

Effects of Heart Orientation on Isolated Heart Electrograms

Marina Ronzhina^{1,2}, Veronika Olejníčková³, Oto Janoušek^{1,2}, Jana Kolářová^{1,2}, Marie Nováková^{2,3}, Ivo Provazník^{1,2}

¹Department of Biomedical Engineering, Brno University of Technology, Brno, Czech Republic

²Center of Biomedical Engineering, St. Ann's University Hospital Brno, Brno, Czech Republic

³Department of Physiology, Faculty of Medicine, Masaryk University, Brno, Czech Republic

Abstract

During certain experiments, there is a need of changing the position of heart as related to recording system. The present paper is focused on the study of morphological parameters of electrogram (EG) recorded from the isolated heart rotated around its longitudinal axis during global ischemia. It is shown that the change of heart position may result in changes of EG parameters values, important for ischemia evaluation.

1. Introduction

There are many different approaches for ischemia evaluation. Generally, ischemia can be manifested with monitoring of morphological parameters of ECG, such as ST₆₀ level and/or T wave amplitude, etc. Many authors studied the effects of body position (i.e. heart position) on human ECG morphology (e.g. [1]). Various approaches focused on detection of the changes in ECG caused by body position changes have been presented (e.g. [2]). The main goal of such methods is to decrease the degree of misclassification of these changes as the changes caused with ischemia. It is especially important in automatic detection of ischemia on ECG. In some animal experiments, there is a need of changing the position of heart in recording system, which may often results in incorrect analysis and interpretation of recorded electrograms (EG). Study of effects of heart orientation on EG morphology may help to avoid some of these difficulties.

2. Methods

2.1. Electrogram recording

The animal experiments were performed in accordance with the guidelines for animal treatment approved by local authorities and conformed to the EU law. Twelve New Zealand rabbits underwent general anesthesia with

i.m. injection of xylazin and ketamin. The heart was then rapidly excised, placed in a bath, filled with Krebs-Henseleit solution (1.25mM Ca²⁺, 37°C), and retrogradely perfused according to Langendorf in the mode of constant perfusion pressure (85mmHg) [3].

Recording of EG was performed by touch-less method using the orthogonal electrode system (three pairs of Ag-AgCl disc electrodes, see Fig.1a) placed in the bath wall [3,4]. The sampling frequency of 2 kHz used to record is sufficient for the correct detection of QRS complexes.

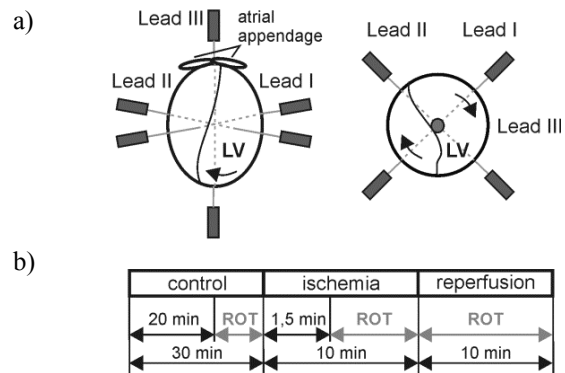


Figure 1. EG recording: a) orthogonal system of electrodes (initial position of the heart), b) experimental protocol. LV - left ventricle, ROT - rotation session.

The experimental protocol included control (stabilization), ischemia (absence of perfusion), and reperfusion phase. Initial orientation of the heart (0° position) was similar to its physiological orientation in the chest (see Fig.1a). In each phase (in 4 experiments it was done only in control and reperfusion phase), heart was rotated around longitudinal axis with 10° intervals within the range of 0°-90° (see Fig.1b), which is sufficient for further reconstruction of EG within the whole range (0°-360°). Additionally, heart was rotated from 0° to 30° at the end of each session. It allows to find the EG parts with unstable morphology within the session. These parts were rejected from further analysis. In ischemia phase, rotation was performed after 1.5min

from the phase onset because of rapid changes in EG morphology during this period. Rotation session lasted approx. 1.5-2min. Recorded signal in each heart position was of approx. 8-10s duration (according to the actual heart rate) and included 10-20 P-QRS-T segments.

2.2. Data preprocessing

The parts of EG with some artefacts were rejected from analysis. The low-frequency baseline wander was then suppressed using Lynn's filter with cut-off frequency of 0.5Hz. After filtering, QRS complexes were detected with the wavelet based detector and verified manually. The QRS-T segments (560 samples or 280ms length) were selected from EG as 59 samples before and 500 samples after detected fiducial point of QRS.

EG from leads I and II within the range 100°-350° were calculated using those recorded within the range 0°-90°. Reconstruction scheme for calculation of QRS-T segments from lead I is shown in Fig.2. Here, rotation of the electrode system around fixed heart is used instead of heart rotation for easier understanding and representing (see Fig.1a to compare).

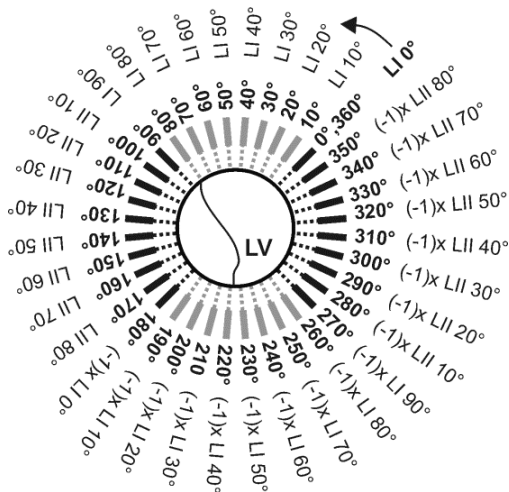


Figure 2. Scheme of EG reconstruction for lead I. Positions reconstructed using EG from lead II are depicted with light gray. LI, LII - lead I and lead II, respectively. LV - left ventricle.

Similar scheme (not shown) was used to reconstruct segments from lead II. Heart orientation changes do not affect EG from lead III. Correlation coefficient for QRS-T segments recorded for different heart orientation from lead III is more than 0.99. Therefore, all segments from this lead were taken into account to define remaining part

(see below).

For further analysis, beginning of Q wave, J point, and the end of T wave were manually detected in selected and reconstructed QRS-T segments, considering data from all three ECG leads.

Within groups of segments (each group includes segments from EG recorded at certain heart position, i.e. at certain angle of rotation around longitudinal axes), correlation reached more than 0.95 (for a few groups more than 0.99). Each heart position was finally represented with the mean QRS-T segment calculated from all segments in the group. For lead III, only one mean segment was calculated from all groups of the segments to represent all heart positions. The methods were realized in Matlab 7.5 (The MathWorks, Inc.).

2.3. Parameters of EG

Various morphological parameters were calculated from mean QRS-T segments using three detected characteristic points (see above): ST30 level (modified ST₆₀ level used for human ECG), maximum of ST-T interval (maxST-T), and angles of heart mean electrical axis (MEA) defined using area under QRS complexes (AUC_{QRS}) with trapezoidal integration: pairs AUC_{QRSI} and AUC_{QRSII}, AUC_{QRSI} and AUC_{QRSII}, and AUC_{QRSI} and AUC_{QRSIII} were used to compute α , β , and γ , respectively. Presented parameters reflect cardiac electrical activity and its changes caused by ischemia.

3. Results

In this study, relationship between parameters calculated from EG recorded during ischemia experiments and heart position was evaluated. The course of ST30 level and maxST-T in control and reperfusion phase is highly individual for each animal. One example is shown in Fig.3a,b, where the courses of parameters in control and ischemia have very similar character and differ in amplitude mainly. In this case, ST30 level and maxST-T for control phase are within the range -400-+400 μ V and -1000-+1000 μ V, respectively. In ischemia, these values are 5-6 times higher. Moreover, these parameters have very similar character in ischemia (see boxplots in Fig.3c). From Fig.3a-c, initial position defined as 0° (see Fig.1 and Fig.2) seems to be suitable for ischemia monitoring because of significant difference between ST30 and maxST-T for control and ischemia (approx.1800 μ V for lead I).

The absolute value of difference between ST30 ($|\text{diff}(\text{ST30})|$) and maxST-T ($|\text{diff}(\text{maxST-T})|$) at initial 0° and other positions is shown in Fig.3d,e. $|\text{diff}(\text{ST30})|$ is in the range 200-500 μ V, 1000-4000 μ V, and 400-800 μ V in lead I in control, ischemia, and reperfusion phase, respectively.

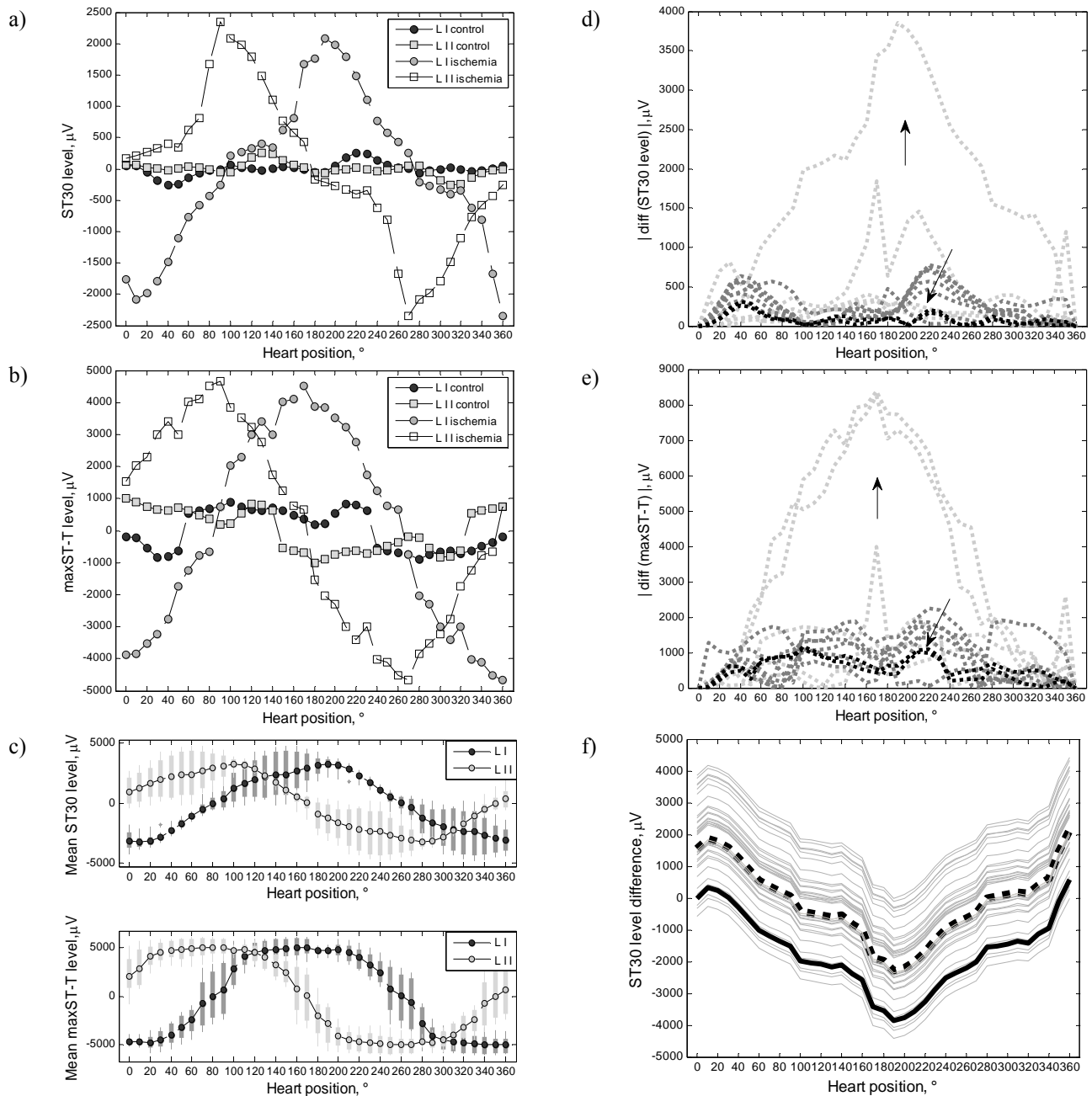


Figure 3. Relationship between EG parameters and heart position: ST30 level (a) and maximum of ST-T (maxST-T) (b) in control and ischemia for lead I (LI) and lead II (LII) (for one animal), boxplots of ST30 level and maxST-T in ischemia for LI and LII for all animals (c), difference between ST30 level (d) and maxST-T (e) at initial (0°) and other heart positions for control (black), ischemia (light gray), and reperfusion (gray) for lead I (for one animal), difference between ST30 level at different initial (0° - 360°) and other heart positions for ischemia for lead I (f) (for one animal).

$|\text{diff}(\text{maxST-T})|$ is in the range $500\text{-}1500\mu\text{V}$, $4000\text{-}8000\mu\text{V}$, and $800\text{-}1500\mu\text{V}$ in lead I in control, ischemia, and reperfusion phase, respectively. The parameters in lead II have similar course with shifting of approx. 90° to the right. In Fig.3d,e, arrows indicate the changes in parameter within the phase: both increase during ischemia and decrease during reperfusion (to the values similar

with that of control phase). Values of both parameters depend on selected initial position of the heart. In Fig.3f, the course of ST30 level difference (not its absolute value) for lead I in ischemia relating to the selected initial position of the heart is shown. For 0° position, the parameter is in the range of $-4000\text{-}150\mu\text{V}$ (solid black line), whereas for 280° initial position, this range is of -

2000-2000 μ V (dotted black line).

Global ischemia causes inversion and shifting (at approx. 60°) of MEA angles course for different heart positions (see Fig.4a,b).

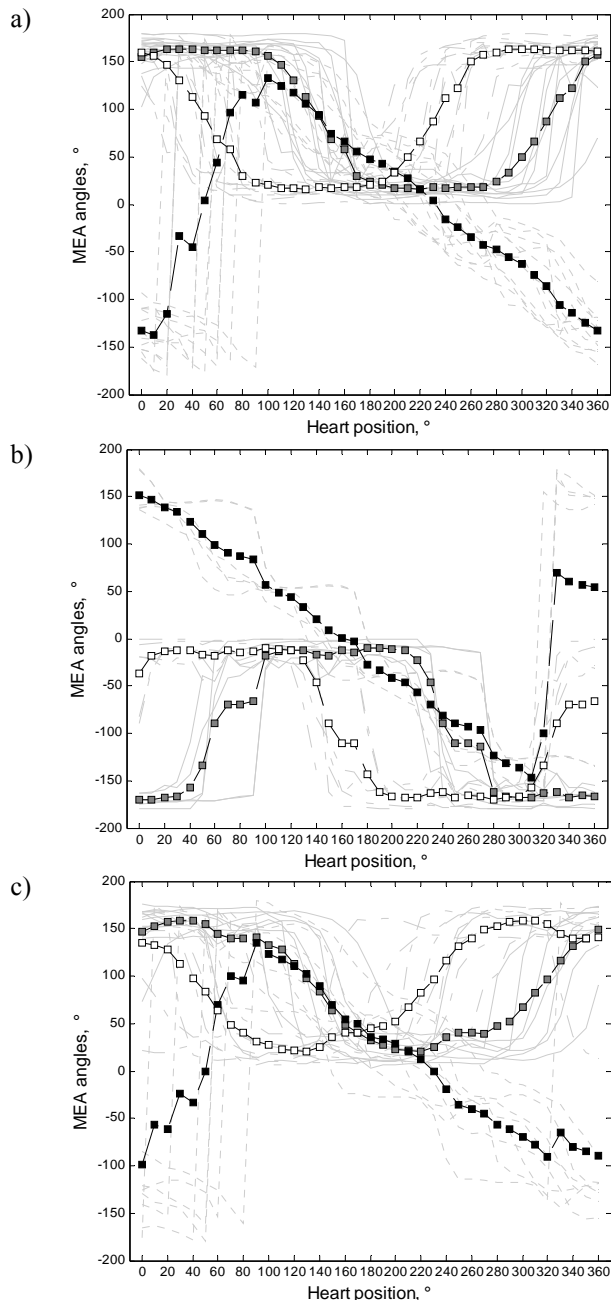


Figure 4. Mean values (all experiments) of angles of mean electrical axis (MEA) in control (a), ischemia (b), and reperfusion phase (c). α , β , γ are depicted with gray, black, and white markers, respectively.

These changes are reversible and disappear at approx. 2nd-3rd minute of reperfusion (compare Fig.4a,c). There are two regions with almost constant α and γ (as an

example, for α it is 0°-100° and 190°-270°) and transient regions (100°-190° and 270°-360° for α), which reflect recording and reconstruction scheme. β has nearly linear course in the whole range.

4. Conclusions

Values of ST30 and maxST-T are highly individual in each animal in control phase. There are not standards for ischemia manifestation using these parameters in isolated rabbit heart. Thus, further experiments are needed to answer if heart rotation around longitudinal axis affects significantly the values of these parameters, which are important for ischemia evaluation, and which heart position is the most appropriate. The present recording scheme with the next reconstruction of some ECGs can be used instead of use of few electrodes to map rapidly changes in heart electrical activity. Presented results may help in studies aimed at analysis of animal ECG and in designing experimental protocols.

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Address for correspondence.

Marina Ronzhina
 Department of Biomedical Engineering
 Faculty of Electrical Engineering and Communication
 Technická 12
 616 00 Brno
 Czech Republic
 ronzhina@feec.vutbr.cz