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Repolarization Pattern of Body Surface Potential Maps (BSPM) in Coronary Artery Disease

O. KITTNAR, J. SLAVÍČEK, M. VÁVROVÁ, M. BARNA, A. DOHNALOVÁ, A. MÁLKOVÁ[1], M. ASCHERMANN[2], J. HUMHAL[2], J. HRADEC[3], J. KRÁL[3]

Institute of Physiology, First Medical Faculty, Charles University, [1]Institute of Physiological Regulations, Czech Academy of Sciences, [2]Second Medical Department, First Medical Faculty, Charles University, and [3]Third Medical Department, First Medical Faculty, Charles University, Prague

Summary

The aim of our study was to assess if repolarization BSPM were able to evaluate the site, size and severity of chronic ischaemic damages and if BSPM were in any way related to the regional attenuation of myocardial contractility or to the site of coronary artery occlusion. The BSPM were obtained from 69 patients suffering from coronary artery disease confirmed by coronarography, with at least 75 % occlusion of at least one coronary artery. According to the site of single occlusion, or a combination of the sites of multiple occlusions, the patients were divided into 6 subgroups. According to the region of attenuated kinetics the same group of 69 patients was also divided into other 6 subgroups. As in the polarity distribution there was only a limited accordance in BSPM with coronarographic and echocardiographic findings, in the localization of extreme values there were very important specific changes in patients with normal kinetics as determined by both contrast ventriculography and two-dimensional echocardiography. The repolarization maps can distinguish patients with coronary artery disease and normal echocardiography from healthy persons with a sensitivity of 85 % and a specificity of 65 % in the case of the isoareal map from the ST segment (RIAM) and 90 % and 85 %, respectively, in the case of the isointegral map from the whole ST-T segments (RIIM).

Key Words

Body surface potential maps – Coronary artery disease – Repolarization – Cardiac wall kinetics

Introduction

The repolarization maps are represented by two phases of a different physiological and pathophysiological content – ST segment and T wave. It is generally accepted that the ST segment is normally isoelectric and the deviations from the isoelectric line in patients suffering from coronary artery disease are supposed to be a sign of ischaemic damage. Numerous studies have proved that the T wave originates from inhomogeneous electrical recovery of the ventricles (Harumi *et al.* 1966, Spach *et al.* 1976) and that T wave inversion is intimately related to the presence of delayed recovery resulting from various pathological states (Harumi *et al.* 1990, Chen *et al.* 1991, Yamaki *et al.* 1992) which most frequently accompany myocardial ischaemia or left ventricular hypertrophy.

Both diagnostic and prognostic significance of repolarization body surface potential mapping (BSPM) in patients with and after acute myocardial infarction was recently demonstrated in many studies (Mirvis 1980, Mirvis 1981, Bell *et al.* 1989, Walker *et al.* 1987). The most important advantage of BSPM techniques described in these studies is their ability to provide more detailed regional cardiac electrophysiological information than the standard 12-lead electrocardiogram. The aim of this study was to assess if the repolarization BSPM were able to evaluate the site, size and also the severity of chronic ischaemic damage, and if they were in any way related to the regional attenuation of myocardial contractility or to the site of coronary artery occlusion (as it was found in the depolarization maps - Horan *et al.* 1990).

Methods

The BSPM were obtained from 69 patients, 51 men and 18 women, 36–64 years old, suffering from coronary artery disease confirmed by coronarography with at least 75 % occlusion of at least one coronary artery. Forty-six of them (32 men and 14 women) had undergone myocardial infarction The period from the onset of acute myocardial infarction was from 3 months to 4 years. Twenty-three patients (19 men and 4 women) have been admitted due to angina pectoris without myocardial infarction in their history.

All the patients underwent diagnostic cardiac catheterization and coronary arteriography by Judkins' technique. The cineangiograms in both right and left anterior oblique views were evaluated visually to estimate the percentage of luminal occlusion. There were 24 patients with only single-vessel disease, 33 with two-vessel disease, and 12 with three-vessel disease. According to the site of single occlusion or combination of the sites of multiple occlusions the patients were divided into another 6 subgroups (Table 1). Both overall and regional contractility of the left ventricle was evaluated from the two-dimensional echocardiography performed in four standard projections and confirmed by the right anterior oblique ventriculograms. According to the region of attenuated kinetics, the same group of 69 patients was divided into another 6 subgroups (Table 1). The patients with right or left ventricular hypertrophy or with bundle branch block were excluded from the study.

Table 1
Two types of subdivision of patients with coronary artery disease (CAD) group in subgroups

GROUP	CHARACTERISTICS	NUMBER
	division according to coronarograms:	
	occlusion of:	
1.1	left anterior descending (LAD)	14
1.2	right coronary artery (RCA)	10
1.3	LAD + left circumflex (LCx)	9
1.4	LAD + RCA	15
1.5	RCA + LCx	9
1.6	RCA + LAD + LCx	12
	division according to echocardiography:	
	hypokinesis or akinesis of region:	
1.A	none (overall good contractility)	20
1.B	anteroseptal (A + S)	7
1.C	anteroapical (A + X)	9
1.D	apical (X)	9
1.E	anterolateroapical (A + L + X)	9
1.F	inferoposterior (I + P)	15
	CORONARY ARTERY DISEASE	**69**
2	**REFERENCE GROUP (healthy volunterees)**	**25**

Table 2
List of quantitative maps parameters (maximal [max] and minimal [min]/ potential [RIPM] and integral [RIIM, RIPM]/ values which are able to distinguish reference group from subgroups of patients). The numbers of RIPM maps represent the moment in which the map is constructed: 1 = 10 % of ST-T segment, 2 = 2 0 %, 4 = 40 %, 5 = 50 %, 6 = 60 %, 7 = 70 % and 8 = 80 %. The statistic significance is represented by crosses: + = 0.05, + + = 0.01, + + + = 0.001. Numbers are the mean values/standard deviation, in RIPM in μV, in RIAM and RIIM in μV.s.

MAP value	DIFFERING SUBGROUPS GROUP FROM: SUBGROUP	SUBGROUP	SUBGROUP
RIIM MIN	2 -331.4 104.1	1.A + -209.0 88.0	1.C + -177.9 35.3	1.D + -186.6 78.1
RIPM1 MAX	2 272.7 97.6	1.A + 174.6 126.7		
RIPM4 MIN	2 -127.8 41.2	1.A + + + -76.9 31.6		
RIPM5 MIN	2 -165.6 55.8	1.A + + + -90.0 34.8	1.C + + + - 94.1 21.8	1.D + + + -86.3 57.8
RIPM6 MIN	2 -209.4 74.4	1.A + + + -105.7 37.1	1.C + + + - 97.3 17.6	1.D + + -94.9 54.3
RIPM7 MIN	2 -241.7 89.5	1.A + + + -119.3 39.7	1.C + + + -112.4 26.5	1.D + + + -112.7 50.5
RIPM8 MAX	2 568.7 206.1		1.C + 307.0 150.3	
RIPM8 MIN	2 -236.2 88.2	1.A + + + -127.7 48.7	1.C + + + -126.1 35.9	1.D + + + -126.9 42.6
RIIM MAX	2 957.1 266.4			1.4 + 580.1 308.9
RIIM MIN	2 -331.4 104.1	1.1 + -207.6 95.4		
RIPM1 MAX	2 272.7 97.6			1.4 + 153.7 132.1
RIPM2 MAX	2 181.1 68.2			1.4 + 99.9 75.8
RIPM5 MAX	2 581.2 191.2	1.1 + 322.4 235.6		1.4 + 309.1 233.6
RIPM5 MIN	2 -165.6 55.8	1.1 + + - 94.2 50.1	1.2 + - 98.0 29.1	1.4 + -102.0 50.6
RIPM6 MAX	2 681.0 213.4	1.1 + + + 371.4 275.9		1.4 + + + 355.8 222.1
RIPM6 MIN	2 -209.4 74.4	1.1 + + + -108.4 63.7	1.2 + -123.9 30.8	1.4 + + + -111.9 46.3
RIPM7 MAX	2 689.9 207.8	1.1 + 393.7 245.4		1.4 + + 373.9 211.4
RIPM7 MIN	2 -241.7 89.5	1.1 + + -130.6 79.0	1.2 + + -144.2 37.4	1.4 + + + -126.6 45.4
RIPM8 MIN	2 -236.2 88.2	1.1 + + -145.7 82.8		1.4 + + -139.5 60.3

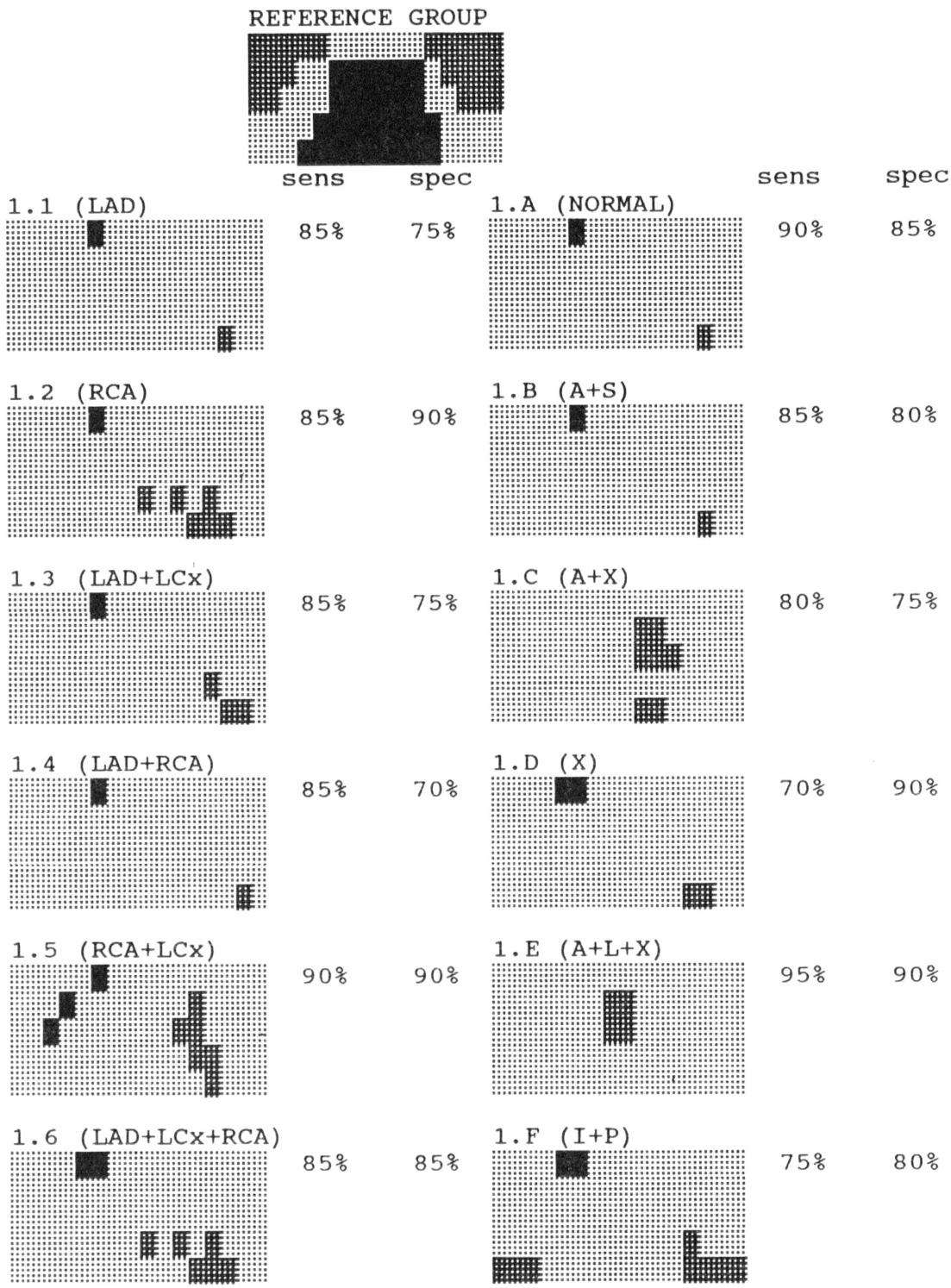

Fig. 1
RIIM map. The electropositivity (black color) and electronegativity (dark gray color) distribution in the reference group [only the regions with 95 % reliability are marked, in the resting regions the positivity or negativity has less than 95 % of appearance]. In the particular pathological subgroups the regions of positivity (black color) and negativity (dark gray color) that are able to distinguish the subgroup from the reference standard are mark with their sensitivity (sens) and specificity (spec).

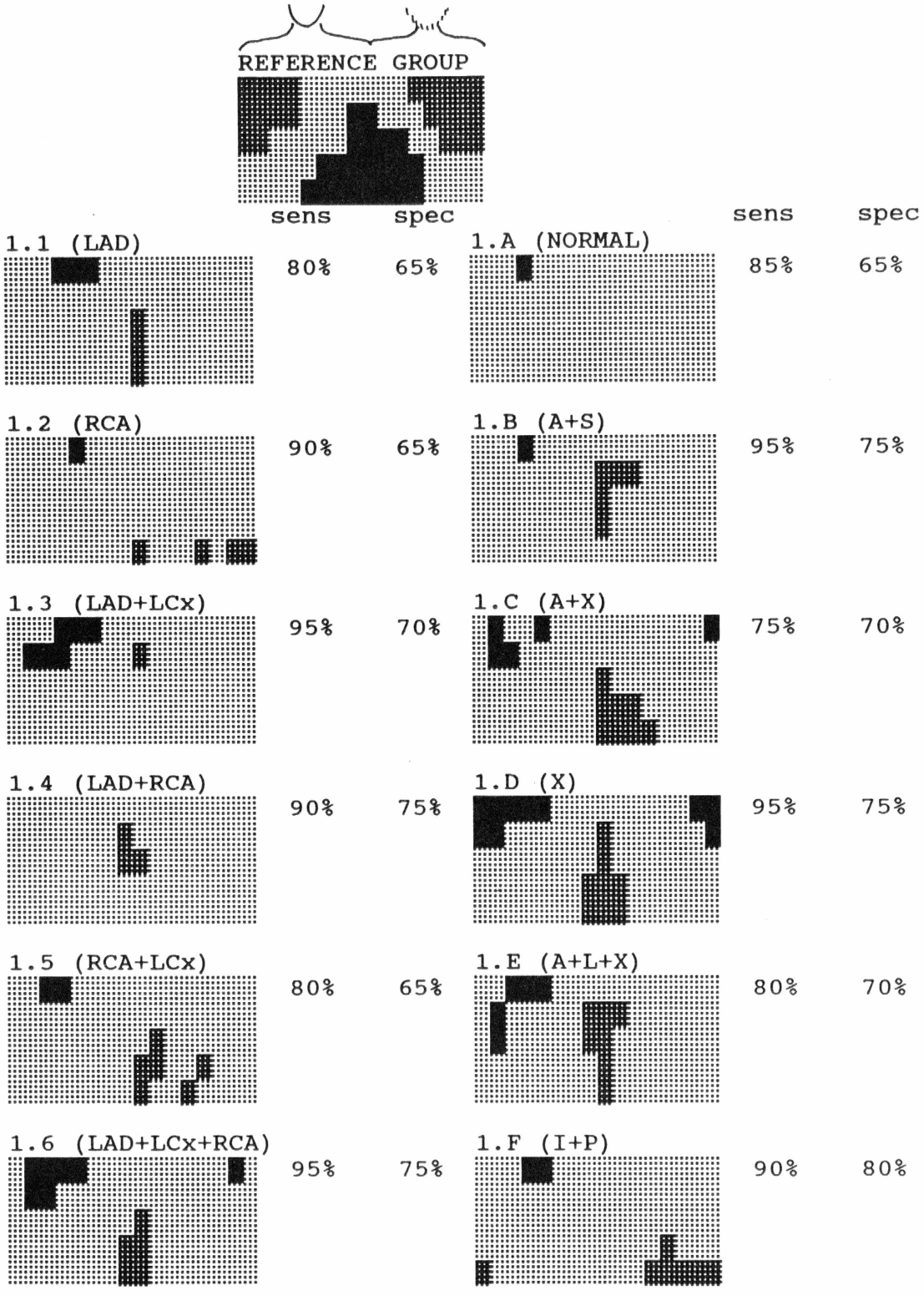

Fig. 2
RIAM map. For the description see Fig. 1.

The reference standard for this study consisted of 25 normal subjects, 15 men and 10 women, aged 22 – 49 years, with no known heart disease or symptoms in their personal history. All of them underwent stress ECG and echocardiographic examination without pathological findings. All of them were non-smokers, had normal blood pressure, blood glucose and cholesterol levels.

Both patients and reference groups were electrocardiologically examined using the CARDIAG 112.2 device. The signals were simultaneously recorded from 12 standard electrocardiographic (ECG) leads, Frank's orthogonal vectorcardiographic (VCG) leads and 80 unipolar leads placed on the chest surface with Wilson's central terminal. The obtained signals were preprocessed and then computed into the pattern of ECG curves, VCG loops and body surface potential maps. The onsets and offsets of the waves and the QRS complex were found automatically from the spatial magnitude curve on the VCG with a possibility of correction. The isopotential repolarization maps (RIPM), an isoareal map (RIAM) from the first 35 % of repolarization, and an overall repolarization isointegral map (RIIM) were used for evaluating the repolarization .

Data from the standard CARDIAG software were then processed by an original program "SK1.C". This program enables the identification in selected maps and stores the maximal and minimal values including their localization and the regions of electropositivity and electronegativity. The data thus obtained are saved in statistical files of the groups and subgroups of patients and can be transferred into conventional statistical software. In this study we used BMDP programs for the analysis of variance in order to asses a significance of groups differences.

Based on the data of true positives, true negatives, false positives and false negatives in the subgroups, information was obtained about the sensitivity and specificity values in the regions of electropositivity or electronegativity that distinguish a selected patient subgroup from the reference group.

Results

The mean values and standard deviations (maximal and minimal values from the above mentioned repolarization maps) of those subgroups that can be clearly distinguished by these values are summarized in Table 2. From the coronarographic point of view both the subgroup with single-vessel disease (LAD and RCA) and that one with LAD-RCA combination differed significantly from the control group. From the echocardiographic point of view the subgroups with decreased kinetics of apical and anteroapical regions and subgroup with normal kinetics could be distinguished from the control group.

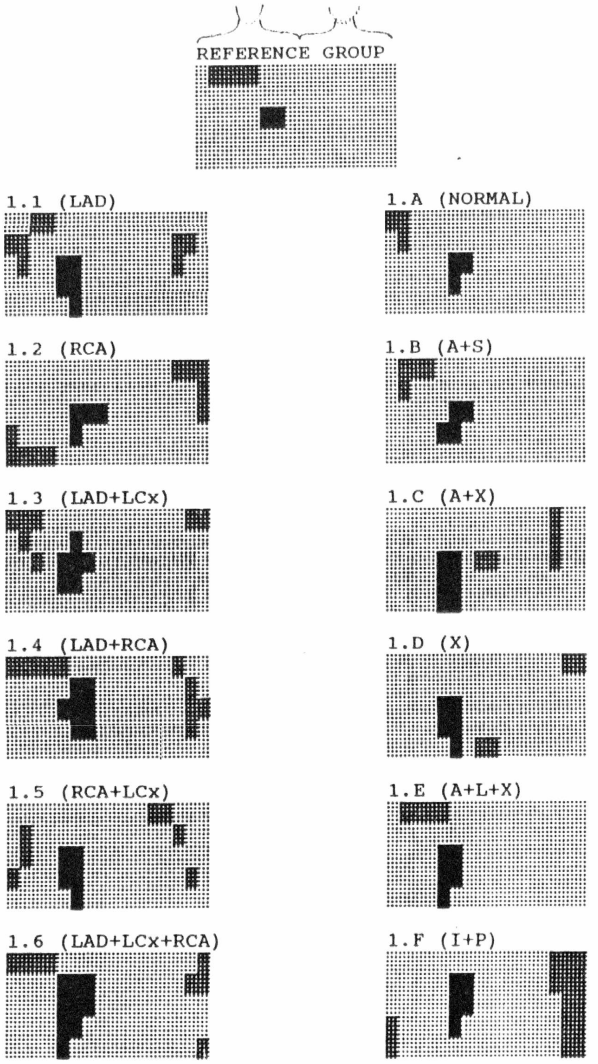

Fig. 3
RIIM map. Localization of maximal (black) and minimal (dark gray) values in the reference standard and in the particular subgroups.

The electropositive and electronegative regions distinguishing the particular subgroups from the reference group on the RIIM and RIAM are shown in Figs 1 and 2. On the RIIM two regions are very typical for coronary artery disease (Fig. 1): the upper left parasternal region which is negative in the control group and positive in coronary artery disease subgroups, and the lower left paravertebral region which is positive in the control group and negative in the coronary artery disease subgroups. Moreover, the results correspond better with the echocardiographic definition of subgroups; especially the subgroups with decreased kinetics of anteroapical, anteroapicolateral and inferoposterior regions have very typical patterns of polarity distribution. Similar results were obtained using RIAM (Fig. 2).

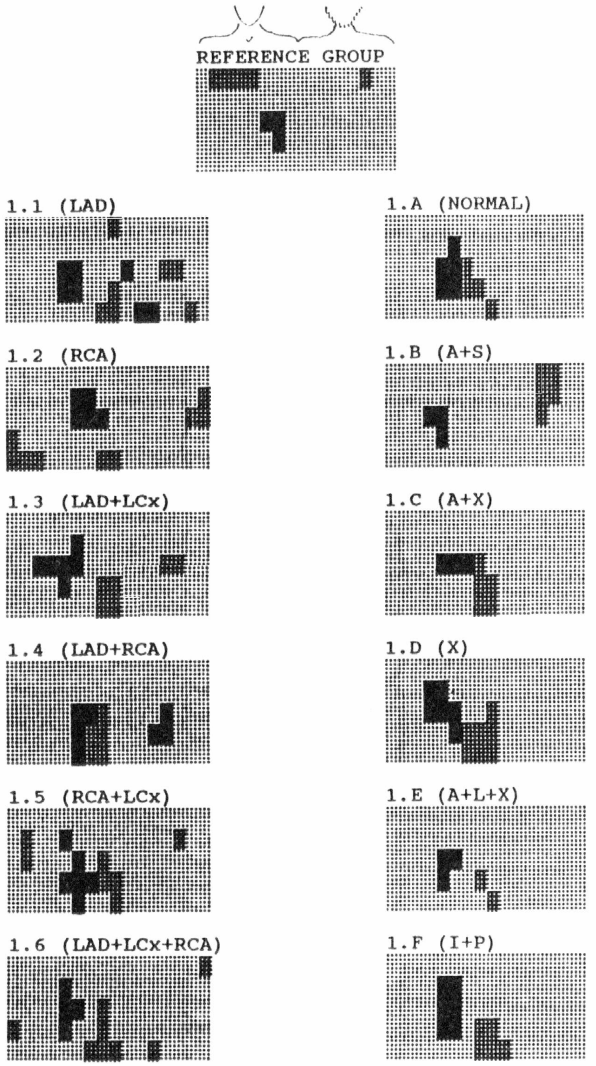

Fig. 4
RIAM map. For the description see Fig. 3.

The localization of the minimal and maximal values on the RIIM and RIAM maps in all subgroups are given in Figs 3 and 4. In both RIIM (Fig. 3) and RIAM (Fig. 4) the regions of maximal values localization cannot distinguish coronary artery disease subgroups from the reference group, but there is a significant difference between control group and coronary artery disease subgroups in minimal values distribution, especially in RIAM.

Discussion

RIPM, RIIM and RIAM were used to estimate the location and the extent of myocardial ischaemia in patients with chronic coronary artery disease. The location and the extent of ischaemic damage were defined using either coronarographic or echocardiographic findings. Some of the subgroups could be distinguished by the maximal and minimal values of the electrical potential in selected maps (Table 2). The RIPM maps during the T wave (the second half of repolarization) were better for clear-cut differentiation; there was no difference between the distinguishing ability of the maximal and minimal values in different periods of repolarization.

The RIIM and RIAM maps were used for the evaluation of electropositivity and electronegativity distribution as the results in specificity and sensitivity values in RIPM maps were less reliable. Furthermore, the advantage of these types of maps is the data compression with retention of the major features of the spatial content and temporal sequence. All subgroups could be distinctly distinguished from the reference group by characteristic regions of abnormal electropositivity or electronegativity (Figs 1 and 2), but there is only a little correlation of BSPM with coronarographic and echocardiographic findings, respectively. This result is not surprising, because each method describes other specific features of the myocardial pathophysiology and the poor correlation between the results obtained by different techniques in the case of indirect measurements of infarct size has already been described (McPherson *et al.* 1985). The most important result, however, concerns the specific changes in potential distribution in patients with coronary artery disease, but who have normal echocardiographic findings. The same maps (RIIM and RIAM) were used for determining the localization of maximal and minimal values. The results were similar, but for distinguishing the particular subgroups from the reference values, only the localization of minimal values was useful. This is not surprising because such a region in the RIAM map represents the site of maximal ST depression and in the RIIM map the site of maximal T wave reversion. Similarly as in the polarity distribution there was a poor accordance in the localization of extreme values in BSPM with the coronarographic and echocardiographic findings. However, very important specific changes were found in patients with normal kinetics determined both by contrast ventriculography and two-dimensional echocardiography.

The present study, however, has two disadvantages. The first is that the reference group is not fully comparable to the group of patients as far as the sex and age distribution is concerned. Nevertheless, from the study of Green *et al.* (1985) performed on a large group of healthy persons of different ages and sex, it can be concluded that the only significant difference between young and old subjects, and between men and women, is in the extreme values; the distribution of polarities and the localization of extreme values do not differ. The second disadvantage is the small number of patients in some subgroups. For this reason, it is not possible to make definite conclusions for some particular subgroups. However, the number of patients in group 1.A (with normal echocardiographic findings) and in the reference group is sufficiently great for drawing the conclusions mentioned above.

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Reprint Requests

O. Kittnar, M.D., Ph.D., Institute of Physiology, First Medical Faculty, Albertov 5, 128 00 Prague 2, Czech Republic.