New Computerized Method for Current Density Vector Map Evaluation

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ABSTRACT

Two clinically useful classification systems for analysis of a structure of a current distribution in human heart have been proposed. The first system is based on topology method and includes the following parameters of structure: number, intensity and orientation of source fronts as well as asymmetry and ellipticity of vortexes. All these parameters are combined into common diagnostic parameter. The second system is based on vector field analysis, it takes into account vector orientation and specific clusters of vectors and also is combined into own common diagnostic parameter. The classification systems are included in software system MAGWIN that have the following components: general database store, preprocessing and averaging , construction of the magnetic maps, construction of the current maps and, in fact, classification systems. 123 patients with proved coronary artery disease (CAD) but normal ECG and Echocardiography at rest as well as 124 healthy volunteers were tested. It was determined that the topology method has high sensitivity and vector method has high specificity. So these methods are supplemented each other in the diagnostic system. The combine classification system with better parameters is proposed.

KEY WORDS

magnetocardiography, current distribution, diagnostics, software system

INTRODUCTION

Nowadays, the method of magnetic field measurements (MCG) [Cremer, 1999] for investigation of the human heart bioelectrical activity is often used for diagnostic of pathologies. This raw information is yet not suitable to derive a medical conclusion because of magnetic field is caused by primary electric currents in the heart and, besides, the noise level of signal is too high. To reconstruct distribution of the current density from the known magnetic field configuration, it is necessary to solve the reverse problem in the theory of the stationary field. Localization of the current sources and imperfections of the conductive medium is a next step in a reverse problem solution. Solution of such a problem would be a considerable step forward in the investigation of the cardiac electrical activity. Apparently, diagnostic systems based on the objective data on the currents distribution and tissue conductivity could serve as a background for more reliable medical conclusions compared to the routine methods. In the present work based upon the existing understanding of the current initiation in the cardiac muscle, the models are considered for current spreading in a healthy heart (ideal distribution) and upon pathological alterations, characterized by additional distributed sources (or fronts of the sources) as well as by the heterogeneous conductivity. A final objective of the research is an elaboration of the tool for the diagnosis of heart injuries, especially the most common and severe. Thereupon, the paper analyses the results of application of the methods in computerized system and diagnostic of patients with verified coronary artery disease (CAD).

METHODS

Two systems for the description of the current density maps were elaborated: the system based on topology method [Vasetsky, 2002] and on vector field analysis. Both systems form numerical indices for deviation of the maps from the normal ones, with values of the indices being normalized to the interval [0,1], at that the higher the magnitude of the index corresponds to the more deviation from the normal map. To receive comparison characteristics, the concept of the „ideal“ map is being utilized. As an ideal the current distribution, map is taken that has a dipole structure with two symmetrical current vortexes, created in a uniform conductive medium by a single sources front with a vector of current density (front direction) oriented to the left bottom from the patient viewpoint (or to the right bottom at the map) in the angle range 10°÷80°, counted clockwise from the horizontal axis of the map.

In the topology method the following four parameters of ideal properties of maps are used: R_f (characterizes presence or absence of additional sources), R_{dir} (determines deviation of the front direction from the ideal one), R_{as} (shows the degree of the current vortex asymmetry), R_{ell} (characterizes an ellipticity of the current vortexes). All parameters are consider to be independent. Parameters of the dipole structure R_f and direction P_{dir} play a decisive role in the classification system, two others, P_{as} and P_{ell}, are subsidiary ones. Summarizing R_{ideal} parameter includes four R_i parameters. Equation that combine this requirements is used as following: $R_{\text{ideal}} = R_f R_{\text{dir}} W + R_f R_{\text{dir}} R_{\text{as}} R_{\text{ell}} (1-W) = R_f R_{\text{dir}} [W + R_{\text{as}} R_{\text{ell}} (1-W)]$, where W is weight of the main parameters. Supplemented parameter $K_{\text{ideal}} = 1 - R_{\text{ideal}}$ characterizes the degree of deviation of the map from the ideal one. Finally, mean value $\overline{K}_{ideal}$ of index of map deviation from the ideal one is calculated at the S-T interval of the cardio cycle.

In the vector method processing of every map is reduced to the following steps: conversion of the coordinates of density current vectors $\boldsymbol{j}_{ij} = (x_{ij}, y_{ij}) \Rightarrow \tilde{\boldsymbol{j}}_{ij} = (l_{ij}, \alpha_{ij})$, where $l_{ij} \in [0,1]$ is a module and $\alpha_{ij} \in [0, 2\pi]$ is a direction; definition function of belonging to the ideal direction b_{ij}; isolation of the clusters with groups of vectors, which meet the condition $b_{ij} l_{ij} \geq l_0$, here l_0 is a constant defined by an expert; definition of a $C_m \in [0,1]$ index, characterizing closeness of the m-map to the „ideal“ one and calculation the mean value $\overline{C}_{ideal}$ for all M maps at the S-T interval.

COMPUTERIZED SYSTEM FOR PROCESSING OF MCG DATA

Suggested classification systems are constituents of the integrated software MAGWIN, providing analysis and interpretation of the magnetocardiograms in clinical conditions. The architecture of the system is represented in Fig. 1.

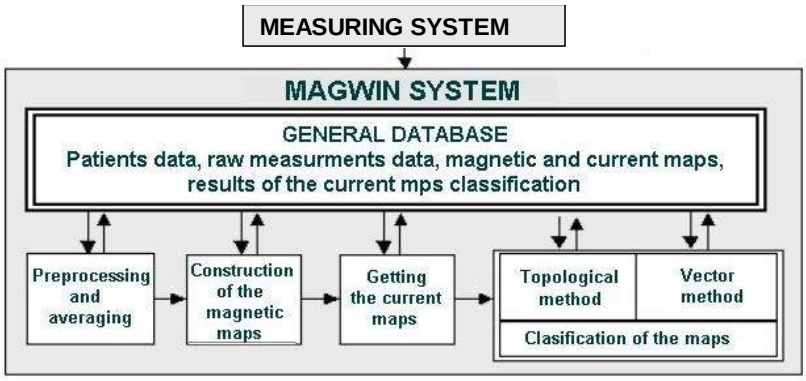

Figure 1. The architecture of the computerized system MAGWIN.

Subsystem for classification of the current maps consists of two parts, utilizing topological and vector methods for getting classification parameters, at that, each system operates independently from another. With topological method, the program generates predetermined number of the consecutive current maps displayed at the screen as level lines or vector field of the current density (Fig. 2) and generalized parameters of all maps in the chosen interval of the cardio cycle. Results of the maps classification by means of the vector method are represented in a special window of the system, providing not only graphical and textual information of interest, but also possibility to modify parameters used in the algorithm of the current density maps classification (Fig. 3).

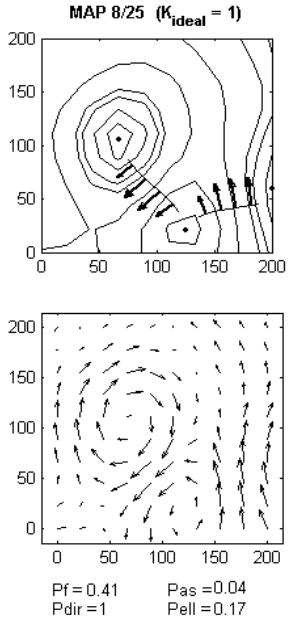

Figure 2. Current map and its parameters in topology method.

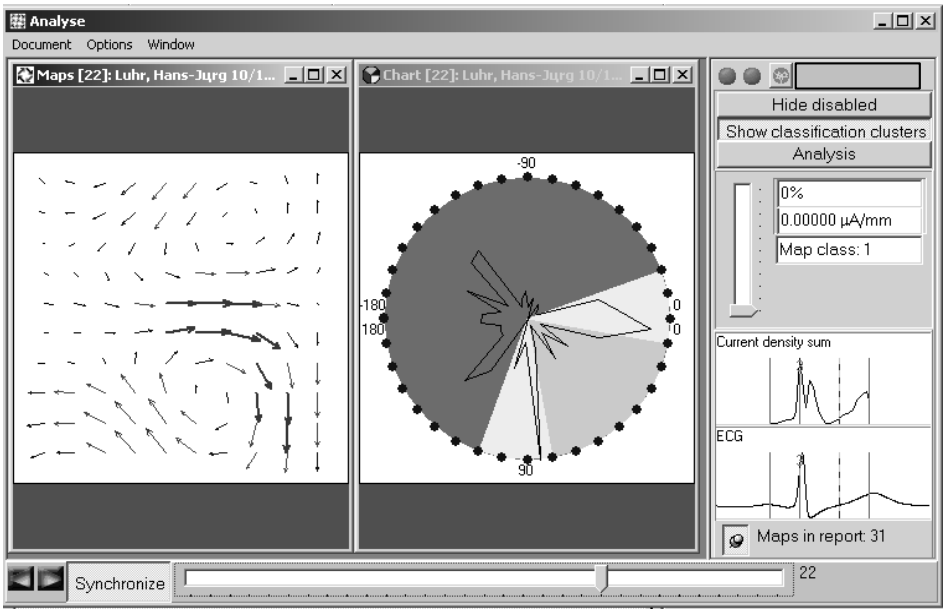

Figure 3. Grafical interface of the vector system for interpretation of the maps.

Testing of the suggested classification systems was performed on MCG data obtained in two samplings. The first group included 123 patients with diagnosed coronary artery disease (CAD), but normal or specifically unchanged rest ECG. Reference group consisted of 124 clinically healthy volunteers. The classification parameters of the topological method provide high sensitivity $S_E = 0.87$, whereas parameters of the vector method result in high specificity $S_P = 0.87$. In this respect, both methods, being realized in the unified computerized system MAGWIN, supplement each other. Depending on the aims and conditions of the diagnostics preference can be given to one of the methods.

DISCUSSION

On the base of suggested approach, collective decision rule can be built, integrating partial solutions of the methods [Fainzilberg, 2002]. Classification parameter combining positive features of both methods seems to be even more perspective. Very promising could be also joint analysis of the primary parameters of maps description, reflecting positive features of both methods. Such classification system could approach the sensitivity of the topological method and specificity of the vector method.

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