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EVALUATION OF ELECTRICAL CARDIAC MEMORY INDUCTION DURING NON-INVASIVE CORONARY STIMULATION TEST

The paper presents an attempt to evaluation of the electrical cardiac memory prevailing in the non-invasive transcutaneous cardiac pacing test. In the survey, 10 healthy volunteers have participated. In all ECG records, we compared: the mean amplitude of 5 consecutive QRS complexes before stimulation with amplitude of the first QRS complex after switching off the pacing. In such comparison we included the amplitudes of QRS or RS complexes in all the 12 standard leads. We also evaluate the shape of the T- wave, level of the ST segment and TP isoelectric line after ventricular pacing switching off. The statistical comparison of obtained results was done with the Wilcoxon rank test and allow us to exclude relevant influence of 30 seconds duration of the non-invasive transcutaneous ventricular pacing test on the ST-T segment morphology.

1. INTRODUCTION

The European population in general, and some countries in particular, are characterized by a high mortality rate caused by **Ischemic Heart Disease** (**IHD**). The mortality rate is strictly connected with the widespread risk factors. For instance, about one million Poles suffer from IHD and circa 100 thousand of them annually have a **myocardial infarction** (**MI**) which is terminal in 40% of cases. A sudden cardiac death at the age above 35 is due to the underlying IHD undiagnosed earlier in as many as 80% of the patients. MI is often the first symptom of this disorder. Coronary atherosclerosis accounting for over 80% of the cases of IHD often begins as early as the first decade of human life and leads to acute (MI, a sudden death) or chronic (angina pectoris) clinical symptoms after latency. Diagnostic procedures in the symptomatic period of atherosclerosis called **Coronary Artery Disease** (**CAD**) entail the application of several methods, from a medical examination – through non-invasive tests – to the state-of-the-art, most expensive, although at the same time most precise invasive examination (coronary angiography).

As IHD frequently remains asymptomatic or undetected, the percentage of people with advanced IHD in the population is unknown. According to epidemiological research, a large percentage of people with unrecognized MI or impaired left ventricular function, has not been identified either. Persons with unknown IHD are not eligible by definition for preventive programs addressed to subjects with a symptomatic disease.

The EUREKA CARDISCREEN E! 3494 project encloses development of a new method and diagnostic system which enables detection of potential cardiovascular disease risk in screening tests of endangered population. As a part of the project we take the standardization of a non-invasive transcutaneous cardiac stimulation test which provides information about risk of acute coronary

syndrome or sudden cardiac death especially in middle age man population. The crucial element of the CARDISCREEN project is working out the new software which analyses the ST segment level in recorded ECG signal before and during the first 10 seconds after switching off the 30-second long transcutaneous ventricular pacing with 130 ppm rate. Developed software must comply with the impact of a number of factors which may fake the result of the cardiac stimulation test. The most relevant factor is so-called the **electrical cardiac memory (ECM)**. According to the definition given by Rosenbaum in 1982 [9], the effect of activation of such cardiac memory reveals during ventricular pacing, bundle branch block, preexcitation or during paroxysmal ventricular tachycardia.

During transcutaneous cardiac stimulation test, usually the right ventricle, the ventricular septum and exceptionally – the left ventricle are stimulated [4,8]. Transcutaneous ventricular pacing may act as a stimulus which enables triggering the ECM. The activation of such memory during 30 seconds of non-invasive ventricular pacing is slightly possible since according to the literature initialization of so-called early cardiac memory occurs at least after 30 minutes of the invasive ventricular pacing [5,6,7,10]. After pacing interruption, triggered cardiac memory causes arising of the negative T wave imitating direction of the QRS complexes which had existed during the earlier episode of an inappropriate way of depolarization. Several trials have been done to explain such effect, for example based on molecular biology [3,5,6,11]. Some of the experiments show that transitory memory of which influence on the stimulation test should be taken into account depends on the stimulation of fast-activated, potential-depended K channels placed in the cell membrane.

The aim of this study was to assess the ECM prevailing in the non-invasive transcutaneous coronary stimulation test.

2. MATERIAL AND METHODS

In the survey, 10 healthy volunteers of mean age 45 (38–60) were participated. All persons had a physical examination and the ECG exercise test to exclude possible coronary heart disease. The ventricular pacing was carried out in a three-electrode system where the active electrode was placed above the electrocardiografic point V3, whereas the two passive electrodes were placed in the sacral and gluteal region symmetrically on both sides of the backbone (Fig. 1) [8].

The surface of each of the ES-130S pacing electrodes (ITAM) was 50 cm^2. The pacing was carried out using the NAP-601 transcutaneous cardiostimulator (ITAM) which applied the rectangular impulses of 30 ms wide and 130 ppm rate. Ventricle excitation threshold was on the average 52 mA (38–72 mA).

In view of, described above, optimal location of the active pacing electrode, the V2 and V3 ECG leads were usually placed by one intercostal space lower than they were in a standard location. The 12-leads ECG signal was saved in memory of a CARDIS-210 digital electrocardiograph (ITAM) before, during the 30-second pacing and during 5 minutes after stopping the pacing.
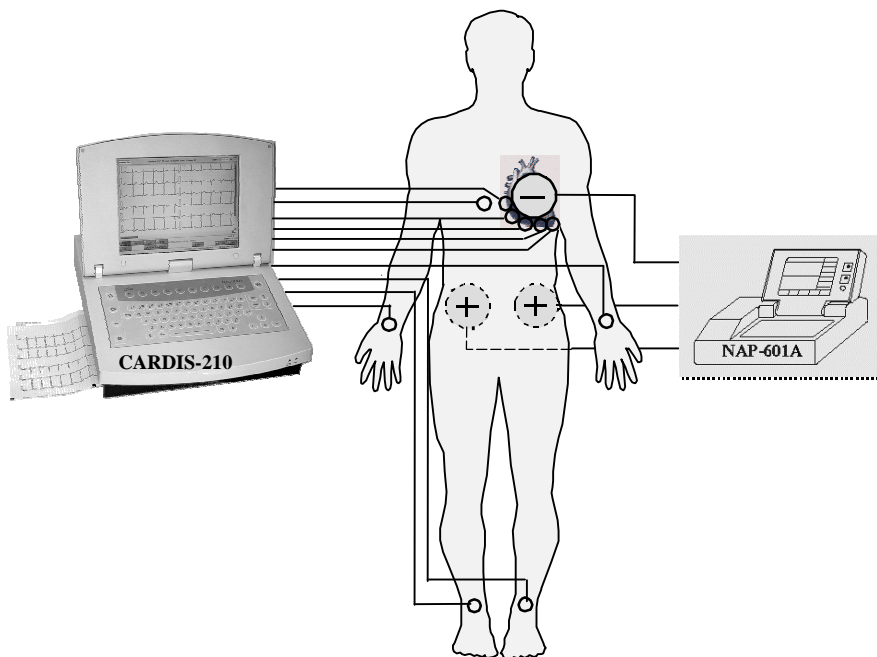
Fig. 1. Configuration of research workstation for assessment of electrical cardiac memory release during a stimulation non-invasive coronary test

Based on the ECG record during pacing the stimulation site have been estimated: occurrence of the left bundle branch block as a sign of the right ventricle stimulation, the right bundle branch block as a sign of the left ventricle stimulation and the normal duration of the QRS complex as a sign of the ventricular septum stimulation (Fig. 2,3).

For all obtained ECG records, we compared the mean amplitude of 5 consecutive QRS complexes before stimulation with amplitude of the first QRS complex after switching off the pacing. In such comparison, we included the amplitudes of QRS and RS complexes in all the 12 standard leads. We also took into account the shape of the T wave and level of the ST segment and TP isoelectric line after ventricular pacing switching off.
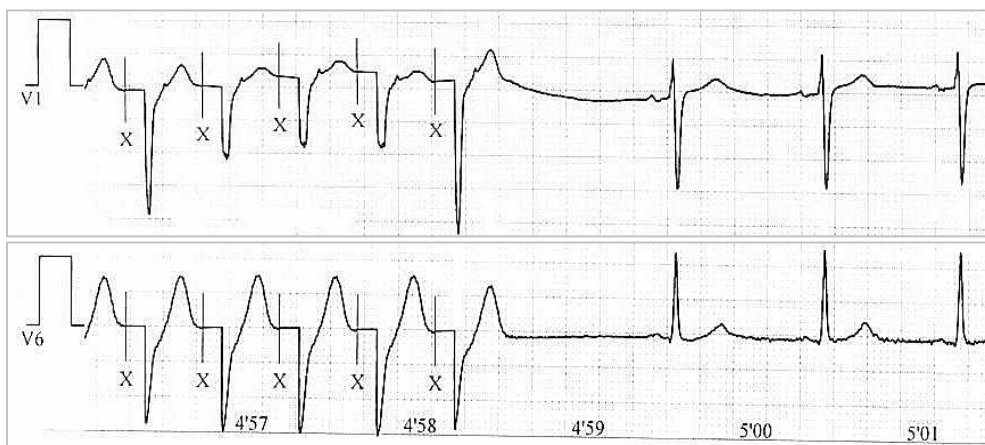

Fig. 2 Example of record of transcutaneous non-invasive stimulation of interventricular septum
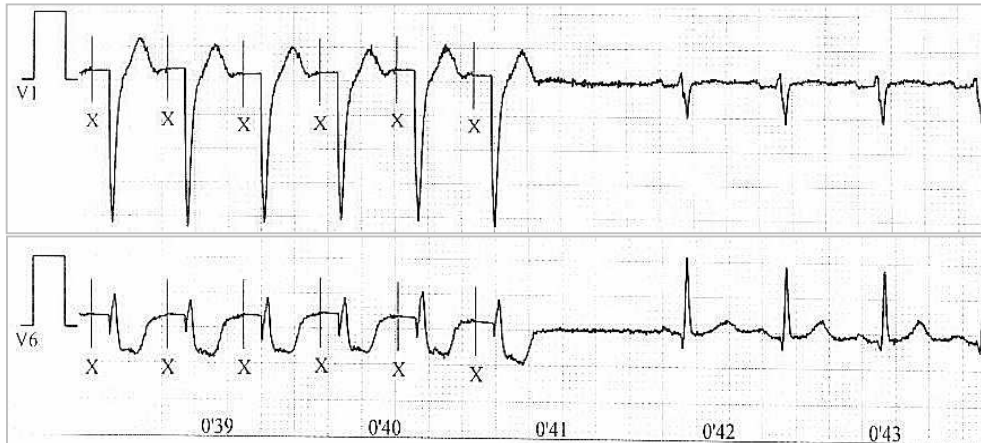
Fig. 3 Example of record of transcutaneous non-invasive stimulation of right ventricle

3. RESULTS

For all the patients after switching off the ventricular pacing we did not observe any case of negative T wave occurrence which was the basic criterion of the ECM activation (the Wilcoxon rank test $p = 0,2936$).

As we can see in the Table 1 the comparisons we made show only small differentiated changes. QRS complex amplitude was decreased in 4/10 and increased in 5/10 patients respectively. The T wave amplitude was slightly increased in 1 person and decreased in 6/10 (the Wilcoxon rank test $p = 0,3743$). Much more uniform changes we observed in the QT segment duration which decreased in 8/10 and increased in 2/10 patients (the Wilcoxon rank test $p = 0,2411$).

	Patient:	1	2	3	4	5	6	7	8	9	10
QRS [mV]	Before	4,1	9,3	7,8	7,3	6,4	7,1	9,3	5,5	11,3	8,1
	After	4,1	8,7	8,2	6,6	5,2	8,1	9,4	5,9	11,0	6,7
T [mV]	Before	1,7	2,1	2,9	2,0	1,2	2,8	2,3	1,1	2,6	1,6
	After	2,6	2,0	2,8	1,9	1,1	1,4	2,4	1,1	2,1	1,6
Q-T [ms]	Before	404	423	345	404	363	400	388	403	356	416
	After	440	422	350	348	338	356	385	402	343	395

Table 1 The QRS and T wave amplitude and the QT-T time results obtained for all patients, before and after pacing.

There was no influence of pacing on the ST segment and TP isoelectric line level. The right ventricle stimulation was recorded in 4/10, the left ventricle in 1/10 and the septum in 5/10 patients. No influence of stimulation site for analysed parameters after pacing switch off have been noticed (Fig. 4).
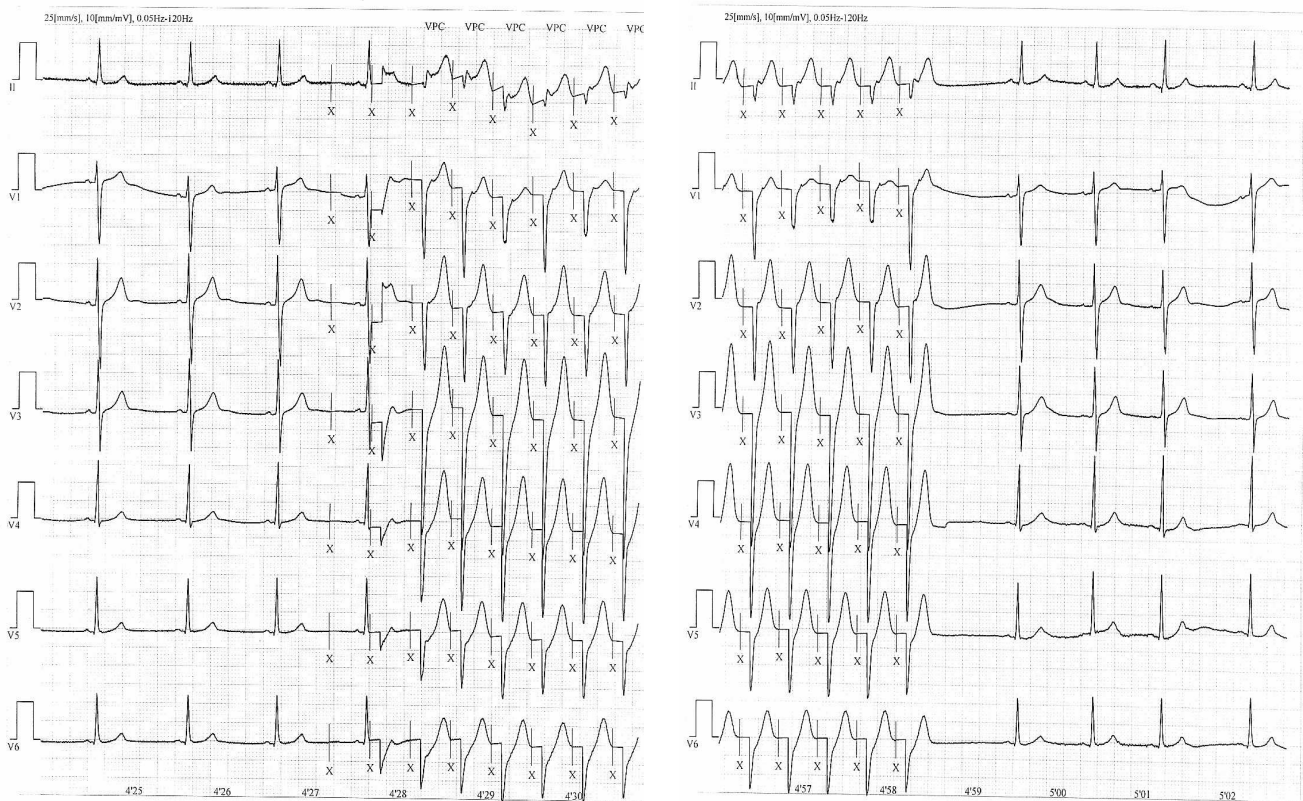
Fig. 4 Example of record of selected ECG leads (II, VI÷V6) during stimulation coronary test in healthy volunteer

4. DISCUSSION

The ECM is a phenomenon described as changes in the T wave morphology which arise due to the specific form of the remodelling as a results of long-time ventricular stimulation. There were some trials focused on the shape of the T wave for electrical ventricular pacing lasting from 30 minutes to 30 days [2]. Changes in the T wave morphology after switching off the pacing are proportional to duration of the ventricular pacing. Electrocardiographic nature of these changes reminds the changes of T wave existing in IHD [10]. The cardiac memory is explained as a result of a density of potassium channels which appears under the influence of pacing [6,12]. It is thought that activation of the cardiac memory depends on after-pacing decreasing of angiotensin II which is connecting with the own receptor and causes its internalization as a result. It is very likely that with the angiotensin II receptor some others receptors are being internalised which yields the decrease of K ions impact and extends the early repolarization phase [1,6].

The transcutaneous ventricular pacing, used in our investigation, met energetic criterion of a stimulus which can activate a cardiac memory effect, in view of using much greater amplitude and width of impulses than used in invasive cardiac pacing. In previous investigations, the cardiac memory effect was triggered after minimum 30-minute ventricular pacing [5,6,11]. Lasting 30 seconds transcutaneous ventricular pacing which we used in the coronary stimulation test even *a priori* seemed to be too short for induction of a cardiac memory effect. The results obtained in our investigation turned out to be fully consistent with the results of the previous trials, because after stopping the pacing the negative T wave – which may suggest false cardiac ischemia - wasn't

recorded in any case. These results excluded the influence of the 30-second transcutaneous ventricular pacing for the shape of T wave which is a symptom of high cardiac ischemia. Also keeping up the S-T segment of an isoelectric line after stopping the 30-second pacing was of a similar importance.

The increase and decrease of R and T wave amplitudes in some cases could be admittedly interpreted as induction of the ECM, however from the stimulation exercise test point of view such situation was completely negligible.

The transcutaneous coronary stimulation test is the only non-invasive test which may be used as a simple and quick screening test of endangered population without clinical symptoms of coronary disease. The computer spiral tomography – very popular nowadays – is not such a valuable tool and moreover is much more expensive in use.

The results obtained in our investigation exclude the false effect of 30-second duration of ventricular stimulation to the ECG signal recorded during the stimulation exercise test. It simplifies automatic analysis which will be provided in the CARDISCREEN project.

5. CONCLUSION

The results obtained exclude relevant influence of 30-second duration of the non-invasive transcutaneous ventricular stimulation on the ST-T segment morphology which is crucial for the ECG-based cardiac ischemia assessment.

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