Application of body surface potential mapping in coronary artery disease diagnosis

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ABSTRACT

Objective: Body surface potential mapping (BSPM) is essentially recommended for detecting and evaluating abnormalities of cardiac electric field specific for various stages of ischemic state of myocardium caused by coronary artery disease (CAD). In this regard, a goal of the present paper was to summarize the BSPM results, which were gathered in our laboratory for several years from the patients with CAD.

Methods: In a group of 110 patients (mean age: 48.4±6.2 years) with angiographically documented critical single-vessel (SVD) coronary artery disease among them 52 patients with left anterior descending artery (LAD) involvement, 40 patients with right coronary artery (RCA) and 18 patients with left circumflex artery (Cx) lesions, without any specific ischemic changes on standard resting 12-lead electrocardiogram (ECG), isointegral and departure ST-T maps were recorded using Fukuda Denshi (Tokyo, Japan) 87-electrode system for BSPM.

Results: Significant decrease of the minimum values of ST-T maps was found only in patients with LAD involvement. Typical distribution of the negative potential was found on ST-T map for each of LAD, RCA and Cx stenosis. Overall sensitivity of abnormal distribution of ST-T maps was 55.5% for the SVD group. In 21/96 of the SVD patients in whom exercise test was performed, the result was negative. Generally, in 12 of these 21 patients, the abnormal ST-T maps were observed (57.1%). The RCA lesion group had abnormal ST-T maps in 75% of the patients with negative exercise test. The corresponding ratios were 71.4% for LAD, and only 16.7% for Cx patients.

Conclusion: ST-T resting maps are of some value in diagnosing stable ischemic heart disease. *(Anadolu Kardiyol Derg 2007: 7 Suppl 1; 16-9)*

Key words: single-vessel disease, resting ECG, body surface potential mapping, ST-T isointegral maps

Introduction

Method of body surface potential mapping (BSPM) is based on specific approach to recording, analysis and presentation of cardiac electric field activity. In this method, electrocardiographic signals are collected simultaneously from numerous leads covering the entire surface of the thorax. Body surface potential mapping is considered to be of great advantage in comparison with standard 12-lead electrocardiogram (ECG) measurements. As it was widely documented, BSPM has a unique spatial resolution, and at the same time, it retains completely a time-signal relation typical for standard ECG. Owing to the above-mentioned features, BSPM examinations enable to assess selectively the individual portions of the myocardium with regard to the local changes ongoing in the cardioelectric space.

Analysis of information obtained using BSPM can be performed in different manners, depending on attainable kind of body surface maps created in computerized systems. Isopotential maps make possible to monitor precisely successive phenomena taking place during depolarization and repolarization of the cardiomyocytes, but, on the other hand, these maps contain such data abundance that sometimes it is difficult to perform any quick interpretation, especially in clinical conditions. The much more simple form of presentation of BSPM results is the isointegral technique, which constitutes a resultant effect of the global heart potential fluctuations integrated within the designated time interval of the cardiac cycle. From the practical point of view, the most useful technique seems to be departure maps, in which the mean values of the heart potentials with the standard deviations established for the normal subjects group are taken into consideration; therefore the departure map present exclusively the evidently pathological heart potential areas (1-10).

Body surface potential mapping is essentially recommended for detecting and evaluating abnormalities of cardiac electric field specific for various stages of ischemic state of myocardium caused by coronary artery disease (CAD). In this regard, a goal of the present paper was to summarize the BSPM results, which were gathered in our laboratory for several years from the patients with CAD.

Methods

Body surface potential mapping examinations were performed using HPM-7100 Fukuda Denshi (Tokyo, Japan) system equipped with 87 recording electrodes mounted on the 13 adhesive strips covering the whole anterior (59 leads) and posterior (28 leads) thoracic surfaces. The ECG signals were sampled simultaneously, with the Wilson's central terminal as reference, at the rate of 1000 Hz, and then averaged for the ten subsequent cardiac cycles. In this system, the thorax is presented on the body

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surface maps in the form of developed cylinder, the left side of which presents the anterior torso (strips B-H), and the right side the posterior torso (strips J-M).

For the purpose of the study, ST-T isointegral maps were created by calculating the algebraic sum of the all instantaneous potentials throughout the ST-T interval assigned from the standard ECG II lead, according to the formula:

$$C_{ij}=S_0^n (a_{ij}),$$

where: C - integral; a - instant potential; ij - vertical and horizontal electrode rows

The second kind of the analyzed maps were ST-T departure maps, which, from definition, concerned the individual patient. The maps were constructed automatically after calculating the departure index (DI), as follows: DI=(P- X)/ SD, where: P - potential value at the given lead point in the patient; X - the mean potential value at the given lead point in the control group; SD-standard deviation for the given lead point in the control group.

Control group

Control group consisted of 95 normal subjects (55 males, 40 females; the mean age: 42.8±11.3 years). The all but one of the subjects had no clinical evidence (history, 12-lead ECG, 24-hour Holter ambulatory monitoring, chest X-rays, echocardiography) of cardiovascular impairments. The BSPM recordings obtained in the control group served for creating the normative group-mean isointegral ST-T maps. Then, these pattern maps were the reference for the BSPM results obtained from the patients with CAD.

Patient group

The patient group comprised 110 subjects with angiographically documented single-vessel (SVD) coronary artery disease. The main data regarding the study SVD group are presented in Table 1.

The all enrolled patients had clinically diagnosed stable form of angina pectoris in the class I-II CCS. In coronary angiography, it was found that in each of the patients only one coronary artery was narrowed by more than 75%, therefore a diagnosis of SVD was made. Echocardiographic examination in 90% of the patients showed normal global left ventricular systolic function with retained ejection fraction (>45%), and in 40% of the patients segmental hypokinesis was observed. The main criterion of including patients to the study group was an absence of any specific abnormalities of ST-T segment on the 12-lead ECG taken at rest, when the patient was free of anginal pain. Patients with previous myocardial infarction, ventricular hypertrophy and bundle branch blocks were excluded from the study.

On the basis of BSPM recordings, in the study group with SVD two types of maps representing ST-T interval were created, i.e., isointegral ST-T maps and departure ST-T maps.

Table 1. Statistical data for SVD patients

No.	M/F	Mean age (±SD)	Artery stenosed		
			LAD	RCA	Cx
110	78/32	48.4±6.2 years	52	40	18

Cx- left circumflex coronary artery, F- female, LAD- left anterior descending artery, M- male, RCA- right coronary artery, SVD- single-vessel disease

Results

Before BSPM registrations, 96 out of 110 patients were recruited to treadmill exercise test according to Bruce's protocol. Positive result of exercise test was noted in 59/96 patients (61.5%), negative one in 21/96 patients (21.9%), and ambiguous one in 16/96 patients (16.6%). Thus, inconclusive exercise test results concerned 38.5% of those SVD patients.

In the patients with SVD, ST-T isointegral and departure maps were analyzed, because repolarization period is an essential exponent of ischemic changes on standard ECG.

Assuming that on BSPMs a pathologically deep and large negative potential area is the crucial feature of local ischemic zone in myocardium, both values of minimum (Table 2) and distribution of negative potential were evaluated.

As it is shown in Table 2, a statistically significant decrease of the negative potential values on the ST-T isointegrals was found only in the patients with critical left anterior descending artery (LAD) stenosis.

In order to perform a more reliable assessment of distribution of negative potentials recorded in the SVD patients within repolarization period, on the basis of ST-T isointegral maps the corresponding ST-T departure maps were created. Visual analysis of the both types of ST-T maps rendered the following information: (1) the number of patients with single-vessel disease, in whom ST-T maps revealed abnormal distribution of negative potential; (2) location of negative potential on ST-T maps typical for stenosis of particular coronary artery.

In general, in the SVD group, the pathological negative potential area was observed in the both types of the analyzed ST-T maps in 61 out of 110 patients (55.5%). The data concerning abnormality of ST-T maps in the subgroups with stenosed LAD, right (RCA) and left circumflex (Cx) coronary arteries are displayed in Table 3.

Table 3. ST-T maps with abnormal negative potential in SVD patients

SVD	No.	Abnormal ST-T maps, n	Sensitivity, %
LAD	52	29	55.8
RCA	40	25	62.5
Cx	18	7	38.9
Total	110	61	55.5

Cx- left circumflex coronary artery, LAD- left anterior descending artery
RCA- right coronary artery, SVD - single-vessel disease

Table 2. Mean values of minimum for ST-T isointegrals in SVD patients vs controls

	Controls	LAD	RCA	Cx
Minimum ST-T isointegral, mVs	-31.80±11.80	-45.70±13.40	-36.80±12.70	-34.50±11.90
p		<0.01	NS	NS

Cx- left circumflex coronary artery, F- female, LAD- left anterior descending artery, M- male, NS- not significant, RCA- right coronary artery, SVD- single-vessel disease

Generally, among the patients of the SVD group, in whom exercise ECG treadmill test was performed (96 patients), the ST-T maps with the pathological negative potential were found in 53 out of 96 patients (55.2%), and 12/53 patients (22.7%) had finished the exercise test with the negative result. The largest percentage of the abnormal ST-T maps was noted in this subset among the patients with RCA stenosis, i.e., in 22 of 33 (66.7%), and 6/22 subjects (27.3%) showed the negative exercise test. As to the patients with LAD disease, pathological ST-T maps were observed in 25 of 49 of them (51.0%), and 5/25 patients (20.0%) manifested the negative exercise test. The least number of distorted maps was found in the subgroup with Cx stenosis, namely in 6 of 14 patients (42.9%); in this case 1/6 subjects (16.7%) had the negative exercise test (Table 4).

From the other point of analysis, in 21 out of 96 patients (21.9%), whose exercise test was found to be negative, in 12/21 (57.1%) the abnormal ST-T maps were observed. In LAD subgroup, 5 of 7 patients (71.4%) with the inconclusive exercise test revealed abnormal distribution of the ST-T maps. Stenosis of RCA was found respectively in a ratio 6/8 (75.0%), and the coronary lesion ratio in Cx subgroup was only 1/6 ratio (16.7%).

The throughout analysis of potential distribution on ST-T maps in the patients with SVD rendered a possibility of creating the schematic pattern map for critical stenosis of individual coronary artery. The pattern ST-T map for LAD stenosis presented a deep, negative potential distributed in the upper middle portion of the left side of the thorax. In turn, the map representative for RCA stenosis showed the negative potential area covering the lower portion of the whole thoracic surfaces. As to the ST-T map typical for Cx stenosis, the prominent negativity was located vertically along the left margin of the thorax.

Discussion

Coronary artery disease, especially in the initial stage, is a local event concerning both electrophysiological and mechanical aspects. As it is commonly know, the patients with angiographically documented stenosis of coronary arteries and clinically overt presentation of angina pectoris often do not manifest the specific abnormalities on standard resting ECG, which would be strongly suggestive for diagnosing ischemic heart disease. The unique selective sensitivity of body surface potential mapping is of great discriminative significance in case of patients with subjective signs of coronary artery disease, but without any evident changes of ST-T interval on 12-lead ECG recordings taken in resting state (11-14).

In the present study, the subject of interest were the problematic patients with angiographically proved single-vessel disease, who manifested in the individual coronary artery lesion causing critical stenosis (at least 75%) of the artery lumen. The all patients had no typical ischemic changes within repolarization period on resting standard ECG. The most of the recruited SVD patients (96/110) underwent exercise treadmill test, which turned out to be inconclusive (negative or doubtful) regarding CAD diagnosis in 37 /96 of those patients, meaning 38.5% of the considered SVD group.

Table 4. ST-T abnormal maps in SVD patients with exercise test results

SVD	No.	Abnormal ST-T maps		Negative tests		Negative tests and abnormal ST-T maps	
		n	%	n	%	n	%
LAD	49	25/49	51.0	7/49	14.3	5/25	20.0
RCA	33	22/33	66.7	8/33	24.2	6/22	27.3
Cx	14	6/14	42.9	6/14	42.9	1/6	16.7
Total	96	53/96	55.2	21/96	21.9	12/53	22.7

Cx- left circumflex coronary artery, LAD- left anterior descending artery, RCA- right coronary artery, SVD- single-vessel disease

It seemed of interest to compare the results taken from routine 12-lead resting ECG with the findings obtained using multielectrode BSPM recorded in patients being also in resting state. For analyzing body surface maps, ST-T period, the most exponent for ischemic changes, was chosen. In order to simplify the interpretation process, isointegral and departure ST-T maps were considered.

The obtained results revealed that quantitative parameters of the maps, i.e., minimum potential extremum values did not show a sufficient sensitivity in detecting myocardial site affected by ischemia. A significant reduction in the minimum values on the ST-T maps was found only in case of LAD stenosis, which probably results from easy-to-record ischemic changes related to location and large size of this coronary artery.

Concerning pathological distribution of negative potential (qualitative parameter), which reflects myocardial zones of ischemia, it was interesting that the pattern ST-T maps, established on basis of abnormal ST-T maps obtained from the SVD patients for particular critically stenosed coronary arteries, showed the strongly individualized location of the negative potential area, which was situated in intriguing accordance to anatomical course in relation to the thorax surfaces of LAD, RCA, and Cx, respectively.

Overall sensitivity of abnormal negative potential distribution on ST-T maps was estimated as 55.5% for the whole SVD group. For the individual critically stenosed artery the sensitivity levels were, as follows: RCA 62.5%; LAD 55.8%; Cx 38.9%.

Furthermore, abnormal distribution of the ST-T maps could be compared in the SVD patients with diagnostically indecisive results of exercise ECG testing. Among the 96 SVD patients, in 21 of them the result of exercise test was negative. It is worth noting that in 12 out of these 21 patients with negative exercise test, the abnormal ST-T maps were observed (57.1%). In the RCA cases, 8/33 patients (24.2%) had the negative exercise test, and in 6 out of these 8 patients (75%), the distorted ST-T maps occurred. It could be concluded that just for this group, ST-T maps turned out to be of the best sensitivity. In the LAD subgroup, where the negative exercise tests were observed in 7/49 patients (14.3%), in 5 out of these 7 patients (71,4%), the ST-T maps were apparently abnormal. Finally, 6/14 (42.8%) of the Cx patients showed negative exercise test, however in this case in only 1/6 subjects (16.7%), BSPM could be of any help in diagnosing CAD.

Summing up the presented results, it could be concluded that, taking into consideration unsatisfactory effects of detecting myocardial ischemia with standard 12-lead ECG, not only resting but exercise one as well, a possibility of using noninvasive BSPM examination seems to be a beneficial alternative.

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