ISSN 1392 – 1215 *ELECTRONICS AND ELECTRICAL ENGINEERING* 2008. No. 4(84)

ELEKTRONIKA IR ELEKTROTECHNIKA

MEDICINE TECHNOLOGY

T115

MEDICINOS TECHNOLOGIJA

A Risk Score for Estimating Coronary Artery Disease in Different-age Patients

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Introduction

Ischaemic heart disease (IHD) is the major cause of morbidity and mortality among adults in economically developed countries. Despite the preventive means a number of patients with IHD has been increasing [1]. The reliable non-invasive detection of coronary artery disease (CAD) is a prime goal for future developments in clinical cardiology. A suspicion and recognitition of coronary artery (CA) stenosis from resting electrocardiogram (ECG) in cases of non–acute ischeamia has been limited until now. Therefore, an analysis of ECG may reveal some specific changes of ECG parameters that could be related to CA lesions and would be beneficial for detecting IHD at its early stages.

It has been reported that pacing or exercise induced acute ischemia is associated with increased QT dispersion (d) in patients with CAD [2; 3]. We hypothesized that changes of ECG parameters of depolarization and repolarization from resting ECG also could be related with extent and severity of CA stenosis.

In this paper we evaluated ECG descriptors for classification or recognition of patients with CA stenosis applying CARDS algorithm and binary regression methods in different-age patients with CAD.

Patients and methods

One hundred ninety nine patients with stale angina pectoris were investigated (140 male and 59 female). One hundred of them (84 male and 16 female) were younger than 60 years old and 99 patients (56 male and 43 female) were 60 years and older. All these patients underwent coronary angiography. It was considered that stenosis of CA lumen $\geq$ 50 % is hemodinamically significant, and stenosis of CA lumen $\leq$ 30% - hemodinamically nonsignificant. The patients with arrhythmias, bundle branch blocks, history of myocardial infarction, ischaemic ECG changes (negative T waves, ST segment changes), and abnormal left ventricular systolic function were excluded from the study. According to the angiographic findings, the patients were divided into 2 groups: stenosis of coronary artery lumen $\geq$ 50% and stenosis of coronary artery lumen $\leq$30%. In the present study, we estimated risk of CA stenosis for patients younger than 60 years old and 60 years and older.

Digital ECG was recorded for all patients (discretisation parameters 12 bit, 2 kHz, recording interval of 10 s, 12 standard leads). Later on these ECGs were processed by computer software, created at 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 were reconstituted from I and II leads. ECGs were filtered by means of high-pass 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 and were calculated by the formula:

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

where $\Delta y_i^{\mathrm{III}}$ – is the sum of QRS, P and T wave amplitudes from III lead, Δy_i^{I} – from I lead. 1.15 and 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° and 0…-180° intervals, tgα value is negative in I and III quadrants and positive − in II and IV quadrants, therefore it was necessary to apply reduction formula of these angles.

QT interval variables were measured automatically employing appropriate computer software. 12-lead resting ECGs 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 10 s. QT and JT intervals were measured from standard (I, II, III, AVR, AVL, AVF) leads and from thoracic (V1-6) leads. QTd and JTd were calculated as follows: from the longest QT or JT interval subtract the shortest QT or JT intervals. QTc and JTc were calculated using Bazett formula (QTc = QT/RR).

Supine resting signal-averaged orthogonal electrocardiograms were obtained (5 min. duration, 2 kHz, 12 bit, 8-lead) in all patients. Standard T wave was marked as an example with following 128 T wave extractions from ECG by correlation method. Vectorcardiographic X, Y, Z orthogonal Frank leads were synthesized using Dower matrix. Three-dimensional T loop was projected onto a vertical plane, and the projection was inscribed into a square. The square was divided into 20x20 subsquares. From the shape of the filled subsquares two parameters of T loop morphology were evaluated: T loop area and T loop index (ratio of T loop area and T loop length) [4].

Statistical analysis was performed using SPSS 10.0 and STATISTICA 5.7 for Windows. Descriptive analyses were performed to assess the distribution of our data. We analyzed the influence of selected ECG variables on extent of CA stenosis, using logistic regression and CARDS algorithm [5]. Univariate logistic regression was calculated to determine the relationship of each ECG variable separately with the presence of CA stenosis. All variables with a p-value < 0.05 in the univariate analysis were included in multivariate logistic regression model by stepwise selection. Categorical values were compared using $\chi 2$ test. The difference was significant if p<0.05. The accuracy of multivariable model was evaluated by receiver operating characteristic (ROC) curves. We used total risk score model to assess the significance of ECG parameters combination for CA stenosis. Estimated odds ratios (OR) from the final multivariate logistic regression model were transformed into integer values: 1 point for odds ratio ≤ 1.5; 2 points for odds ratio at interval between 1.5 and 2.5; 3 points for odds ratio at interval between 2.5 and 3.5, and 4 points for odds ratio ≥ 3.5.

Results and Discussion

Hemodinamically significant stenosis of CA lumen were diagnosed significantly more often in the group of elder patients (p=0.002). In 54% patients younger than 60 years were diagnosed stenosis of CA lumen ≥ 50% (56% male and 44% female). In 74.4% patients 60 years and elder were diagnosed stenosis of CA lumen ≥ 50% (87.5% male and 58.1% female, p=0.001).

Assessment of risk and prognosis of CA lesions ≥ 50% in patients younger than 60 years.

Probability of CA lesions ≥ 50% was defined by means of solution tree statistics method, classifying the parameters of QRS, QT interval, and T loop morphology into the risk area (table 1).

Table 1. The distribution of QRS, QT interval and T loop morphology parameters into the risk areas in patients younger than 60 years

Variable	Risk area	χ^2 p	Sensi-tivity	Specifi-city
JTd	(≤19)U(>37)	0,038	55,6	65,2
QTd	(≤16)U(>63)	0.042	9.3	100
QTdapex	>43	0,011	13.0	100
JTdapex	[32; 35]U(≥44)	0,016	20.4	95,7
QTcmin	(>370)	0,003	85,2	41,3
JTcd	[35; 38]U(>56)	0,003	29,8	93.5
αQRS-T	[10; 32]U(≥52)	0,024	57.7	65.2
Tarea	(>206)	0,034	55.6	65.9
Tindex	(>1,56)	0,040	50.0	70.5
QRSmin	[71; 79]U(>84)	0,012	55.6	69.6
QRSmean	(<74.3)U(>80.9)	0,009	88.9	32.6
QRSmax	[84;86]U[104;107]	0,030	18.6	95.7

The logistic regression model included all these informative variables for estimation of the probability for CA lesions. We removed insignificant variables by step procedure. Final model included 6 binary variables (IN) (table 2). χ^2 of this logistic model equals 33.89 df 6. Age and gender and their interaction did not improve the prognostic probability of this model (p>0.05).

Table 2. Multivariate associations and score of parameters that showed the strongest relation with CA stenosis in patients younger than 60 years

Variable	β	p	OR	PI	s
INJTd	1,322	0,012	3,750	1.333 – 10.552	4
INQTcmin	1.480	0,012	4.395	1.376 – 14.033	4
INJTcd	1,443	0,053	4.232	0.981 – 18.259	4
INαQRS-T	1,062	0,038	2.893	1.059 – 7.902	3
INTindex	0,924	0,073	2.519	0.919 – 6.906	3
INQRSmax	1,549	0,087	4.708	0.799 – 27.757	4
Constant	-2,717				

s-score, IN-binary variable.

On the ground of multivariate logistic model we developed a risk score for CA stenosis which was performed using logistic regression OR given in table 2. The sum score represented the aggregate information for predicting the probability of CA lesions. The value of risk score varied from 0 to 19. In 34 patients the score was higher than 10, and CA lesions ≥ 50% were recognized accurately in 30 (88.2 %) patients. In 34 patients the score was between 7 and 10, CA lesions ≥ 50% were recognized also in 17 (50 %) patients. In 28 patients the score was less 7, and CA lesions ≥ 50% were recognized accurately only in 5 (17.9%) patients. Sensitivity and specificity of CA lesions ≥ 50% was 90.4 % and 52.3% when risk score was higher than 6., and 76.9 % and 76% when risk score was higher than 7 in patients younger than 60 years.

Assessment of risk and prognosis of CA lesions ≥ 50% in patients 60 years and older.

Probability of coronary artery lesions ≥ 50% was defined by means of solution tree statistics method, classifying the parameters of QRS, QT interval, and T loop morphology into the risk area (table 3).

Table 3. The distribution of QRS, QT interval and T loop morphology parameters into the risk areas in patients 60 years and older

Variable	Risk area	χ^2,p	Sensitivity	Specificity
JTdapex	(>21)	0,005	64.4	68.0
QTcmax	(≤422)	0,023	49.3	76.0
JTcmin	(<300)	0.013	52.1	76.0
JTcd	(>22)	0,012	90.4	32.2
αQRS-T	(≤6)U(≥55)	0,008	45.1	84.4
Tarea	(>115)	0,007	95.7	26.1
Tlenght	(>365)	0,020	43.5	82.6
QRSmin	(>70)	0,021	62.2	64.0

The logistic regression model included all these informative variables for estimation of the probability for CA lesions. We removed insignificant variables by step procedure. Final model included 6 binary variables (table 4). χ^2 of this logistic model equals 46 df 6. Age and the interaction of age and gender did not improve the prognostic probability of this model (p>0.05). Including gender significantly improved the logistic regression model: χ^2 was equal 49.33 df 7 (Table 4).

Table 4. Multivariate associations and score of parameters that showed the strongest relation with CA stenosis in patients 60 years and older

variable	β	p	OR	PI	s
INJTdapex	2.201	0,009	9.031	1.734 – 47.033	2
INQTcmax	1.419	0,009	11.239	1.813 – 69.65	3
INαQRS-T	2.859	0,004	17.451	2.465 – 123.5	4
INTarea	2.326	0.041	10.238	1.101 – 95.24	2
INTlenght	1.495	0,078	4.461	0.846 – 23.511	1
INQRSmin	2.040	0,025	7.693	1.289 – 45.921	2
Male	1.383	0.075	3.988	0.869 – 18.289	1
Constant	-5,711				

s-score, IN-binary variable.

The value of risk score varied from 0 to15. In 27 patients the score was higher than 9, and CA lesions ≥ 50% were recognized accurately in all (100 %) patients. In 47 patients the score was between 7 and 9, CA lesions ≥ 50% were recognized also in 46 (97.9 %) patients. In 29 patients the score was between 6 and 7, and CA lesions ≥ 50% was recognized accurately in 17 (58.6%) patients. In 12 patients the score was less 5, and CA lesions ≥ 50% was recognized accurately in 2 (16.7 %) patients. Sensitivity and specificity of CA lesions ≥ 50% was 89.2 % and 65.2% when risk score was higher than 5.

Age is well known risk factor for IHD, it‘s morbidity is increasing with the age, therefore we had a look at a possibility to suspect CA lesions from resting ECG in different-age patients. The main finding in our study was that complex of ECG parameters may suspect CA lesions ≥50% with sensitivity and specificity of 76.9 % and 76% in patients younger than 60 years as well as with sensitivity and specificity of 89.2 % and 65.2% in patients 60 years and older, respectively.

Our results demonstrate that αQRS-T, QTcmax, Tarea and QRS duration could be beneficial for detecting CA stenosis at its early stages. So we recommend for practical physicians to turn attention not only into the ischaemic ECG changes (negative T waves, ST segment changes) but also into ECG parameters of depolarization and repolarization. The utility of these ECG-parameters clinicians should consider for the screening of the patients during preventive examination.

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Submitted for publication 2008 02 10

J. Vencloviene, G. Urbonaviciene, I. Bluzaite, S. Kaminskiene, Z. Bertasiene, R. Unikas, M. Tamosiunaite. A Risk Score for Estimating Coronary Artery Disease in Different-age Patients // Electronics and Electrical Engineering. – Kaunas: Technologija, 2008. – No. 4(84). – P. 67–70.

In this paper we evaluated ECG descriptors for classification or recognition of patients with coronary artery (CA) stenosis applying CARDS algorithm and binary regression methods in different-age patients with coronary artery disease (CAD). 199 patients with stale angina pectoris and without ischaemic ECG changes were investigated (140 male and 59 female). One hundred of them (84 male and 16 female) were younger than 60 years and 99 patients (56 male and 43 female) were 60 years old and older. The patients were divided into two main groups according to CA stenosis degree: stenosis of CA lumen ≥ 50% and stenosis of CA lumen ≤30%. Digital ECG was recorded for all patients (discretisation parameters 12 bit, 2 kHz, recording interval of 10 s, 12 standard leads). ECG parameters of depolarization and repolarization were evaluated by computer software, created at Institute of Cardiology, Kaunas medical university. On the ground of multivariate logistic model we developed a risk score for suspicion of CA stenosis. Sensitivity and specificity of CA

lesions ≥ 50% was 90.4 % and 52.3% when risk score was higher than 6., and 76.9 % and 76% when risk score was higher than 7 in patients younger than 60 years. Sensitivity and specificity of CA lesions ≥ 50% was 89.2 % and 65.2% when risk score was higher than 5 in patients 60 years and older. Tabl. 4, bibl. 5 (in English; summaries in English, Russian and Lithuanian).

Й. Венцловиене, Г. Урбонавичене, И. Блужайте, С. Каминскене, З. Берташене, Р. Уник, М. Тамошюнайте. **Бал риска для определения сужений коронарных артерий у пациентов разного возраста // Электроника и электротехника. – Каунас: Технология, 2008. – № 4(84). – С. 67–70.**

В этой статье мы определили связь между степенью повреждений коронарных артерий (КА) и параметров ЭКГ, оценивая алгоритм CARDS и бинарные методы логической регресии. В исследование были включены 199 больных с *angina pectoris*, без ишемических изменений в ЭКГ. Сто из них (84 мужщин и 16 женщин) были моложе чем 60 лет и 99 пациентов (56 мужщин и 43 женщин) были 60 лет и старше. Всем больным была выполнена коронарография и цифровая ЭКГ. Пациенты были разделены на 2 группы согласовывая с степенью повреждений КА: стеноз КА ≥ 50% и стеноз КА ≤30%. После автоматического анализа ЭКГ системой, были определены параметры деполяризации и реполяризации. При анализе логической регресии был найден бал риска для прогнозирования повреждений КА. Чувствительность и специфичность повреждений КА ≥ 50% был 90.4% и 52.3% когда бал риска более чем 6, и 76.9% и 76% когда бал риска более чем 7, у пациентов моложе чем 60 лет. Чувствительность и специфичность повреждений КА ≥ 50% был 89.2% и 65.2% когда бал риска более чем 5 у пациентов 60 лет и старше. Табл. 4, библ. 5 (на английском языке; рефераты на английском, русском и литовском яз.).

J. Venclovienė, G. Urbonavičienė, I. Blužaitė, S. Kaminskienė, Z. Bertašienė, R. Unikas, M. Tamošiūnaitė. Skirtingo amžiaus ligonių, sergančių išemine širdies liga vainikinių arterijų pažeidimų rizikos įvertinimas // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2008. – Nr. 4(84). – P. 67–70.

Šiame straipsnyje nustatėme elektrokardiogramos (EKG) parametrų ryšį su vainikinių arterijų (VA) susiaurėjimais, pritaikant CARDS algoritmą ir logistinės regresijos metodus. Ištirti 199 ligoniai (140 vyrų ir 59 moterys), kuriems buvo nustatyta stabili krūtinės angina ir nenustatyta išeminių pokyčių EKG. Šimtas ligonių (84 vyrai ir 16 moterų) buvo jaunesni nei 60 metų. Devyniasdešimt devyni ligoniai (56 vyrai ir 43 moterys) buvo 60 metų ir vyresni. Visiems ligoniams atlikta koronarografija, užrašyta skaitmeninė EKG bei įvertinti depoliarizacijos ir repoliarizacijos parametrai. Pagal koronarografijos duomenis ligoniai buvo suskirstyti į dvi grupes: kuriems buvo nustatyti VA susiaurėjimai ≥ 50 proc. ir kuriems buvo nustatyti VA susiaurėjimai ≤30 proc. Taikydami logistinės regresijos metodą, sukūrėme rizikos balų sistemą VA susiaurėjimams įtarti. Ligoninių jaunesnių nei 60 metų, jautrumas ir specifiškumas, prognozuojant VA susiaurėjimus ≥ 50 proc. buvo 90,4 proc. ir 52,3 proc. kai rizikos balas aukštesnis nei šeši, taip pat 76,9 proc. ir 76 proc., kai rizikos balas aukštesnis nei septyni. 60 metų ir vyresnių ligonių jautrumas ir specifiškumas, prognozuojant VA susiaurėjimus ≥ 50 proc., buvo 89,2 proc. ir 65,2 proc., kai rizikos balas didesnis nei penki. Lent. 4, bibl. 5 (anglų k.; santraukos anglų, rusų ir lietuvių k.).