# Analysis of the Ventricular Depolarisation Using Autocorrelation Maps in Young Adult Men and Women

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***Abstract.*** *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 autocorrelation maps in young adults in time standardised QRS complex. We constructed 21 isopotential maps at equidistant intervals form the QRS complex in 90 young adult controls (42 men). For each QRS complex, every IPM was compared with every IPM using Pearson's correlation coefficient r. These values were displayed in form of ACMs, squared graphs with values r = 1.000 on the main diagonal and symmetrical according to it. The mean QRS complex duration was (92 ± 12) ms. The mean correlation coefficients of single ACMs were 0.087 ± 0.044. The high positive correlation r ≥ 0.900 covered in average (26 ± 5) % of the whole ACM. Negative correlations occurred mainly parallel to the main axis with the mean value - 0.543 ± 0.054. We identified three basic types of ACMs according to the form of regions with positive and negative correlations. In the type I, high positive correlation at beginning of the QRS complex and along the main diagonal changed into a negative correlation reaching the borders of the ACM (15 men, 12 women). In the type II, the negativity was followed by a positivity at the borders of the ACM (23 men, 32 women). In the type III, the positivity was followed by a second negativity in the corners of the ACMs (4 men, 4 women). The ACMs display the large normal variability in ventricular depolarisation by eliminating the influence of the torso.*

*Keywords: Body surface potential mapping; QRS complex; Autocorrelation maps; Time standardisation*

## 1. Introduction

Voltage distributions over the whole chest surface can be displayed in form of a set of isopotential maps that can be analysed quantitatively using the Pearson´s correlation coefficient [1] allowing the construction of autocorrelation maps. These maps were firstly introduced in 1976 [2] to express the normal ventricular repolarization in the body surface distribution of T potentials. The autocorrelation analysis was used to analyze the effect of intra-thoracic heart position on electrocardiogram [3] or the beat-to-beat repolarization measurements [4].

The aim of this retrospective study was to analyse the autocorrelation maps in young adults in time standardised QRS complex.

## 2. Subject and Methods

We studied 90 young adults, 48 women, 42 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 [5, 6]. All data were registered in supine position during normal expiration. Linear baselines were taken through TP segments in each electrocardiogram. The onset and offset of the QRS complex were established manually from the root mean square signal. For time standardisation, the QRS complex duration of each subject was divided into 20 equidistant parts. We constructed 21 isopotential maps for each QRS complex [7]; the first map corresponded to the QRS complex beginning, the last map to its end (see Fig. 1). For each subject, every isopotential map (map A) of a single beat was compared with every isopotential map (map B) of the same beat using Pearson´s correlation coefficient $r_{AB}$ [1]

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

where

$U_{Ai}$ ($U_{Bi}$) the value of electric potential in the $i^{th}$ point of the map A (B),
$\bar{U}_A$ ($\bar{U}_B$) mean value of electric potential in the map A (B).

Comparisons were presented in form of autocorrelation maps, squared graphs displaying the correlation coefficients of every possible pair of potential distribution with values $r = 1$ on the main diagonal and symmetrical due to it (see Fig. 2). We analyzed the form of the regions with high positive correlation $r \geq 0.9$ where the potential distribution changed slowly.

## 3. Results

The isopotential maps of the QRS complex revealed typical features (see Fig. 1). At the beginning, an anterior maximum appeared that moved downwards and leftwards simultaneously with increasing value till the middle part of the QRS complex. Then its value decreased and the maximum moved to the back or to the upper part of the anterior chest. Low negative potential covered the lower part of the chest at the beginning of the QRS complex. Around its middle, a distinct negativity occurred in the upper right anterior chest (right epicardial breakthrough) and the minimum moved towards the maximum. During the last third of ventricular activation, low negative potential covered either the upper or the lower part of the chest.

The mean QRS complex duration was (92 ± 12) ms. The mean correlation coefficients of single autocorrelation maps were 0.087 ± 0.044 (range 0.011 – 0.207). The high positive correlation r ≥ 0.900 occurred predominantly along the main axis but also in other areas. It covered in average (26 ± 5) % of the whole autocorrelation map (mean 0.970 ± 0.004; 15 % – 40 %). Negative correlations occurred mainly parallel to the main axis with the mean value - 0.543 ± 0.054 (down to r = - 0.994). No statistically significant differences were found between the groups of men and women in any analysed parameter.

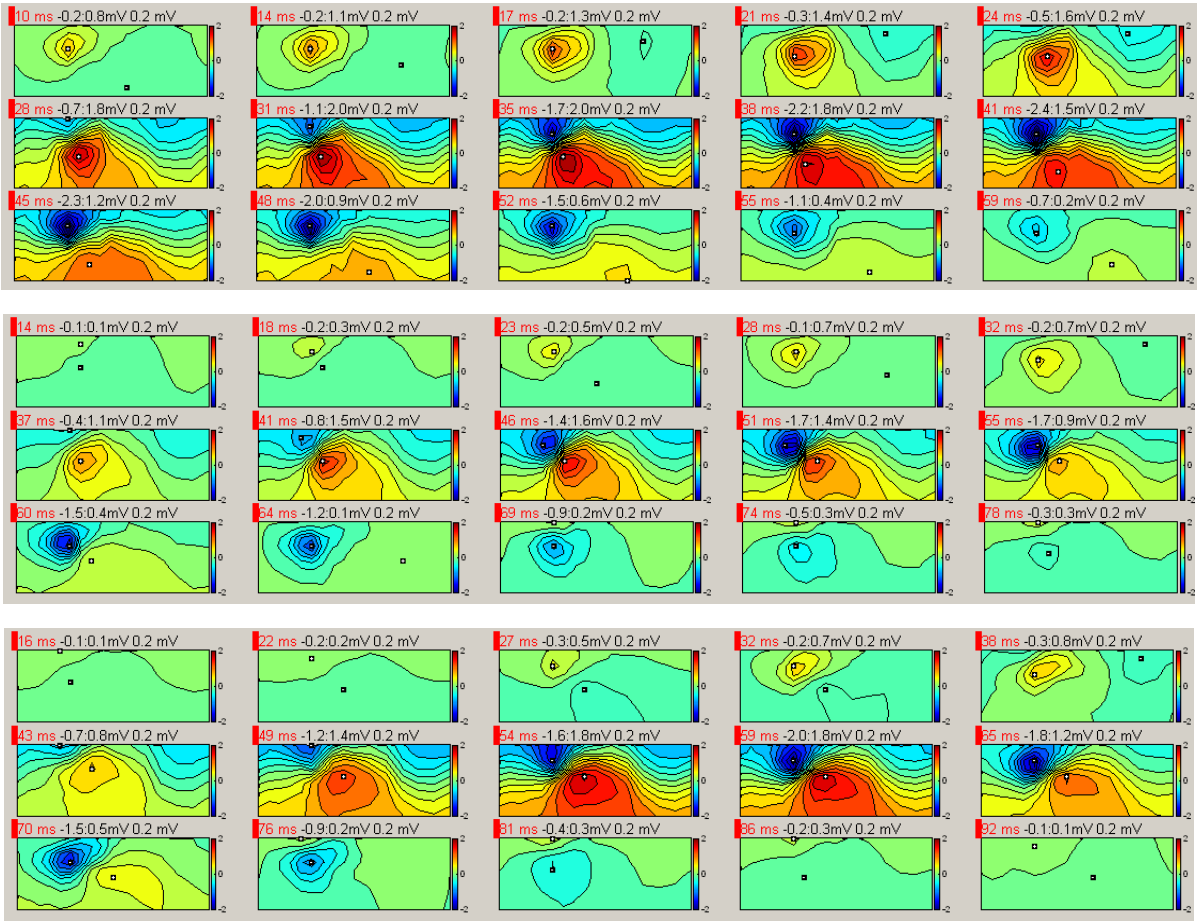


Fig. 1. Examples of isopotential maps of evaluated subjects W-I, W-II, W-III. The maps 4 to 18 are always displayed. The left half of the rectangles corresponds to the anterior chest, the right half to the back. Step between isopotential lines is 0.2 mV.

We identified three basic types of autocorrelation maps according to the form of regions with positive and negative correlations. In the type I, high positive correlation at beginning of the QRS complex and along the main diagonal changed into a negative correlation reaching the borders of the autocorrelation maps (15 men, 12 women; 30% of all maps). In the type II, the negativity was followed by a positivity at the borders of the autocorrelation maps (23 men, 32 women; 61%). In the type III, the positivity was followed by a second negativity in the corners of the autocorrelation maps (4 men, 4 women; 9%).

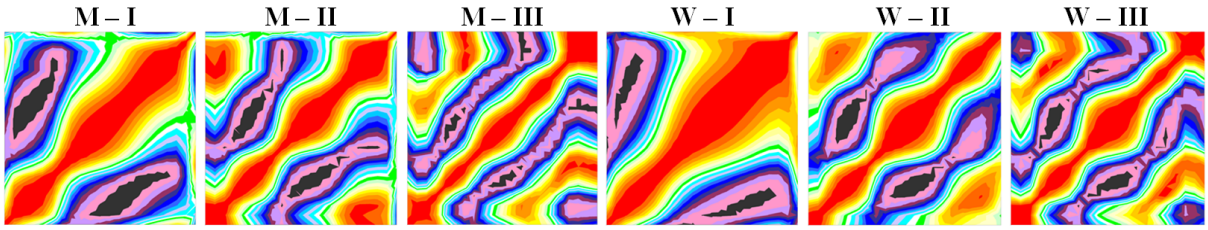


Fig. 2. Examples of 3 different types (I, II, and III) of autocorrelation maps in men (M) and in women (W). The time increases from bottom to top and from left to right. The autocorrelation maps W-I, W-II, and W-III correspond to the isopotential maps in Fig. 1.

## 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), are very little influenced by the geometry of the volume conductor (thorax) that connects it to the lead system, and are very sensitive to variations in the activation sequence. Comparing the QRS complex autocorrelation map with corresponding isopotential map sequence we found, that the wider is the area of high positive correlation area, the smaller is the change in shape of the activation sequence between successive instants (compare Fig. 1 and Fig. 2).
Great variety of shapes of autocorrelation maps occurred among the studied subjects. However, we could identify three main types of autocorrelation maps. Two types are similar to those identified earlier in [8] that were divided into 12 classes. The elimination of the thorax contribution to the body surface potential maps opens the possibility to evaluate the extent of the heart activation and recovery variability in a normal population.

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