Ventricular Repolarisation Analysed in Young Adult Men and Women Using Autocorrelation Maps

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Abstract. *Electrocardiographic voltage distributions over the whole chest surface can be displayed in form of a set of isopotential maps (IPMs) that can be analysed quantitatively using the Pearson´s correlation coefficient allowing the construction of autocorrelation maps (ACMs). The aim of this retrospective study was to analyse the ACMs in young adults during the time standardised ST-T interval assuming slow changes of repolarisation. We constructed 21 IPMs at equidistant intervals for 89 young adult controls (41 men). For each ST-T interval, every IPM was compared with every IPM using Pearson's correlation coefficient r. These values were displayed in form of ACMs. The mean correlation coefficients of single ACMs were 0.838 ± 0.073. The high positive correlation $r \geq 0.900$ covered in average (53 ± 13) % of the whole ACM area. Negative correlations occurred at the ACM borders with the mean value - 0.067 ± 0.062. We identified 4 basic types of ACMs according to the values of correlation coefficients. In the first 3 types, only positive correlation coefficients occurred. In the type I, the high positive correlation coefficients $r \geq 0.900$ covered at least 75 % of each single ACM area (7 cases); in the type II, 50 % - 75 % (42 cases); in the type III, 25 % - 50 % (30 cases). In the type IV, negative correlation occurred (10 cases). This is in accordance with our hypotheses that the ST-T map pattern changes only slowly in healthy subjects.*

Keywords: Body surface potential mapping; Ventricular repolarisation; Autocorrelation maps; Time standardisation

1. Introduction

Voltage distributions over the whole chest surface can be displayed in form of a set of isopotential maps (IPMs) that can be analysed quantitatively using the Pearson´s correlation coefficient [1] allowing the construction of autocorrelation maps (ACMs). Autocorrelation maps concerning body surface potential mapping were first introduced in 1976 [2] to express the normal ventricular repolarization in the body surface distribution of T potentials. Until now, the autocorrelation maps were used to analyse the effect of intrathoracic heart position on electrocardiogram [3], and the atrial activation and ventricular depolarisation in healthy young adults [4, 5].

The aim of this retrospective study was to analyse the autocorrelation maps in young adults during the time normalised ST-T interval. We assumed that the ST-T map pattern changes only slowly in healthy subjects, therefore, the autocorrelation maps should present prevailingly positive values of correlation coefficients close to 1.

2. Subject and Methods

We studied 89 young adults, 48 women, 41 men, mean age (18.6 ± 0.4) years. None of the subjects had signs of cardiovascular diseases or cardiovascular risk. All subjects had normal

12-lead standard electrocardiographic and echocardiographic findings as well as blood pressure values.

Unipolar electrocardiograms for body surface potential mapping were registered using the limited 24-lead system after Barr based on a grid of 10 rows and 15 columns and processed using the mapping system ProCardio [6, 7]. All data were registered in supine position during normal expiration. Linear baselines were taken through two sequential TP segments in each electrocardiogram. The onset of the ST segment (equal to the QRS complex end) and the offset of the T wave were established manually from the root mean square signal. For time standardisation, the ST-T interval of each subject was divided into 20 equidistant parts. We constructed 21 isopotential maps for each subject [8]: the first map (map 1) corresponded to the ST segment beginning, the last map (map 21) to the T wave end (Fig. 1). For each subject, every isopotential map (let say map A) of a single beat was compared with every isopotential map (let say map B) of the same beat using the Pearson´s correlation coefficient r (r_{AB}) [1]

$$r_{AB} = \frac{\sum_{i=1}^{150} \left(U_{Ai} - \overline{U}_A\right) \cdot \left(U_{Bi} - \overline{U}_B\right)}{\sqrt{\sum_{i=1}^{150} \left(U_{Ai} - \overline{U}_A\right)^2} \cdot \sqrt{\sum_{i=1}^{150} \left(U_{Bi} - \overline{U}_B\right)^2}}, \quad (1)$$

where U_{Ai} (U_{Bi}) is the value of the electric potential in the i^{th} point of the map A (B),

$\overline{U}_A$ ($\overline{U}_B$) is the mean value of the electric potential of the whole map A (B).

Comparisons were presented in form of autocorrelation maps, i. e. squared graphs displaying the correlation coefficients of every possible pair of IPMs. The ACMs have the values $r = 1$ on the main diagonal and are symmetrical due to it (Fig. 2). We analyzed the regions with positive correlation $r \geq 0.500$ corresponding to slow potential distribution changes. Results are given in form of mean values ± standard deviations. Parameter comparisons between men and women were performed using unpaired t-test as all evaluated data were normally distributed.

3. Results

The isopotential maps of the ST-T interval revealed typical features (Fig. 1). Positive potentials appeared over the most of the anterior and the left lateral chest with the maximum located in the midprecordial region. Negative potentials occupied much smaller areas on the right upper anterior and posterior chest. The spatial distribution of positive potentials remained constant throughout the whole ST-T interval only changing the values of a single maximum. A single minimum moved between the upper anterior and posterior chest.

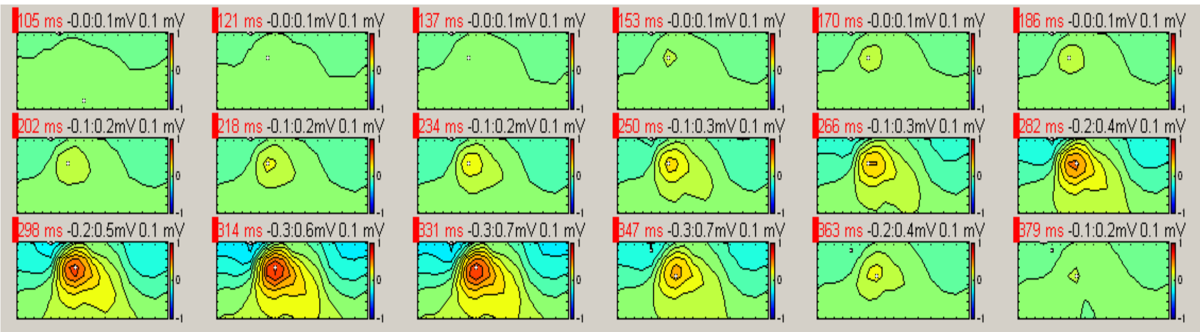

Fig. 1. The sequence of isopotential maps corresponding to the type II of ACM. The maps 2 to 19 are displayed. The left half of the rectangles corresponds to the anterior chest, the right half to the back.

The mean ST-T interval duration was (300 ± 31) ms. The potential values in single isopotential maps changed from - 0.55 mV to 1.51 mV in men, from - 0.54 mV to 0.93 mV in women. The mean correlation coefficients of single ACMs were 0.838 ± 0.073 (range 0.613 – 0.961). The high positive correlation coefficients $r \geq 0.900$ covered in average (53 ± 13) % of the whole ACM area (mean r: 0.966 ± 0.004; 28 % – 88 %) while $r \geq 0.500$ covered in average (93 ± 7) % (mean: 0.875 ± 0.035; 71 % – 100 %). Negative correlations occurred at the borders of ACMs corresponding to the comparisons between the IPMs of the ST segment and the IPMs of the T wave. The mean value was - 0.067 ± 0.062 (minimum $r = -0.164$). They were found in only 2 men (5 %), but in 8 women (17 %). Differences between men and women of selected analysed parameters are given in Table 1.

Table 1. Selected analysed parameters in men and women subgroups.

Parameter	Men	Women	Significance
ST-T interval duration [ms]	293 ± 31	306 ± 30	NS
T wave maximum [mV]	1.04 ± 0.25	0.57 ± 0.16	p < 0.05
T wave minimum [mV]	- 0.30 ± 0.10	- 0.28 ± 0.06	NS
Mean correlation coefficients of single ACMs	0.866 ± 0.048	0.815 ± 0.083	p < 0.05
Correlation coefficient $r \geq 0.900$ in ACMs [%]	57 ± 12	50 ± 14	p < 0.05
Mean of single ACMs for $r \geq 0.900$	0.968 ± 0.004	0.965 ± 0.003	p < 0.05
Correlation coefficient $r \geq 0.800$ in ACMs [%]	76 ± 12	67 ± 15	p < 0.05
Mean of single ACMs for $r \geq 0.800$	0.940 ± 0.011	0.935 ± 0.014	p < 0.05

We identified four basic types of ACMs according to the values of correlation coefficients. In the first three types, only positive correlation coefficients occurred. In the type I, the high positive correlation coefficients $r \geq 0.900$ occupied at least 75 % of each single ACM area (4 men, 3 women). In the type II, the high positive correlation coefficients occupied from 50 % to 75 % of each single ACM area (25 men, 17 women). In the type III, the high positive correlation coefficients occupied from 25 % to 50 % of each single ACM area (10 men, 20 women). In the type IV, negative correlation occurred (2 men, 8 women). According to the Pearson chi-square test, the frequency difference of ACM types between men and women is statistically significant ($p < 0.05$).

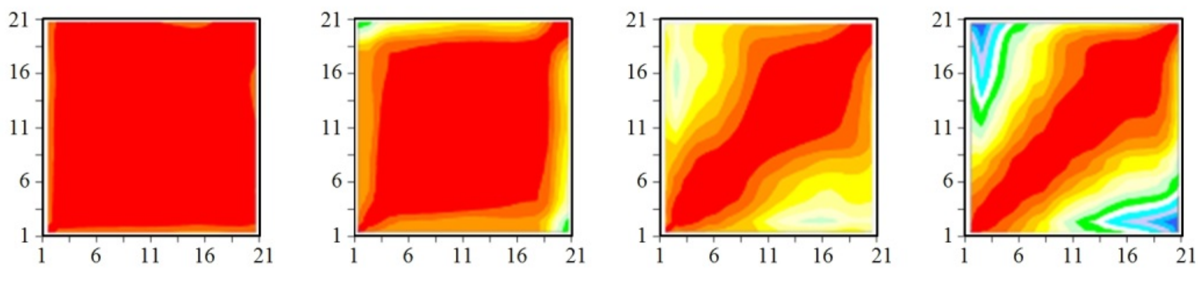

Fig. 2. Examples of 4 different types of autocorrelation maps for women (from left to right: I, II, III, and IV). The numbers on the axes correspond to the sequential map numbers. The red colour represents the correlation coefficients from 0.9 to 1.0; next colours represent lower values with the step 0.1. The autocorrelation map II corresponds to the isopotential maps in Fig. 1.

4. Discussion and Conclusions

According to the experimental study concerning the QT interval [3], the autocorrelation maps reflect only phenomena taking place in the electric source (myocardium). They are very little influenced by the geometry of the volume conductor (thorax) that connects it to the lead system, but very sensitive to variations in the activation sequence.

Although different shapes of autocorrelation maps occurred among the studied subjects, at least 28 % of the ACMs area revealed high correlation coefficient $r \geq 0.900$ in all subjects. This is in accordance with our hypothesis that the ST-T map pattern changes in healthy subjects only slowly, even very slowly.

We could identify 4 main types of autocorrelation maps. It is not clear yet, why they occurred with different frequency in men and in women, but it could be due to “flatter” isopotential maps in women than in men (such differences are known from previous studies, for example [9]). Very low potentials values (at noise level) lasting for longer time may occur at the beginning of the ST segment and at the end of the T wave and this also may influence the form of the autocorrelation maps in some cases.

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