ASSESSMENT OF THE INFARCT SIZE FROM HIGH-RESOLUTION ECG COMPUTER-BASED SYSTEM

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The present study describes the implementation of computer-based multichannel ECG system in intensive coronary care unit for monitoring of patients with acute myocardial infarction (AMI), thus providing a convenient method for precise assessment of the infarct size. The ECG PC-based system was designed to acquire, process, analyze, visualize the standard leads, as well as to allow the application of advanced examinations and tests on the acquired high-resolution ECG signals. Fifteen patients with clinical symptoms, ECG and laboratory signs for AMI with ST-elevation from the Department of Internal Medicine "Prof. St. Kirkovic", Medical University - Sofia were examined with the developed ECG system. We studied the approach for analysis of the high-resolution ECG recordings, especially the synthesized VCG leads with some additional transforms, aiming to provide adequate information about the infarct size and localization.

Keywords: multichannel ECG acquisition system, high-resolution ECG, VCG

1. INTRODUCTION

The fast development of electronics and computer-based systems advances progressive solutions (hardware and software) for improvement of the diagnostic ability of many cardiac diseases. The most frequently encountered heart disease of patients with sudden cardiac death is the coronary artery disease. The development of reliable and easy for practical application methods for assessment of the size and localization of the acute myocardial infarction (AMI) could be of great benefit for estimation of the myocardial injury, evaluation of the risk for appearance of the main complications (cardiac arrest, myocardial rupture, rhythm and conduction disturbances etc.), assessment of the therapy effect for limitation of the myocardial necrosis zone, as well as the prognosis of the consequent mortality [1,2].

The easiest, reliable and widely accessible non-invasive method for cardiac diagnostics is the multichannel (standard 12-lead) electrocardiography (ECG) and the three-lead orthogonal system vectorcardiography (VCG) [3,4]. However, the application of VCG is not routinely established in the clinical practice due to the need of high-qualified medical personnel for its interpretation. In this respect, several studies are aimed at investigation of automatic algorithms for assessment of VCG loop descriptors and their diagnostic capabilities [5,6]. The continuous ST-segment monitoring by either 12-lead ECG or VCG provides reliable information regarding ST-segment changes in patients with AMI, as well as allowing the clinician to continuously follow the dynamic changes of the associated syndromes [7].

The present study describes the implementation of the computer-based multichannel ECG system [8] in intensive coronary care unit for monitoring patients with AMI. The experimental study demonstrated the correct performance of the PC-based system in synchronous acquisition of high-resolution ECG signals from eight channels, with subsequent signal processing procedures. The applied advanced examinations of the synthesized VCG leads and loops proved that this method is convenient and applicable for precise assessment of the infarct size.

2. ECG SYSTEM

The ECG PC-based system was designed to acquire, visualize and apply different processing techniques on the synchronously captured high-resolution ECG signals from 8 analog input channels. The architecture of the developed ECG system is shown in fig.1. Generally, the ECG system consists on two parts: (i) remote front-end amplifier module and (ii) PC module, working with PC interface board and PC software for ECG data visualization, processing, recording and printing. Both the performance of the front-end signal acquisition module and the software for signal processing and analysis are essential for improvement of the diagnostic interpretation of the ECG signals.

2.1. Remote front-end floating amplifier module

The main characteristics of the floating module are listed bellow:

- Acquisition of high-resolution ECG signals - SR = 1 kHz, 12 bit resolution;
- Synchronous signal acquisition from 8 channels (the electrodes are placed on the two arms, the left leg (reference) and the six standard chest points);
- Small size, low weight and low consumption of the front-end floating amplifier, which is realized with small number of operation amplifiers. Each of the eight amplifier channels consists of one non-inverting op.amp. in the first stage, followed by a RC circuit with the standard for the ECG diagnostics time-constant of 3.2 s, and next buffered with non-inverting op.amp. The total gain is about 200 times;
- Body driving scheme for common mode power-line interference suppression. The left leg potential F is compared to the ground and the inverted difference is fed back to the body, thus rejecting the common mode voltage at the inputs of the channels R, L, $C_1 \div C_6$. The effect is equal to that of the well-known instrumentation amplifier, obtained by larger number of op.amps.
- low-consumption CMOS digital section, which is realized with simple drive logic for control of the synchronous capturing process of the 8-input channels;
- The 8 input channels are multiplexed, sampled by one-channel analog-to-digital converter (ADC) to 12-bit unsigned numbers and sent them in serial format to the PC module through an opto-coupler.

The total consumption of the system, which operates with small number of chips, without microprocessor control, is decreased to less than 15 mA. Moreover, the small size and weight make it convenient for floating signal acquisition module, which could be mounted in the patient cable branching box and supplied by a battery.

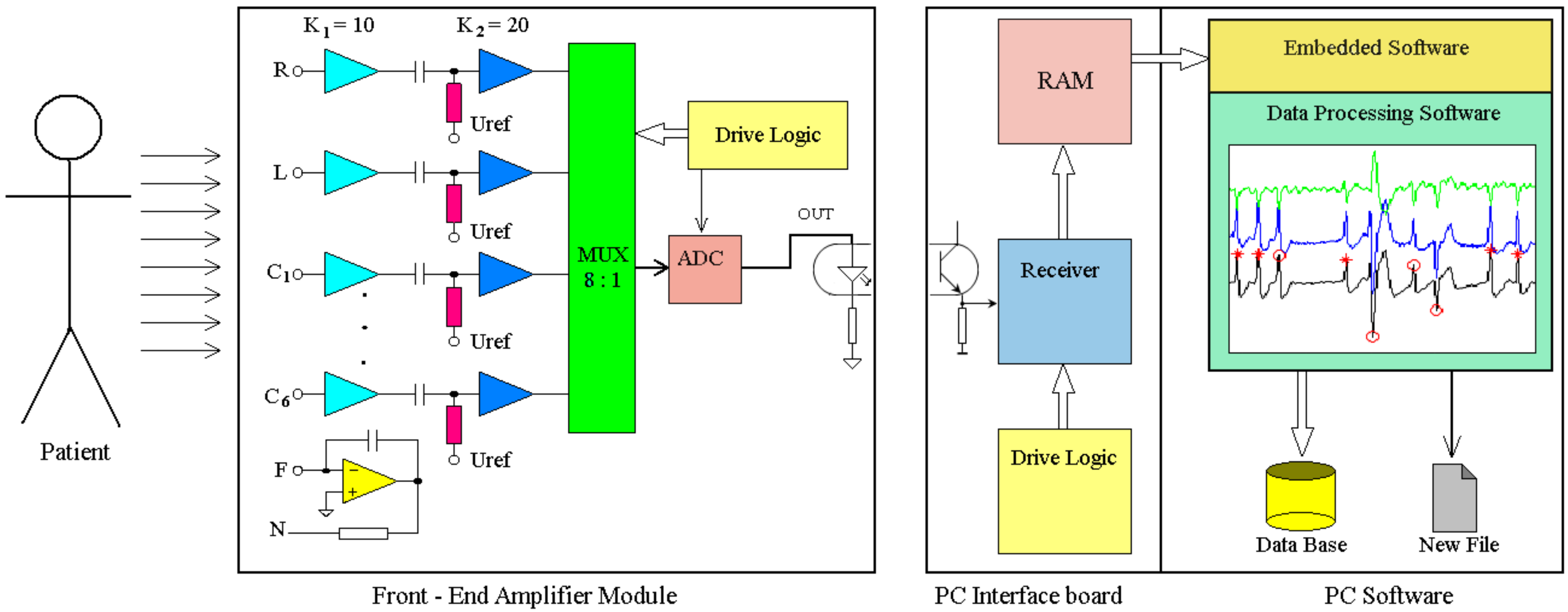

Fig.1. Block circuit of the PC-based multichannel ECG system

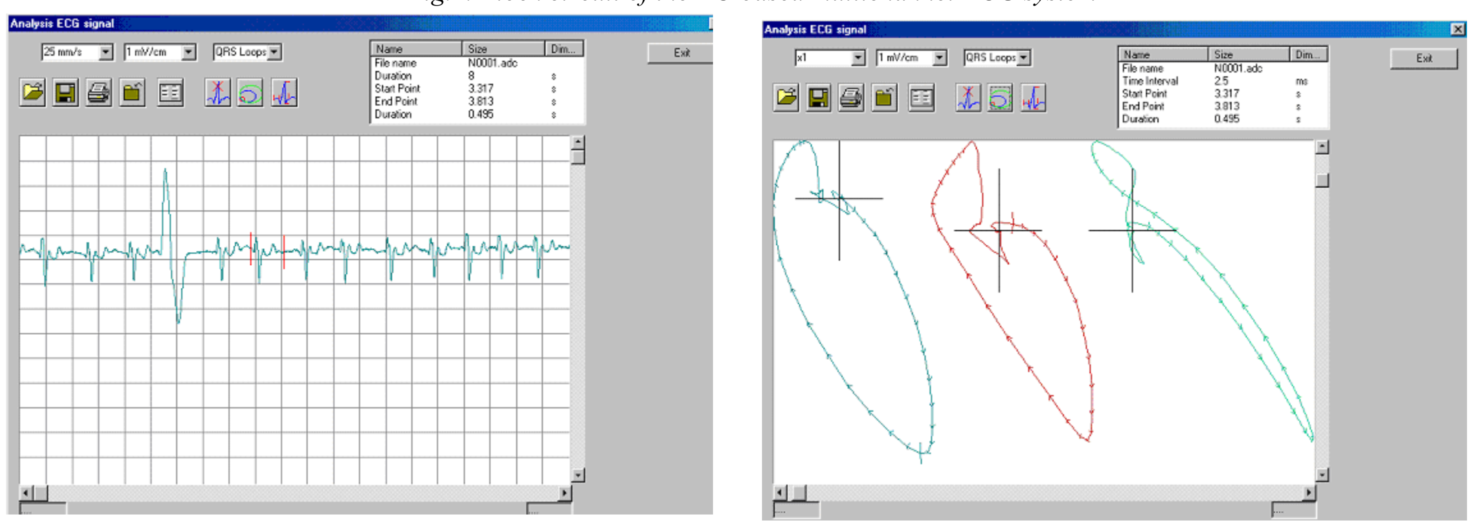

Fig.2. General view of the PC software

2.2. PC module

The PC module was realized with: (i) PC interface board for synchronization of the ECG data transfer and (ii) PC software running under OS Windows (fig.2), which is responsible for the following operations on ECG data reception:

- Calculation of the 12 standard ECG leads, using the mathematical transforms [3];
- ECG data buffering;
- Filtration: 0.64 Hz high-pass (bilinear transform) for baseline wander suppression, 50Hz band-pass (moving averaging procedure) for mains interference elimination;
- Real-time visualization, and printing;
- Reading and saving from/to HDD;
- QRS detection and heart rate calculation;

3. HIGH-RESOLUTION ECG PROCESSING

3.1. Method

We study an approach for analysis of high-resolution ECG recordings aiming to provide adequate information about the infarct size and localization. The method is based on assessment of the synthesized VCG. We calculate the orthogonal X_o,Y_o,Z_o leads from the 12 standard leads by applying the transformations [4]:

$$\left| \begin{array}{l} Xo = 0.4*II-0.8*(II+III)/3+0.2*V5+0.5*V6+0.1*V4 \\ Yo = 0.3*III+0.8*II+0.5*(II+III)/3-0.2*V5-0.3*V6 \\ Zo = -0.1*III-0.2*II+0.4*(II+III)/3-0.3*V1-0.1*V2-0.1*V3-0.2*V4-0.1*V5+0.4*V6 \end{array} \right. \quad (1)$$

There is 60^0 zone between lead I and lead II in the standard ECG with projection on the left ventricle, which is not directly reflected by any of the leads [9]. Therefore, to supply additional information, we apply synthesis of the orthogonal X, Y, Z leads (named X1,Y1,Z1), but lead *III*=2*(*II*+*avR*) is substituted in Eq.1 with inversion of the lead *avR* (-*avR*) (named X2,Y2,Z2). Thus, we examined the possibility for improvement of the AMI diagnostics.

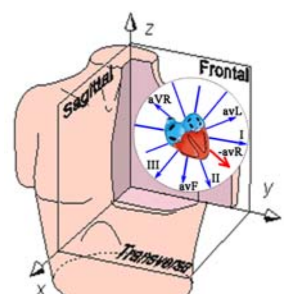

Fig.3. Projections of the lead vectors in the frontal plane

The most informative indexes extracted from the orthogonal leads, which show maximal deflection compared to the respective norms, are assessed for each infarct localization type (inferior, infero-lateral, anterior). Taking for a basis an amplitude change of $\Delta A=1mm$ for these indexes, we calculate the equivalent increase in the serum enzyme activity:

$$\Delta E = \Delta A * (E2 - E1)/(A2 - A1) \quad [U/L], \quad (2)$$

where *E1* is the initial enzyme value [*U/L*], *E2* is the peak enzyme activity [*U/L*], *A1* is the initial index amplitude [*mm*], *A2* corresponds to the index value when maximal amplitude change is reached [*mm*].

3.2. Results

The ECG PC-based system was implemented in the intensive coronary unit of the Department of Internal Medicine "Prof. St. Kirkovic", Medical University - Sofia for study of 15 patients (average age 70 ± 12.5 years) with clinical symptoms, ECG and laboratory signs for AMI with ST-elevation. An example of ECG recordings - 12 ECG leads, synthesized VCG leads (+/- avR) and VCG loops are shown in fig.4-6.

Fig.4. Example of high-resolution ECG recordings of patient with anterior AMI - 12 standard ECG leads

Fig.5. Example of high-resolution ECG recordings of patient with anterior AMI - synthesized VCG orthogonal leads (X1,Y1,Z1: +avR) and (X2,Y2,Z2: -avR, e.g. obtained by inversion of the lead avR).

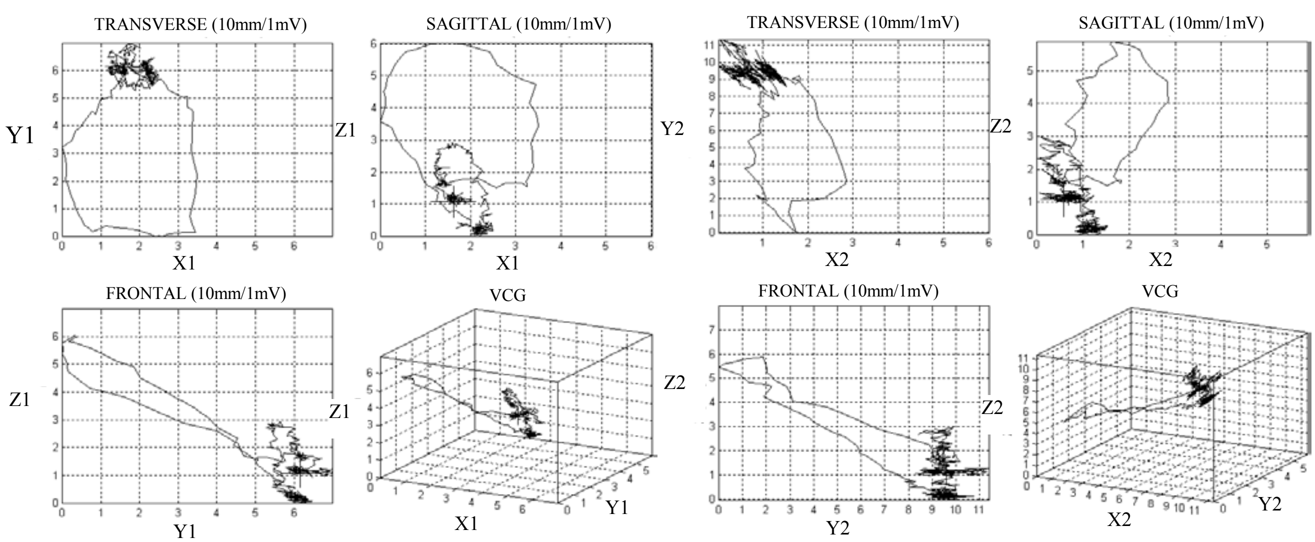

Fig.6. Example of high-resolution ECG recordings of patient with anterior AMI - VCG loops

We estimated the mean values of the indexes, which are known to show changes during lesion and myocardial necrosis [1,2]. Moreover, we determined the indexes, which show the most significant dynamics for the respective infarct localization compared to the norm of healthy controls:

- inferior AMI: Q-wave amplitude in Z1,Z2, Y1, Y2; R-wave amplitude in Y1,Y2;
- anterior AMI: Q-wave amplitude in X2,Y2; R-wave amplitude in X, X1, X2,Y1;
- infero-lateral: Q-wave amplitude in Y1,Y2, Z1,Z2; R-wave amplitude in Y1,Y2;

Table 1 contains the equivalent changes of the calculated serum activity (CK and CK-MB) for Q-wave and R-wave amplitude change of 1 mm. The correlation between the electrophysiological and enzyme variables gives the possibility for estimation of the volume of the necrotic tissue in gram/equivalents, after preliminary calculation on the basis of serum peak levels of the enzyme activity, taken from [10].

Inferior AMI			Infero-lateral AMI			Anterior AMI		
IN DEX	**CK [U/L]**	**CK-MB [U/L]**	**IN DEX**	**CK [U/L]**	**CK-MB [U/L]**	**IN DEX**	**CK [U/L]**	**CK-MB [U/L]**
$Z1_Q$	348,6±168,5	26,8±3,7	$Y1_Q$	166,55±88,9	14,1±3,9	$X2_Q$	266,0±193,7	15,6±6,7
$Z2_Q$	249,8±28,8	28,1±4,3	$Y2_Q$	201,1±97,7	14,9±2,9	$Y2_Q$	647,5±427,7	14,3±4,9
$Y1_Q$	433,2±48,9	14,8±2,7	$Z1_Q$	263,0±288,4	28,1±4,9	$X1_R$	159,6±63,7	5,48±2,3
$Y2_Q$	668,1±283,4	13,9±4,2	$Z2_Q$	154,6±66,2	28,5±4,7	$X2_R$	115,8±47,1	6,88±3,06
$Y1_R$	175,5±76,2	18,7±2,1	$Y1_R$	179,8±101,8	19,0±1,4	$Y1_R$	168,8±3,7	3,1±0,88
$Y2_R$	76,9±13,9	18,4±1,6	$Y2_R$	103,8±64,8	19,5±0,8			

Table 1. Enzyme activity increase for 1mm Q-wave and R-wave amplitude change

4. Conclusion

By application of computer-based multichannel ECG acquisition system in intensive coronary care unit, we studied the approach for analysis of the high-resolution ECG recordings, especially the synthesized VCG leads with some additional transforms. The results are promising, showing to provide adequate information about the infarct size and localization.

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