Electrocardiographic Body Surface Maps (BSM) in Patients with Ischemic Heart Disease Examined by Coronary Angiography

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Abstract: ECG body surface maps (BSM) is one of the noninvasive methods for the detection of ischemic heart disease. In the present work we registered the BSM in 25 patients, 18 men, mean age 56.8 (31–83) years, 7 women, mean age 58.7 (43–72) years with coronary artery disease and in 23 healthy persons, 17 men, mean age 55 (46–60) years, 6 women, mean age 57 (42–70) years. Using diagnostic system Cardiag we measured 32 parameters of heart electric field (ECG, VCG, isopotential, isointegral, and isoarea maps). The results of BSM examination were compared with the results of coronary angiography (CAG) and other noninvasive methods. Twenty-four patients were BSM positive, 5 of them with negative CAG. In one case both BSM and CAG were negative. None of persons with positive CAG were BSM negative. The values of positive BSM in patients with negative CAG approached more to the values of positive CAG persons than to controls. Despite of small number of persons examined in our study one can conclude that the BSM method detects the damage of myocardium by another way than the CAG.

Key words: ECG – VCG – body surface maps-ischemic heart disease – coronary angiography

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Introduction

Recording of ECG body surface maps (BSM) is one of the possible noninvasive detection of coronary heart disease (CHD) [1]. The ECG stress test and coronary angiogram (CAG) records reviewed in 435 patients with chest pain showed 44 cases with normal CAG (false positive exercise test) and 33 cases with both CAG and stress test negative. The left ventricular hypertrophy (LVH), history of hypertension or diabetes mellitus was the main factors influencing ECG stress test for detecting CHD [2].

In the present work we measured by the method of BSM 25 patients with angina syndrome the diagnosis of them being supported by the abnormality of stress ECG test, radionuclide imaging, echocardiography, biochemical parameters (creatin phosphokinase, troponins) and examined by CAG with the aim to ascertain if the BSM method is more precise than the classic ECG in the detection of CHD [3–5]. The ECG, vectorcardiogram (VCG) and BSM registered at the same time by the same analyser is capable to describe in detail the heart electric field changes [6–8]. The diagnostic system Cardiag 112.1 analyses 32 parameters of ECG, VCG and BSM. The BSM findings in 23 healthy controls of the same age (57 ± 12 years) were performed to verify the differences in heart electrical field parameters in patients [9–15].

Methods

In 25 patients, 18 men, mean age 56.8 (31–83) years, 7 women, mean age 58.7 (43–72) years the cardiologic finding consisted of expressive angina pains. They were examined by ECG, stress ECG testing, spirometry, scintigraphy, and echocardiography. In 8 patients the hypertension was in anamnesis, but stabilized with the therapy in the time of the BSM and coronary angiography (CAG) examination. In one patient, the left ventricular hypertrophy (LVH) was ascertained by ECG and echocardiography. In the other patients the left ventricular mass was of normal value.

The control group consisted of 23 healthy volunteers, 17 men, mean age 55 (46–60) years, 6 women, mean age 57 (42–70) years. In both groups the ECG, VCG and BSM were performed by diagnostic system Cardiag 112.1 and 32 parameters of heart electric field were evaluated independently to the clinical diagnosis and the CAG [16]. In the present work there are only the repolarization isopotential (RIPM), isointegral (RIIM), and isoarea (RIAM 35, RIAM 80) maps parameters shown, the maximum and minimum (extreme) of them being statistically different in patients in comparison with the controls. These parameters were found to be sensitive to the ischemic changes [17–19]. Also other parameters including ECG and VCG were evaluated according to the menu of diagnostic system.

For the statistical comparison the patients were divided to two groups: CAG positive and negative, and compared with controls. The CAG positive patients have been compared with the BSM positive ones to verify the positivity of BSM [16,17]. But in 5 CAG negative patients the BSM positivity has been observed. The diagnosis of CAG positive patients was unstable angina pectoris, patients after myocardial infarction, with metabolic syndrome, diabetes mellitus type II, dyslipoproteinemia. In all of them the BSM finding was positive.

The results of examination in 5 BSM positive and CAG negative patients are described in detail.

Patient No. 1: woman, 51 years, nontoxic goitre, obesity, dyspnea relieved after isosorbitdinitrate (Maycor), the exercise stress ECG testing incomplete for decreased efficiency and the ventricular extrasystoles, echocardiography negative, BSM ischemia in lateral wall of left ventricle.

Patient No. 6: man, 31 years, hypertrophic cardiomyopathy, stabilized hypertension, obesity, dyspnea during exercise ECG stress test, echocardiography positive, ejection fraction 54%, in ECG left ventricular hypertrophy (LVH), BSM ischemia in lateral wall of left ventricle.

Patient No. 7: woman, 65 years, hypertension, blood pressure compensated, the effort dyspnea decreased after verapamil (Isoptin), stress ECG test positive, BSM without ischemia, but only the irregular repolarization.

Patient No. 14: woman, 43 years, hypertension, the blood pressure normalized by therapy, the effort angina, the positive stress ECG test, the negative echocardiography, BSM repeatedly examined, the irregular repolarization pattern improved.

Patient No. 15: man, 58 years, hypertension improved by therapy, obesity, echocardiography – decreased kinetics of the left ventricle, in CAG the spasm of right coronary artery was observed. In BSM the ischemia in anterior, lateral and posterior wall of left ventricle was found.

The results of BSM measuring were statistically evaluated with t-test for two independent groups.

Results

No signs of silent ischemia – ECG, VCG and BSM abnormalities – were found in the control group. The ECG repolarization isointegral map (RIIM) of the T wave is shown in Fig. 1 in control (upper part) and in patient with nontransmural posterolateral ischemia and fibrosis (lower part). The regular concentricity of isointegral lines in the electropositivity (grey colour) is present in the map of control person. The irregularities both in electropositivity and in electronegativity (white colour) are marked in the map of the patient showing an altered repolarization. The lateral profile of the maps shows the regularity of the T wave in control (upper part) and the irregularities in the patient. Moreover, in control there is the positivity in whole anterior and lateral thorax, while in patient the electronegativity in the lower part of thorax is marked proving the ischemia and fibrosis. The numbers in Fig. I show the maximum and minimum (extreme) in

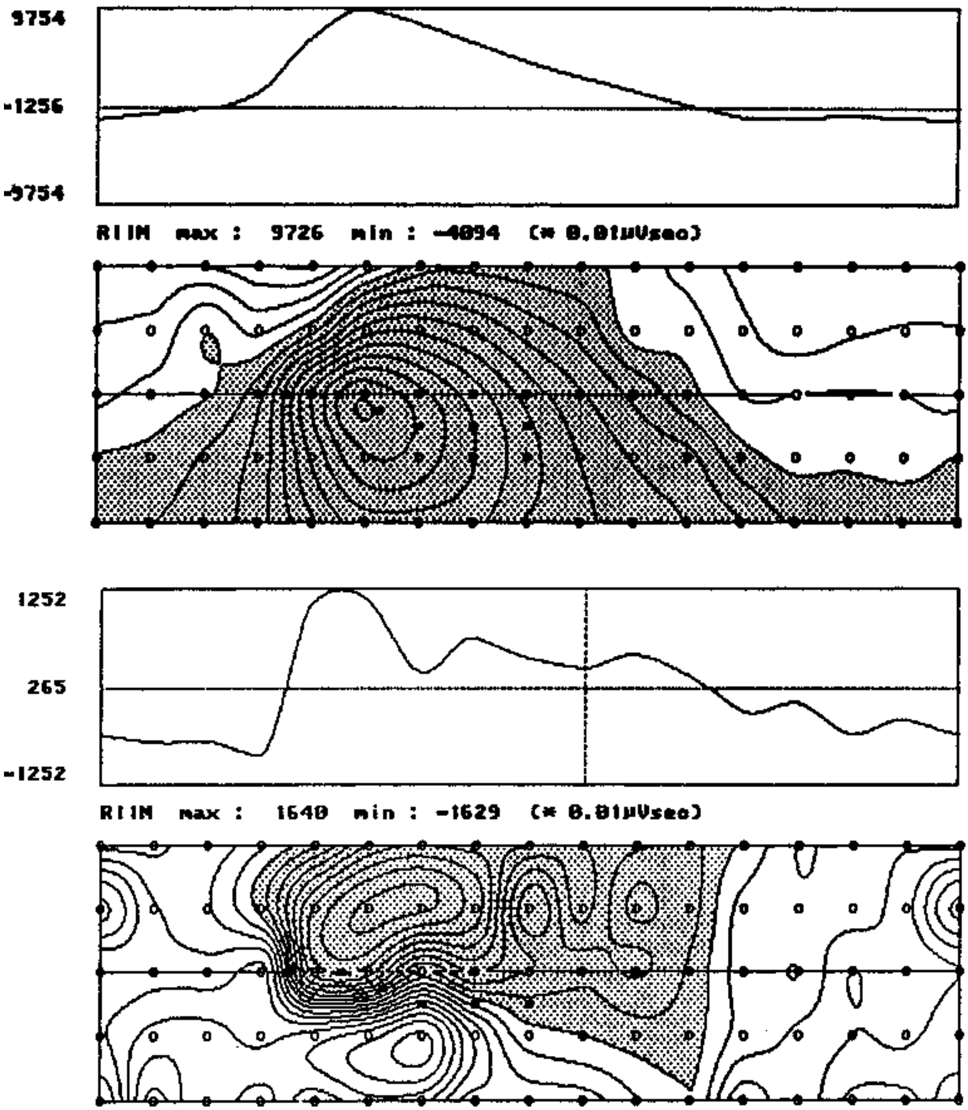

Fig. 1 – Repolarization isointegral maps (T wave, RIIM) in control (50-year-old) man (upper two figures) and in 52-year-old man with nontransmural posterolateral fibrosis and myocardial ischemia (lower two figures) registered with diagnostic system Cardiag.
The upper two figures in each pair there are the profile pictures of the planar map measured in 4th intercostal space. The numbers are the absolute values of maximum and minimum in µVs x 0.01.
The lower pictures show the electropositive (grey colour) and electronegative (white colour) values of integrals in T wave on the surface of thorax. Left half of figures – the front of thorax, the right halves – back of thorax. Sixteen electrodes are regularly localized on thorax at the five floors: fossa jugularis, 2nd, 4th,6th intercostal space, the same distance beneath 6th intercostal space. The distance of lines: 2 µVs.

electropositivity and electronegativity on the surface of thorax in μVs $\times$ 0.01. The absolute values of maximum and minimum are higher in control than in patients showing the hypopolarization in the ischemic tissue. One can compute from the irregular decrease of maximum (extreme) the "valley" between two "hills". The absolute value of it is 5 μVs (fibrosis).

The localization of stenosis in the coronary arteries of patients according to the CAG is summarized in Tab. 1. The comparison of repolarization parameters of the heart electrical field measured by BSM method is shown in Tab. 2 in CAG negative and positive patients and in controls. Differences between CAG positive and negative patients (column N$\times$P in Tab. 2) were not significant in all measured BSM parameters. Significant differences of these parameters were found between CAG negative and controls (column N$\times$C) and CAG positive and controls (column P$\times$C in Tab. 2). The other measured parameters didn't differ and were not shown in Tab. 2.

The relation of ECG and BSM positive repolarization changes and CAG positive and negative findings in the patients (number of patients) is marked in Tab. 3. In 24 patients the BSM positive finding confirmed the clinical examination. Five of them (4 women, 1 man) ie. 20% were CAG negative (for the more detailed description of them see Methods) including 1 woman with proven coronary vasospasm, but without degenerative changes in the coronary arteries. I one patient (woman, Tab. 3) with angina syndrome both the CAG and the BSM were negative. It is probably either false negativity, or the diagnosis ought to be verified by the measurement of troponin, myoglobin, or by other methods like magnetic resonance.

The comparison of repolarization changes in the classic 12-leads ECG and in BSM showed positive ECG findings only in 10 patients from 19. The ECG positive (pathologic) changes in our patients were the negative T wave, the ST elevation higher than 1 mm. The non-specific ECG changes were the ST segment

Table 1 – Localization of coronary stenosis in 25 patients with coronary heart disease (CHD)

Coronarographic finding	Number of persons
Stenosis RIA	2
Stenosis Rcx	2
Stenosis ACD	2
Stenosis Rdg	1
Stenosis RIA + ACD	4
Stenosis ACD + RCx	2
Stenosis RIA + RCx	1
Stenosis RIA + ACD + RCx	5
Negative finding	6

RIA – ramus interventricularis anterior of the arteria coronaria sinistra; RCx – ramus circumflexus; ACD – arteria coronaria dextra; Rdg – ramus diagonalis denivelation (depression or elevation) lower than 1 mm, the decreased R wave height, and the T wave decreased amplitude. In 5 patients these changes were present but in 4 patients with CAG positive finding (stenosis in coronary arteries). The ECG finding was negative (Tab. 3). On the other hand, among the patients

Table 2 – Comparison of maximum and minimum (extreme) in the repolarization isopotential (RIPM), isointegral (RIIM), and isoarea (RIAM) maps in patients with positive and negative coronarography, and in controls (left part)

	Coronarography		Controls	T-tests		
	Negat.	Posit.		N×P	N×C	P×C
Parameter	Mean (s.d.) N=6	Mean (s.d.) N=19	Mean (s.d.) N=23	Probab. Signif.	Probab. Signif.	Probab. Signif.
RIPMmax (μV)	408.17 (211.92)	553.95 (223.55)	–	0.1725	–	–
RIPMmin (μV)	–193.8 (118.0)	–283.5 (159.5)	–	0.2188	–	–
RIIMmax (μVs)	51.4 (28.6)	54.7 (26.6)	10.28 (3.68)	0.7962	0.0172 *	0.0000 ****
RIIMmin (μVs)	–30.6 (25.7)	–34.0 (23.7)	–3.44 (1.06)	0.7688	0.0489 *	0.0000 ****
RIAMmax35 (μVs)	2.48 (0.9)	3.50 (1.7)	5.31 (2.5)	0.2006	0.0157 *	0.0150 *
RIAMmin35 (μVs)	–3.41 (3.25)	–2.71 (2.46)	–2.11 (0.95)	0.5795	0.3805	0.3331
RIAMmax80 (μVs)	6.38 (2.14)	9.95 (5.64)	1.53 (0.70)	0.1472	0.0028 **	0.0000 ****
RIAMmin80 (μVs)	–7.64 (8.3)	–6.78 (6.8)	–0.55 (0.21)	0.7845	0.0910	0.0003 ***

Mean ± standard deviation; n-number of persons. Right part – the statistical significance and comparison of t-tests; N×P – coronarography negative × positive patients; N×C – coronarography negative × controls; P×C – coronarography positive × controls. * $p<0.05$; ** $p<0.01$; *** $p<0.001$; **** $p<0.0001$

Table 3 – Comparison of repolarization changes in 12-leads ECG and 96-leads BSM in relation to coronary angiography finding (the more detailed description see text of Results)

Coronarography		Positive	Negative
ECG finding	positive	10	1
	nonspecific	5	2
	negative	4	3
BSM finding	positive	19	5
	negative	0	1

with negative CAG, the only ECG positive finding was present in the patient with coronary artery spasm. In two patients the non-specific ECG findings were present, while in 3 patients no repolarization changes were identified (Tab. 3).

The comparison of the parameters in 12-leads ECG in controls and in patients with CAG examination is shown in Tab. 4. The prolongation in QT duration and the decrease in frontal QRS angle (semihorizontal position of the heart) were shown in the patients with CHD ($p<0.05$). For the detection of the repolarization parameters of the heart electric field in CHD our results showed BSM to be the more sensitive method than the classic ECG.

Discussion

In three patients with the negative CAG finding and the positive BSM one, the worsened angina syndrome, obesity, and the positive stress ECG testing were present. In 24 patients from 25 the positive BSM finding testified the possible ischemic damage of myocardium, in one patient both the CAG and the BSM were negative. In 19 patients the different degree of the organic damage in coronary arteries and the positive BSM finding were present. The BSM parameters were more pronounced in these patients than in patients with CAG negative finding, but the differences in those parameters were not significant (Tab. 2, column N×P). Significant differences were observed between the above parameters and those in controls (Tab. 2, columns N×C,P×C). One cannot consider the positivity of BSM, which was not confirmed by CAG, as a false positive finding. In 4 from 5 patients CAG negative and BSM positive the arterial hypertension was present. But only in one of them the left ventricular hypertrophy (LVH) was proved by ECG and echocardiography. The ischemia in frontal wall of left ventricle according to the BSM finding is relative to the LVH, although one cannot exclude the other mechanisms. In the other two patients with stabilized hypertension the echocardiographic finding was negative and in BSM only irregularities in the repolarization of lateral wall of LV without ischemic changes were present.

In patients No.1 and 15 (see Methods) the ischemic BSM changes were observed, in one of them together with the worsened angina, positive stress ECG test (No. 1) and in the other (No. 15) accompanied by the fault in microcirculation in the presence of chronic obstructive pulmonary disease (COPD) and by polyglobulia. It means that the noninvasive BSM method is relatively exact in comparison with the routine invasive method of CAG. However, the detection of local changes in activation and repolarization by BSM method in LVH can describe the ischemic changes also in the negative CAG finding [23]. In hypertension without LVH, the BSM method registered in patients with the negative CAG findings only small irregularities of repolarization. LVH and the history of hypertension or diabetes mellitus are the mean factors influencing ECG stress test for detecting CHD [24].

The comparison of repolarization parameters of heart electrical field in controls and in patients with negative CAG (Tab. 2, right part, column N×C) showed a lower difference than the comparison of controls and patients with the positive CAG (Tab. 2, right part, column P×C), in the absolute values of maximum and minimum in isointegral and isoarea maps. While in patients with positive CAG the changes in concentricity of potential lines were more pronounced, following the more "hills" and "valleys" (Fig. 1, lower part) in patients with CAG negative these changes were less pronounced. The more detailed description of maximum and minimum is marked in higher sensitivity of measurement and higher density of lines (the distance of isointegral lines 1 μVs, while in routine measurement the distance is 2 μVs). In the literature, the BSM method was used to analyse rather the localization than the absolute values of maximum and minimum in patients with CHD [3, 4, 19] and with LVH [5]. For this detection the specialized program and the departure and scatter maps of extreme are necessary to perform [5]. But in the routine measurement one has to do the conclusion from the measurement of one patient similarly as in classic ECG evaluation.

From the former experiences one can support that the BSM positivity in comparison with the coronary angiographic method is not in the same relation [21–23]. The present work showed, that the BSM method sensitively evaluated changes in electrical activation and repolarization of myocardium, but on the other level, than the CAG. One can express a hypothesis that the patients with positive BSM method can suffer from the segmental or global heart failure, which is not possible to detect by CAG. The BSM positive changes can be related to the changes in arteriolo-capillary hemodynamics in systemic hypertension [25], but also to the damage of cell membranes and other effects which, unfortunately, escape to the exact detection (sonography, magnetic resonance spectrography, thermography, and the other methods). The microcirculation defects in myocardium cannot be detected by CAG method [1], which is also insufficient for the detection of degenerative changes in coronary arteries in comparison with the results of intravascular sonography or direct angioscopy [6]. The detection

Table 4 – The heart rate, PQ, QRS, QT (ms) intervals and the QRS angle in the frontal plane (degrees) in 23 controls and in 25 patients with CHD examined by coronarography with the 12-lead ECG (the men and women examined together). Mean values ± standard deviations

	Controls (n=23)	CHD (n=25)	p
Heart rate /min.	71±10	66±18	–
PQ (ms)	142±18	160±20	–
QRS (ms)	93.3±10	116±12	–
QT (ms)	360±20	402±18	<0.05
QRS angle (degrees)	+45±16	+13±12	<0.05

of vasospasm doesn't correlate in Prinzmetal angina including the ECG changes, which are manifested only in 3% of the cases. To precise the CAG in spasm it is convenient to observe the index of fraction flow by repeatedly measured intravenous pressure [9].

The routine ECG and the changes of stress exercise ECG test have in CHD the important validity, which is of about 72–75%. From the contemporary noninvasive methods one ought to use the SPECT method and biochemical markers, but the BSM method is more precise than the routine ECG (Tab. 4) with the next perspective, which appraises the aetiology of BSM changes.

In spite of these facts we are aware that the more-leads- ECG has only restricted possibilities in the clinical diagnosis of CHD. It is an auxiliary but valuable examination method [26].

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