Estimation of Area at Risk in Myocardial Infarction

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Abstract

This study presents a new method for estimation and imaging of the area at risk (AaR) in myocardial infarction (MI). The values of the ST-segment deviations of 12-lead ECG signal were used as input parameters. Based on DECARTO model, the spherical surface was chosen as a reference surface to approximate the ventricular wall. On this surface, the spatial ST vector was projected. The center of AaR was defined as an intersection of the spatial ST vector with spherical surface; the size of the AaR was set to be proportional to the number of electrical leads with ST-segment deviations.

The method was tested using data of 10 patients with acute MI. The visual comparison showed good agreement with the AaR_{ECG} estimates based originally on the Selvester QRS scoring as well as with a non-electrocardiographic imaging method (SPECT).

1. Introduction

The early and correct estimation of size of myocardium jeopardized in acute myocardial infarction has considerable clinical importance. Several methods based on evaluation of ECG signals were proposed for calculation of size of area at risk in myocardial infarction [1, 2].

The relation between spatial distribution of the heart's electrical field and the anatomical structure of the heart as a generator of this electrical field have to be considered to estimate the location and the size of AaR due to changes in electrical activity of the heart.
The hexaxial coordinate system of the standard 12-lead ECG provides a complicated system of understanding and analyzing the relation between the resultant vector of the cardiac electric field, the anatomical structure of the heart and its position in the chest. The more feasible system for study of such relations is vectorcardiographical presentation of ECG.

In the previous study [3], the bio-mathematical model DECARTO was introduced to visualize the VCG considering the equivalent generator of the cardiac electric field as uniform double layer with in time varying size and location on a spherical surface approximating the ventricular wall. DECARTO model makes graphical presentation of QRS vector with topographic information directly related to anatomical shape of left ventricle possible and allows a direct comparison of ECG (VCG) data with cardiac imaging techniques [4]. According to DECARTO model, the vector of the cardiac electric field points out the direction of the electrically activated area on the imaginary spherical surface of ventricle and the size of activated area is proportional to the ratio between current size of the electrical vector and maximal vector during QRS.

In orthogonal vectorcardiography, the location and extend of AaR due to epicardial injury have been shown to be associated with the orientation and magnitude of the spatial ST vector. In this study, the basic DECARTO principle was adopted for mathematical transformation of ST vector to obtain a topographic representation of AaR on the reference surface used in DECARTO. Results of estimation of AaR were compared to other techniques used for AaR estimation.

2. Methods

2.1. Study population

The study population consisted of 10 patients with acute MI (Lund University Hospital, Sweden). The patients who met the following inclusion criteria were included in this study:

- ST segment elevations on the admission ECG;
- Documented complete coronary occlusion treated by primary percutaneous coronary intervention (PCI) with stenting, resulting in TIMI grade 3 flow;
- SPECT performed within 3 hours after PCI. The Tc tetrofosmin was administered after angiography had shown occlusion, but before opening by PCI;

Six patients had the occlusion in the proximal left anterior descending coronary artery (LAD), three in the right coronary artery (RCA) and one in the left circumflex (LCX).

2.2.1 ST vector estimated Area at Risk (ST-AR)

Standard 12-lead ECG data were used as an input. The spatial ST-vector was obtained by two different methods:

- Selection of pseudo-orthogonal subset of standard 12 lead ECG: V5, aVF and V2.
- Dower's inverse transformation [5] of the 12-lead ECG.

The spherical surface was chosen as a reference surface for approximation of the ventricular wall. The intersection of ST-vector with this spherical surface was labeled as a center of the AaR (Figure 1).

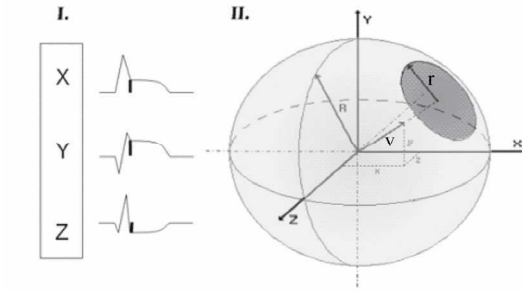

Figure 1: The values of the ST segment deviations were used to calculate the spatial vector **v**. The spatial vector **v** is projected on the surface of the reference sphere (with diameter **R**). The orientation of the spatial vector **v** points to the center of the estimated AaR (with diameter **r**).

The size of the AaR (displayed in Figure 1 as circle with diameter r) was computed according to the number of leads with ST deviation > 0.5 mV and the number of leads with deviation following equation:

$$S_{ST-AR} = \frac{S_{Sph}}{72} \times \left(\Sigma \mathrm{Limb}_{ST\Delta} \times \Sigma \mathrm{Chest}_{ST\Delta}\right)$$

Where $S_{ST\text{-}AR}$ is the surface of the AaR, S_{Sph} is the virtual sphere surface, $\Sigma limb_{ST\Delta}$ is the sum of limb leads with ST deviation and $\Sigma chest_{ST\Delta}$ is the sum of chest leads with ST deviation.

Rectangular and polar projections of the reference spherical surface were used for the presentation of ST-AR. The final AaR projections were done in a coordinate system that was rotated with respect to the VCG coordinate system (in Euler angles α = 9,8; β = 50,7 ; γ = 68,7), to achieve comparable images with SPECT and AaR_{ECG}.

The ST-AR visualizations were performed using Iris Explorer (NAG, United Kingdom).

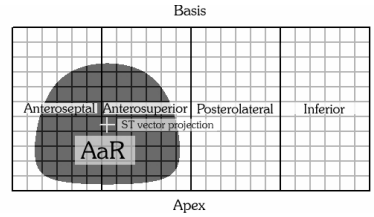

Figure 2: Rectangular view of the ST-AR image. The area at risk is displayed on the rectangular grid, where the base of the heart is represented as the top and the apex as the bottom of the grid.

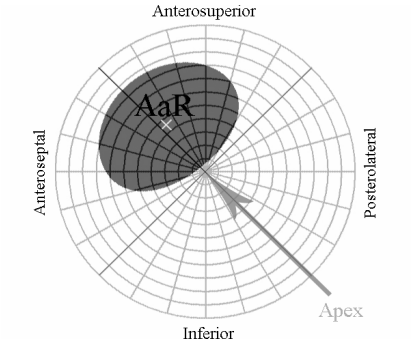

Figure 3: Polar view of the ST-AR image. The apex is projected in the center of the projection.

2.2.2 ECG estimated area at risk (AaR_{ECG})

The leads with ST segment deviation were used to distribute the ECG estimated risk regions on a Mercator projection of the epicardial surface. The distribution was based on the presence of points, given for each of the 12 segments, by the Selvester QRS score for each lead. The 12 segments on the Mercator projection were manually adjusted so that each segment had the same shape and size, containing the amount of AaR estimated by two research physicians blinded to each other. These adjusted Mercator views were then converted into polar plots using specific graphic applications (Corel, Ottawa, Canada).

2.2.3 Single photon emission computed tomography (SPECT)

The patients underwent MBq ^{99m}Tc tetrofosmin myocardial perfusion SPECT placed in supine position and imaged in steps of 6.5 degrees (Amsterdam Health, Buckinghamshire, UK). Short- and long-axis images gated to ECG were reconstructed, covering left ventricle. Using SPECT, polar plots were generated

using the quantitative data for perfusion.

3. Results

Figure 4 shows the location and size of AaR for 10 patients obtained by ST-AR, AaR_{ECG} and by SPECT. The presented ST-ARs were derived from ST vector calculated by Dower's inverse transformation and they are shown in both, the rectangular and the polar projections. The spatial orientation of ST vectors calculated by Dower's inverse transform and ST vectors determined by the selection of leads was nearly identical, the average difference was 11.76° ± 4.55° (average ± standard deviation).

In the LAD subgroup, the ST-ARs were dominantly located in the lower part of anteroseptal area, except for the patient #47 where ST-AR was located in the upper pole. In patients of the RCA and LCx subgroups, the ST-ARs were located in the posterolateral and inferior area. Visual comparison of locations and sizes of the AaR presented by ST-ARs (rectangle projection) and AaR_{ECG} showed a good agreement in the LAD subgroup with respect to the location and positions. In the RCA and LCx groups the position of ST-ARs was shifted to the apical direction. The comparison between polar projection of ST-ARs and polar (bull-eye) projections of SPECT showed the same characteristics as comparison between ST-ARs and AaR_{ECG}, however there were differences in the size of the AaR estimates. Despite of the differences found between ST-ARs and AaR_{ECG} /SPECT findings, there was a good agreement in the location of the AaR in terms of the posterolateral and inferior surfaces involvement, except for the patient #86. In this patient, the AaR was located in the anteroseptal surface, while AaR_{ECG} and SPECT estimated AaR was located on the inferior surface.

4. Discussion and conclusions

The presented ST-AR method estimated the AaR in myocardial infarction using the orientation of the spatial ST vector. The calculated locations of the AaRs from the test ECG data pointed to the area supplied by the particular coronary artery what is in good agreement with the results obtained by the SPECT and AaR_{ECG} methods for the AaR estimation. In RCA group the AaR showed shifts to the apex when compared with SPECT and AaR_{ECG}, while AaR_{ECG} were located more to the base in a good agreement with SPECT. In the LCx patient (#63) the ST-AR estimated AaR is shifted less to the base than the AaR_{ECG} estimated AaR in comparison to SPECT The shifts are probably due to differences between the anatomical axis of the heart and the VCG coordinate system used for ST vector projection. Visual comparison of the extent/size of the AaR showed smaller degree of the agreement between ST-AR and the AaR determined by SPECT and $AaR_{ECG.}$ Possible reasons could be due to the method of calculation (number of electrodes with ST deviations, equal contribution of each electrode) and differences between information provided by individual methods, as changes detected by SPECT do not necessarily need to be reflected in the changes of the electrical properties of myocardium to affect the ST vector of the surface electrocardiogram. Moreover, the limitations resulting from the representation of cardiac electric field by single resultant vector and small number of patients have to be considered. Despite of all mentioned limitations, the presented ST-AR method seems to be promising for fast diagnostics of the AaR and can be also used for direct comparison and superimposition of estimated AaRs with imaging methods in cardiology.

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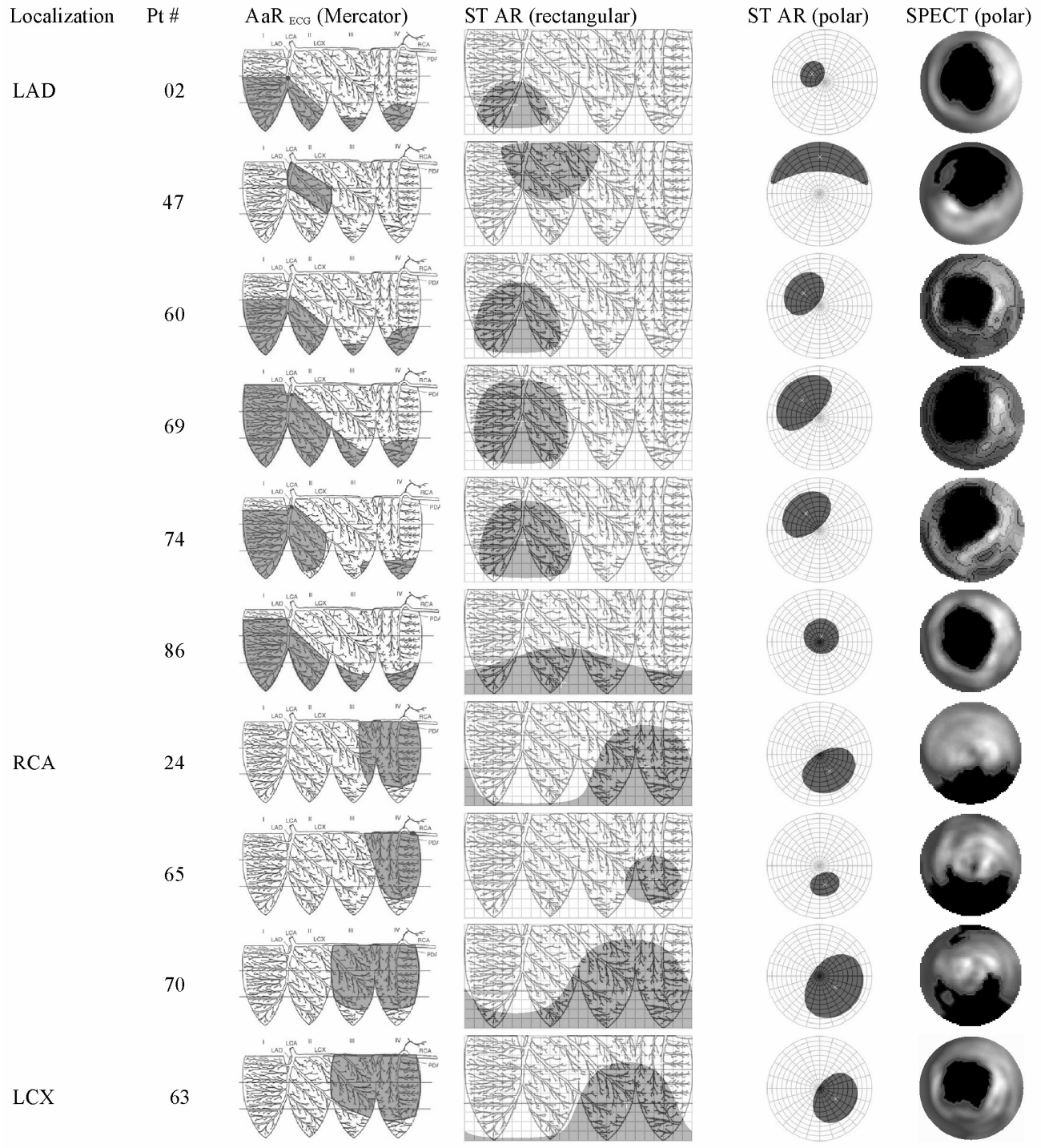

Figure 4: The comparison of AaR images. Columns from left to right: the ECG estimated area at risk AaR_{ECG}, the rectangular projection of ST-AR, the polar projection of ST-AR and the polar projection of SPECT. Patients with the occlusion in the left anterior descending artery (LAD), right coronary artery (RCA) and left circumflex artery (LCX).