

Electric Tomography of the Cardiac Muscle

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Abstract

High incidence of disease coronary in Poland and in the world means a high risk of heart infarct and sudden death. To meet the need for fast, non-invasive and cheap diagnostic method a new technique of electric tomography of the cardiac muscle has been proposed. The technique is based on the numerical enhancement of the ECG signals recorded in particular layers, i.e. in subsequent intercostals space while the cardiac muscle is treated as a loss dielectric, in which the generated dipoles are calculated and localised.

Keywords: electric tomography, ECG, cardiac muscle

Introduction

Early and fast diagnosis of the coronary disease has been an important subject of research for many years. It is known that the standard ECG record may prove an unreliable diagnostic source as it may show no deviations from the standard despite the confirmed coronary disease or past heart infarct. There are many effective and reliable diagnostic methods of the cardiac muscle status but they are in general invasive. Therefore, much attention has been devoted to improvement of the ECG as a non-invasive method to make it more informative. Such an improvement can be realised by enhancement of the resolution of the digital ECG recordings, permitting monitoring of activity of particular cardiac muscle regions. The enhanced resolution permits determination of the direction and value of the instantaneous electric dipole related to the process of depolarisation, but fails to localise this dipole in the cardiac muscle. To overcome this problem a new method called electric tomography of the cardiac muscle has been proposed.

Method

The hitherto applied method improving the diagnostic worth of standard rest ECG is the NURSE- ECG based on numerical enhancement of the signal resolution, allowing

detection of instantaneous changes in the electric potential of the cardiac muscle on its depolarisation [1-7]. Implementation of the digital ECG recording has permitted the use of a special computer program increasing the resolution of the electric signals. This improvement permitted detection of relatively small changes in the electric activity of particular fragments of the cardiac muscle caused by ischaemia, past infarct or the effect of medication, undetectable in the standard ECG recording. Interpretation of the high-resolution ECG signals is performed with the method of vectorcardiography [2]. NURSE-ECG recording is realised by a 12-lead digital ECG apparatus (the one we have been using is made by MEDEA)[3]. The ECG signals from each electrode are subjected to computer analysis to enhance their resolution. The result of the computer analysis is a plot illustrating the cardiac muscle depolarisation in three planes: frontal, transversal and sagittal, corresponding to the movement of the instantaneous vector of depolarisation of the intraventricular septum and left and right chamber. The electric activities of particular segment of the cardiac muscle chambers and interventricular septum are calculated and compared with their analogues for a healthy person. NURSE-ECG provides the information on the value and orientation of instantaneous electric dipoles induced in the cardiac muscle but fails to localise these dipoles. The method of electric tomography of the cardiac muscle

has been proposed to complete the information of by determination of the position of the instantaneous electric dipole induced in the cardiac muscle. Results of the electric potential measurements depend significantly on the distance of the dipole from the measuring electrode. To eliminate the effect of the differences in the anatomy between men and women, a new type of ECG leads has been proposed, known by the back system, Fig. 1. In this system the measuring electrodes are localised as follows: V₂ lead – right line beside vertebra (about 4 cm from the spine to the right); V₃ lead – left line beside vertebra (about 4 cm from the spine to the left); V₄ lead – back line armpit; V₅ lead – a point at the half of the body thickness; V₆ lead – front line armpit. The value of the instantaneous electric dipole related to the depolarisation of the cardiac muscle is described by the equation:

$$\Phi = \frac{1000 * d}{r^2} * \cos \vartheta \quad (1)$$

where: d – the value of the instantaneous dipole, r – the radius, cos ϑ – the cosine of the angle between the plane of measurement and the direction dipole-electrode.

The software used for layer by layer visualisation of the electric dipoles at first randomly selects the dipole position

its length and direction, then calculates the values its potential at the positions of the electrodes. The error of the dipole determination is calculated by the least square method. Electric dipoles obtained are graphically presented in the frame of the cardiac muscle divided into the upper, middle and bottom layer (the latter is the apical layer). Each layer is divided into fragments: anterior, lateral and posterior wall and anterior part of the septum. The segments are coloured according to their activity: yellow corresponds to the highest activity, while red to the lowest (Fig. 2). The X axis is that of abscissae, the Z axis is that of ordinates, while the Y axis is perpendicular to a selected plane. Preliminary results obtained for the patients who have had cardiac muscle infarct have brought significant differences in the values and positions of the instantaneous electric dipoles.

Concluding remarks

The method of electric tomography of the cardiac muscle permits monitoring of activities of particular segments of the cardiac muscle and detection and localisation of relatively small changes in the electric activity and therefore seems very promising from the

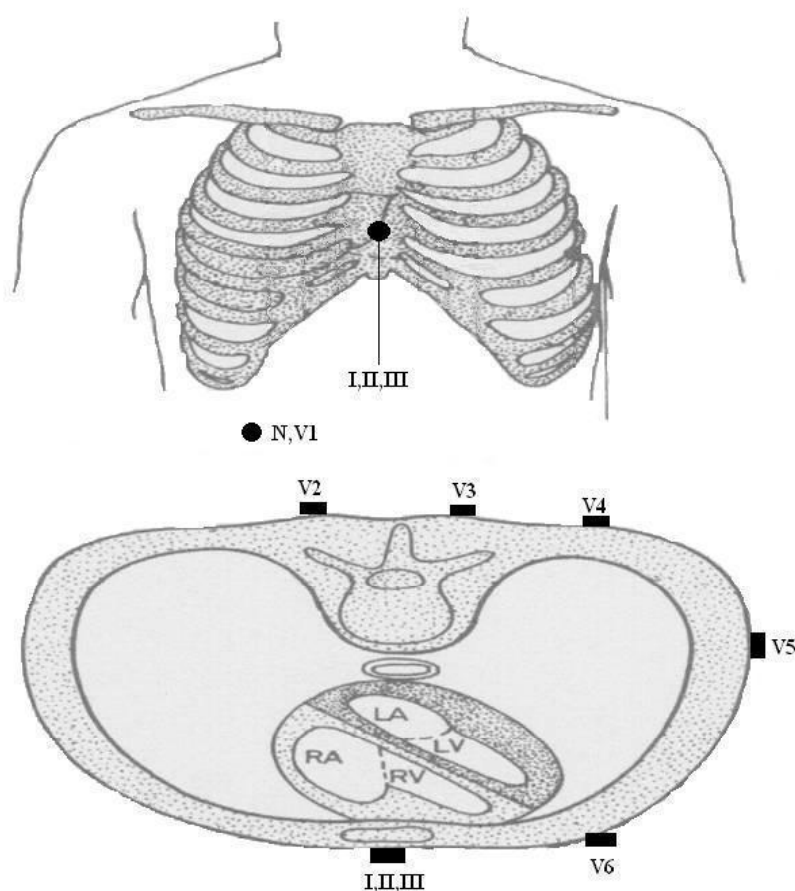


Fig. 1. System back-drain

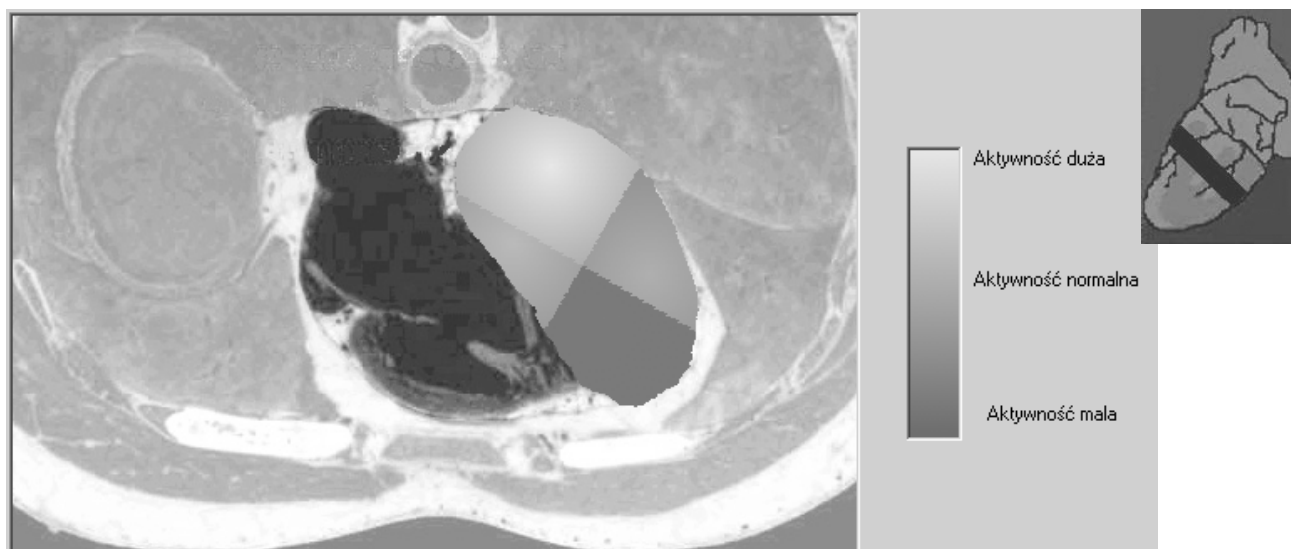


Fig. 2. Graphically exposition dipols in heart contour

diagnostic point of view. As follows from the results of preliminary investigation the method is correct. The drawback of the method that needs to be solved is the lack of temporal synchronisation of measurements of subsequent tomographic layers. The method will be further developed to improve the visualisation and to standardise the activities of the cardiac muscle measured.

References

1. Koper A., Krzymieniewski R.: Analysis of resonance excitations by linear transformation technique theory, *Acta Magnetica*, **2**, 3-9, **1985**.
2. Krzymieniewski R.: Computer enhancement of complex spectroscopic spectra resolution, *Mol. Phys. Reports*, **6**, 174-80, **1994**.
3. Levkov CH.L.: Orthogonal electrocardiogram derived from the limb and chest electrodes of the conventional 12-lead system, *Medical and Biological Engineering & Computing*, **25**, 155-9, **1987**.
4. Krzymieniewski R., Panek G., Stepień R.: High resolution vectorcardiogram, *Journal of Medical Physics*, **24**, 181-5, **1999**.
5. Tomasik T., Windok A., Skalska A., Kulczycka – Życzkowska J., Kocemba J.: *Elektrokardiografia for practice doctor*. University Medical Print „Vesalius”, Krakau **1996**.
6. Kwoczyński J.: *Elektrokardiografia*. State Publishing House Doctor, Warsaw **1977**.
7. Krzemińska-Pakuła M.: *Graphic method in diagnostics disease disposition circulation*. State Publishing House Doctor, Warsaw **1991**.