Assessment of Heart Position in a Torso Model Using an Inverse Solution

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Abstract. *Knowledge of actual heart position is important for finding results in inverse problem of electrocardiography. Magnetic resonance images of real subjects revealed large variability of the heart position in relation to ecg lead V2 usually placed in the 4th intercostal space and considered as the anatomical reference. The use of standard torso model in which the location of modeled heart is constant thus cannot reflect its actual position sufficiently. The method for finding the approximate position of heart in a standard torso model corresponding to the actual heart position in an observed subject is presented.*
Position of single dipole obtained by an inverse solution from body surface potential measurements was used to locate the initial site of ventricular depolarization and suggested as representative position of the left ventricular septum. This approach was studied in 25 subjects with well documented geometry and measured ecg potentials in 62 leads. For each subject the heart in standard torso model was moved to a new position corresponding to the inversely estimated initial site of ventricular depolarization.
The individually estimated heart position in the standard torso model better corresponded to the real torso geometry configuration than that derived from the anatomical leads placement.

Keywords: standard torso model, inverse solution, integral maps, position of heart

1. Introduction

It is generally known that for correct solution of the inverse problem in electrocardiology the knowledge of individual realistic torso model is needed [1]. The best way to obtain such individual geometrical data is the use of CT or magnetic resonance imaging (MRI) technique. At present, however, this technique is still expensive and not always available in common cardiological practice. Recently we suggested to use the inverse solution for identification of one or two small ischemic lesions and tested the method on simulated data computed in a standard torso model [2]. However, the study on a set of 25 well documented geometrical data from normal subjects [3] revealed the great variability of heart position relative to the anatomically placed leads positions, mainly in vertical direction, that could strongly influence the inverse solution if only the standard torso model is used. In this work we suggest a method for individual approximation of real position of the heart from the electrocardiographic (ecg) data of the observed subject.

2. Subject and Methods

Data from 25 healthy subjects (15 men and 10 women) published in [1], [3] were used to study the possibility to assess individual position of their hearts. The geometry of each of them was obtained by MRI and then described by triangulated surfaces consisted of the model of torso, lungs, ventricular myocardium and the volume of ventricular cavities. The ecg data measured in 62 leads of the Amsterdam lead system were recorded for each subject. Positions of leads were documented along with the geometrical data. The precordial lead V2 was carefully placed with respect to the fourth intercostal space.

For each subject 62 raw signals recorded for 10 s with sampling rate of 1000 Hz were processed. The Lynn's low-pass filter with 50 Hz stop-band was applied in signal processing [4]. Then the signal was time averaged to create one representative time course of the heart cycle in each lead. Finally, the baseline of averaged signals was corrected by setting the mean potential of the PQ interval to zero. The QRS onset was defined manually from rms signal computed from all measured leads.

Five integral maps (IMs) for various time intervals up to 20 ms from the QRS onset were computed. Assuming that the knowledge of the heart position is not known, the position of the initial depolarization of ventricles was computed from IMs using the inverse solution to one dipole in homogeneous torso model. Location of a dipole that best represented the input IM was searched among positions of cubic 3 mm grid in the torso model and was considered as the estimated septum position.

First the similarity between the inverse solutions in individual models and the standard torso model was tested. For each measured subject the inverse solution was computed in its individual torso model obtained from MRI and also in the standard torso model. Then the vertical distance between the lead V2 and the inversely obtained dipole location was evaluated in each model.

After observing the results for the localization of initial ventricular depolarization in individual models and the corresponding individual position of the heart in each torso model, position of the individual reference point iRP was assigned in each individual heart to represent the position of the heart in torso as well as the site of the initial ventricular depolarization. Correspondingly, standard reference point sRP was assigned in the heart in the standard torso model. Then the heart in the standard torso model was moved to a new individual position such that the sRP corresponded to the inversely estimated location of the initial activation of ventricles computed in the standard model from individual ecg measurement. The improvement of the standard model configuration was evaluated.

3. Results

Because the variability of the heart position in relation to the lead system is studied in this work the base point representing the position of leads is considered the ecg lead V2 placed in the 4th intercostal space. Fig.1 demonstrates the vertical variability of the distance between the reference point in the heart in real chest models and the vertical position of lead V2. If the standard torso model for each subject is used this vertical distance is assumed to be constant.

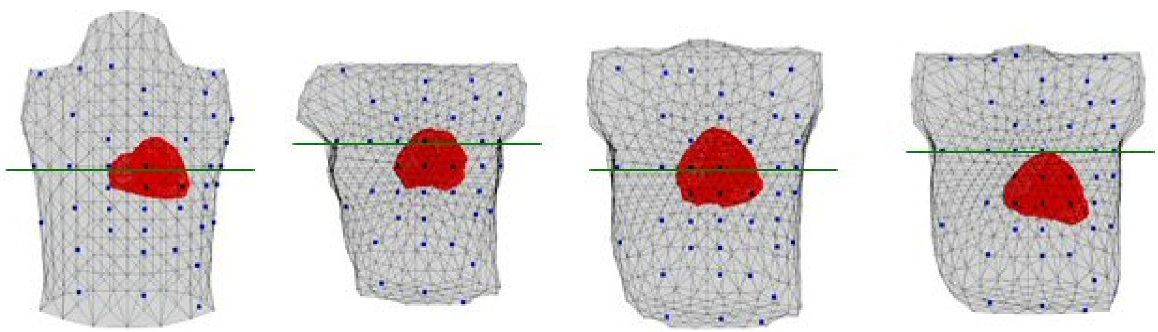

Fig. 1. The standard torso model (left) and examples of 3 real chest models. Dots indicate the leads placement, vertical position of lead V2 is marked by a horizontal line.

In each object the inversely estimated position of the initial ventricular activation was computed as the geometrical center of locations obtained from all 5 integral maps. In most cases these locations were almost in the same place and were located in the volume of the left ventricle near septum. The mean standard deviation of the 5 results from their geometrical center for all observed subjects was 0.3 cm.

The inverse solution was computed from IMs of each subject in the individual torso as well as in the standard torso model. The vertical distance between the inversely estimated position of initial activation and the corresponding lead V2 in each model and each subject (denoted PP) is depicted in Fig. 2.

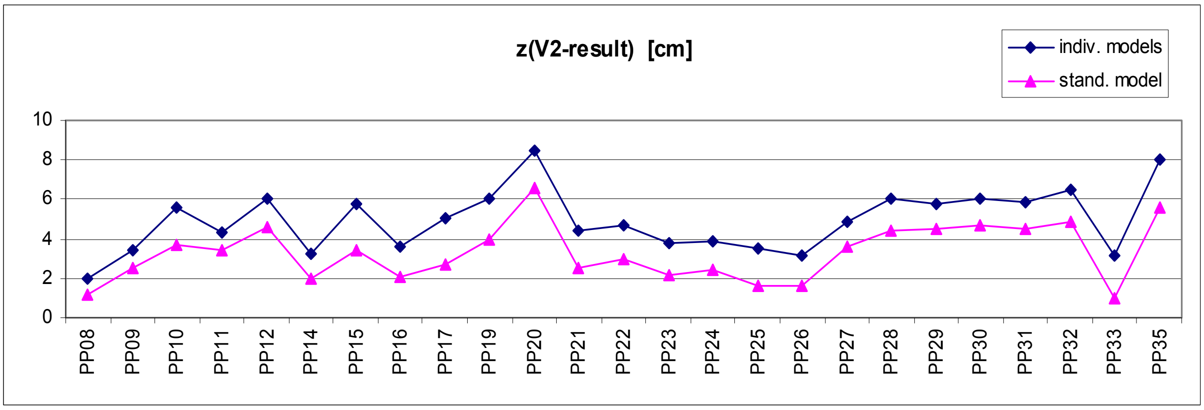

Fig. 2. The vertical distance between the inversely estimated position characterizing the initial ventricular activation and the position of the corresponding lead V2 computed for each measured subject in individual and standard torso model.

In agreement with the obtained localization of the initial ventricular activation in individual models, position of the individual reference point iRP in each heart model was defined in the left ventricular septum. The reference point sRP in the heart of the standard torso model was defined similarly.

For each individual subject the heart position in the standard torso model was adjusted by a vertical shift of the sRP to the inversely estimated vertical position of the initial site of ventricular of activation. The vertical distance between the reference point in the heart model and lead V2 in the original individual torso models, in adapted standard torso models and in the standard torso model is shown in Fig. 3. Most of the adapted standard torso models corresponded better to the original individual chests than the standard torso model.

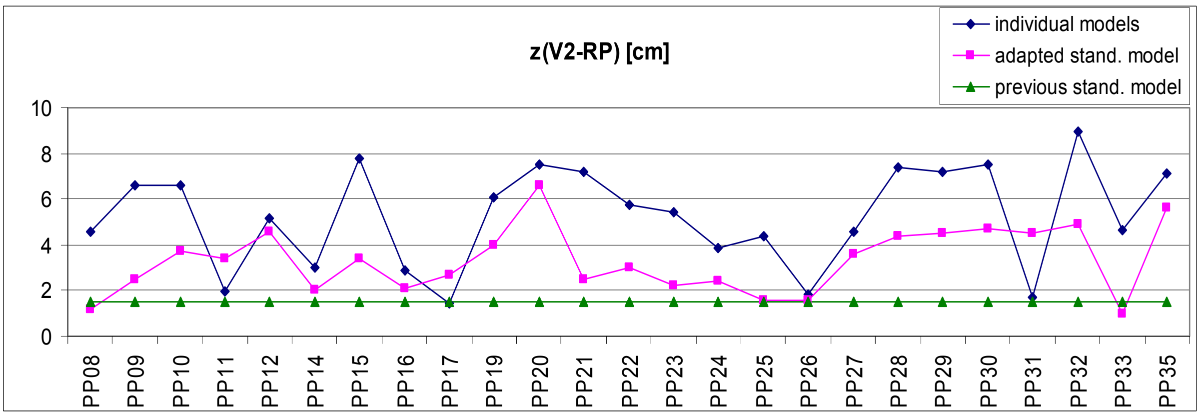

Fig. 3. The vertical distance between the reference point in the heart and the lead V2 in three types of models.

The mean difference between the vertical distance V2 to RP in individual torso models and in the standard torso model was 3.73 cm (std 2.2 cm); the mean difference between vertical distance of V2 to RP in individual torso models and in the adapted standard torso model decreased to 1.93 cm (std 1.9 cm).

4. Discussion

Although the suggested method improved the vertical position of the heart in the standard torso model, the mean error of almost 2 cm still remains remarkable. Two reasons for this large error could be considered. The first one is the inequality of outer geometry of the individual models and the standard one. In Fig.2 a systematic error is apparent between the results obtained in individual and standard torso model. The role of adaptation of the standard torso dimensions to the individual subject together with the placement of electrodes on the torso model should be evaluated.

The second reason for relatively large error in the present study could be the differences in electrophysiological properties of the volume torso conductor as well as the individual variability of the normal sequence of excitation of the ventricles. In spite of the fact that in individual models the geometry was known very precisely the position of the inversely located dipoles varied within the left ventricular septum in quite wide range. The reference point situated in the left ventricular septum was only approximate definition of the initial site of activation. For 25 subjects studied in this work the mean distance between the reference point and the inversely estimated initial site of activation was 2.17 cm (std 0.9 cm), the vertical distance only 0.5 cm but with std 1.7 cm.

5. Conclusions

From the results it can be stated that it is possible to adjust the vertical heart position in a standard torso model using information from measured ecg signals. Besides the adaptation of torso geometry to dimensions of an individual subject and proper placement of leads, the suggested method considerably improves the individual torso model configuration without using demanding CT or MRI techniques.

Acknowledgements

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