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Evaluation of T-wave alternans in comparison with ECG stress test and scintigraphic examination in patients with coronary artery disease

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Abstract— **The results of study on T-wave alternans in the group of patients with ischemic heart disease are shown. The body surface potential maps were recorded with use of 67 channel high-resolution ECG system. Electrocardiographic stress test was performed during the patient examinations. The T-wave alternans ratio was calculated and results were compared with data obtained by single-photon emission computed tomography (SPECT). Significant correlations between results of T-wave alternans analysis and SPECT test have been found.**

Keywords: T-wave alternans, stress test, SPECT, myocardial ischemia, sudden cardiac death

I. INTRODUCTION

Sudden cardiac death (SCD) is the leading cause of cardiovascular mortality in developed countries [1-5]. The efforts of many medical scientists are concentrated on the prediction and the prevention of SCD by different diagnostic tools and therapies. At present, there is no generally accepted non-invasive risk index of SCD. T-wave Alternans (TWA) is a very promising marker of the vulnerability to ventricular arrhythmia [6-7]. It is defined as a beat-to-beat change in the T-wave amplitude that repeats every other heart beat and indicates the spatial heterogenity of the ventricular repolarization. Both temporal and spatial distribution of the electrical potentials generated by heart on the surface of the body could be investigated by high resolution body surface potential mapping (HR-BSPM) [8-9]. In the presented study the results of the TWA assessment by using FFT-based method are shown [10]. Patients were also examined with use of electrocardiographic stress test and single-photon emission computed tomography (SPECT). Results of those tests were compared with T-wave alternans ratio.

The aim of the study was to analyze the distribution of the T-wave alternans amplitude on the body surface and comparison of these results to results of standard ECG exercise test and SPECT examination outcomes.

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II. METHODS

The study group consisted of 22 patients with ischemic heart disease (Table 1).

TABLE I. STUDY GROUP CHARACTERISTIC.

Number of patients	22
Number of patients after myocardial infraction	**13** (59%)
LVEF	**51** (±12.4)
Age	**55** (±13.8)

High resolution measurements of 64 surface ECG leads were carried out in unshielded room during stress test on the supine ergometer. Patients were qualified for stress testing by physicians from the Cardiology Clinic. The ECG signals were digitized with 4096 Hz sampling frequency and 16 bits amplitude resolution. ECG electrodes were placed on the thorax surface according to modified Amsterdam optimal lead set [11-12], as shown in Fig. 1.

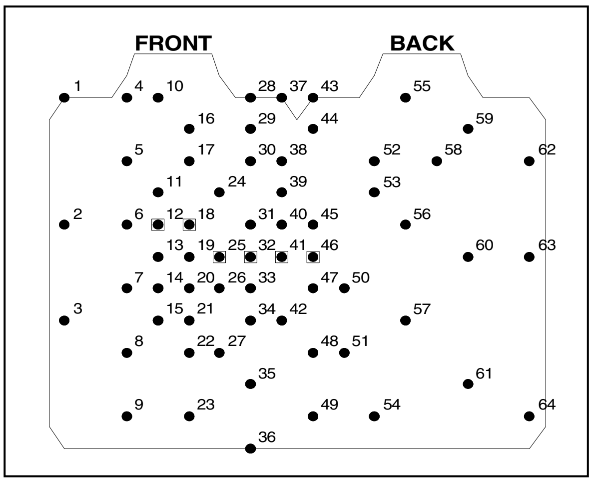

Figure 1. ECG electrodes arrangement on the body surface

Stress test was performed generally according to the standard protocol. The initial load was 50W and it was incremented by 25W every 2 minutes. Because of T-wave alternans measurements the test was modified to obtain for some time heart rhythm pacing with constant frequency of 100bpm. Standard stress test protocol was carried out until heart rhythm of 100bpm was reached and it was interrupted for 2 minutes. Manual load control was applied in such a way to receive stable heart rhythm of 100bpm ± 5bpm. For further T-wave alternans analysis only this part of electrocardiogram with stable heart rhythm was used. The following pre-processing procedures were applied:

a) All disrupted PQRST waves were excluded from the analyzed electrocardiogram (always an even number of beats was removed)

b) Baseline drift was eliminated with the use of cubic splines [13].

c) QRS was detected using the algorithm designed by Pan and Tompkins [14].

d) T-waves locations were estimated using Bazett formula [15].

The ECG signals used consisted at least of 128 T-waves. FFT-based method [16] was used for estimation of the T-wave alternans ratio. In this method, power spectrum for each sample point of 128 time- aligned T waves is calculated by squaring the magnitude of the fast Fourier transform. The cumulative power spectrum is estimated by summing the power spectra obtained for each sample point. In the cumulative spectrum, the beat-to-beat fluctuation in the amplitude of the T waves appears as the spectral peak at the frequency of 0.5 cycles per beat. From the cumulative spectrum, alternans ratio AR can be obtained:

$$AR = \frac{P_{0.5} - \overline{noise}}{\sigma_{noise}} \quad (1)$$

where: $P_{0.5}$ - amplitude of the spectral peak at the frequency 0.5 cycles per beat; $\overline{noise}$, σ_{noise} - mean level and standard deviation of the noise registered in the spectrum in the predefined window located outside the alternans frequency (from 0.35 to 0.45 cycles per beat).

T-wave alternans ratio was calculated independently in all 64 leads. According to work [6], the results are classified as „alternans positive" if the alternans ratio (AR) exceeds 2.5.

Stress test was classified as positive, which means that ischemic heart disease was detected, when one of the following conditions was fulfilled:

a) ST decreasing more than 0.1mV (60ms after J point)

b) ST increasing more than 0.2mV

c) Acute coronary syndrome

d) Ischemic symptoms

e) Cardiac arrhythmia

f) Test must be interrupted before getting diagnostic result

SPECT test was carried out for diagnosis of heart ischemia. The underlying principle is that under conditions of stress, diseased myocardium receives less blood flow than normal myocardium. SPECT imaging performed after stress reveals the distribution of the radiopharmaceutical, and therefore the relative blood flow to the different regions of the myocardium. Diagnosis was made by comparing stress images to a set of images obtained at rest.

RESULTS

Patients were divided in to two groups according to the value of T-wave alternans ratio: TWA positive (TWA+) 10 patients and TWA negative (TWA-) 6 patients. For every patient, maximum of T-wave alternans ratio was calculated in 64 leads. Positive T-wave alternans was detected for values of more than 2.5.

Patients were classified as TWA+ when alternans ratio exceeds the value of 2.5 at least in one electrocardiographic lead. In TWA+ group mean maximum of alternans ratio (calculated in 64 leads) was equal 6.18 (SD 5) and in group TWA- 1.38 (SD 0.6). In the TWA+ group the significant value (more than 2.5) of T-wave alternans ratio was detected in minimum one lead and maximum 23 leads of all 64 leads. Distribution of the T-wave alternans ratio on the body surface for patients with TWA positive is shown in Fig. 2. Minimum value for all maps was rounded to 2.5 to show only diagnostically significant values.

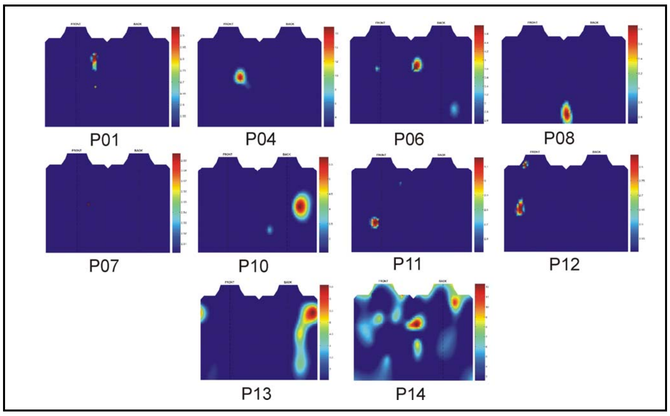

Figure 2. Distribution of T-wave alternans ratio on the body surface

T-wave alternans ratio greater than 2.5 was the most often detected in leads number 30 and 60, in the group of TWA positive patients. The highest value of T-wave alternans ratio was detected in lead number 25 of patient P04.

The results of examinations with use of tree methods: T-wave alternans, ECG stress test and SPECT are shown in Table 2.

The obtained results of T-wave alternans were in accordance with the SPECT examination in 71% of patients, however the agreement between T-wave alternans and ECG stress test is only 52%.

TABLE II. RESULTS OF TESTING

	P01	***P02***	***P03***	***P04***	***P05***	***P06***	***P07***	***P08***	**P09**	**P10**	***P11***
TWA	+	-	-	+	-	+	+	+	-	+	+
SPECT	+	-	+	+	-	-	+	+	-	+	ni
Stress ECG	-	-	-	-	+	+	***nd***	+	nd	nd	-
	P12	***P13***	***P14***	***P15***	***P16***	***P17***	***P18***	**P19**	**P20**	***P21***	**P22**
TWA	+	+	+	-	-	+	+	+	-	+	+
SPECT	+	-	+	+	-	-	-	+	-	-	+
Stress ECG	+	-	+	+	-	-	-	-	-	+	+

where:; nd – not diagnostic value; ni – no information

DISCUSSION AND CONCLUSIONS

TWA is rhythm-dependant phenomenon and electrocardiographic recordings should be carried out at heart rhythm of about 100bpm. In our study ECG stress test was used for the assessment of ischemic heart disease and to increase heart rhythm for the purpose of T-wave alternans testing.

The analysis of distribution of the T-wave alternans ratio on the body surface showed strong diversity, depending on the electrode location [8]. It shows advantage of body surface potential mapping in TWA analysis, because in most patients classified during our study as TWA positive, diagnostically significant value of TWA will not be obtained with use of standard 12 lead ECG. The distribution of the values of T-wave alternans ratio may be influenced by location of myocardial infarction.

No correlation was observed between results of T-wave alternans and ECG stress testing, however significant correlation was detected between results of TWA and SPECT test. It can indicate that TWA and SPECT have better sensitivity for detection of ischemic heart disease in patients at risk of ventricular arrhythmia.. Obtained results need to be confirmed by study on larger patients group, however, reliable classification of patients at risk needs log term follow-up of the studied group.

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