The 64 Channel System for High Resolution ECG Mapping

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Abstract

The purpose of this work was an improvement of the heart micropotential measurements and analysis by simultaneous use of two noninvasive methods: body surface mapping and high-resolution electrocardiography.

Software for body surface mapping and multi-lead high resolution analysis was developed. Analysis of QRS duration and energy of 25ms in terminal QRS complex was applied both for each single lead and orthogonal X,Y,Z lead system. Results were visualized on 3D torso.

Preliminary recording was carried out on 3 normal subjects and 3 myocardial infarction patients.

1. Introduction

High resolution electrocardiography (HR ECG) and body surface potential mapping (BSPM) are noninvasive methods used for evaluation of electric activity of the heart. So far these ECG techniques are usually used separately but the combine application of both methods could improve effectiveness of noninvasive ECG diagnosis of ventricular tachycardia, as well as ventricular and atrial fibrillation. The application of the high resolution technique to the BSPM was recently tested clinically with 28-lead ECG system. This approach significantly improved the sensitivity of the ECG [1]. The aim of this study is further improvement of ECG diagnosis by development of the high resolution 64-channel system. The system with such lead number is recommended as the optimal BSPM mapping system for picking up the major part of information in the ECG [2] .

2. Methods

The multi-lead system for HRECG acquisition consisting of 64 low-noise amplifiers with own A/D converters (*BIOSEMI*, the Netherlands) is operating in the electrically shielded room.

The series data are transferred via optical fiber to receiver interface connected to DMA board in PC Pentium II (Fig.1). The amplifier/converter part of the system is battery supplied. ECG signals are acquired with 4096 Hz sampling frequency, digitized at 16-bit resolution and recorded for at least 300 seconds. The low resistance Ag/AgCl pediatric electrodes LFR-310 (*Bio-Lead-Lok*, Poland) were applied both in strips and as single electrodes.

The lead system proposed at the University of Amsterdam is used [3]. System includes 32-lead Lux optimal system [4],[5], six standard ECG leads and orthogonal X,Y,Z leads (Fig.2).

3. Signal analysis

The analysis software includes programs both for multi-lead, time domain high resolution analysis and for three-dimensional ECG map visualization. The analysis begins from reducing sampling frequency from 4096 Hz to 1024 Hz, what yields preliminary noise reduction. Subsequently data are filtered with filter removing baseline drifts. Signal averaging is applied to all channels simultaneously, after the interactive cross-correlation procedure. Cross-correlation coefficient is set as 0.98.

The filtering procedure is applied using the 40-Hz high-pass bidirectional Butterworth 4^{th} filter [6] or polynominal filter [7] to eliminate low-frequency components. The high resolution ECG analysis includes both conventional analysis of combined vector magnitude computation from orthogonal X,Y,Z leads and individual lead analysis.

The QRS duration and the energy of 25 ms interval in terminal QRS complex were calculated for each lead individually. Simson's algorithm was used for automatic QRS detection both in combined vector magnitude of the X,Y,Z and in single leads[8]. Manual correction was feasible.

The spatial distribution of the QRS duration and energy of 25 ms interval in terminal QRS complex were visualized on the torso.

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4. Results and discussion

The 64–channel system for high resolution ECG mapping was developed and technically tested. In the high resolution ECG analysis, one of the most important factor is a very high signal to noise ratio. The noise level influences measurements of the QRS onset and especially the offset in the filtered signal. It limits the accuracy of the evaluation of the QRS duration, which is the best indicator in the diagnosis of ventricular tachycardia in the time domain analysis. The raw data from our system contain the noise varying from 2 µV to 5 µV (RMS value). The patient's relaxation, warm surrounding and skin preparation (only shaving if needed) were observed. To improve the signal to the noise ratio, temporal averaging over 150 beats in each lead was simultaneously applied. The received noise level varied from 0.1 µV to 0.5 µV (RMS value). The noise level depended both on the lead location on the torso and on the individual subject skin properties (Fig. 3).

Another important factor is the method of the averaged signal filtering. The 40-Hz high-pass bidirectional Butterworth 4th filter was used as a commonly used filter for removing low-frequency signals. With this filter, the mid-QRS area, where the bidirectional implementation meets, is not properly defined. Because of the nonlinear phase response, this filter distorts the signal and introduces temporal shifts of the high-frequency signals [9].

The preliminary test recording and the analysis were carried out on 3 normal subjects and 3 myocardial infarction (MI) patients.

Two parameters used in the time domain analysis: the filtered QRS duration and energy of the 25 ms interval in the terminal QRS complex were calculated. Both the QRS onset and the QRS offset were identified individually for each lead. The QRS duration was significantly longer in MI patients. The spatial distribution of QRS duration is shown in figure 4a and 4b.

In the figure 5a and 5b the spatial distribution of energy of the 25 ms interval in the terminal QRS complex is shown - both for MI patients and for normal subjects. The darker areas correspond to the higher energy values. The maximum of the energy can be clearly seen in patients after MI. The energy of the 25 ms interval corresponds to late potentials. Wang et al. [9] suggest that the site of the maximal late potentials (RMS values of 40 ms intervals behind S point in QRS complex) tends to be at the periphery of the infarction zone.

We hope that the energy of the terminal 25ms interval in the QRS complex could be a good parameter in the analysis of the spatial distribution of late potentials and their correlation to the site of the origin of premature ventricular complexes.

5. Figures

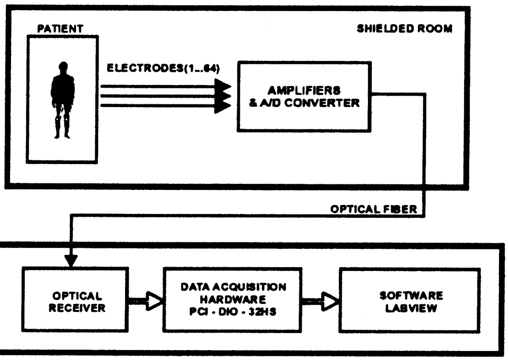

Figure 1. Acquisition system setup for the HR ECG mapping.

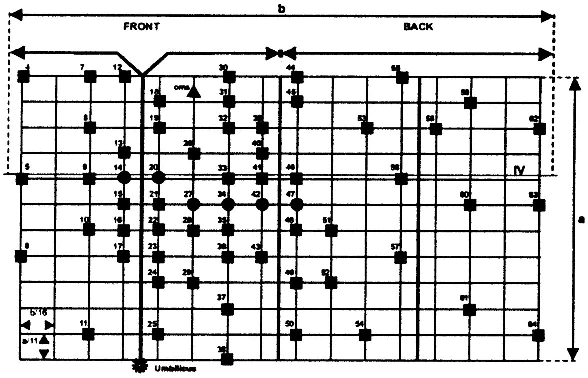

Figure 2. The electrodes location on the torso.

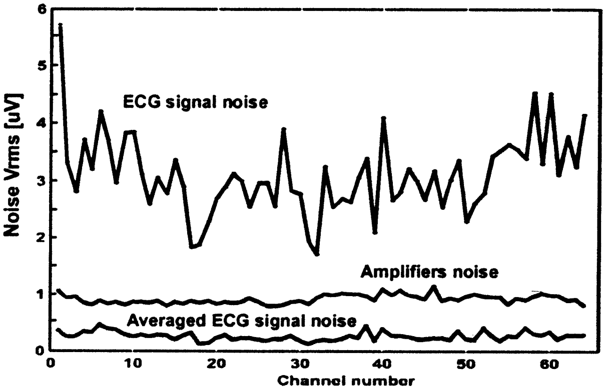

Figure 3. The oise level of the multi-lead ECG recording.

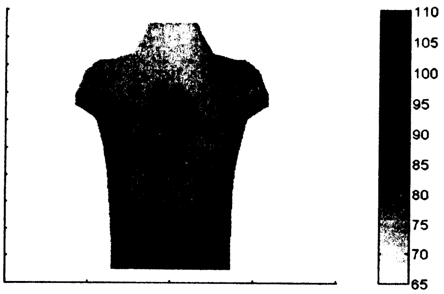

Figure 4a. The spatial distribution of the QRS duration on the chest of the MI patient.

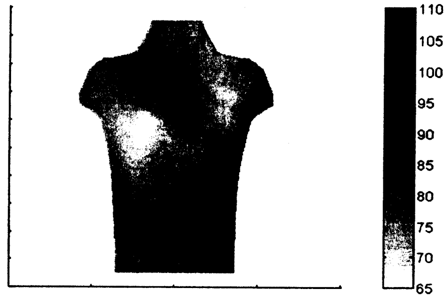

Figure 4b. The spatial distribution of the QRS duration on the chest of healthy subject

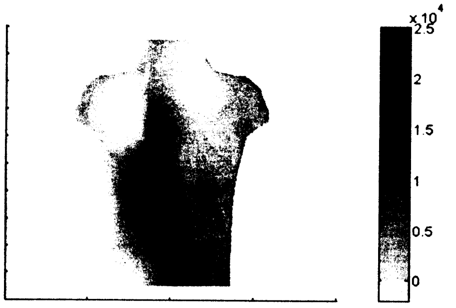

Figure 5a. The spatial distribution of the energy of the 25 ms interval in the terminal QRS complex on the chest of the MI patient.

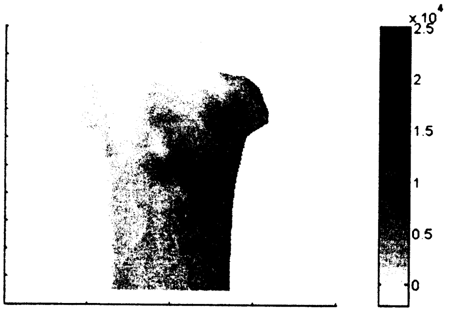

Figure 5b. The spatial distribution of the energy of the 25 ms interval in the terminal QRS complex on the chest of the healthy subject.

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