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NEW OPPORTUNITIES OF PHASEGRAPHY IN MEDICAL PRACTICE



The results of the modernization of phasegraphy (an innovative method of electrocardiogram processing) have been presented. New software and hardware which expand the method capacity have been described. The results of tests on clinical facilities of medical partner has been showed.

Keywords: phasegraphy, electrocardiogram, and medical diagnostic.

Phasegraphy is an innovative method for processing electrocardiograms (ECG). It has been developed at the International Research and Training Center for Information Technologies and Systems of the NAS of Ukraine and the Ministry of Education and Science of Ukraine [1, 2]. The method is based on research carried out within the framework of international project 01 KX 96115/1 *Computer-Aided Technology for Cardio Inflammatory Disturbance Analysis Based on Phase Space Cognitive ECG*, the Transform program, with *L.U.M. GmbH* (Germany) [3].

The main specific feature of phasegraphy is the transition from the scalar ECG signal $z(t)$ in any lead to its mapping on the phase plane with coordinates $z(t)$ and $\dot{z}(t)$, where $\dot{z}(t)$ is signal rate. This fundamentally distinguishes the phasegraphy from other similar approaches based on the signal mapping on the plane with coordinates $z(t)$ and $z(t-\tau)$, where τ is time delay. This distinction has enabled to expand the ECG diagnostic sign system based on the evaluation of the speed characteristics of the process and thereby to increase the sensitivity and specificity of ECG diagnostics.

The project used data of *BIOSET 8000* digital electrocardiograph with traditional 12 leads, and based on clinical material the proposed method for analyzing rheumatoid arthritis patient ECG has been proved high informative [4].

Further development of phasegraphy research takes into account the constantly growing share of cardiac pathologies in the structure of morbidity and the difficulties of using multichannel electrocardiographs for conducting mass preventive surveys. To solve this problem, a new task was posed: to adapt the phasegraphy method to the patients, including to make it suitable for the domiciliary use of digital electrocardiograph.

This task has been successfully solved within the framework of *Pattern Computer* State R&D Program and completed with the creation of the domestic *FASEGRAPH*[®] software and hardware complex that has been commercially produced by the Petrovsky Kyiv Automated Machinery Plant.

When designing this complex, the authors consciously rejected multichannel ECG record because of being aimed at its adapting to mass preventive surveys and non-professional users (without medical education). For this purpose, a portable sensor was developed. It ensures the

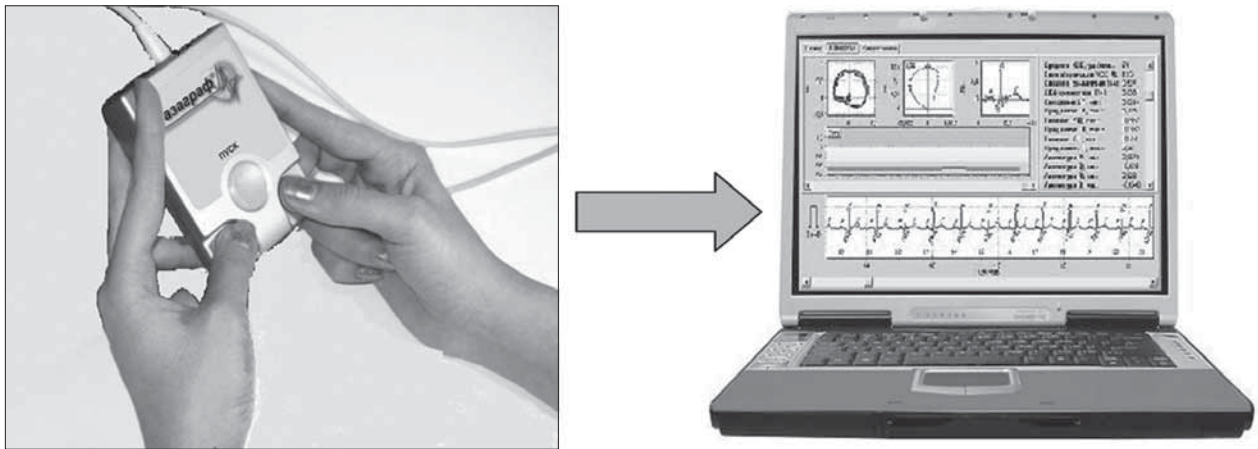


Fig. 1. FASEGRAPH® complex

convenience of the first standard lead ECG record using finger electrodes (Fig. 1).

Despite the fact that similar single-channel sensors with a simplified method of ECG record (Home ECG monitors) have been already quite widespread in the medical equipment markets, the phasegraphy has undoubted advantages in comparison with the known counterparts such as *Health Frontier* (Canada), *Win Health* (United Kingdom), *Vitaphone* (Germany), *Cardiovit MT100/200/3 Schiller* (Switzerland), *Monebo* (USA), *J1 Portable ECG Monitor* (China), *CardioQVARK* (Russia) and others that enable controlling the heart rate only. The principal phasegraphy advantage is knowledge-intensive information technology that implements an innovative method of processing the signal on phase plane $z(t), \dot{z}(t)$, which enables to detect subtle changes in the waveform, to ensure the personification of diagnostic solutions and to provide an integral information on the state of heart and on the initial signs of cardiac pathologies, not the sensor itself.

Differentiation of noisy functions being an ill-posed mathematical problem, the special computation procedures for filtration and regularization ensuring reliable estimation of $\dot{z}(t)$ are used for practical implementation of phasegraphy. As a result, many additional ECG diagnostic signs based on speed characteristics of the process, including

phase trajectory variance σ_{QRS} , orientation angle of average phase trajectory α_{QRS} , β_T , factor that characterizes symmetry of repolarization fragment (wave T) of average phase trajectory and some other indices (Fig. 2) can be determined.

Although the clinical importance of T wave symmetry analysis had been showed in [5], there were no digital electrocardiographs using this indicator, insofar as its reliable determination by real ECG data distorted by both internal and external perturbations is very complicated. FASEGRAPH® has enabled this for the first time in applied medicine.

It should be noted that ECG with normal ($\beta_T < 0.7$ units) and pathologic ($\beta_T > 1.05$ units) values of T wave symmetry are almost undistinguishable in the time plane, while transition to the phase plane $z(t), \dot{z}(t)$ makes their reliable identification possible (Fig. 3).

Clinical trials have confirmed that the analysis of additional diagnostic signs on single-channel ECG enables to increase the sensitivity and specificity of the diagnosis even in the cases when conventional ECG analysis in 12 leads is not informative [6].

The proposed method for ECF interpretation in the phase plane $z(t), \dot{z}(t)$ has attracted professional attention, including of foreign specialists [7–10]. The generalized results of the method approbation, which preceded the commercial production of FASEGRAPH® complex have been

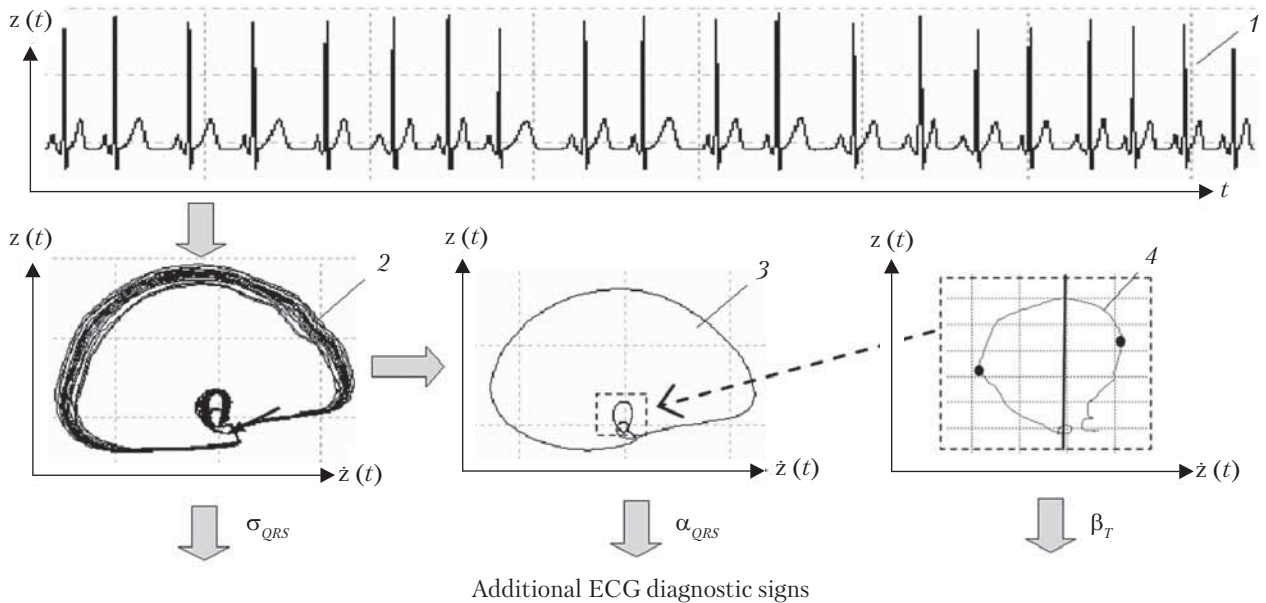


Fig. 2. Underlying concept of phasegraphy method 1 – initial ECG; 2 – ECG phase trajectory; 3 – averaged phase trajectory; 4 – repolarization fragment of averaged phase trajectory

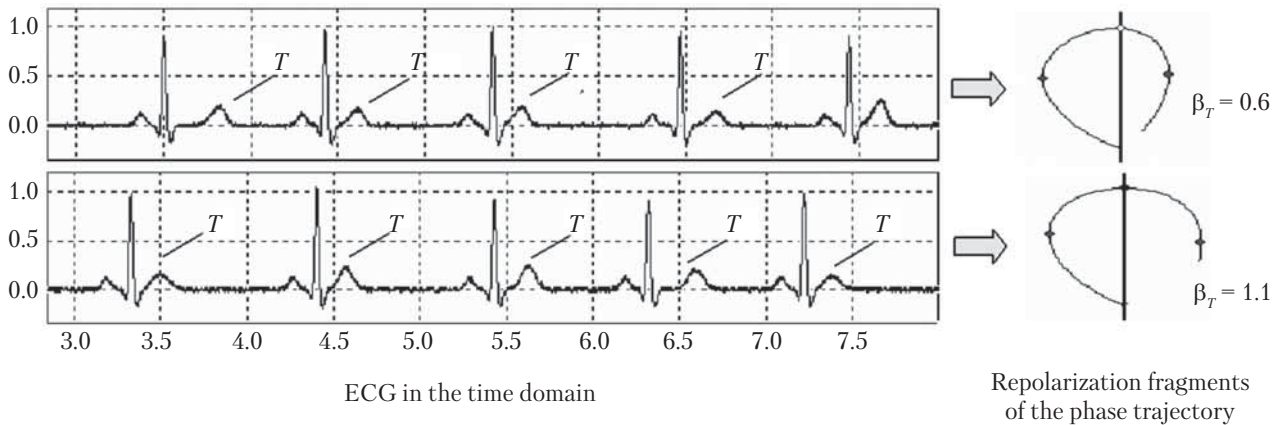


Fig. 3. ECG with normal (upper) and pathologic (lower) β_T factor

described in detail in the monograph [1], and the experience of its use by independent researchers has been presented in [11]. Successful results of phasegraphy application to pediatric cardiology have been described in [12–14].

Pursuant to the Decree of the NAS of Ukraine No. 35 of 17.02.16, in order to expand the scope of phasegraphy application within the framework of

innovative R&D project of the NAS of Ukraine (reg. No. 0116U005032), the method has been improved and tested at the clinical base of the medical partner, Practical Center for Preventive and Clinical Medicine of the State Administration of Affairs (PCPCM).

Below, there is a summary of the research results.

ANALYSIS OF MYOCARDIUM ELECTRIC INSTABILITY

A serious manifestation of cardiovascular diseases is a sudden cardiac death, when a patient dies almost instantaneously (from a few seconds to an hour) after the beginning of heart attack. One of the predictors of sudden cardiac death, which has recently gained wide recognition in clinical studies, is based on an analysis of the so-called electrical heart alternation, in particular, the T wave alternation [15–18].

Computer analysis of the alternation effect becomes an important characteristic of modern medical diagnostic systems. At the same time, according to experts, the existing computer algorithms do not ensure the required reliability of its detection in real clinical conditions. Moreover, in some studies, in particular in [19], the electrical alternation effect is identified with ECG micro-oscillations (variance), which does not fully correspond to the original interpretation of this term.

The term «alternation» is borrowed from linguistics and means regular repeated occurrence of sounds in words. Therefore, the electrical heart alternation means regular repeated occurrence of the characteristics of ECG informative fragments reflecting electrical processes in individual parts of the heart muscle, for example, alternating T wave with high and low amplitude in consecutive cycles [20]. In this respect, it is reasonable to consider the realization of several random variables that vary with limited variances in respect to «their» mean values as an adequate alternation effect generation model [21].

Fig. 4 shows a model ECG with T wave amplitude generated by one random value varying within 30% of its average $A_T = 0.2$ mV (Fig. 4, *a*), and by two random values (Fig. 4, *b*), generating T wave amplitude alternation effect with an alternation level of 60 μ V. These signals are visually undistinguishable, since wave amplitude RMSD for both signals are almost identical: $\text{RMSD}_a = 0.036$ units and $\text{RMSD}_b = 0.03$ units.

In order to reliably distinguish these signals, an additional software module has been devel-

Table 1

Model ECG Processing Results

Chaoticity estimate method	Model signal with T wave distortion	
	Random	Alternation
Conditional entropy	1.056	0
Approximate entropy	0.512	0.030
Masking entropy	1.5041	0
Permutational entropy	1.485	0.693
Hurst index	1.485	0

oped within the framework of the innovative project, in which several improved algorithms for entropy estimations of time series chaoticity have been implemented [22]. This module, in the interactive mode, allows the user to select and to configure the parameters of computational procedures, which, unlike variance, do not depend on values of observed random variable and therefore, characterize the variety of values rather than its dispersion.

Table 1 shows the results of model ECG chaoticity estimates. One can see that ECG with T wave alternation (Fig. 4, *a*) has a significantly less chaoticity, which opens a way to detecting the mentioned effect.

Fig. 5 shows rhythmograms of patient **A**, 67 years old, with a moderate arrhythmia ($SDNN_A = 63$ ms) (Fig. 5, *a*) and apparently healthy man **B**, 31 years old, with almost same heart rate variability ($SDNN_B = 50$ ms), (Fig. 5, *b*).

The distinctive feature of patient **A** rhythmogram is alternating three values of $R-R$ interval durations in the heart cycle sequence. There are no such distinctions in patient **B** rhythmogram. It should be noted that the mentioned differences in heart rate almost unnoticeable on the initial ECGs based on which the rhythmograms were built.

At the same time, in this case, material differences in rhythmogram chaoticity (Table 2).

Clinical studies have showed that the introduction of additional module for estimating the chaoticity of ECG element shape indicators into phasegraphy makes it possible to reveal statisti-

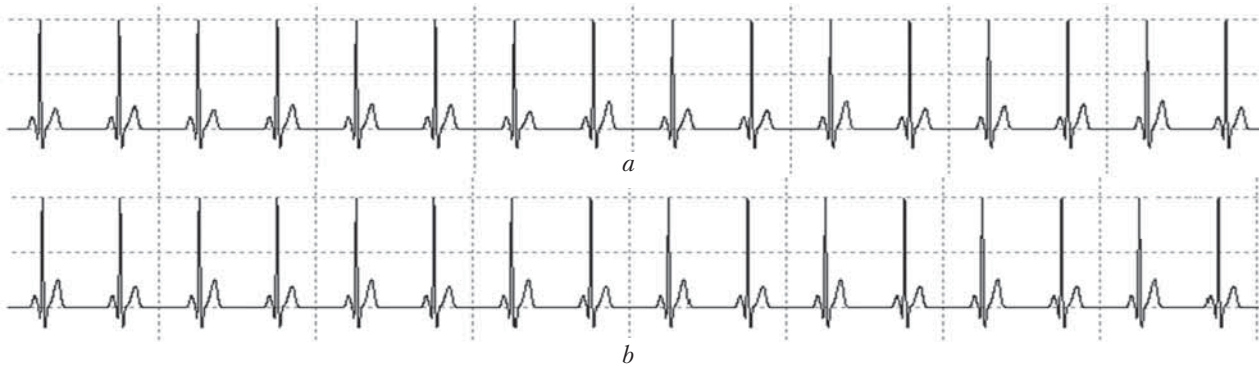


Fig. 4. Model ECG: with random distortion of T wave amplitude (a) and with alternation of T wave amplitude of various degrees (b)

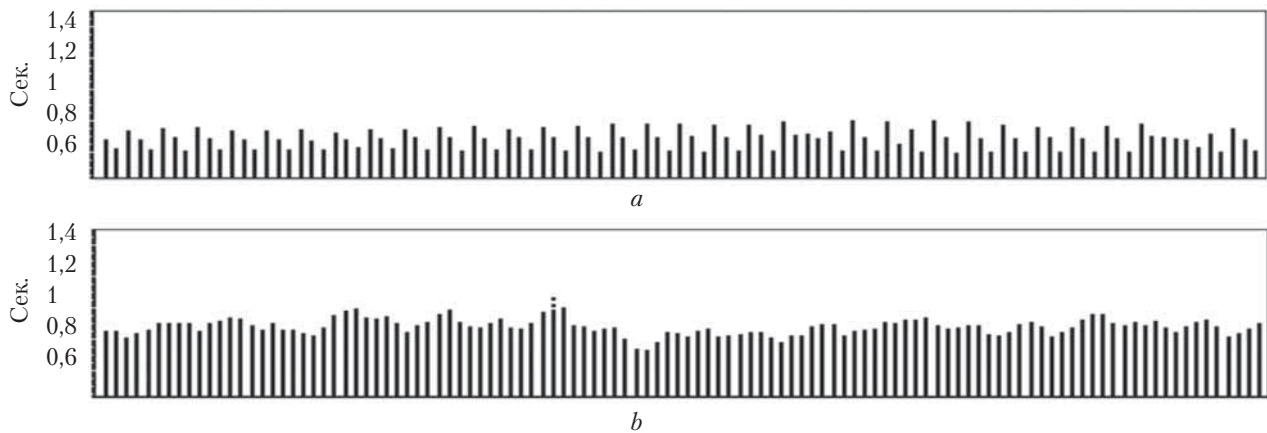


Fig. 5. Rhythmograms of female patient A (i) and apparently healthy man B (b)

cally significant subtle differences in ECGs of healthy and ill patients, as well as in ECGs of people with various levels of body fitness.

**COGNITIVE GRAPHIC IMAGES
FOR EVALUATING THE ORGANISM RESPONSE
ON LOAD BY THE PHASEGRAPHY METHOD**

Additional diagnostic information on assessing the cardiovascular system reserve capabilities can be derived from analysis of subtle changes in ECG signals recorded by the phasegraphy method under load. In medical conditions, such studies can be carried out on the basis of traditional means, cycle ergometer and treadmill.

However, such tools are hardly suitable for the field tests, when playing sports, at workplace, etc. This requires not only portable devices for mea-

suring ECG, but also simple methods that enable to receive online test results in a convenient and understandable form.

To fulfill this requirement, a new method (Fig. 6) for qualitative assessment of the adequacy of the organism's response and the cardiovascular system recovery in terms of indicators $x_i^{(1)}, x_i^{(2)}, x_i^{(3)}$, $i = 1, \dots, N$ of single-channel ECG recorded by FASEGRAPH® in the three states: rest $x_i^{(1)}$, immediately after dosed load $x_i^{(2)}$, and after 3 min relaxation $x_i^{(3)}$ has been proposed [23].

Each triplet $x_i^{(1)}, x_i^{(2)}, x_i^{(3)}$ forms a unique graphic pattern characterizing dynamics of changes in the i -th indicator in the three mentioned states.

For the experimental determination of a typical ECG response to a short-term load (20 deep knee bends in 30 seconds), a statistical analysis of

Table 2

Comparison of Heart Rate Chaoticity

Chaoticity estimate method	Patient B	Patient A	Difference, %
Conditional entropy	0.713	0.530	-25.7
Approximate entropy	0.533	0.301	-43.5
Masking entropy	1.142	0.348	-69.5
Permutational entropy	1.323	1.261	-4.7
Hurst index	0.688	0.538	-21.8

ECG records of 112 volunteers aged 19–24 years has been carried out. Among them, there are 35 persons actively playing sports (soccer, boxing, wrestling, biathlon, athletics, etc.) with at least 4 years of training experience.

The studies have confirmed (Table 3) that for the healthy people, the load leads to increasing cardiac rate and T wave symmetry factor β_T and decreasing ST segment depression factor δ_{ST} , duration Δ_T and T wave amplitude A_T .

Respectively, cardiac rate and β_T factor have a *maximum* physiological pattern, while δ_{ST} , Δ_T , and A_T have a *minimum* pattern. The analysis takes into account only parameter changes exceeding 5%.

To decide the cardiovascular system is tolerant to load or not, it is proposed to compare the current patterns of indicators based on test results with the physiological patterns of the respective indicator [24]. Undoubtedly, this decision shall be based on direct analysis of $x_i^{(1)}$, $x_i^{(2)}$, and $x_i^{(3)}$ values calculated during the tests.

However, it would be more convenient to make conclusions based on cognitive graphic image that visually reflects these data. To build such an image, a simple computation procedure is used. This procedure enables to reproduce patterns of all five indicators in the same scale. As a result, cognitive graphic image is generated. It is convenient for interpreting the test results: it is enough to visually determine the number of current patterns convex upwards.

Clinical studies have confirmed the reproducibility of cognitive graphic images that hold its

shape at different time for specific tested patients and enable to make unambiguous decisions.

Naturally, for more complete assessment of organism response to load, the proposed method can be generalized for the case when other ECG indicators, in particular, wave shape parameters P , intervals PQ and QT , as well as statistical and spectral indicators of heart rhythm variability (HRV) estimated based on ECG in the state of rest, at a load peak, and in restitution are used during the tests.

REALIZATION OF PHASEGRAPHY ELEMENTS ON MOBILE DEVICES

To raise effectiveness of preventive medicine reliable and affordable means which the patient can use in everyday life to assess his/her functional state and to accumulate data for getting professional medical advice are required. Therefore, within the project framework, a new digital medicine platform *FASEGRAPH-Mobile* realizing phasegraphy elements on Android mobile devices (smartphone, tablet) has been launched.

Patient's mobile application provides:

- ✦ record and preprocessing of single-channel ECG;
- ✦ control of dosed physical load;
- ✦ display of test result on personal indicator (Fig. 7, a).

In order to record ECG-signal, an advanced ECG sensor of the 1st standard lead, which ensures digital data transfer to patient's mobile application via Bluetooth interface is used.

Using original computation procedures in real time ensures removal of isoelectric line drift and data filtration with minimum distortions of useful signal and automatic search of QRS -complexes by which current cardiac rate is measured and displayed on smartphone screen (Fig. 7, b).

In order to record ECG both in the state of rest and after physical load the application has a module ensuring convenience of doing the required number of knee bends in required time. The rate of knee bending is set according to physician's recommendations with patient's age and level of

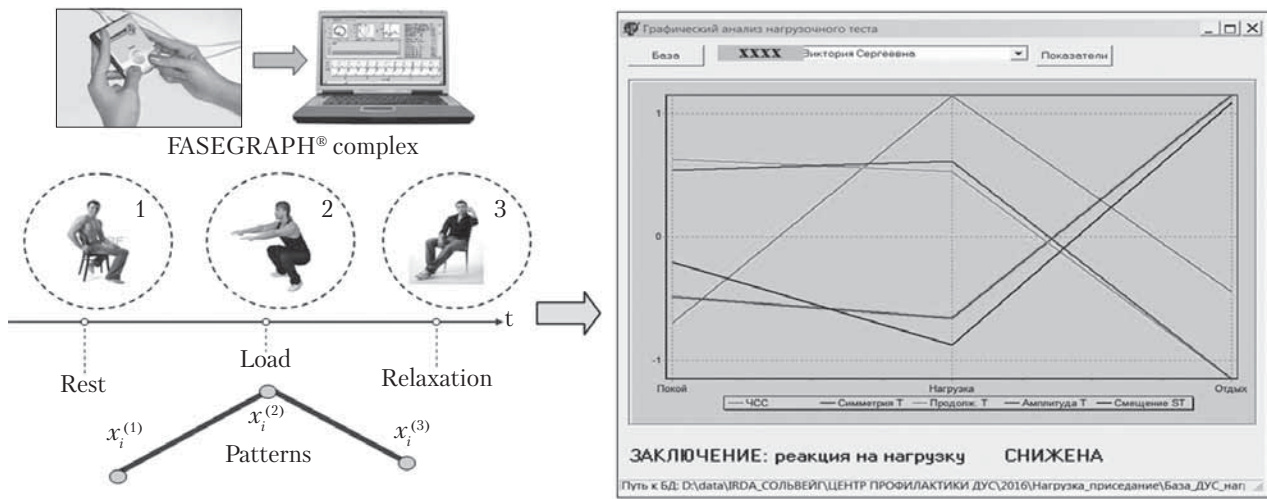


Fig. 6. Scheme of survey under physical load

Table 3

Healthy Organism Response on Load and Physiological Patterns

Indicator	Response to load, %			Physiological pattern	
	Increase	Decrease	Fixed	Pattern	Occurrence, %
Cardiac rate, beats/min	92.9	5.4	1.7	Maximum 	75.9
β_T , unit	91.1	5.4	3.5	Maximum 	67.0
A_T , mV	14.2	82.1	3.6	Minimum 	50.0
Δ_T , s	19.6	71.4	8.9	Minimum 	50.0
δ_{ST} , mV	21.4	78.6	0	Minimum 	43.8

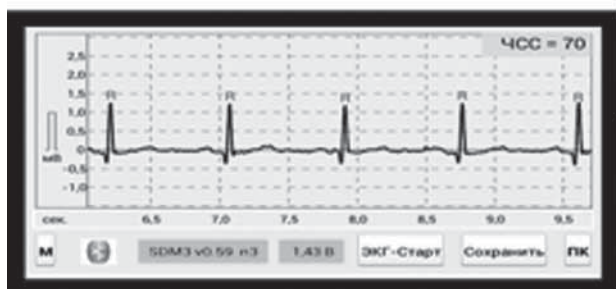
body fitness taken into account. The patient has to do the exercise at a required rate synchronously with virtual «trainer» (Fig. 7, c).

Phasegraphy uses a specific approach to ECG interpretation: diagnostic solutions rely upon both the comparison of current β_T factor with the population norm $\beta_T < 0.7$ units and the patient-

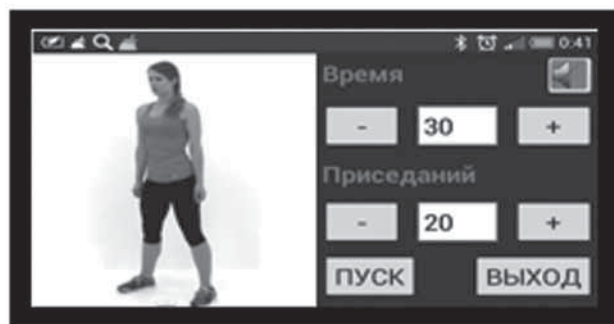
specific norm [25]. To this end, the device has a function of computation and permanent adjustment of patient-specific norm with the patient seeing the result on the indicator (Fig.7, d) in simplified form in understandable graphic images and voice messages on his/her current functional state as compared with patient-specific norm.



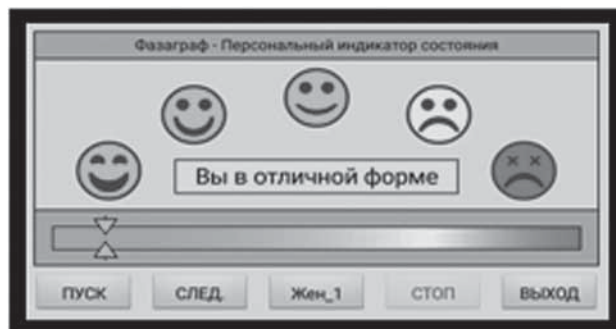
a



b



c



d

Fig. 7. Windows of FASEGRAPH –Mobile platform: *a* – main window of the application; *b* – ECG display window; *c* – load control window; *d* – patient-specific indicator

FASEGRAPH-Mobile realization enables ECG record and analysis in patient's mobile application and open a way to building a client-server system ensuring a virtual connection between the physician and the patient via Internet (Fig. 8).

In addition to data storage, the server provides automatic prioritization of ECGs requiring particular physician attention. ECGs with atypical cycles or the reference cycle significantly differing from the reference cycles of the preceding ECGs are considered suspicious.

Atypical ECG cycles can be caused by random perturbations (artifacts) or generated by extrasystoles, i.e. premature contractions of the heart muscle that arise in response to an impulse in some part of the heart other than the normal impulse from the sinoatrial node. The functional extrasystoles do not pose a particular danger and can arise in apparently healthy people with neurotic disorders.

At the same time, sudden appearance of extrasystoles can contain important information about the organic lesions of the heart, in particular, they can be the first sign of the development of acute myocardial infarction. Therefore, when building a system for remote monitoring of cardiac activity, it is important to have «intellectual» means providing automatic recognition of suspicious ECGs with atypical cycles, which require particular attention of the professional.

To solve this problem, the server software implements a unique computational procedure for evaluating the closeness of processed ECG cycles based on the Hausdorff distance [26]. This procedure enables not only to detect atypical ECG cycles, but also to select extrasystoles and artifacts and to classify them provided there is a sufficient number of extrasystoles on the ECG. The estimation of Hausdorff distances enables to make a decision on the degree of deviation of the current ECG reference cycle from the reference cycles of previous ECGs.

It should be noted that final diagnostic conclusions are made by the professional, while the server only provide support for him/her by notifying of

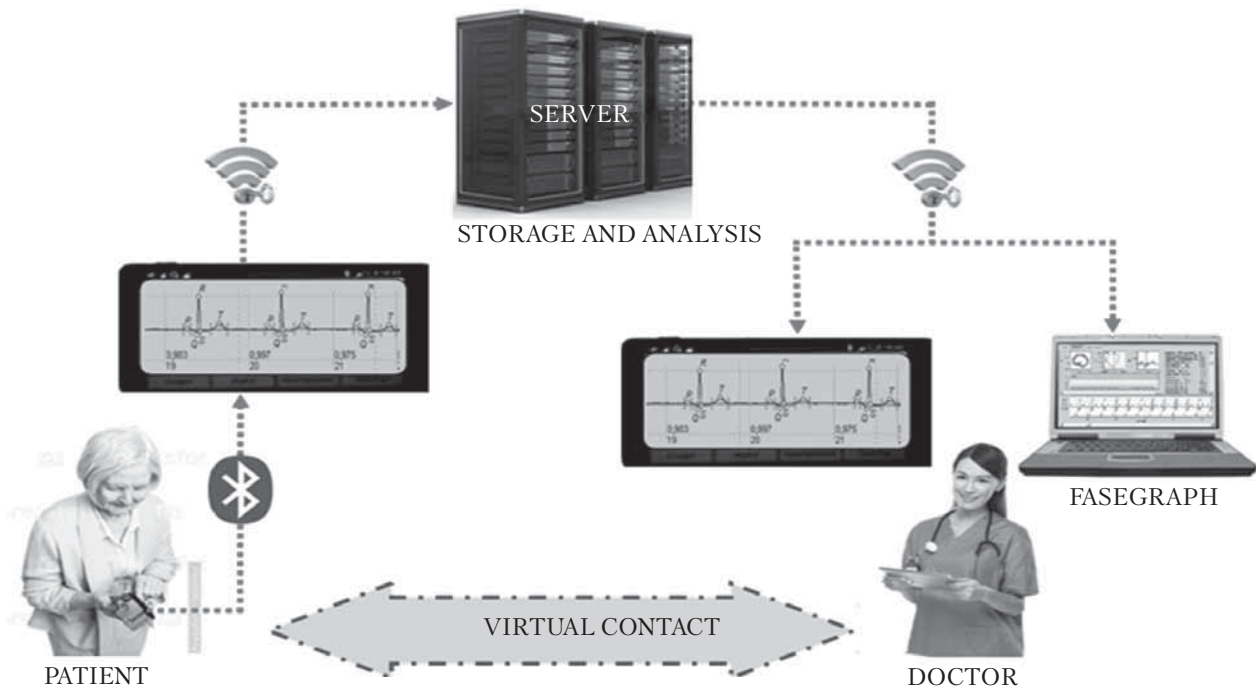


Fig. 8. Client-server system for communication between the doctor and the patient

suspicious ECGs. Having assessed these ECGs visually, the doctor can use additional diagnostic information provided by FASEGRAPH®, if necessary. This organization of interaction between patient applications and the server optimizes physician's time for provision of medical services to patients.

USE OF PHASEGRAPHY FOR PREVENTIVE MEDICAL EXAMINATION OF POPULATION

Within the project framework, 590 (410 female and 180 male) outpatients subject to annual preventive medical examination have been surveyed using FASEGRAPH® at PCPCM [27]. The age structure is as follows: up to 30 years old – 85 patients; 31–60 years old – 423 patients; over 61 years old – 82 patients.

β_T factor describing symmetry of repolarization section was estimated as integral indicator of ischemic changes. Based on the results of previous studies, $\beta_T < 0.7$ units is assumed normal and $\beta_T > 1.05$ units is deemed pathologic.

For the study group ($n = 590$), β_T ranges from

0.429 to 1.76 units, with an average of 0.858 ± 0.167 units; 63 patients have $\beta_T > 1.05$ units; flat or negative T wave is observed in 18 patients. Based on these results 81 patients (about 14%) are referred to the group with probable ischemic changes in myocardium.

While processing the results, some interesting peculiarities of β_T have been found. In particular, statistically significant ($p < 0.01$) gender differences have been established for β_T in the age group under 40. In this group, $\beta_T < 0.75$ units is observed in $53 \pm 5.5\%$ cases for men and in $33 \pm 3.3\%$ cases for women. The men have β_T ranging from 0.75 to 0.95 units in $34.9 \pm 5.2\%$ cases; the women – in $55.5 \pm 3.4\%$ cases.

Statistically significant correlation ($r \approx 0.325$; $n = 576$; $p < 0.01$) between β_T and patient's age (years) described by linear regression equation has been found as well.

$$\beta_T = 0.004092 \times \text{Age} + 0.6804.$$

Hence, at an age of 20 years the mean β_T is equal to 0.78 units and until 60 years it grows up

to 0.93 units, which logically is in good agreement with known data on increasing incidence of ischemic disease among aged population.

Also, strong correlation ($r \approx 0.8$; $n = 576$; $p < 0.01$) between β_T and segment shift ST (δ_{ST} , mV), described by linear regression equation has been established.

$$\beta_T = -4.454\delta_{ST} + 0.7724.$$

In this way, β_T factor of T wave symmetry increases as ST segment depression ascends and δ_{ST} approaches a threshold of -0.1 mV.

Screening of 590 patients using phasegraphy method has made it possible to divide them into three ischemic disease risk groups depending on β_T value:

- ✦ *low risk*: 103 patients (17.5%) with $\beta_T < 0.7$ units;
- ✦ *medium risk*: 424 patients (72%) with $0.7 \leq \beta_T \leq 1.05$ units;
- ✦ *high risk*: 63 patients (11%) with $\beta_T > 1.05$ units.

The phasegraphy results have been compared with outpatient medical record data in the two opposite groups: the low risk and the high risk ones (see Table 4).

According to Table 4 sensitivity Se and speci-

Table 4

Comparison of Phasegraphy Results with Patient Medical Record Data

Deviation from the norm upon phasegraphy results	Deviation from the norm upon results of conventional medical survey		Total
	(-) not detected	(+) detected	
(-) no deviations detected: $\beta_T < 0.7$	99	4	103
(+) deviations detected: $\beta_T > 1.05$	7	56	63
Total	106	60	166

ficity Sp of phasegraphy method for the tested patients from the mentioned opposite groups are $Se = 56/60 = 93.3\%$ and $Sp = 99/106 = 93.4\%$.

Spearman's correlation factor is $\rho = 0.901$ at a statistic significance of $p < 0.01$. Hence, the correlation between the phasegraphy results and the results of conventional medical survey is very high, according to the Chaddock scale.



Fig. 9. Dynamics of β_T factor before and after CABGS

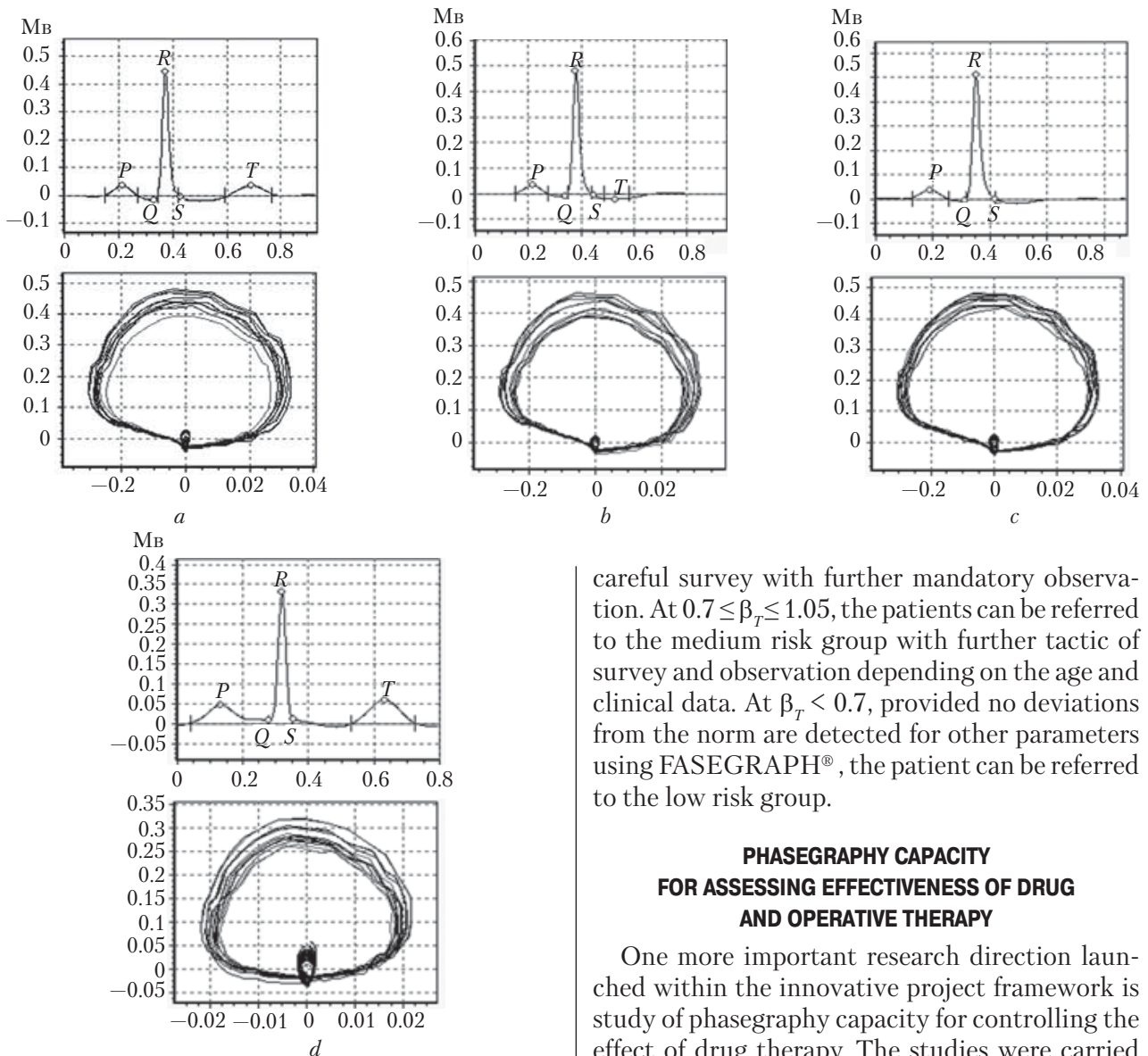


Fig. 10. Dynamics of ECG reference cycles and phase patterns during the stenting *a* – before surgery; *b* – angioplasty; *c* – stenting of left coronary artery; *d* – stenting of right coronary artery

In the view of simplicity and convenience of surveys using FASEGRAPH® the phasegraphy method can be recommended for mass medical surveys aimed at stratifying the cardiovascular disease risk.

At $\beta_T > 1.05$ the patients shall be referred to the high risk group that requires immediate more

careful survey with further mandatory observation. At $0.7 \leq \beta_T \leq 1.05$, the patients can be referred to the medium risk group with further tactic of survey and observation depending on the age and clinical data. At $\beta_T < 0.7$, provided no deviations from the norm are detected for other parameters using FASEGRAPH®, the patient can be referred to the low risk group.

PHASEGRAPHY CAPACITY FOR ASSESSING EFFECTIVENESS OF DRUG AND OPERATIVE THERAPY

One more important research direction launched within the innovative project framework is study of phasegraphy capacity for controlling the effect of drug therapy. The studies were carried out using an advanced ECG sensor that ensured ECG record from fixed single-use electrodes (with the help of additional wire) and wireless signal transfer from the patient to FASEGRAPH® via Bluetooth interface. While infusing the drug, each 5 minutes, ECG was recorded for 150 s, with conventional and original parameters of ECG and CRV measured.

Totally, results of 48 procedures (intravenous dropping) have been analyzed. Particular attention has been paid to informativity of β_T factor

for assessing the dynamics of changing T wave symmetry in the course of potassium drugs (*Asparkam* and *Panangin*) infusion.

It has been established that in 80% cases, β_T values monotonously decrease under the action of potassium drug, whereas the conventional parameter (ST segment depression) observed in parallel shows less stable dynamics as an adequate picture is obtained for 25% cases.

This preliminary result shows the possibility of using the phasegraphy method for differential diagnostics of functional and structural changes in myocardium in the case of individual approach to assessing effectiveness of drug therapy influencing metabolism, electric potential, and conductivity in the myocardium cells.

For the first time, within the project framework, the phasegraphy potential for analyzing ECG of patients after coronary artery bypass graft surgery (CABGS) has been studied. Fig. 9 shows positive dynamics of β_T factor before and after surgery of 60-years-old patient M. The surgery included installation of 3 shunts caused by disease of 3 coronary arteries. After the surgery, as coronary blood circulation is being restored, T wave symmetry factor whose value before surgery reached $\beta_T = 1.6$ units gets normalized.

Interesting results have been obtained when assessing the dynamics of changes in the ECG phase patterns directly in the course of stenting the coronary arteries. Fig. 10 shows the dynamics of changes in graphic images observed during stenting in 69-years-old patient with chronic ischemic heart disease.

Of course, here are only the first encouraging results of applying the phasegraphy method to clinical practice for the evaluation of subtle ECG changes for the pharmacological and operative treatment of cardiac patients. These studies will continue as data accumulate.

Currently, FASEGRAPH® has been successfully used at more than 100 organizations in Ukraine (medical and sports organizations, diagnostic centers, enterprises with an increased technogenic risk, schools, etc.), as well as by in-

dividuals at home. New research results obtained during the project implementation significantly expand the scope of phasegraphy practical application and increase the method competitiveness and attractiveness for potential investors.

CONCLUSIONS

Within the innovative project framework, phasegraphy algorithmic and software components have been improved and tested on clinical facilities of medical partner (PCPCM). In particular, new approach to assessing heart electric alternation and original method for qualitative evaluation of organism response to load have been developed.

To expand the scope of phasegraphy application the method elements have been realized as mobile appliances for Android smartphones and tablets, which opens a way to the creation of client-server system for remote monitoring of cardiac activity based on phasegraphy method.

The clinical studies have confirmed that Ukrainian-made FASEGRAPH® complex enables reliable determination of β_T factor of T wave symmetry, which contains important additional diagnostic information on ischemic changes in myocardium. For the first time, phasegraphy capacity for assessing effectiveness of drug therapy and surgical treatment of cardiologic patients has been showed on real clinic material.

Continuation of this research is of paramount importance for further establishment of Ukraine's priorities in the field of creation of effective mobile means of digital medicine based on the innovative phasegraphy method.

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**НОВІ МОЖЛИВОСТІ ФАЗАГРАФІЇ
В ПРАКТИЧНІЙ МЕДИЦИНІ**

Представлено результати модернізації фазаграфії — інноваційного методу обробки електрокардіограм. Описано нові програмні та технічні засоби, які розширили споживчі властивості методу. Наведено результати випробувань фазаграфії на клінічній базі медичного партнера.

Ключові слова: фазаграфія, електрокардіограма, медична діагностика.

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**НОВЫЕ ВОЗМОЖНОСТИ ФАЗАГРАФИИ
В ПРАКТИЧЕСКОЙ МЕДИЦИНЕ**

Представлены результаты модернизации фазаграфии — инновационного метода обработки электрокардиограмм. Описаны новые программные и технические средства, которые расширили потребительские свойства метода. Приведены результаты испытаний фазаграфии на клинической базе медицинского партнера.

Ключевые слова: фазаграфия, электрокардиограмма, медицинская диагностика.