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Magdalena Grajek[1], Ryszard Krzyminiewski[2], Ryszard Kalawski[2],
Mariusz Kulczak[2]

# Changes in the cardiac muscle electric activity as a result of Coronary Artery Bypass Graft operation

[1]Institute of Physics, A. Mickiewicz University, Umultowska 85,61-614 Poznan, Poland
[2]Cardiac Surgery Ward, Strus Hospital, Poznan, Poland
e-mail: maza0@op.pl or magra@hoth.amu.edu.pl

Many bioelectric signals have a complex internal structure that can be a rich source of information on the tissue or cell processes. The structure of such signals can be analysed in detail by applying digital methods of signal processing. Therefore, of substantial use in diagnosis of the coronary arterial disease is the method of digital enhancement of increasing signal resolution ECG (NURSE-ECG), permitting detection of temporary changes in the electric potentials in the cardiac muscle in the process of depolarisation. Thanks to the application of NURSE-ECG it has become possible to detect relatively small changes in the electric activity of particular fragments of the cardiac muscle undetectable by the standard ECG method, caused by ischemia, the effect of a drug or infarct.

The aim of this study was to identify and analyse changes in the electric activity of the cardiac muscle as a result of the Coronary Artery Bypass Graft (CABG) operation. In this study the method of NURSE-ECG has been applied in order to identify and analyse changes in the electric activity of the cardiac muscle as a result of the CABG operation. In the study performed in cooperation of the Institute of Physics Adam Mickiewicz University and the Strus Hospital, Cardiac Surgery Ward, 37 patients with advanced coronary arterial disease were asked to participate. The patients were examined prior to the operation, on the day after the operation and two months after the operation and a year after the operation. The ECG recordings were subjected to a numerical procedure of resolution enhancement by a NURSE-ECG program to reveal the tentative changes in the electric potential of the cardiac muscle on its depolarisation. Results of the study have shown that the NURSE ECG method can be applied to monitor changes in the electric activity of the cardiac muscle occurring as a result of CABG operation. One the second day after the operation in the majority of patients (70%) a rapid decrease of the total cardiac muscle activity was observed. The NURSE ECG seems to be a promising supplementary method in medical diagnosis. In particular it can be applied for qualification of patients for CABG operation and for verification of the operation effects.

**Key words:** coronary artery bypass graft, depolarization, numerical sygnal resolution enhancement electrocardiography, NURSE-ECG.

## Introduction

One of the civilisation diseases of the 21st century certainly is the coronary arterial disease leading to angina pectoris. The treatment of this condition is adjusted to the advancement of atherosclerotic processes and includes pharmacological therapy, angioplasty and bypasses.

Coronary arterial disease and angina pectoris are the most frequent causes of death, hospitalisation and work disability. In Poland it has affected about one million of people, so intense research is made into effective methods of its therapeutic treatment.

The routine diagnostic method applied for diagnosis of cardiac muscle conditions is the standard ECG which has little diagnostic value. The ECG recording is often correct even for persons known to have changes in 2 or 3 coronary arteries [1]. In view of the above, much effort has been directed to finding improved diagnostic methods allowing evaluation of the electrical activity of particular fragments of the cardiac muscle. One of such methods is based on a digital enhancement of the ECG signal permitting detection of the electrical activity of particular regions of the cardiac muscle [2].

The aim of this study was to identify and analyse changes in the electrical activity of the cardiac muscle as a result of the Coronary Artery Bypass Graft (CABG) operation.

## Methods

Many bioelectric signals have a complex internal structure that can be a rich source of information on the tissue or cell processes. The structure of such signals can be analysed in detail by applying digital methods of signal processing. Therefore, of substantial use in diagnosis of the coronary arterial disease is the method of digital enhancement of increasing signal resolution ECG (NURSE-ECG), permitting detection of temporary changes in the electric potentials in the cardiac muscle in the process of depolarization [3]. The enhanced resolution of the ECG signal is achieved with the help of special software based on the application of the linear Fourier transform and the methods of convolution and deconvolution. The method of linear transformation has been successfully applied for increasing resolution and analysis of spectroscopic spectra [4]. The efficiency of the method and reliability of the results have been verified and confirmed by other authors [5].

The procedure for enhancement of resolution is based on the calculation of the Fourier transform and is described as a splot:

$$F(x) = \int K(x - x')\,\Psi(x')\,dx' \tag{1}$$

Where the function $\Psi(x')$ describes the positions and intensities of individual lines and $K(x - x')$ is a function (core) describing the shape of an individual line. In our calculation we choose Gaussion line as a core. In order to find the position and intensity of the line, the explicit form of the function $\Psi(x')$ is found as:

$$\Psi(x) = \frac{1}{\sqrt{2\pi}} \int \frac{\widetilde{F}(y)}{\widetilde{K}(y)} \cdot \exp(-ixy)\,dy \tag{2}$$

where $\widetilde{F}(y)$ is the Fourier transform of the function $F(x)$ described by:

$$\widetilde{F}(y) = \frac{1}{\sqrt{2\pi}} \int F(x) \cdot \exp(-iyx)\,dx \tag{3}$$

and $\widetilde{K}(y)$ being the Fourier transform of the function $K(x - x')$.

Figure 1 illustrates the results of signal resolution for individual evolution heart.

The digital processing of the standard ECG records by the NURSE-ECG program gives curves of the shape similar to that of the traditional ECG signal but of much enhanced resolution of the QRS complex. It should be emphasised that the NURSE-ECG procedure of signal resolution enhancement does not require any preliminary assumptions asto the number of peaks (components) in the ECG signal analysed anddoes not generate additional artefacts. In order to facilitate the interpretation of ECG records of enhanced resolution the method of vectorcardiography is employed [3]. The result is a plot of the excitation-depolarization signal in three planes: the anterior, transversal and saggital. The plot corresponds to the motion of the temporary

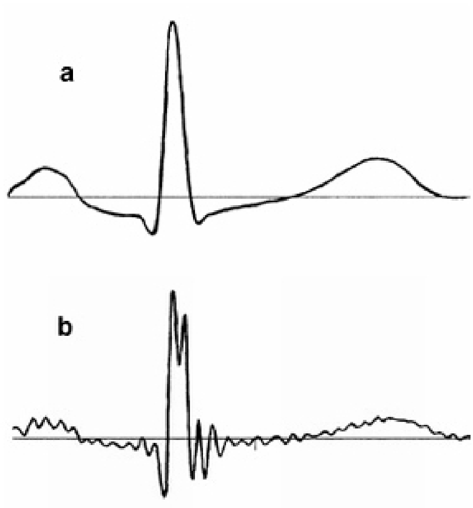



**Figure 1.** Fragment of the ECG recording: a — standard, b — after analysis by the signal resolution enhancing method NURSE-ECG

depolarization vector of the interventricular septum and the left and the right ventricle during a single evolution of the cardiac muscle. The gradual propagation of the excitation in the cardiac muscle generates certain changes in the direction and magnitude of the temporary values of the resultant vectors of the ventricle depolarization.

The NURSE-ECG recordings were made with a 12-lead digital ECG (in our experiment made by MEDEA). The signals from each ECG electrodes are subjected to the resolution enhancement procedure. In the NURSE-ECG method the standard procedure of drawing the vectorcardiographic curve was used, however, the initial signal was that of ECG with digitally enhanced resolution. The vectorcardiogram recorded in NURSE-ECG method we shall call the high signal resolution vectorcardiography HRVEC. As follows from Figure 2, the HRVEC vectorcardiography offers more exact and precise reproduction of the cardiac muscle depolarization than the standard vectorcardiogram.

The NURSE-ECG permits determination of the value and orientation of the temporary electric dipoles induced in the cardiac muscle. To enable analysis and interpretation of the signals, the cardiac muscle has been divided into segments whose activities are to be determined. The activity of a given segment of the cardiac muscle is calculated within the solid angle of 60° with respect to the normal to the fragment surface, according to the equation:

$$Akty = \sum_{t} [R(t)]^2 \cdot \cos[R(t), F] \tag{4}$$

*R(t)* — the temporary vector of depolarization at a time of 1 ms
*F* — the vector describing the electric dipole generated in a given fragment of the cardiac muscle

Direction cosines of the vectors of electric activity (*F*) of particular segments of the cardiac muscle in the orthogonal Frank system Table 1.

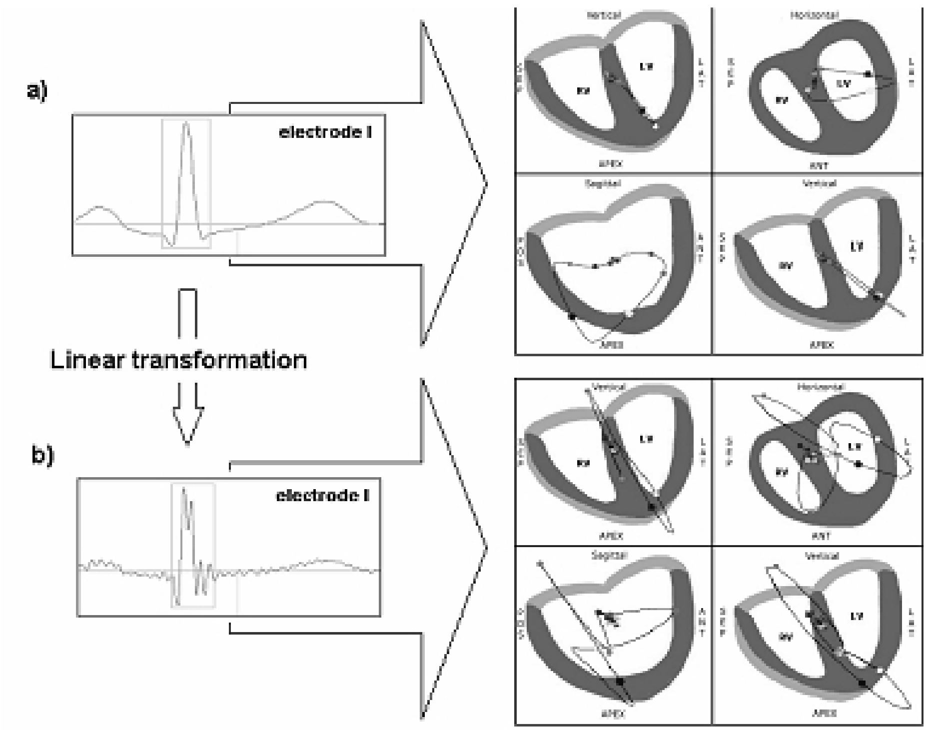



**Figure 2.** Presentation ECG signal in vectorcardiogram form: a) standard signal ECG and respondent him vectorcardiogram; b) signal ECG with high-resolution and respondent him high-resolution vectorcardiogram

**Table 1.** Direction cosines of the unitary vectors of electric activities (*F*) of particular segments of the cardiac muscle in the orthogonal Frank system

| Cardiac muscle region | F in the orthogonal Frank system XYZ | | |
|---|---|---|---|
| anterior part of the septum | 0 | 0 | −1 |
| anterior wall | 0.3 | 0.17 | −0.94 |
| lateral wall | 1 | 0 | 0 |
| posterior wall | −0.1 | 0.17 | 0.98 |
| interior wall | 0 | 1 | 0 |
| left posterior branch | 0.35 | 0.87 | 0.35 |
| basal anterior segment | 0.3 | −0.71 | −0.64 |
| basal posterior segment | −0.3 | −0.71 | 0.64 |

The direction cosines of the vector describing the electric dipoles of individual fragments of the cardiac muscle are determined in the orthogonal system of Frank coordinates and the unit of the activity defined in the above way is $mV^2$. The total electric activity of a given segment of the cardiac muscle is a sum of the temporary activities in the duration of the QRS complex [1, 13]. The electric activities of particular segments of the ventricles and interventricular septum are referred to those recorded for a healthy person.

The results of NURSE-ECG are very well correlated with those of the scintigraphic examination (SPECT) informing about dysfunction of the cardiac muscle perfusion, realize sensivity = 71% and specificity = 43% of the method [5, 12].

The results of NURSE-ECG are very well correlated with those of the scintigraphic examination (SPECT) informing about dysfunction of the cardiac muscle perfusion [5]. A good correlation was also noted between the results of the coronarography, displaying the narrowing of a given coronary artery and the decrease in the electric activity of particular segments of the cardiac muscle recorded by the NURSE-ECG [7, 9]. At present in Poland the high resolution NURSE-ECG is used for monitoring of hospitalised patients at a few renowned medical centres [6, 10].

In this study the method of NURSE-ECG has been applied in order to identify and analyse changes in the electric activity of the cardiac muscle as a result of the Coronary Artery Bypass Graft operation. The method was applied in the patients qualified for the CABG operation, on the first or second day after the operation, two months after and a year after the operation. The Coronary Artery Bypass Graft operation is performed on the patients with coronary artery disease in whom no improvement has been or can be achieved by Percutaneous Transluminal Coronary Angioplasty (PTCA). In the patients with changes in many coronary arteries PTCA may involve a higher risk than CABG operation [11]. The latter procedure is based on bypassing the obstacles in the coronary arteries and supplying the blood to the fragments of the arteries after the narrowing by artificial vessels joining the main aorta with the coronary arteries. Such a solution ensures better perfusion of the cardiac muscle. The vessels used to make these artificial connections are collected from the shank of the patient or from the internal thoracic artery, that runs on the internal surface of the sternum. The patient subjected to CABG requires total anaesthesia thoracotomy. The operation requires the cardiac arrest and application of the extracorporeal circulation.

## Results

In the study performed in cooperation of the Institute of Physics Adam Mickiewicz University and the Strus Hospital, Cardiac Surgery Ward, 37 patients with advanced coronary arterial disease were asked to participate. This group included 6 women and 31 men and the mean age of the patient was 56 ± 1.2 years (Table 2). The patients were examined prior to the operation (examination 1) and on the day after the operation (examination 2) and two months after the operation (examination 3) (Table 3) by a 12-lead TELE-EKG instrument made by Pro Plus. Examinations in a year after the operation (examination 4) were performed with an ECG instrument Medea-kardiograf, model 5012 made by Medea-Gliwice of the sampling frequency of 500 Hz and conventional system electrodes. The ECG recordings were subjected to a numerical procedure of resolution enhancement by a NURSE-ECG program to reveal the tentative changes in the electric potential of the cardiac muscle on its depolarization.

An exemplary result of NURSE-ECG is shown in Figure 3, together with a spatial representation of the cardiac muscle with the weakest and the strongest fragments of the cardiac muscle. The projections of the cardiac muscle onto the three planes transversal,

**Table 2.** Total electric activity in %: relation patient activity for to total activity of standard health person. Selected fragments activity in %: SD — inferior wall, SB — lateral wall, SP — anterior wall, ST — posterior wall, by '+' we marked being a part of the given group

| Patients examine before operation | | | | | |
|---|---|---|---|---|---|
| Number patient | ECG normal | ECG negative T in III, avF, V6 | ECG Q in II, III, avF | ECG levogram | Total electric activity % /selected fragments activity % |
| 1 | | | | + | 154 |
| 2 | | | | + | 202 /SB=27, ST=32, SD=39 |
| 3 | | | | + | 29 /SB=27 |
| 4 | | | + | + | 149 /ST=49 |
| 5 | + | | | | 98 /SD=40 |
| 6 | | | | + | 66 /SB=22, SP=29 |
| 7 | | + | + | + | 43 /SD=8, SB=8 |
| 8 | | | | + | 186 /SD=16 |
| 9 | | | + | + | 62 /SB=25, SD=30 |
| 10 | | + | | + | 104 /SP=28 |
| 11 | | | | + | 153 |
| 12 | | | | + | 51 /SB=14, SD=17 |
| 13 | | + | | + | 93 /SB=36 |
| 14 | | | + | | 133 /SD=18 |
| 15 | | | | + | 96 /ST=26 |
| 16 | | + | | | 85 /SD=14 |
| 17 | | + | + | + | 316 /SD=16 |
| 18 | | | | + | 139 /SB=34 |
| 19 | | | + | + | 57 /SD=26, SB=22 |

| Patients examine before operation | | | | | |
|---|---|---|---|---|---|
| Number patient | ECG normal | ECG negative T in III, avF, V6 | ECG Q in II, III, avF | ECG levogram | Total electric activity % /selected fragments activity % |
| 20 | | + | | + | 22 /SD=4, SB=15 |
| 21 | | | + | + | 83 /SD=41 |
| 22 | | + | | + | 67 /SB=11 |
| 23 | | | + | + | 70 /SD=3 |
| 24 | | | | + | 101 /SB=8 |
| 25 | | | | + | 127 /SB=37 |
| 26 | | + | | | 181 |
| 27 | | + | | + | 58 /SD=9 |
| 28 | | + | | + | 38 /ST=16, SD=30 |
| 29 | | | | + | 176 /SB=47 |
| 30 | | | + | + | 61 /SB=34 |
| 31 | | | + | + | 85 /SD=20, ST=24 |
| 32 | | | | | 53 /SB=32, SD=40 |
| 33 | | | + | + | 17 /SB=6, SD=9 |
| 34 | | + | | + | 240 |
| 35 | | + | | | 331 |
| 36 | + | | | | 35 /SB=11 |
| 37 | | | | + | 42 / SD=3 |

saggital and frontal are included with the vectorcadriographic loop of high signal resolution characterising the course of the cardiac muscle activation. The electric activities of particular fragments of the cardiac muscle are presented in numerical values on a histogram in comparison with the standards obtained for a healthy person of the age close to that of the patient. The electric activity of a given fragment of the cardiac

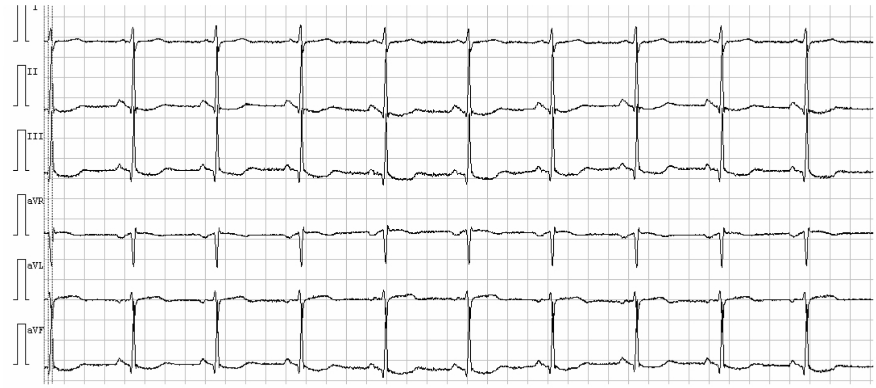
**Table 3.** Change in the electric activity of the cardiac muscle after the CABG operation; increase(+) or decrease(−): in total activity (column a), and in activity of selected fragments of the cardiac muscle (column b)

| Changes in electric activity after CABG | | | | | | |
|---|---|---|---|---|---|---|
| Patient number | Changes on the y second day after CABG [%] | | Changes in 2 months after CABG [%] | | Changes in one year after CABG [%] | |
| | a | b | a | b | a | b |
| 1 | −59.00 | – | −60.00 | – | −21.00 | – |
| 2 | 9.00 | SB=−41, ST=−31, SD=+51 | 4.00 | SB= −33, ST=−3, SD=−36 | 47.00 | SB=−7, ST=−75, SD=−39 |
| 3 | −14.00 | SB=−30 | −48.00 | SB= −33 | −41.00 | SB=−33 |
| 4 | −46.00 | ST=−67 | – | – | −35.00 | ST=−22 |
| 5 | 2.00 | SD=+13 | – | – | −45.00 | SD=−18 |
| 6 | 53.00 | SB=−81, SP=−21 | – | – | −9.00 | SB=−72, SP=−65 |
| 7 | −60.00 | SD=−50, SB=−75 | – | – | −49.00 | SD=+62, SB=+25 |
| 8 | −26.00 | SD=−44 | – | – | −57.00 | SD=−50 |
| 9 | 44.00 | SB=−92, SD=+310 | – | – | −27.00 | SB=−28, SD=+66 |
| 10 | −38.00 | SP=−189 | – | – | 9.00 | SP=+71 |
| 11 | −42.00 | – | – | – | −23.00 | – |
| 12 | −71.00 | SB=−29, SD=−35 | – | – | – | – |
| 13 | 29.00 | SB=−22 | – | – | −4.00 | SB=+69 |
| 14 | −38.00 | SD=−50 | – | – | −36.00 | SD=+572 |
| 15 | −54.00 | ST=−76 | – | – | – | – |
| 16 | 22.00 | SD+414 | – | – | – | – |

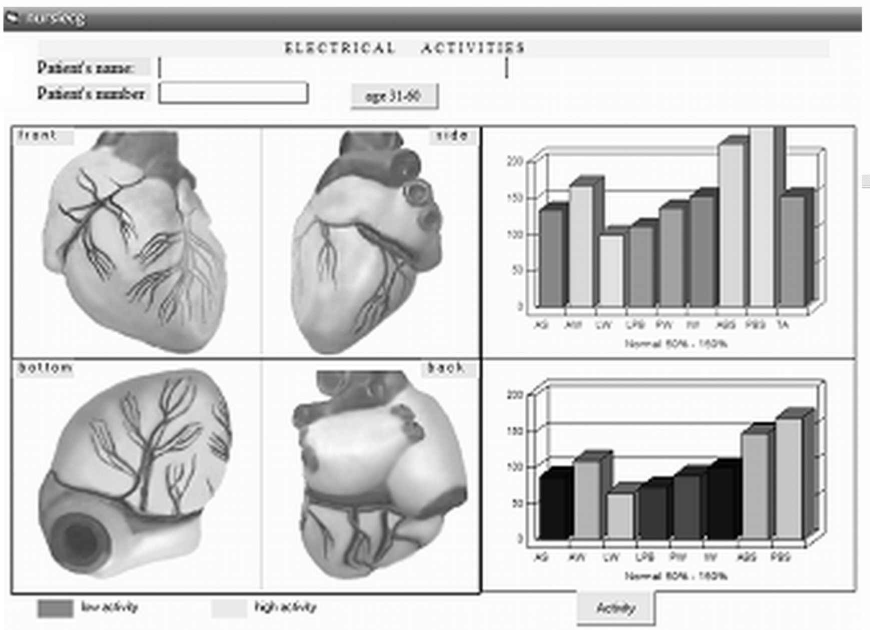
| Patient number | Changes in electric activity after CABG | | | | | |
|---|---|---|---|---|---|---|
| | Changes on the y second day after CABG [%] | | Changes in 2 months after CABG [%] | | Changes in one year after CABG [%] | |
| | a | b | a | b | a | b |
| 17 | −2.00 | SD=+350 | – | – | – | – |
| 18 | −91.00 | SB=−76 | – | – | – | – |
| 19 | −32.00 | SD=−46, SB=−18 | – | – | – | – |
| 20 | −9.00 | SD=+200, SB=−80 | – | – | – | – |
| 21 | −65.00 | SD=−44 | – | – | – | – |
| 22 | −28.00 | SB=+82 | – | – | – | – |
| 23 | 11.00 | SD=0 | – | – | – | – |
| 24 | −71.00 | SB=+100 | – | – | – | – |
| 25 | −48.00 | SB=+41 | – | – | – | – |
| 26 | −103.00 | – | – | – | – | – |
| 27 | −2.00 | SD=+133 | – | – | – | – |
| 28 | 110.00 | ST=+531, SD=+190 | – | – | – | – |
| 29 | −83.00 | SB=−77 | – | – | – | – |
| 30 | 44.00 | SB=+100 | – | – | 43.00 | SB=+108 |
| 31 | – | – | – | – | – | – |
| 32 | – | – | – | – | – | – |
| 33 | – | – | – | – | – | – |
| 34 | – | – | – | – | – | – |
| 35 | – | – | – | – | – | – |
| 36 | – | – | – | – | – | – |
| 37 | – | – | – | – | – | – |

**Figure 3.** Results of the NURSE-ECG patient examination before the operation: a) standard ECG; b) histogram of electric activity of particular fragments of the heart muscle; c) advance loop depolarization; d) electrical activity of fragments heart muscle

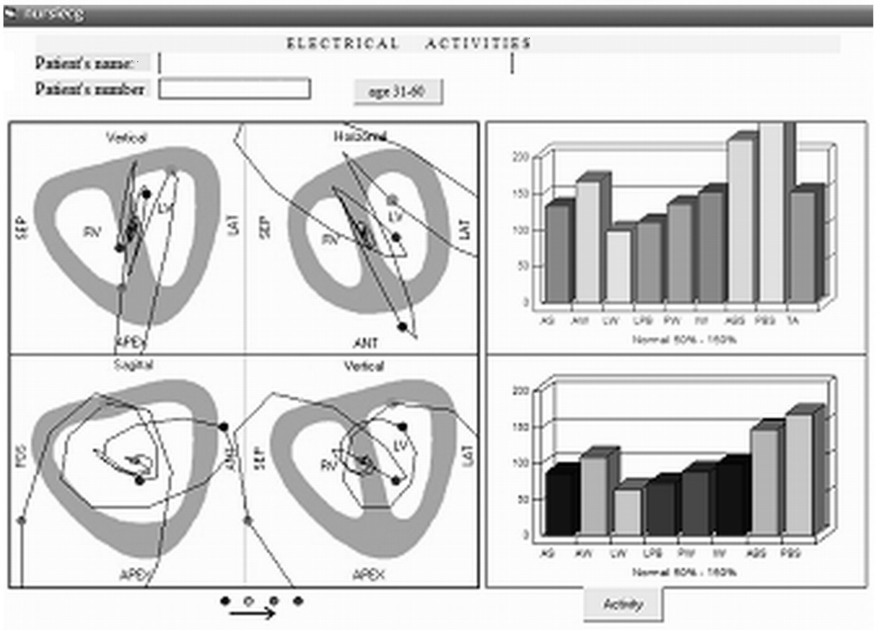
a)



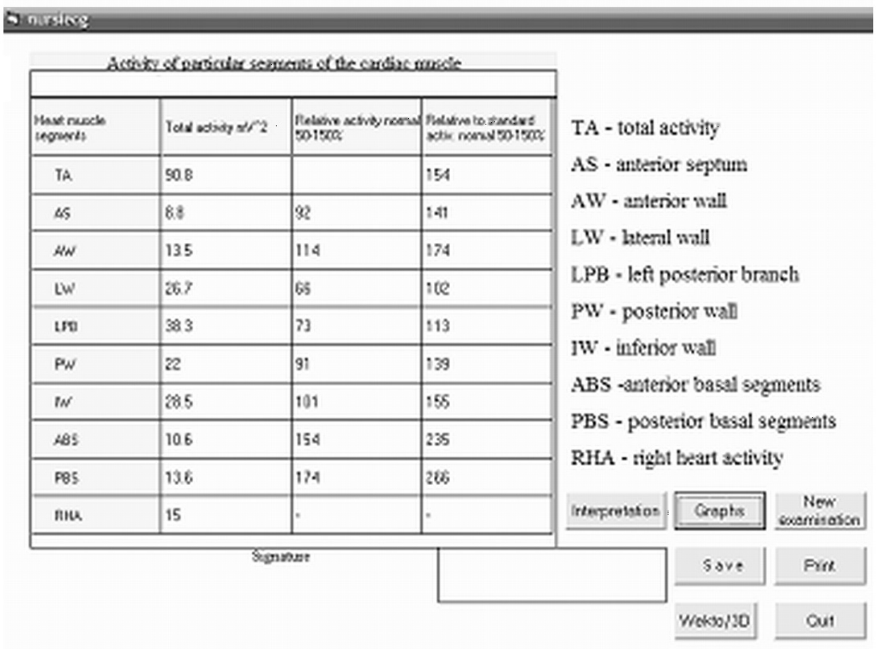

b)



c)




d)



Activity of particular segments of the cardiac muscle

| Heart muscle segments | Total activity nV^2 | Relative activity normal 50-150% | Relative to standard activ. normal 50-150% |
|---|---|---|---|
| TA | 90.8 | | 154 |
| AS | 8.8 | 92 | 141 |
| AW | 13.5 | 114 | 174 |
| LW | 26.7 | 66 | 102 |
| LPB | 38.3 | 73 | 113 |
| PW | 22 | 91 | 139 |
| IW | 28.5 | 101 | 155 |
| ABS | 10.6 | 154 | 235 |
| PBS | 13.6 | 174 | 266 |
| RHA | 15 | - | - |

Signature

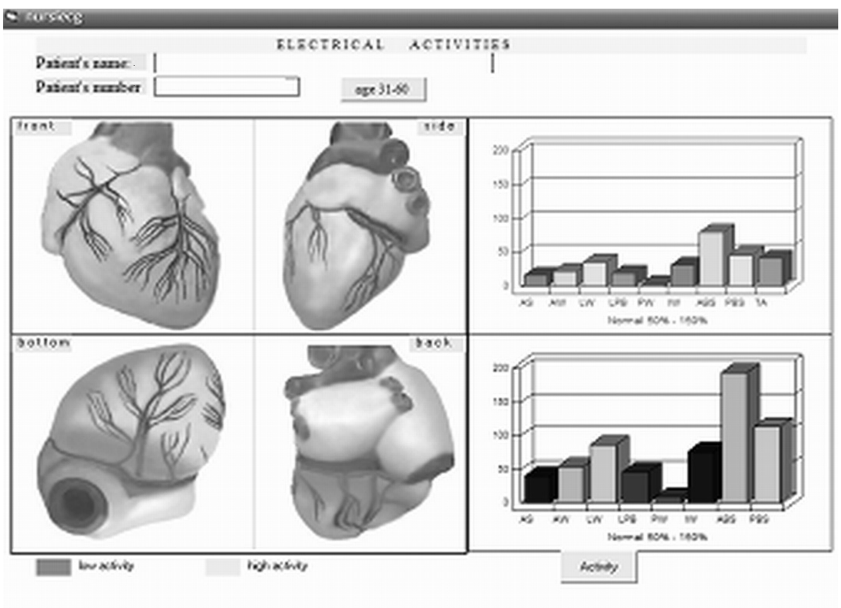
TA - total activity
AS - anterior septum
AW - anterior wall
LW - lateral wall
LPB - left posterior branch
PW - posterior wall
IW - inferior wall
ABS -anterior basal segments
PBS - posterior basal segments
RHA - right heart activity

Interpretation | Graphs | New examination | Save | Print | Wekto/3D | Quit

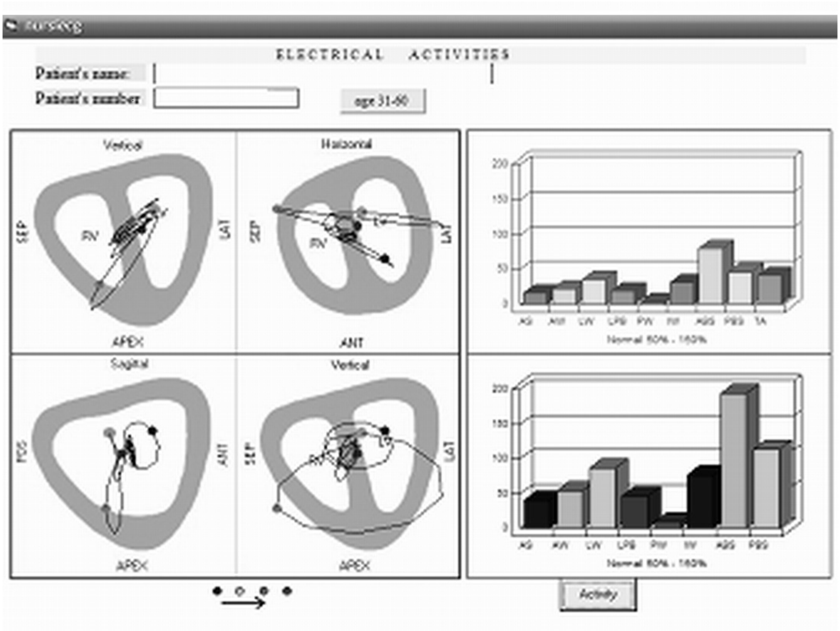
**Figure 4.** Results of the NURSE-ECG patient examination in two days after CABG: a) standard ECG; b) histogram of electric activity of particular fragments of the heart muscle; c) advance loop depolarization; d) electrical activity of fragments heart muscle

a)

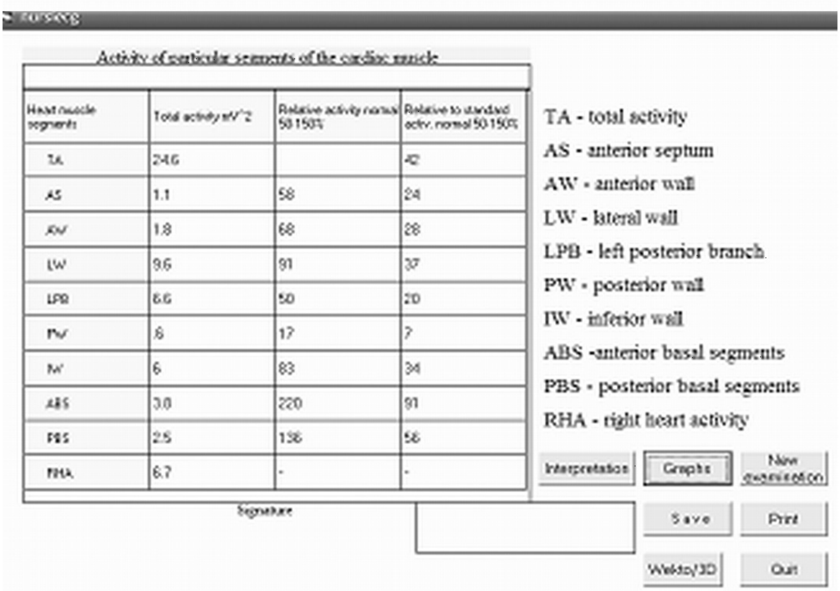

b)



c)




d)


Activity of particular segments of the cardiac muscle

| Heart muscle segments | Total activity mV^2 | Relative activity normal 50-150% | Relative to standard activ. normal 50-150% |
|---|---|---|---|
| TA | 24.6 | | 42 |
| AS | 1.1 | 58 | 24 |
| AW | 1.8 | 68 | 28 |
| LW | 9.6 | 91 | 37 |
| LPB | 6.6 | 50 | 20 |
| PW | .6 | 17 | 7 |
| IW | 6 | 83 | 34 |
| ABS | 3.8 | 220 | 91 |
| PBS | 2.5 | 136 | 56 |
| RHA | 6.7 | - | - |

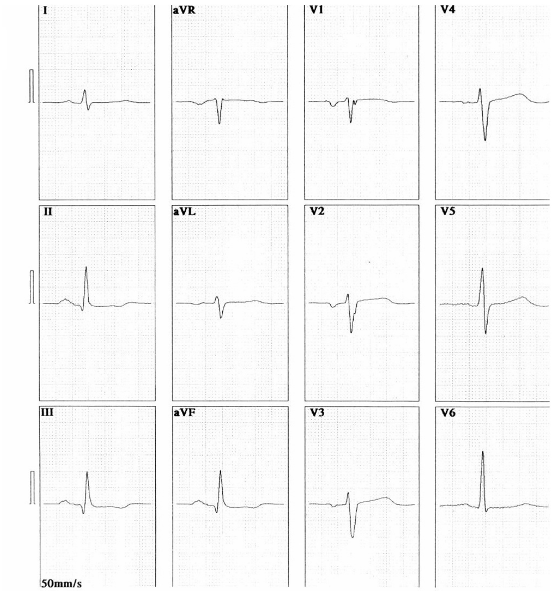
Signature

TA - total activity
AS - anterior septum
AW - anterior wall
LW - lateral wall
LPB - left posterior branch
PW - posterior wall
IW - inferior wall
ABS -anterior basal segments
PBS - posterior basal segments
RHA - right heart activity

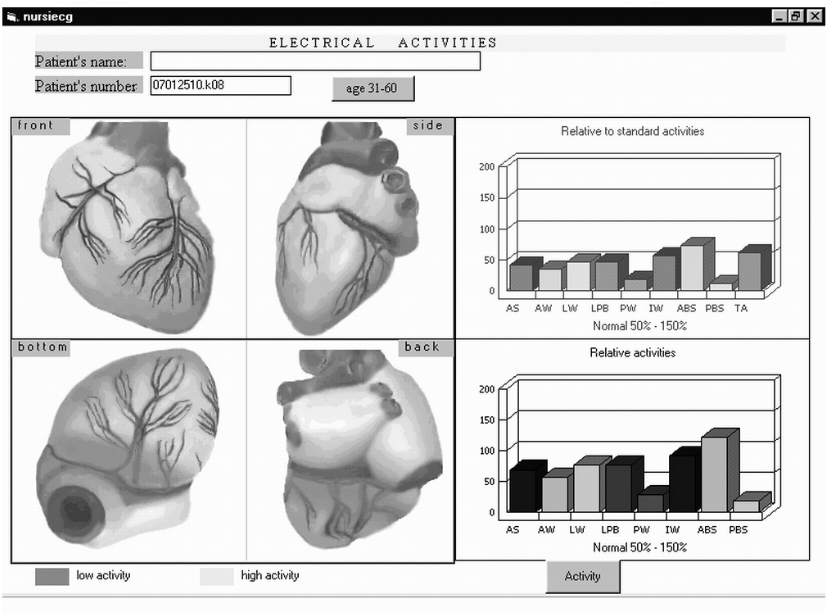
Interpretation | Graphs | New examination | Save | Print | Wekto/3D | Quit

**Figure 5.** Results of the NURSE-ECG patient examination in two months after CABG: a) standard ECG; b) histogram of electric activity of particular fragments of the heart muscle; c) advance loop depolarization; d) electrical activity of fragments heart muscle

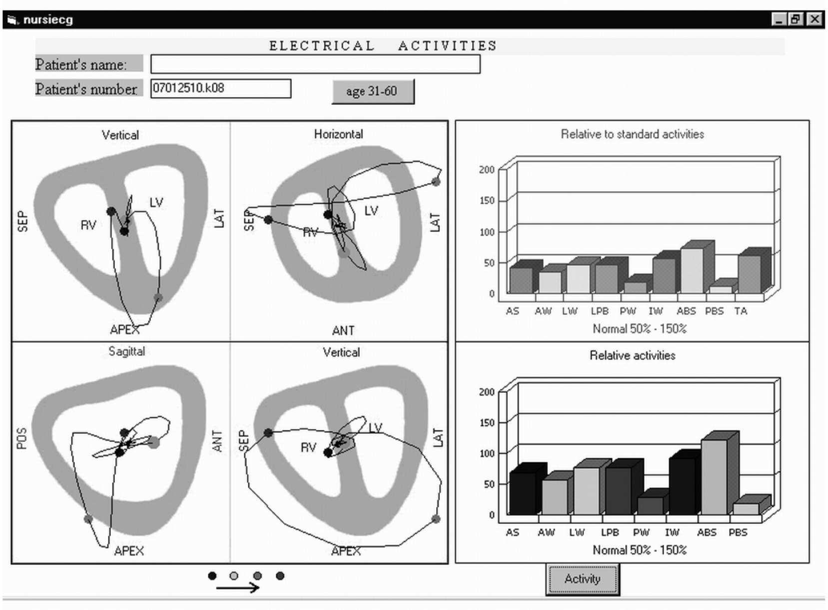
a)



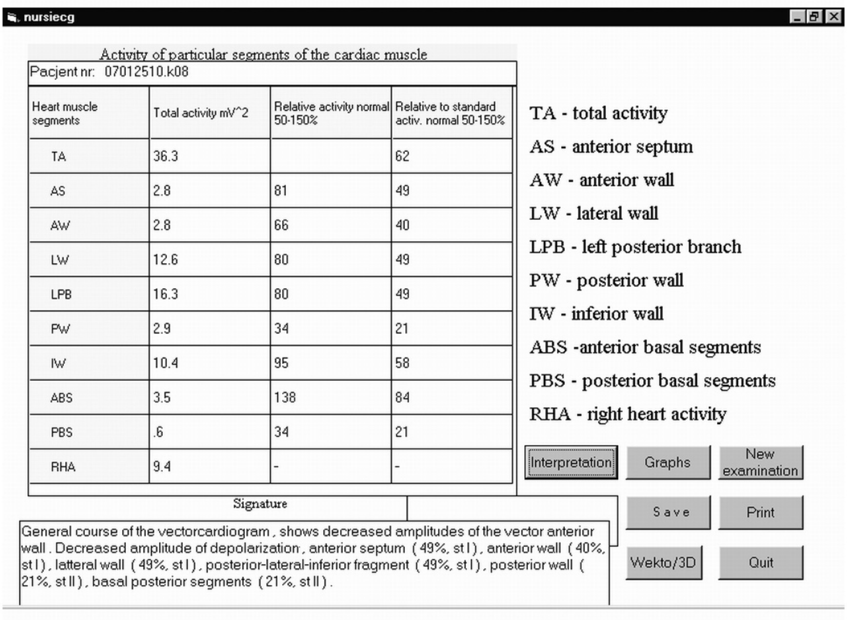

b)



c)




d)




Activity of particular segments of the cardiac muscle

Pacjent nr: 07012510.k08

| Heart muscle segments | Total activity mV^2 | Relative activity normal 50-150% | Relative to standard activ. normal 50-150% |
|---|---|---|---|
| TA | 36.3 | | 62 |
| AS | 2.8 | 81 | 49 |
| AW | 2.8 | 66 | 40 |
| LW | 12.6 | 80 | 49 |
| LPB | 16.3 | 80 | 49 |
| PW | 2.9 | 34 | 21 |
| IW | 10.4 | 95 | 58 |
| ABS | 3.5 | 138 | 84 |
| PBS | .6 | 34 | 21 |
| RHA | 9.4 | - | - |

TA - total activity
AS - anterior septum
AW - anterior wall
LW - lateral wall
LPB - left posterior branch
PW - posterior wall
IW - inferior wall
ABS -anterior basal segments
PBS - posterior basal segments
RHA - right heart activity

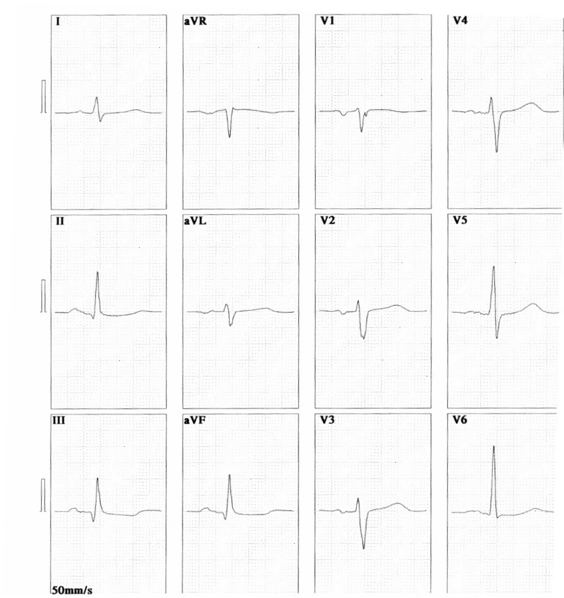
Interpretation | Graphs | New examination | Save | Print | Wekto/3D | Quit

Signature

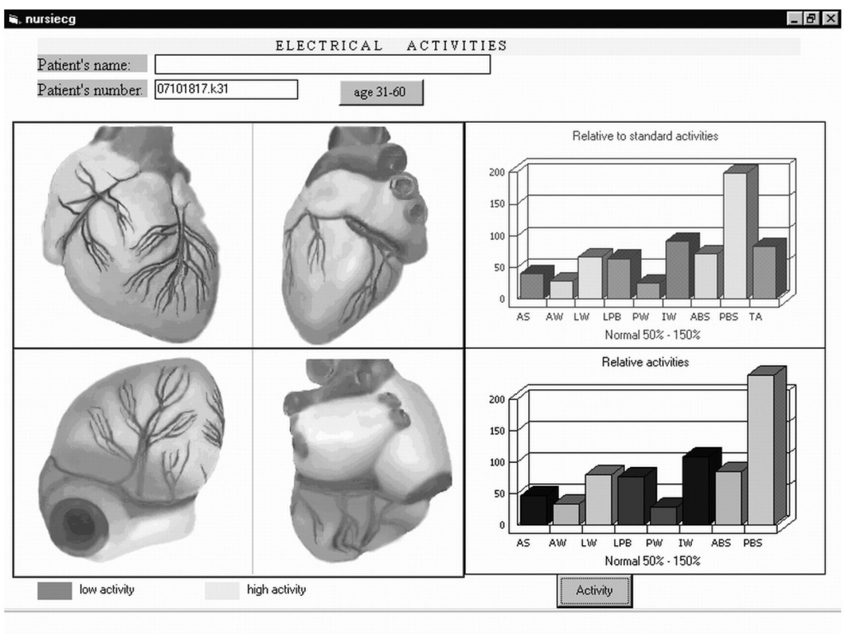
General course of the vectorcardiogram, shows decreased amplitudes of the vector anterior wall. Decreased amplitude of depolarization, anterior septum (49%, st I), anterior wall (40%, st I), latteral wall (49%, st I), posterior-lateral-inferior fragment (49%, st I), posterior wall (21%, st II), basal posterior segments (21%, st II).

**Figure 6.** Results of the NURSE-ECG patient examination in one year after CABG: a) standard ECG; b) histogram of electric activity of particular fragments of the heart muscle; c) advance loop depolarization; d) electrical activity of fragments heart muscle.

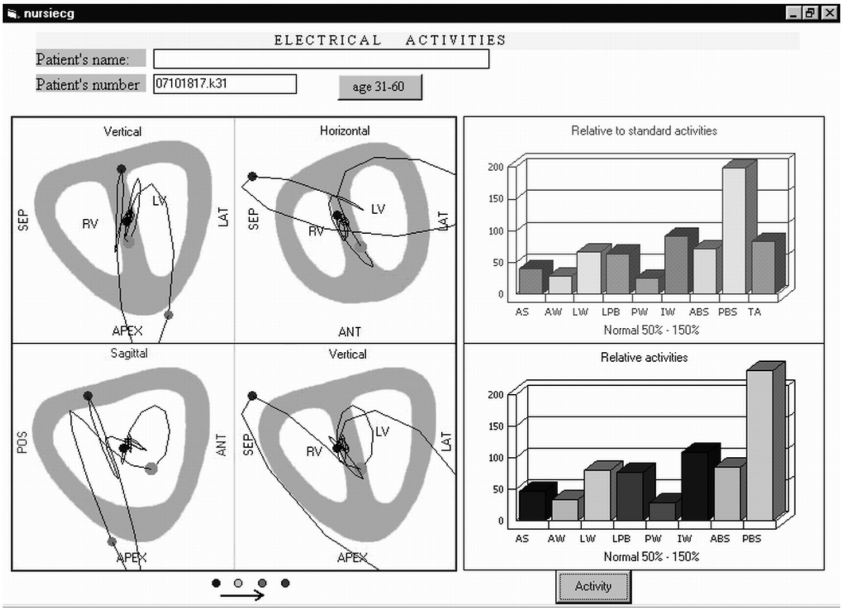
a)



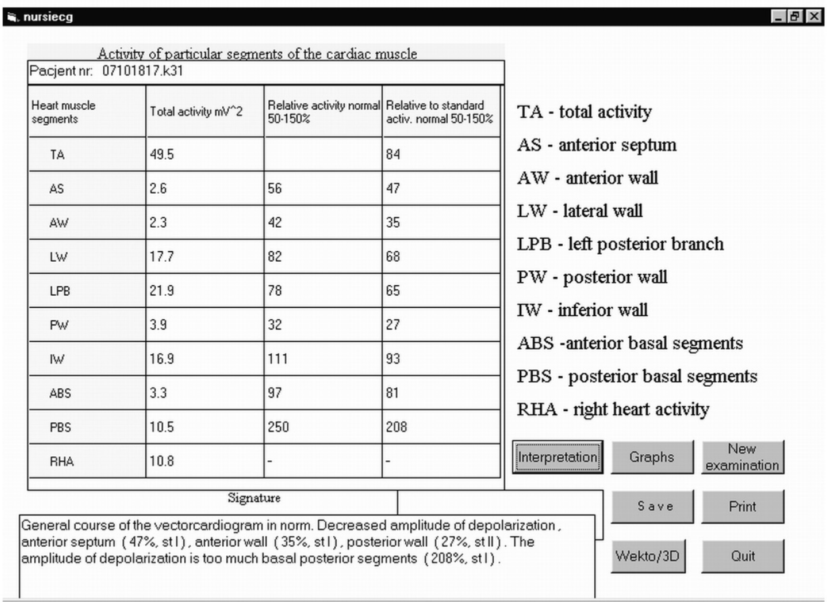

b)



c)




d)




Activity of particular segments of the cardiac muscle

Pacjent nr: 07101817.k31

| Heart muscle segments | Total activity mV^2 | Relative activity normal 50-150% | Relative to standard activ. normal 50-150% |
|---|---|---|---|
| TA | 49.5 | | 84 |
| AS | 2.6 | 56 | 47 |
| AW | 2.3 | 42 | 35 |
| LW | 17.7 | 82 | 68 |
| LPB | 21.9 | 78 | 65 |
| PW | 3.9 | 32 | 27 |
| IW | 16.9 | 111 | 93 |
| ABS | 3.3 | 97 | 81 |
| PBS | 10.5 | 250 | 208 |
| RHA | 10.8 | - | - |

TA - total activity
AS - anterior septum
AW - anterior wall
LW - lateral wall
LPB - left posterior branch
PW - posterior wall
IW - inferior wall
ABS -anterior basal segments
PBS - posterior basal segments
RHA - right heart activity

Interpretation | Graphs | New examination | Save | Print | Wekto/3D | Quit

Signature

General course of the vectorcardiogram in norm. Decreased amplitude of depolarization, anterior septum (47%, st I), anterior wall (35%, st I), posterior wall (27%, st II). The amplitude of depolarization is too much basal posterior segments (208%, st I).

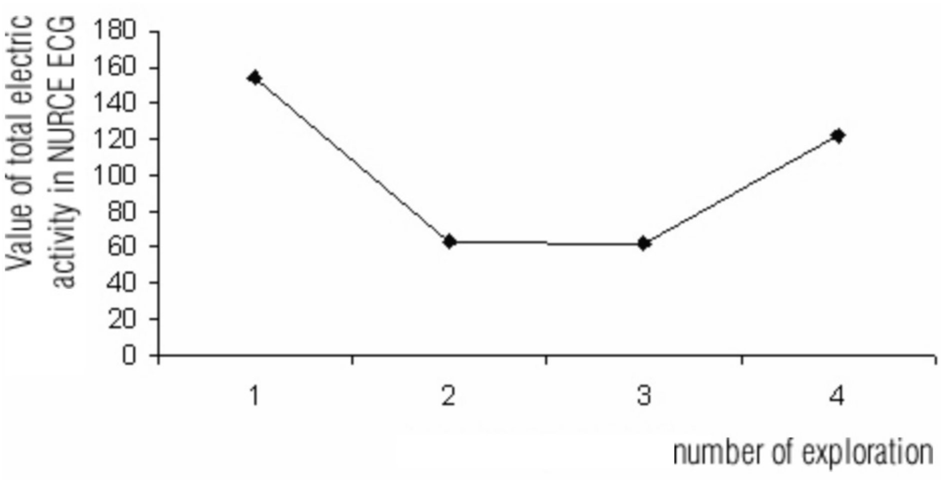



**Figure 7.** Example of the time changes in the electric activity of the cardiac muscle of the value total activity in NURSE-ECG

muscle is assumed to be normal if its values oscillate in the range of 50–150% of the standard.

Figure 3 presents the NURSE-ECG result obtained for patient 1 with elevated activity of some fragments of the cardiac muscle interpreted as a corelated with the hypertension. Figure 4 presents the NURSE-ECG recording of the patient 1 taken on the two days after CABG showing clearly a rapid decrease in the activity and a change in the character of the depolarisation loop. Figures 5 and 6 present the NURSE-ECG results of the patient 1 recorded 2 months and one year after the operation responsible. The electric activities of individual fragments of the cardiac muscle slowly increased. As evident, the character of the depolarisation loop is partly preserved, except for the fragment corresponding to the posterior wall of the cardiac muscle evidently showing much lower activity. The time changes in the electric activity are displayed in Figure 7.

The time changes in the cardiac muscle activity (data recorded on the two days, two months and a year after the operation) observed in response to the CABG operation are illustrated by the data in Table 3. The values of electric activity disease in time were calculated from the following formula:

$$change\,[\%] = \frac{research\_2 - research\_1}{research\_1} \cdot 100 \; . \qquad (5)$$

## Discussion

Results of examination 1 (prior to the CABG operation) are shown in Table 1. From among the 37 ECG recordings as many as 30 revealed the character of levogram. The ECG of two patients showed no deviation from the standard. Two characteristic features were noted in the ECG recordings of the patients. In the group of 37 patients, 32% had ECG with a negative T complex in the signals from the leads III, avF and V6, and 30% had a negative Q complex in the signals from the leads II, II, avF. The last column of Table 2 gives the total electric activity of the cardiac muscle and the activities of selected fragments of the cardiac muscle, determined thanks to the use of NURSE-ECG. In 24% of patients from the group of 37 studied, an increased total activity of the cardiac muscle was noted, while in 19% of the patients the total activity of the cardiac muscle was decreased noted. The cardiac total activity of the other 57% of the patients was close to the standard. Besides the total activity, also the fragments of the cardiac muscle of the lowest activity were identified. The symbols SB, SD, SP and ST used in the Table refer to the lateral wall, inferior wall, anterior wall and posterior wall. In 51% of the 37 patients studied the weakest fragment of the cardiac muscle was the inferior wall, while in 49% of the patients the weakest fragment was the lateral wall.

Hitherto the only examination used to establish the prognostic for the patients after CABG has been the standard ECG, in which certain risk indicators have been defined. The problem is discussed in the paper in the Circulation [8]. The authors studied a large group of 8166 patients of which 20% died in up to 6 years after the operation. The following factors affecting the risk of death have been taken into regard:

1) ventricular rate 90 vs. 60 gives a 1.34 times increase in the risk of death,
2) the distance PR 200 vs. 150 ms gives a 1.05 increase in the risk of death,
3) the length of QRS 120 vs. 80 ms gives 1.24 increase in the risk of death Sokolow-Lyon voltage (AHR 3.5 mV vs. 1.5 mV) gives a 1.18 increase in the risk of death,
4) ST-segment slope −0.1 mV vs. 0 mV gives 1.16 increase in the risk of death.

According to the authors, the scale made on the basis of these parameters permits determination of the risk of death for the CABG patients before the operation on the basis of ECG results only. We have checked also the results obtained for our patients assuming the same risk indicators. We have taken into regard two most significant indicators of the risk of death, that is the frequency of ventricular contractions of above 90 Hz and the length of the QRS complex greater than 120 Hz. From among our patients only in three patients the ECG revealed QRS longer than 120 ms. In subsequent examinations by NURSE-ECG no characteristic changes in the electric activity of the cardiac muscle were detected.

On the second day after the operation in the majority of patients (70%) a rapid decrease in the total activity of the cardiac muscle was observed, while 30% of the patients showed an increasing tendency in the cardiac muscle activity in Table 3. The increase or decrease in the electric activity of selected fragments of the cardiac muscle was not always consistent with the increase or decrease in the total activity of the cardiac muscle. In 56% of the patients a decrease in the selected fragments of the cardiac muscle was observed, in 33% an increase was noted, while in 11% of the patients the activity of one fragment of the cardiac muscle increased, while that of the other fragments decreased. In two months after the operation a decrease in total activity of the cardiac muscle was noted in 67% patients, while in 33% of them an increase was evident. Activity of selected fragments of the cardiac muscle all patients affirmed decrease electric activity. In one year after the operation, 13 patients were examined, of them 85% revealed a further decrease in the total activity of the cardiac muscle, in 15% a small increase in the total activity was observed. In 36% of the patients the electric activity of selected fragments of the cardiac muscle increased, in 55% of the patients it decreased, while in 9% of the patients the activity of certain fragments increased, while that of other ones decreased.

## Conclusion

Results of the study have shown that the NURSE ECG method can be applied to monitor changes in the electric activity of the cardiac muscle occurring as a result of CABG operation and one year after surgency. On the second day after the operation in the majority of patients (70%) a rapid decrease in the total activity of the cardiac muscle was observed, while 30% of the patients showed an increasing tendency in the cardiac muscle activity.

In one year after the operation in above 30% of the patients the total activity of the cardiac muscle increased, while in the other patients it decreased.

The NURSE ECG seems to be a promising supplementary method in medical diagnosing. In particular it can be applied for qualification of patients for CABG operation and for verification of the operation effects.

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