

Noninvasive detection of repolarization changes in the heart

Eva Heblakova, Milan Tysler, Marie Turzova, Jana Svehlikova, Krisztina Szokolczai*,
Kristof Haraszti*, Slavomira Filipova**

Institute of Measurement Science, Slovak Academy of Sciences, Bratislava, Slovakia

*Research Institute for Technical Physics and Materials Science, Budapest, Hungary

**Slovak Healthcare University, Bratislava, Slovakia

ABSTRACT

Objective: Previously reported inverse method based on dipolar representation of differences in QRST integral maps with and without manifestation of local repolarization changes has shown the ability to identify small areas in the myocardium responsible for these changes in a group of patients with coronary artery diseases underwent revascularization. The aim of this study was to verify this approach on a group of 4 healthy persons and a group of 7 patients suffering from effort angina pectoris.

Methods: Changes in QRST integral maps after nitroglycerine sublingual application were examined and single dipole best representing the difference QRST integral map was inversely computed.

Results: After attempted compensation of heart rate variations, changes in QRST integral maps greater than expected intra - individual variability (over 15%) were detected in 4 persons. Obtained difference integral maps could be sufficiently approximated by maps generated by single current dipole only in 2 persons with relative root mean square (rms) error less than 35%; in the rest of subjects relative rms error of the dipolar map approximation was greater than 50%.

Conclusion: Results suggest that small repolarization changes might be detectable after nitroglycerine test, however this test did not induce detectable changes in some patients with effort angina pectoris. (*Anadolu Kardiyol Derg 2007; 7 Suppl 1; 130-2*)

Key words: body surface potential mapping, dipole model of cardiac generator, assessment of ischemic lesions

Introduction

In electrocardiographic signals, presence of ischemia is usually detected by ST segment depression or elevation and by changed shape of the T wave. These findings reflect changed repolarization properties of ischemic cells, namely shortening and decreasing of their action potentials.

It is widely accepted that integrals of potentials over the ventricular depolarization - repolarization period (QRST interval) depend on the shape and duration of action potentials in myocardial cells and not on the sequence of the ventricular activation (1). Therefore, differences in QRST integral maps caused by ischemic regions can be used for their identification.

This knowledge was previously used to propose a method for inverse assessment of single ischemic lesion using differences in patient's QRST integral maps with and without manifestation of the ischemia (2). Inverse method was based on the presumption that small ischemic lesion creates additional generator responsible for changes in surface QRST integral map that can be represented by a single current dipole. The method was verified on simulated body surface difference integral maps corresponding to subendocardial and subepicardial lesions with decreased and/or shortened action potentials located in typical positions in the myocardium during occlusions of three main coronary arteries. Mean localization error for small lesions was 11 mm and mean error of dipole orientation was 8° in homogeneous torso model. Localization of large transmural lesions was worse: mean localization error was 16 mm and mean error of dipole orientation

was 17°. Mean relative root mean square (rms) error between simulated difference map and map produced by the computed dipole was 12% for small lesions and 16% for large transmural lesions (3).

The aim of this study was to test the inverse method and its possibility to detect repolarization changes in the myocardium after application of nitroglycerine to patients previously diagnosed with effort angina pectoris.

Methods

Measurements of body surface potentials were performed on a group of 4 healthy persons – group A (h1 – h4) and 7 volunteers suffering from effort angina pectoris – group B (p1 – p7). Two patients in group B were previously diagnosed with stress-induced ischemic events, taking no medication regularly and 3 patients were diagnosed with ischemic heart disease and were taking beta – blockers.

Electrocardiogram (ECG) recordings of 1-minute length were taken using Amsterdam lead system (62 body surface electrodes) and 2 limb leads. Measurement was done before (record 0) and five times (records 1 to 5) every 3 minutes after sublingual nitroglycerine application (Nitromint spray, EGIS Pharmaceuticals). Difference QRST integral maps (DI maps) as a difference between reference QRST integral map of record 0 and QRST integral maps of each record after nitroglycerine application were computed. To compensate the influence of heart rate changes due to haemodynamic effect of nitroglycerine and to

extract expected changes caused by relieved ischemia, DI maps were linearly corrected to remove correlation with reference QRST integral map.

To confirm health condition of considered healthy subjects, their QRST integral maps were compared with available template (obtained from 72 healthy people measured in 32 leads according to Lux (4)) and departure QRST integral maps representing deviations from QRST integral map template were computed.

Common realistic homogeneous torso model and realistic geometry of heart ventricles divided into 28 volume elements were used in the inverse computations. From obtained DI maps, corresponding equivalent dipole source was inversely computed at the centre of each segment of the ventricular volume as

$$M_i = T_i^+ \Phi, \text{ for } i=1, 2, \dots, 28 \quad (1)$$

where Φ are values from the DI map in 62 body surface points, T_i^+ is pseudo inverse of the transfer matrix between the i -th segmental dipole and values in DI map, M_i represents QRST integral of the i -th segmental dipole. Minimal rms error between

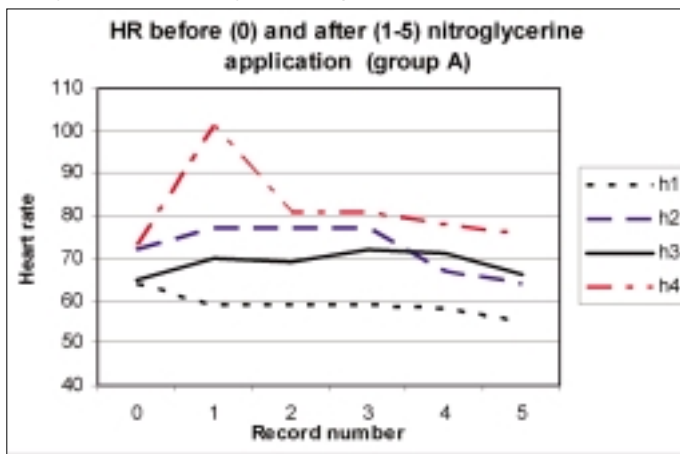


Figure 1. Change of heart rate after nitroglycerine application in a group of healthy subjects (h1-h4) record number 0 corresponds to the measurement before, numbers 1 – 5 to measurements every 3 minutes after nitroglycerine application

HR- heart rate

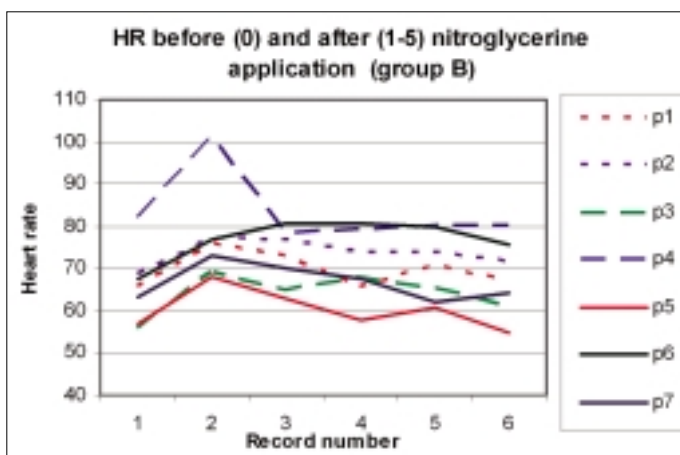


Figure 2. Change of heart rate after nitroglycerine application in a group of subjects (p1-p7) diagnosed with effort angina pectoris; record number 0 corresponds to the measurement before, numbers 1 – 5 to measurements every 3 minutes after nitroglycerine application

HR- heart rate

measured DI map and map produced by a segmental dipole was used as a criterion for the best equivalent dipole representing the DI map.

Results

Although all departure maps had negative extremes greater than 2 standard deviations, departure maps of group A achieved extremes smaller than 3 standard deviations while departure maps of group B had extremes larger than 3 standard deviations from QRST integral map template.

Effect of nitroglycerine was monitored by change of heart rate (Fig.1, Fig. 2). Nitromint sublingual application was followed by increase of heart rate with peak effect predominantly in 3-6 minutes in both groups except for one subject from group A (h1) which was excluded from further evaluation.

Relevance of DI maps for the inverse computation was examined by evaluation of the relative rms differences between normal (record 0) and changed (record 1-5) QRST integral maps. As relative rms differences observed between simulated normal and changed QRST integral maps corresponding to small lesions were 20-45%, this difference was required to be greater than 15% to account for possible intra-individual variability in QRST integral maps. One healthy subject from group A (h4) and 3 subjects from group B (p1, p2, p3) fulfilled mentioned condition (Fig. 3), especially in the first 2 records after nitroglycerine was applied. DI maps of these subjects were inversely approximated by single current dipole (Fig.4). For subject h4, relative rms error between measured DI map and map produced by the equivalent segmental dipole was 33%, for subjects p1, p2 and p4 relative rms errors were 51%, 60% and 31%, respectively.

Discussion

Due to nitroglycerine-induced coronary dilatation effect, changes in repolarization properties of ischemic cells, manifested as changes in QRST integral maps, were mostly expected in group B. Patients treated by beta – blockers responded to nitroglycerine with slight increase of heart rate but no significant change in difference maps was found. In one subject of group B (p3 patient diagnosed with stress-induced ischemic events, taking no medication) only weak changes in difference maps occurred, probably because the effect of increased heart rate

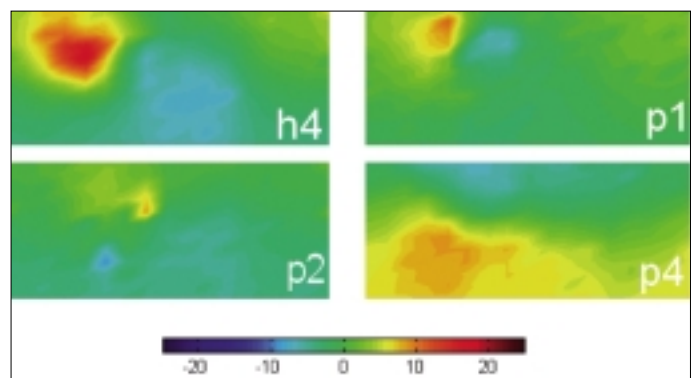


Figure 3. Difference maps (maps of differences between QRST integral maps measured before and after nitroglycerine application) of one healthy subject (h4) and 3 subjects suffering from effort angina pectoris (p1, p2, p4). Color scale of maps is in $\mu\text{V.ms}$.

attenuated positive action of nitroglycerine and induced raised oxygen demand of the working myocardium. Remaining subjects of group B and one healthy person showed significant changes in QRST integral maps responding mainly to different repolarization properties of myocardial cells. Good dipolar representation of changes in difference map could refer to a small local region of ischemic cells. To the contrary, insufficient dipolar representation of the difference map in two cases could indicate great dispersity of the affected region.

Conclusion

After attempted compensation of heart rate variations, changes in QRST integral maps greater than changes expected due to possible intra - individual variability were detected in four persons and no significant changes were revealed in patients

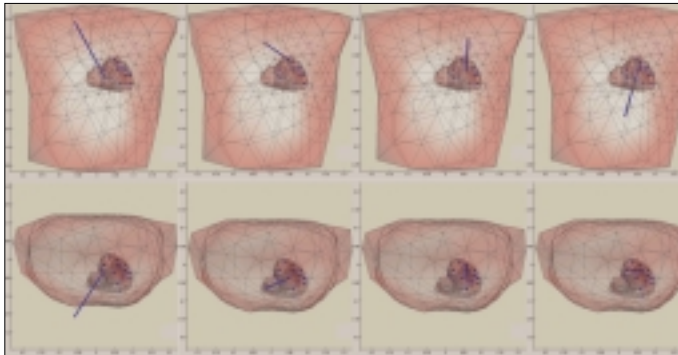


Figure 4. Visualization of the best dipolar approximation inversely computed from difference maps of one healthy subject (h4, first from the left) and 3 subjects suffering from effort angina pectoris (p1, p2, p4; from the left respectively)

suffering from angina pectoris, which were under regular doses of beta – blockers. From DI maps obtained in these four cases, only in two cases, the changes could be sufficiently represented by single current dipole; in the rest of DI maps relative error of dipolar approximation was over 50%.

These results suggest that small repolarization changes might be detectable after nitroglycerine test; however, in some patients with effort angina pectoris no significant changes were detected or could not be represented by a single dipole.

Acknowledgement

This work was supported by grants 2/7092/27 from the VEGA grant agency, APVV-51-059005 from the APVV agency and grant GVOP 3.1.1-2004-05-0196/3.0.

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