Variation of ECG Features on Torso Plane: An Innovative Approach to Myocardial Infarction Detection

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Abstract

Objective: The aim of this study is to found how well one can characterize the location and extent of relatively compact infarcts using electrocardiographic evidence.

Method: Here, we address a method base on behavior of some ECG's features, which are Q, amplitudes and ST dispersion. We call these Q and ST curves. At the first step, by plotting the variability of Q, amplitude and ST dispersion for nodes which lies in lines on torso plane, these curves are obtained. The behavior of the mentioned curves for normal lines both in horizontal and vertical line differ from the abnormal ones. A threshold method is used here to determine the infarcted area.

Results and Conclusion: The method is evaluated on Challenge 2007 database. The results are EPD=8, SO=0.944, and CED=1. The method achieved the best EPD and CED scores and the second place for SO and overall ranked the highest scores (first rank) in CinC/PhysioNet Challenge 2007.

1. Introduction

Although extensively utilized, the limitations of the conventional 12-lead ECG for optimal detection of cardiac abnormalities are widely appreciated [1]. The main deficiency in the 12-lead approach is the fact that only 6 chest electrodes are incorporated which cover a relatively constrained area of the pericardium. The main reason for the choice of the location of the conventional pericardial electrodes, suggested by Wilson over 70 years ago [2,3], was the need to adopt some standard which to this day has remained relatively unchallenged.

One of the most widely studied alternatives to the 12-Lead ECG in both clinical and experimental electrocardiology has been the body surface potential map (BSPM). In this approach, anything between 32 and 219 electrodes [4] are used in an attempt to sample all electrocardiographic information as projected onto the body's surface. The merits of this enhanced spatial sampling are obvious, in that, localized abnormalities that are perhaps difficult to detect using the 12-lead approach can readily be picked up with the additional electrodes. As well as this ability to provide more diagnostic information, BSPMs facilitate an alternative method for visualization as recorded data can be displayed as a sequence of contour maps, allowing isolation of significant electrocardiographic events in space and time.

BSPM provide the spatial as well as the temporal and amplitude components of cardiac electrical activity, whereas the ECG scalar waveforms only present the voltage variation with time in a given site [5].

Body surface potential maps have two major advantages over the conventional 12-lead ECG: 1) to explore the entire chest surface; 2) to be more sensitive in detecting local electrical events [5].

Today, the application of BSPM in Myocardial Infarction (MI) detection is progressively increasing and becomes field of interests of many cardiologists.

D. Finlay et al. [6] applied commonly used feature selection methodology to the BSPM domain in order to select electrode subsets that are best for discriminating between normal subjects and those with MI.

Extensive investigations were made by Sippens-Groenewegen et al. [7-9] to assess the value of BSPMs in localizing the site of origin of ectopic ventricular activation in patients with a structurally normal heart and with myocardial infarction.

L. D. Ambroggi et al. [5] used various methods in analyzing of BSPM includes "eigenvector analysis" and "Principal component analysis (PCA)" to study repolarization potentials.

In this work, we introduce a simple but effective way to detect the location and extension of MI. Here by assuming some imagined on-torso lines, variations of some ECG features through these lines, plotted. Then by implying some threshold based roles, the location on infarcted area on heart surface obtained. Similar method has been used to estimate the extension of MI as well.

2. Methods

In this paper, we address a new method based on behavior of some important ECG's features affected by MI, includes Q-wave amplitude and ST-segment dispersion (depression and evaluation) [10, 11]. We call consequent plots as Q and ST curves respectively.

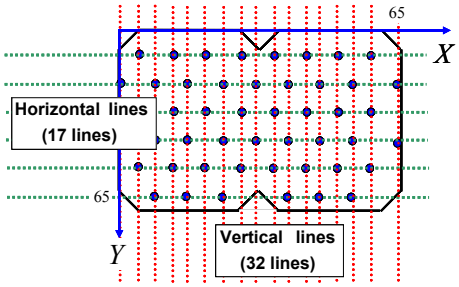

Figure 1. Definition of horizontal vertical line on Torso plane

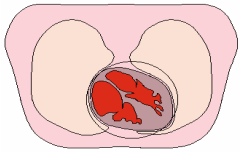

Figure 3. The location of heart in the thorax

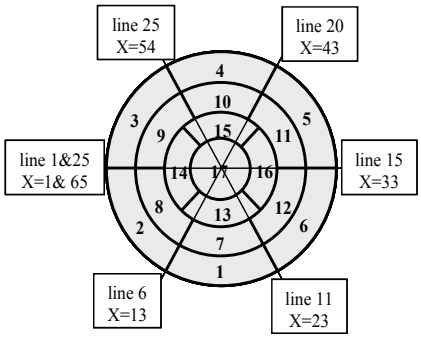

Figure 4. The relation between LV segments bounds and on-torso vertical lines in the circle of segments

At the first step, the Q wave amplitude and ST dispersion in each 352 nodes have been extracted based on our previous algorithm [12] and their vicinity.

Horizontal and vertical lines on torso surface are then considered on the basis of node placement and label *(x,y)* which is showed in Figure 1. We suppose that there are 17 horizontal and 32 vertical lines. X-axis corresponds to vertical lines and shows the x location of every vertical line, varied between 1 to 65 and Y-axis corresponds to horizontal lines as well. Y-limits varied between 1 to 33.

By plotting the variation of Q wave amplitude and ST dispersion for on-torso horizontal and vertical lines, these curves are obtained. Figures 2 represent these curves for training case number one.

By assuming the location of the heart in the thorax (Figure 3), we estimate the boundaries of the heart segments on on-torso vertical lines. Figure 4 illustrates these vertical lines.

We then examine Q wave curves for the two train cases both in vertical and horizontal on-torso lines, to highlight main features of Q curves in these cases by considering reported infarct segments. We then inferred many characteristics of the Q curves that are illustrate the boundaries of infarct segments, for instance:

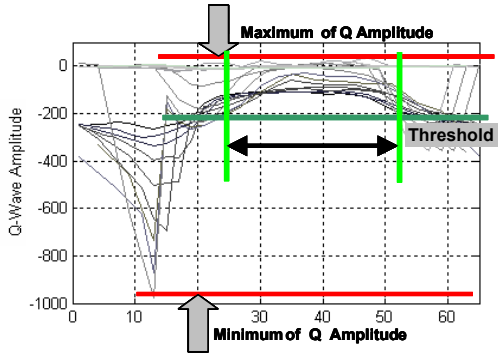

Figure 5. The threshold used for Q wave amplitude in horizontal curves (case #1)

1- The values of Q curves in vertical lines (also by observing the vertical lines in horizontal plots) against the infarcted sections, is nearly zero (we apply a threshold to neglect value of Q wave) as equation 1. (see Figure 5)

$$Threshold = \frac{1}{5} \times \{\max(Q) - \min(Q)\} \qquad (1)$$

2- Horizontal curves in normal area are smooth and pseudo-sinusoid. However in area with MI, they show non-smooth variations. Figure 6 depicts this difference.

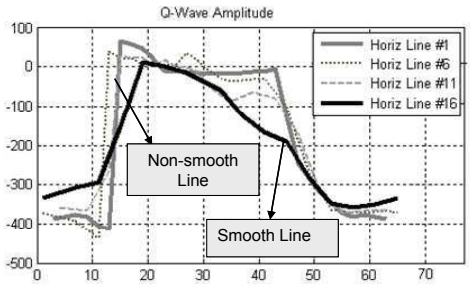

Figure 6. Classification between smooth line form non-smooth line using their slopes and threshold method (case # 2)

Smooth and non-smooth lines are classified based on applying a threshold method on their slopes. First, the values of M_i^n, the slopes of n^{th} horizontal or vertical lines at the location i, is calculated using equation 2. Then the plot of $|M_i^n|$ is considered. Then by implying a

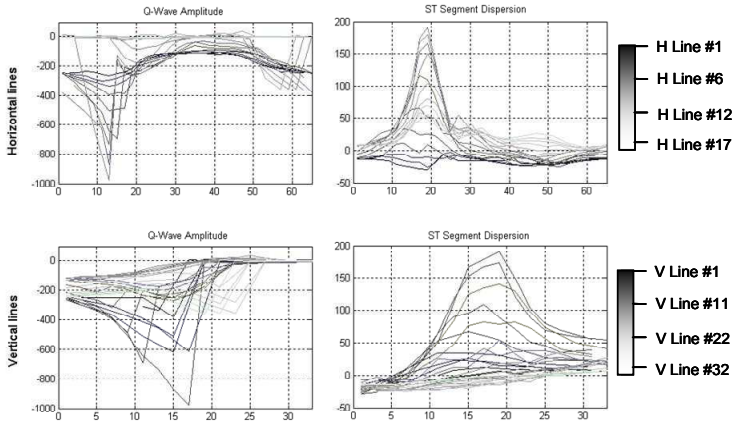

Figure 2. The Q wave amplitude and ST segment dispersion curves used for training in Case #1:
(Two upper figures) the curves for horizontal lines (horizontal plots)
(Two lower figures) the curves for vertical lines (vertical plots)

threshold (equation 3), the non-smooth lines classified from the smooth ones. On the other hand, regions on torso plane in which, the sudden changes occurred in Q curves, have been determined.

$$M^n{}_i = \frac{Q^n{}_{i+1} - Q^n{}_i}{X_{i+1} - X_i} \qquad (2)$$

$$\left|M^n{}_i\right| \geq \alpha \,.\, \max\left|M^n{}_i\right| \qquad (3)$$

$$\alpha \,.\, \max\left|M^n{}_i\right| : \text{ threshold}$$

3- The sudden changes in vertical lines represent the boundaries of infarcted sections in the opposite side of segment circle illustrated (figure 3).

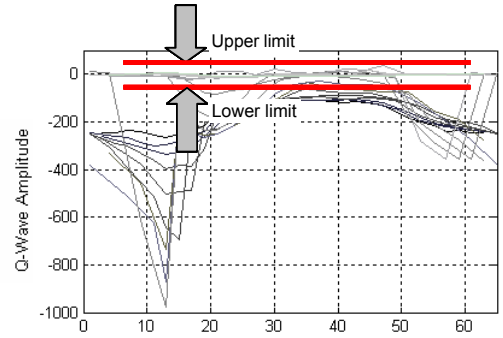

Figure 7. The threshold used for Q wave amplitude in horizontal curves on lower torso plane

4- The values of Q curves in the lower horizontal lines, especially the lines that lies near to the end of torso plane (with high values of Y component), is close to zero for infarcted cases at the apex region while for non-infarcted apex region, this lines do not behave similarly. A threshold is applied to detect the infarcted elements in this region. Figure 7 shows the upper and lower limits of the implemented threshold, in training case number one.

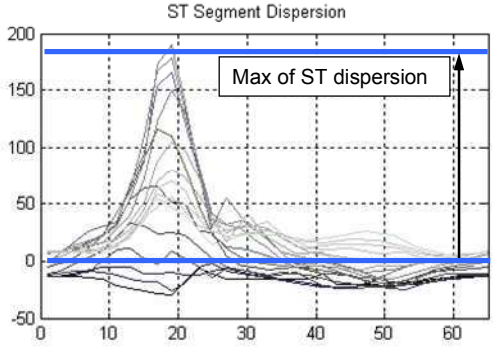

Figure 8. Use of ST for MI extent estimation (case #1)

5- To evaluate the extent of infarction in myocardial muscles, we use ST segment dispersion [10-11]. We suggest that the extent of MI is proportional to inverse of maximum ST segment dispersion in each case.

$$MI\ extent \propto \frac{1}{Max\ \ ST\ \ Disp.} \qquad (4)$$

We then estimate extent of two test cases by considering value of extent in the two train cases.

To obtain the center of infracted sections, geometric center of evaluated infarct sections is considered.

3. Results

The results from the participants are compared to a gold standard that consists of expert analysis of

gadolinium-enhanced MRI data. The scoring procedure for the challenge consists of the percentage discrepancy of the estimated infarct size or EPD, a number between 0 to 8 (lower is better), the overlap between the infarct segments or OS, numbered between 0 to 2 (higher is better), and the distance between the centroids as compared to the gold standard or CED, numbered between 0 to 8 (lower is better).

Our first entry using very rough thresholds, results EPD = 21, OS = 0.374, and CED = 2. By improving the definition of these thresholds more precisely, in the third and final entry our method achieved the best EPD = 8, the second place for OS = 0.944, and the best CED = 1. Overall, the proposed threshold based algorithm ranked the highest scores in CinC/PhysioNet Challenge 2007.

The final results of the method submitted to the challenge are represented in table 1.

Table 1. Result of the method for subjects #3 & 4

Case No.	Locations	Centroid	Extent %
3	3 4 8 9 10 11	10	50
4	7 8 9 10 14 15 16	14	20

4. Discussion and conclusions

In this paper, we address an innovative method for detection of MI location, size and extension using BSPM data implying a threshold method. The results of assessment of the method on CinC/PhysioNet Challenge 2007 database [13], show the proposed method can estimate the location of both cases medially. However the results of EPD show the method can estimate the extent of infarction properly. The method achieved the best EPD and CED scores and the second place for SO and generally ranked the highest scores in CinC/PhysioNet Challenge 2007. The simplicity of the method is its major advantage.

Future works can focused on implying other ECG parameters such as T wave amplitude, QRS complex duration, and R wave amplitude on on-torso lines to detect the location of infarcted area more precisely.

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