Application of SFHAM Model for Diagnosis of Ischemic Heart Disease

[1]J. S. Janicki, [2]A. Teresińska, [3]W. Leoński, [1]M. Chąpiński, [4]M. Sobieszczańska, [5]R. Piotrowicz

1Physico-Medical Research Institute, Puszczykowo, Poland
2Department of Nuclear Medicine, Institute of Cardiology in Warsaw, Poland
3Institute of Physics, University of Zielona Góra, Zielona Góra, Poland
4Department of Pathophysiology, Wrocław Medical University, Wrocław, Poland
5Department and Clinic of Cardiac Rehabilitation, Institute of Cardiology, Warsaw, Poland
Email: prezes@ibf.com.pl

Abstract. Introduction. *The ECG examination allows to obtain information about the electrical processes occurring in the heart, the course of which may be disturbed by a number of pathological changes occurring in it. However, the both, currently used criteria and issues in interpretation of the results, lead to limited diagnostic value of this method. Any improvement in ECG examination requires considerable extension of currently applied electric signals analysis. To achieve this, we have used proposed in [1] model of the electrical activity of the heart – SFHAM. This model describes the morphology of the QRS complex, and was implemented in the SATRO ECG system. Our main aim was to assess the effectiveness of SATRO ECG system in CHD diagnosis, and compare its results with those of myocardial perfusion scintigraphy Tc99m SPECT.*

Methods and Materials. *For a group of 243 subjects (75 females and 168 males, average age: 58±10 years) supposed to have CHD, standard resting and stress ECG (ECG (R) and ECG (S), respectively), and examinations of myocardial perfusion disturbances using perfusion scintigraphy method SPECT were performed. Then, with use of SATRO ECG system, parameters describing electric activity of various segments of the left ventricle were calculated on basis of ECG (R) results.*

Results. *Sensitivity of SATRO ECG in CHD diagnosing was equal to 100% and specificity 70%, whereas predictive values of the positive and negative results were equal to 98% and 100%, respectively. Moreover, statistical kappa Cohen test showed that statistical correlation between SATRO ECG and SPECT methods ($k=0.817$, $p<0.001$) exists. Such correlations are not detected when SPECT was compared to ECG (R) ($k = 0.055$, $p = 0.031$) and ECG (S) ($k = 0.018$, $p = 0.294$).*

Conclusions. *SATRO ECG examination method seems to be more useful in detecting perfusion defects recognized with use of SPECT method, as compared with resting and stress ECG. The results of the comparative assessment revealed a high correlation between test results of SATRO ECG and SPECT in diagnosis of the both: CHD and location of the blood supply to the heart muscle disorders.*

Keywords: ECG; QRS complex; SATRO ECG; SFHAM; CHD

1. Introduction

The existing ECG diagnosis methods of myocardial ischemia, based on the analysis of ECG signals most often concern the evaluation of parameters related to the shape of the ST-segment and QRS complex. However, the mentioned features of ECG are relatively insensitive and less specific symptom of ischemia, particularly if the analysed electrocardiogram was performed during the period when patients did not suffered from pain,

and for persons with a low probability of coronary artery disease (CAD) [2,3]. Moreover, QRS vectorcardiogram analysis based on a standard method of convolution and deconvolution and described in [4, 5], not lived to see the independent tests that would confirm its effectiveness in the assessment of CHD.

A low diagnostic value of ECG components related to ventricular muscle repolarisation mechanism, encourages for drawing attention to the potential application of observations of ventricular depolarization abnormalities in the diagnosis of CHD. However, the evaluation of parameters of the electrical activity of individual segments of the left ventricle of heart requires a significant exceeding the limits established by methods of analysis used so far. At this point, newly defined and applied models of electrical heart activity could be helpful.

Thus, discussed here, *single fibres heart activity model* (SFHAM) proposed in [1], could be potentially exploited for our purposes. This model was implemented in diagnostic system SATRO ECG. For recollection, within the frame of SFHAM, electrical activity of the heart is presented as the effect of propagation of electric charge waves along a "effective" myocardial fibres. Each fibre represents a particular segment of the left ventricle, and this representation is related to the both: anatomy of ventricle and structure of the hearth's electrical conduction system. For each of the fibres, based on the dynamics of charges flow through the cell membrane, propagation of the depolarization wave was determined. Decrease in conduction velocity inside the fibres caused by ischemia reduces the density of the resultant electric charge. This reduction, influences the ECG signal measured on the surface of the chest.

The main objective of this study is objective verification of SATRO ECG method, in particular, the evaluation of SATRO ECG system in the both: diagnosis of CHD and location of the disorders in blood supply to the heart muscle. Such verification can be done with use of the results obtained from perfusion scintigraphy Tc99m SPECT examination.

2. Methods and Materials

In this study 243 people over 30 years of age (75 women and 168 men, mean age 58±10 years), with a diagnosis of ischemic heart disease or its suspicion, were included. All individuals were subjected to ECG (R), ECG (S) and resting-stress perfusion scintigraphy SPECT examination. The patients with implanted defibrillators, left bundle branch block, the diagnosis of hypertrophic and dilated cardiomyopathy, and treated with digitalis or antiarrhythmic drugs of group I and III were excluded from the study. The research program was carried out with the consent of patients and approval by the Ethics Committee (the approval No. 740/2003) to conduct clinical research at the Institute of Cardiology in Warsaw.

Parameters of the electrical activity of individual segments of the left ventricle were calculated using the SATRO ECG system on the basis of ECG (R) signals. According to the model SFHAM [1], the total potential, which forms a QRS complex, consists mostly of potentials generated during the sequential depolarization of five anatomical segments of the left ventricle. These are: *interventricular septum* (*IS), anterior wall (AW), inferior wall (IW)*, *lateral wall (LW)* and *posterior wall (PW)*. This model does not take into account the potentials that occur during depolarization of the right ventricle, what generally should not affect the results of the calculations, since their values are much smaller and duration is longer, compared to the parameters of the partial potentials of the left ventricle [6, 7].

It was therefore assumed that each of the partial potentials forming QRS complex is generated by charge waves flowing through some effective fibers representing particular segments of the left ventricle. Practical implementation of this model was implemented in the SATRO ECG system, where, based on measurements of the standard ECG, the parameters of the partial potentials were calculated. The values of these potentials are compared with the certain

standards, defined by us. As a result, it was possible to select segments of reduced electrical activity in an automatic way.

In order to confirm validity of our assumptions concerning applicability of discussed method for the evaluation of myocardial perfusion disturbances, the perfusion scintigraphy method combined with registration of Tc99m SPECT (SPECT) was chosen. The latter method allows a precise location of perfusion abnormalities in several parts of each segment of the left ventricle. In order to compare the results of the both methods, a reduction of the quantities of these areas to five major segments was made. It was assumed that the perfusion disturbances in any part of the segment of the left ventricle, e.g. anterior wall, concern the entire anterior wall. However, perfusion disturbances in such area as inferior-lateral segment were treated as a disturbance in the inferior and lateral walls. This allowed for a comparison of the observed location of ischemia with use of both methods.

3. Results and Statistical Analysis

Positive results of CHD were observed: for SATRO ECG in 229 subjects, which accounted for 97% of the study group, for SPECT in 233 (96%), and for ECG (S) in 73 (30%), while for ECG (R) in 142 (61%). The number of nondiagnostic patients was: for SATRO ECG – 7 (3%), and for ECG(S) – 87 (36%). These results are shown in Table 1.

Table 1. Confirmation (+) or exclusion (-) of ischemia and nondiagnostic patients (0) in methods: SATRO ECG, SPECT, ECG (R), ECG (S)

	Result (+) (number of patients)	Result (–) (number of patients)	Result (0) (number of patients)
SATRO ECG	229	7	7
SPECT	233	10	0
ECG (R)	142	101	0
ECG (S)	73	83	87

For SATRO ECG and SPECT methods perfusion was also evaluated in the individual segments of the left ventricle of myocardium, as shown in Table 2.

Table 2. Number of patients with perfusion disturbances in individual segments of the left ventricle on basis of the results of SATRO ECG and SPECT.

	IS	AW	IW	LW
SPECT	131	190	198	161
SATRO ECG	131	181	203	173

Table 3. The effectiveness of the SATRO ECG, ECG (R), ECG (S) methods relative to SPECT in CHD diagnosis and location of perfusion disturbances in individual segments of the left ventricle.

	SATRO ECG					ECG (R)	ECG (S)
	IS	AW	IW	LW	Total		
sensitivity [%]	87	89	95	94	100	59	47
specificity [%]	83	76	63	72	70	70	62
positive predictive value [%]	87	93	93	87	98	97	95
negative predictive value [%]	83	63	72	85	100	6	6

For the group of diagnostic patients: sensitivity, specificity and predictive positive and negative values were calculated for each of the methods: SATRO ECG, ECG (R), ECG (S), relative to the reference method SPECT. The results are shown in Table 3.

Sensitivity of the SATRO ECG system in CHD diagnosis was 100%, specificity 70%, positive predictive value 98%, and negative 100%. For comparison, the results of ECG (R) and ECG (S) in CHD diagnosis were: sensitivity: ECG (R) - 59%, ECG (S) - 47%, specificity:

ECG (R) - 70%, ECG (S) - 62%, positive predictive value: ECG (R) - 97%, ECG (S) - 95%, and negative: ECG (R) - 6%, ECG (S) - 6%.

The statistical kappa Cohen's test results showed that diagnosis results of CHD in SATRO ECG method has statistically significant correlation with the results of SPECT method - ($k = 0.817$, $p < 0.001$), as shown in Table 4. What is important, results corresponding to ECG (R) and ECG (S) methods did not show such correlation. For ECG (R) we had $k = 0.055$, $p = 0.031$, whereas for ECG (S) we obtained $k = 0.018$, $p = 0.294$.

Table 4. The results of kappa Cohen's test for the results of SATRO ECG, ECG (R) and ECG (S) relative to SPECT and the levels of significance (p).

	SATRO ECG					ECG (R)	ECG (S)
	IS	AW	IW	LW	Total		
Cohen's kappa	0.708	0.610	0.619	0.694	0.817	0.055	0.018
p-value	<0.001	<0.001	<0.001	<0.001	<0.001	0.031	0.294

4. Conclusions

The results of the comparative assessment revealed a high correlation between the test results of SATRO ECG and SPECT, both in the diagnosis of CHD and location of the disorders in blood supply to the heart muscle.

Only SATRO ECG examination had statistically significant ($p < 0.001$) discriminative value in predicting a positive result of SPECT.

Applying the SATRO ECG system analysis of the parameters to determine the activity of individual segments of the myocardium during depolarization process, indicates the potential possibility to expand the range of non-invasive methods of CHD.

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