary angiography data are presented in Table 1.

The 1st and the 2nd groups differed significantly only in age, the 2nd group patients were significantly older (60,8±9,5 and 56,4±10,2 p=0,003), there were more men (p=0,054) and more cases of unstable angina (p=0,054). Comparing QT interval variables between the 1st and 2nd groups, significant differences were not determined. Several tendencies were determined: the values of QTd, QTdp, JTdp, QTc max, QT cd have been found higher for the 2nd group (correspondingly QTd 35,2±1,2 and 32,4±1,3 ms, p=0,128; QTdp 20,4±1,2 and 23,4±1,2 ms, p=0,092; JTdp 25,2±1,3 and 22,2±1,3 ms, p=0,117; QTc max 420±2,2 and 425±1,8 ms, p=0,090; QTcd 36±1,2 and 33,0±1,4 ms, p=0,130). Comparing HR variability parameters between the groups significant differences were not found. Other clinical, electrocardiographic and echocardiographic signs didn't differ too.

Table 1. General characteristic of the patients

Data	1st group (n=71)	2nd group (n=128)	p Value
Age (years)	56,4±10,2	60,8±9,5	0,003
men women	44 (62 %) 27 (38%)	96 (75%) 32 (25%)	0,054 0,054
Stable angina Unstable angina	35 (48%) 36 (52%)	46 (36%) 82 (64%)	0,05 0,05
ECG characteristics of LVH	32 (45%)	59 (46%)	0,890
1st degree AV block	9 (13%)	17 (13%)	0,903
Increased MMI	36 (55%)	78 (63%)	0,235
EF (%)	48,6±2,8	47,8±3,5	0,121

MMI – myocardial mass index, EF – ejection fraction, LVH-left ventricular hypertrophy, AV-atrioventricular

In additional study population QTd and QTcd did not differ between the patients with coronary artery disease (CAD) and without it (patients with hemodinamically unsignificant narrowing of coronary arteries), as well (Table 2).

Table 2. General characteristic, QT dispersion and corrected QT dispersion in patients with and without coronary stenosis in additional study population

		CAD n=67	No CAD n=27	p
Age	Years	62.1 ± 11.7	61.1 ± 10.2	0.706
Sex	M/F	59/8	10/17	< 0.0001
EF	%	61.7 ± 10.3	66.0 ± 10.3	0.07
QTd	Ms	30 (20-40)	20 (10-40)	0.655
QTcd	Ms	27(18.5-38)	23(10-44)	0.779

M/F – male/female, EF- ejection fraction

Using regression method, clinical, QT interval, HRV and T loop morphology parameters for revealing coronary artery stenosis ≥ 50 %, were assessed. In our study three informative parameters have been found: age, T loop area and T loop index. (Table 3)

Table 3. Informative clinical and T loop morphology parameters for prediction coronary artery stenosis ≥ 50 %

Parameters	OR	CI 95 %	χ^2	χ^2, p
Age ≥50 years	2,1	0,99-4,31	3,93	0,047
T loop area ≥226	2,2	1,12-4,25	5,38	0,02
T loop index ≥1,5	2,2	1,15-4,03	5,89	0,015

OR – odds ratio, CI – confidence interval

Sensitivity and specificity of age and T loop index for prediction coronary artery stenosis were estimated using ROC curves. Area under age ROC curve was 0,626, p=0,003; under T loop index – 0,608; p= 0,014.

Using multinomial logistic regression method we have estimated complex influence of informative parameters for probability of coronary artery stenosis ≥ 50 %. Optimal logistic model for probability of coronary artery stenosis ≥ 50 % was compiled by inclusion method. Variables into logistic regression model have been included as long as p value has decreased. Into final model we included age, gender and T loop index (table 4).

Table 4. Informative complex parameters for probability of coronary artery stenosis ≥ 50 % applying logistic regression method

Informative parameters	χ^2	p	ß coefficient
Age	8,9	0,008	0,065
Gender	3,65	0,001	-0,107
T loop index	6,53	0,049	0,447

$$p(x) = e^g / (1 + e^g), \quad g = \text{logit } p. \tag{2}$$

Prognosis of coronary artery stenosis was made according to g=logit

$$p = -2,39 - 1,067 \times \text{gender} + 0,065 \times \text{age} + 0,447 \times \text{T loop index}, \tag{3}$$

$$\chi^2 = 21,88 \quad p = 0,0001. \tag{4}$$

Sensitivity and specificity of logistic model to predict coronary artery stenosis was evaluated using ROC curve. When logit p=0,424, sensitivity and specificity of logistic model was 76 % and 55 %, when logit p=0,6 sensitivity and specificity was 64 % and 60 % accordingly (area under the curve is 0,701; p=0,0001) (Fig. 1). T loop area into final logistic model was not included because of significant correlation between T loop and T loop index (r=0,745; p=0,0001).

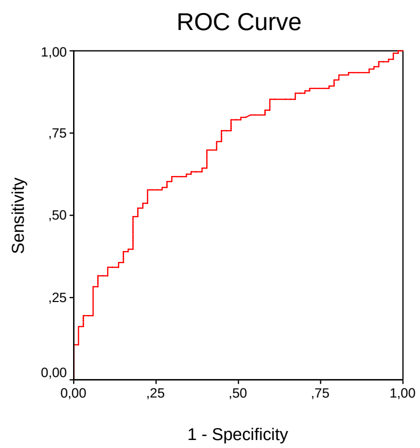

Fig. 1. Logistic model ROC curve

Data of coronary artery stenosis prediction using computer ECG analysis method. Evaluation of coronary artery stenosis was performed using three ECG bases to find the most accurate classification for the patients without previous MI. 1st base contained 240 patients with angina pectoris (240 patients), 2nd base (1st base+ECGs of healthy people=270 ECGs) and 3rd base (2nd base+ECGs of patients with acute MI=460 ECGs). We have found that as the base increases – specificity decreases, but sensitivity – increases. Sensitivity and specificity of the method using the third base was 37 % and 75 %; using the second base – 55 % and 58 %; using the first base – 50 % and 44 % accordingly (Fig. 2).

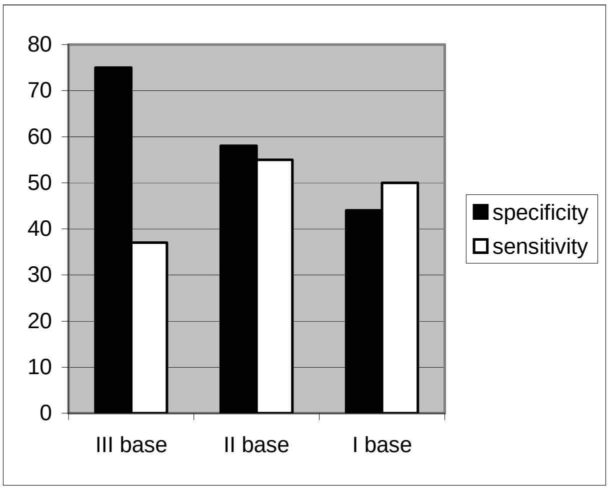

Fig. 2. Sensitivity and specificity of the computer ECG analysis method for coronary artery stenosis evaluation using three bases

Computer ECG analysis was performed for one, two and three vessel disease. Sensitivity for prediction one vessel disease, using various bases was 40%, 62% and 58%; for two vessel disease – 25%, 41% and 34%; for prediction three vessel disease – 39%, 64% and 50% accordingly.

When the classification has been performed using the IInd ECG base the sensitivity for coronary artery stenosis was 55%, specificity – 58%. Best results for prognosis were obtained for one and three vessel disease. Analysing the results of coronary artery stenosis prediction using computer ECG analysis method when coronary artery stenosis ≥ 50 % are diagnosed, it was established that QTc max (p=0,023), T loop area (p=0,008) and T loop index (p=0,005) values were higher, VLF (p=0,004), TP (p=0,019) values were lower for patients which state of coronary arteries was assessed wrongly. Analysing the results of coronary artery stenosis prediction, using computer ECG analysis method when coronary artery stenosis ≤ 30 % were diagnosed, it was determined, that angle between QRS and T wave (αQRS-T) values were higher (p=0,011) and VLF values were lower (p=0,042) for patients which state of coronary arteries was assessed wrongly, there were more cases of hypertension (p=0,065) and increases of MMI (p=0,018) in these patients. The computer ECG analysis program was further tested, additional informative parameters have been found: αP – angle between QRS and P vectors; αQRS-T; QTc and age. Tutelage set of ECGs consisted of 190 patients without previous MI. The additional parameters have increased efficacy of the program: sensitivity has increased to 85%, specificity – to 65% (r=0,5). The best results have been obtained at predicting one vessel disease: sensitivity has increased to 88%. Prediction of two vessel disease has increased to 82%, three vessel disease – to 84%.

According to computer ECG classification using singular value decomposition method [1], all the patients were divided into two categories: I category – coronary artery condition was evaluated properly; II –category – coronary artery condition was evaluated wrongly. Coronary artery condition was evaluated wrongly in 87 cases: in 64 men (46%) and in 23 women (39%) (age 59,9±9,2). In this category stable angina was diagnosed in 34 patients, unstable angina – in 53 patients, the first degree AV block was diagnosed in 11 cases, ECG characteristics of LVH were established in 40 patients and MMI increase – in 51 patients. One vessel disease was diagnosed in 19 patients, two vessel disease – in 19 patients, three vessel disease – in 19 patients, nonsignificant coronary artery lesions in 30 patients. Comparing clinical, electrocardiographic, echocardiographic and coronary angiography data no differencies were found between the categories (Table 5).

Comparing QT interval, HR variability and T loop morphology parameters between the categories significant differences were not found.

Table 5. General characteristics of the categories

Data	I category (n=112)	II category (n=87)	P value
Age (years)	58,7±10,5	59,9±9,2	0,403
Men	76 (54 %)	64 (46 %)	0,382
Women	36 (61 %)	23 (39 %)	0,382
Stable angina	47 (58 %)	34 (42 %)	0,412
Unstable angina	65 (55 %)	53 (45 %)	0,412
Hypertension	80 (54 %)	68 (45 %)	0,204
1st degree AV block	15 (58 %)	11 (42 %)	0,876
ECG signs of LVH	49 (55 %)	40 (45 %)	0,525
MMI increase	60 (52 %)	56 (48 %)	0,758
EF (%)	48,2±0,3	47,4±0,7	0,170
I group	41 (%)	30 (42 %)	0,276
II a subgroup	33 (63%)	19 (37 %)	0,026
II b subgroup	13 (41 %)	19 (59 %)	0,026
II subgroup	25 (57%)	19 (43 %)	0,026

AV-atrioventricular, LVH-left ventricular hypertrophy, MMI-myocardium mass index, EF-ejection fraction

To find additional informative parameters and to improve further results of the computer prognosis of coronary artery stenosis, several classifications of the patients were performed. Firstly, the patients with significant coronary artery stenosis (II group) according to results of prognosis where divided into two classes: I – a state of coronary arteries was evaluated properly, II – a state of coronary arteries was evaluated wrongly (prediction of coronary artery stenosis ≤ 30 %). Comparing the classes, it was found that QTc max values were higher for the first class patients (QTc accordingly 429±2,6 and 420±2,3; p=0,023), tendencies of higher QTd and QTcd values were determined

Comparing HRV parameters between the classes, VLF and TP values were higher for the second class patients (VLF accordingly 602±83,5 and 353±36,9, p=0,004; TP accordingly TP 1985±238,8 and 1350±144,9, p=0,019), a tendency of higher max RR interval and coefficient of variation values were higher for the class .

Comparing T loop morphology parameters differences between the classes, T loop area and T loop index values were higher for the first class patients (T loop area accordingly 218,3±7,1 and 188,9±8,5; p=0,008; T loop index accordingly 1,65±0,09 and 1,25±0,10; p=0,005) (Table 6).

Table 6. T loop morphology parameters of the I and II class expressed as mean ± SE

Parameters	I class (n=67)	II class (n=56)	p
T loop area	218,3±7,1	188,9±8,5	0,008
T loop index	1,65±0,09	1,25±0,10	0,005
αQRS-T	37,5±3,9	35,1±4,6	0,694

αQRS – T – angle between QRS and T vectors in frontal plane

According to results of coronary artery stenosis prediction using computer ECG analysis method, the first patient group (stenosis of coronary artery ≤ 30%) was divided into two classes: III – a state of coronary artery was evaluated properly; IV – a state of coronary artery was evaluated wrongly (prediction of coronary artery stenosis ≥ 50 %). Comparing clinical, electrocardiographic, echocardiographic data it was determined that there were more men (p=0,029), more cases of the 1st degree AV block (p=0,021), hypertension (p=0,065) and increases of MMI (p=0,018), ischemic ECG changes were determined more often (p=0,047) in the fourth patient class.

Comparing QT interval variables significant differences between the third and fourth classes we did not find, a tendency of higher JTd, QTc max, QTcd and JTc values was determined for the fourth class.

Studying HR variability parameters, VLF values were higher for the third class (VLF accordingly 741±153,9 and 364±65,7, p=0,042)

Comparing T loop morphology parameters, only αQRS-T values were higher for the fourth class patients (αQRS-T accordingly 39,1±5,9 and 21,9±3,5, p=0,011), a tendency of higher T loop area was determined for the class.

Discussion

Coronary artery stenosis prediction from ECG parameters is very actual for the patients without previous MI. There are only few publications and their results are sometimes controversial. In our study there was no difference between QT interval parameters. U.Stierle [2] made a comparison of QT interval parameters between healthy men and patients with IHD and there we no significant difference. J. Koide [3] in his studies hadn't confirmed difference in QT interval and its dispersion in patients with different extent of coronary artery stenosis. Van Leeuwen [4] on the other hand revealed that healthy men have shorter QTc interval and lower extent of QT dispersion comparing with patients with IHD without previous MI.

T loop morphology parameters are vectorcardiographic parameters which are usually used for risk for ventricular arrhythmia and sudden death risk stratification. There are some studies about changes of these parameters during acute ischemia: K. Nowinski [5] noticed that during acute coronary artery occlusion (especially in case of LAD angioplasty) T loop area enlarges and its shape changes - becomes more round. But we haven't found works about their usefulness in prognosis of coronary artery stenosis. We consider that T loop morphology parameters more accurately reflect heterogenecity of ventricular repolarisation and this heterogenecity might be associated with coronary artery stenosis. Our results confirm this consideration.

In recent time the interest in heart rate variability and its correlation with coronary artery stenosis is growing. In our study we didn't reveal significant differences in heart rate variability in patients with different extent of coronary artery stenosis and it disagrees with data from other studies [6,7] which show that in patients with IHD heart rate is growing and heart rate variability is decreasing. We suppose that medicine (beta-blockers, ACE inhibitors, calcium channel blockers) could pervert results in our study because the most part of patients used at least one of these drugs. The software for prognosis of coronary artery stenosis in our study was improved many times. A lot of experiments for classification were made until the most informative complex of parameters was discovered: αP – angle between QRS and P vectors; αQRS-T; QTc and age. Vectorcardiographic parameters thought to be more informative for detection of coronary artery stenosis comparing with usual 12 lead ECG [8] and our study confirms that. Recent investigations show that P wave changes reflect not only enlargement of right atrium or conduction disorder in atrium but myocardial ischemia too [9,10]. There are some data that during PTCA in acute myocardial ischemia the duration of P wave and its dispersion increases [11]. By applying a complex of informative parameters sensitivity has increased to 85 %, specificity to 65 %. So results are quite promising and, of course, we need future investigations.

Conclusions

Informative clinical and electrocardiographic parameters to determine VA stenosis ≥ 50 % were following: T loop index ≥1,5, T loop area ≥226 and age ≥50 years.

QTd and QTcd were not informative parameters for prediction of coronary artery stenosis.

By applying a complex of informative parameters (αP – angle between QRS and P vectors; αQRS-T; QTc and age) sensitivity for detection coronary artery stenosis has increased to 85 %, specificity to 65 % (r=0,5).

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Presented for publication 2006 03 01

J. Bluzas, A. Bastys, S. Kaminskiene, G. Urbonaviciene, Z. Bertasiene, R. Zaliunas, I. Bluzaite, P. Ammann, H. Rickli. Complex Informative ECG Parameters for Suspition Coronary Artery Lesions // Electronics and Electrical Engineering. – Kaunas: Technologija, 2006. – No. 3(67). – P. 77-82.

The aim of the study was to determine a complex of informative electrocardiogram (ECG) parameters in revealing coronary artery lesions. Parameters of heart rate variability, QT and T loop morphology were analysed in 199 patients (additional group for QT dispersion analysis only, consisted of 94 patients). Informative signs to determine coronary artery stenosis ≥ 50 % were following: T loop index ≥ 1,5, T loop area ≥ 226 and age ≥ 50 years. QTd and QTcd were not informative parameters for this determination. By applying a complex of parameters (αP – angle between QRS and P vectors; αQRS-T angle between QRS and T vectors; QTc and age) sensitivity for detection coronary artery stenosis has increased to 85 %, specificity to 65 % (r=0,5). Ill. 2, bibl. 11 (in English; summaries in English, Russian and Lithuanian).

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Целью настоящей статьи является исследование комплекса информативных показателей ЭКГ для распознавания поражения коронарных артерий. У 199 больных были исследованны параметры вариабильности сердечного ритма, QT интервала и T петли (дополнительная группа для исследования дисперсии включала 94 больных). Информативные признаки для определения коронарного стеноза более 50 проц. были: индекс T петли 1,5, площадь T петли ≥ 226 и возраст ≥ 50 лет. QTd и QTcd не были информативными для такого прогноза. Используя комплекс информативных показателей (αP – угол между QRS и P векторами; αQRS-T угол между QRS и T векторами; QTc и возраст) чувствительность для определения коронарного стеноза повысилась до 85 %, специфичность – до 65 % (r=0,5). Ил. 2, библ. 11 (на английском языке; рефераты на английском, русском и литовском яз.).

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Tyrimo tikslas – nustatyti informatyvių elektrokardiogramos (EKG) parametrų kompleksą koronarinių arterijų pakenkimui numatyti. Širdies dažnio variabiliškumo, QT intervalo ir T kilpos morfologijos parametrai buvo analizuoti 199 ligoniams (papildomai 94 ligoniams buvo analizuota tik QT dispersija). Buvo nustatyti informatyvūs požymiai vainikinių arterijų stenozės ≥ 50 proc. numatymui: T kilpos indeksas ≥ 1,5, T kilpos plotas ≥ 226 ir amžius ≥ 50 metų. QTd ir QTcd šiuo požiūriu nebuvo informatyvūs. Buvo surastas požymių kompleksas: αP – kampas tarp QRS ir P vektorių; αQRS-T kampas tarp QRS ir T vektorių; QTc ir amžius, kurį naudojant jautrumas, numatant vainikinių arterijų stenozę padidėjo iki 85 %, specifiškumas iki 65 % (r=0,5). (anglų kalba; santraukos anglų, rusų ir lietuvių k.).