SYSTEM 'RESERVE' FOR PRE- AND POST FLIGHT CARDIORESPIRATORY SYSTEM EXAMINATIONS OF COSMONAUTS

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Abstract: The scientific results of investigationsperformed in the long term space flights on the orbital station "Mir" and International Space Station (ISS) showed an importance of evaluation and prediction of organism reserves in pre- and post flight periods. The investigations of cardiovascular system have the supreme priority, because this system is a sensitive indicator of adaptation reactions of whole organism. Because there are some restrictions for scientific program on the ISS, the pre- and post flight examinations of cosmonauts play an important role. The new conception of diagnostic device construction was build. This conception is realizing in the new diagnostic device "Reserve" for medical support of space flight of Russian cosmonauts on ISS. The new system "Reserve" combines newest space medicine technologies and modern clinical methods for examination a cardiorespiratory system. This system can save compatibility between experiments on the ISS and pre- post flight examinations. Full examinations of cosmonauts on the Earth may be performed by the system for changes caused by microgravity to be revealed. The presence of traditional clinical methods permits to use the "Reserve" in different fields of physiology and clinical medicine. The system is useful to investigate states between norm and pathology ("prenosological diagnostic").

Introduction

The scientific results of investigations performed in the long term space flights on the orbital station "Mir" and International Space Station (ISS) showed an importance of evaluation and prediction of organism reserves in pre- and post flight periods [4]. In weightlessness the homeostasis of main systems is known to be supplied by tension of regulatory systems, which have functional reserves [1]. Therefore during cosmonaut's examinations it is necessary to examine the vital system's homeostasis, include cardiovascular and respiratory systems, but to estimate physiological function regulation mechanisms.

The investigations of cardiovascular system have the supreme priority, because this system is a sensitive indicator of adaptation reactions of whole organism [5]. During space flight there is no opportunity to have a complex investigation program for cardio-vascular and respiration systems, because strict restrictions are for both equipment weight and examination duration in the space flight. In this case, all scientific experiments on the ISS must be composed in order to get more information in a short time. For example, the duration of the experiment "Pulse" being conducted on ISS is 20 minutes for examination in the rest and in the four functional tests. At examining a cosmonaut the electrocardiogram, photopletismogram and pneumotachogram are recorded [2]. In near future, there is a plan to install the new device "Pneumocard" on the International space station's board. The "Pneumocard" has two additional channels to record seismocardiogram and impedance cardiogram and extensive examination program to test the regulation process [3].

Because there are some restrictions for scientific program on the International space station, the pre- and post flight examinations of cosmonauts play an important role. It is important to start examination as early as possible. The best time for the examinations is just after landing in touchdown area. Such kind examinations need a mobile and compact device combining modern clinical and physiological methods. One of the main feature of this device must be the ability to process signals recorded during the space flight.

It is necessary to develop the new type of mobile diagnostic device for cosmonaut's examinations by methods of both space medicine and traditional medicine.

Materials and Methods

A new conception of diagnostic device construction had built before developing the new device. The main idea of the conception is to combine the space medicine diagnostic methods with traditional medicine methods in single whole. Three key positions are:

1. To develop the new software to record and proceed signals, where the space medicine methods are expanded by methods of traditional medicine.
2. To develop the new software to process signals from both space experiments and pre-, post flight examinations.
3. To construct an uniform database for signals of space experiments and pre-, post flight examinations.

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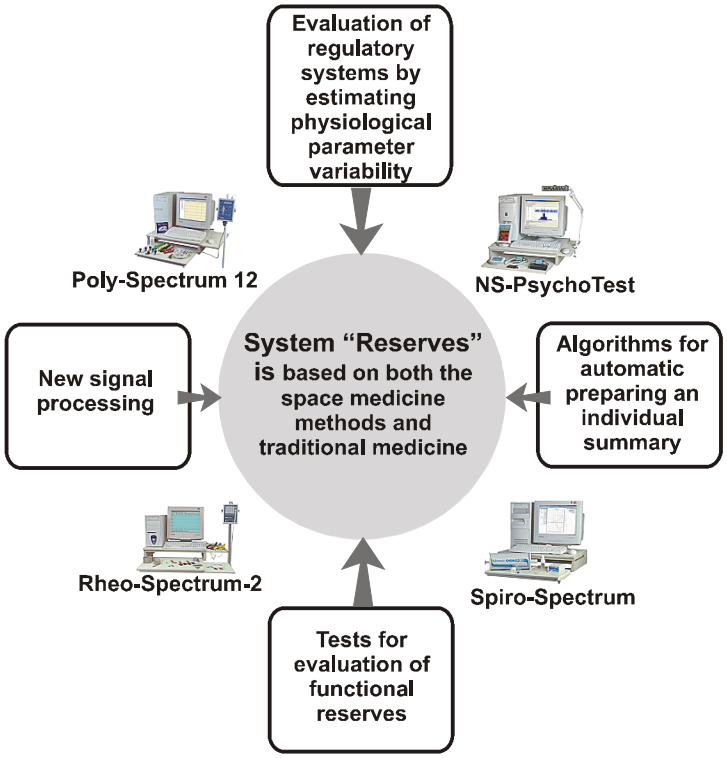

Figure 1: System "Reserve" is based on space medicine technology and commercial diagnostic equipments.

The conception is realizing in the new diagnostic device "Reserve" for medical support of space flight of Russian cosmonauts on ISS. The new diagnostic device is based on present devices and methods. The device "Pneumocard" being developed for ISS in collaboration Russia and Germany was taken as analog of a space device. An analogs of the "Reserve" in the traditional medicine were modern stationary commercial devices from "Neurosoft" (Russia, Ivanovo) for diagnostic cardio-vascular and respiratory systems: 'Poly-Spectrum 12', "Rheo-Spectrum-2", "Spiro-Spectrum", "NS-PsychoTest". These devices are widely used in hospitals over the world.. Automatic form input is in the 'Reserve' too in order to use paper forms for psychological testing.

The 'Reserve' software is developing on C# for the .NET. The big advantage of the software is to process signals recorded by 'Pneumocard', "Pulse" and commercial devices. Processing results are saved in uniform database.

So, the new system "Reserve" combines newest space medicine technologies and modern clinical methods for examination a cardiorespiratory system (Figure 1).

The use of new conception for the diagnostic device developing opens new ways to improve investigation methods in the direction to harmonize parameters of cardiorespiratory homeostasis and parameters of autonomous regulation.

Results

The system "Reserve" consists of hardware and software parts.

The hardware part is the four commercial diagnostic devices: "Poly-Spectrum 12", "Rheo-Spectrum-2", "Spiro-Spectrum". "NS-PsychoTest", a blood pressure monitoring module, a capillar blood carbonation module.

Electronic parts of the diagnostic devices were combined in the one module placed in upper part of a metal case. The system "Reserve" needs a power supply 220 V AC or 12 V DC.

The compact size and autonomic power supply, a rechargeable battery or car's board electric, let to use the "Reserve" far from civilization.

The device "Reserve" is presented on Figure 2.

Sockets are located on the upper part of the metal case. The lower part of the case has special sections for electrodes and sensors. During examination the lower part can be covered by a special plate. In this case the examiner may use the one as a table.

Total weight of "Reserve" is 14 kilograms.

The readiness time for examination is 10-15 minutes.

In comparison with "Pneumocard", the "Reserve" has an additional investigation methods, that gives for examiner to record 26-th physiological signals. All recording signals has sampling rate at 1000 Hz and a 32 bits A/D converter. In Table 1 the differences between "Pneumocard" and "Reserve" are shown.

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Figure 2: Device “Reserve”.

Table 1: The methods are used in the space flight (“Pneumocard”) and pre-/post flight examination (system “Reserve”)

Methods	Pneumocard	Reserve
Electrocardiogram	I lead	12 standard leads, X, Y, Z by Frank
Seismocardiogram	+	+
Sphigmocardiogram	+	+
Pneumotachogram	+	+
Impedance cardiogram	+	+
Rheogram (from extremities and encephalon)		+
Rheoencephalogram		+
Blood pressure monitoring		+
Blood capillar carbonation monitoring		+
Psychophysiological testing with simultaneously registration of physiological signals		+
Volume and velocity characteristics of respiration		+
Sphygmogramm from arteria carotis, femoral artery		+
Volume sphygmogram		+
Phonocardiogram		+
Questionnaire		+

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The tool kit of different methods, for examination cardio-vascular system, presented in the one system allows to put into practice the idea about full examination of the regulation process and the functional reserves of the organism.

The hardware part of the system "Reserve" is controlled by universal software developed for Microsoft .NET.

The scheme of the software is presented on Figure 3.

The software consists of two main units: investigation, analytical.

The Investigation unit conducts investigation according with scientific program. The Form input subunit performs input data from form and recognizes a hand writing data. The form input is performed by scanning with following recognition. The forms can be psychological tests as well as anthropometry data. The second subunit, Preliminary signal processing subunit, records physiological signals and performs preliminary signal processing (filtering, smoothing and so on).

The Analytical unit is connected with Investigation unit via Database in which the forms and the native physiological signals are saved. All necessary operations to prepare a Medical report are performed in the Analytical unit. The saved physiological signals are directed from Database to Signal processing subunit for key points to be recognized. After signal processing the physiological signals with recognized key points and the data of forms from Database are combined for further analysis in Infromatical and algorithm subunit. Key parameters and indexes are calculated on this stage of analysis. The parameters and indexes have taken from both space medicine and clinical medicine. All calculated indexes and parameters are transmitted to Decision-making unit, last state of analysis. On the last stage the program must estimate a cosmonaut's readiness for a space flight, functional reserves, stress stability, risk of regulation system disorders and to predict adaptation reactions.

The native signals and results of processing are saved in the Database.

In according to goals and objectives of examination the examiner can freely change the scheme of examination, type of recording physiological signals and so on. It is possible to record simultaneously any 8 of 26 signals by system "Reserve".

Signals are recorded during any functional tests including psychophysiological tests. The program's screen-short during the rest and test for estimation volume-velocity respiration parameters is presented on Figure 4.

Today, the system "Reserve" includes several functional tests presented in Table 2.

Developed system "Reserve" combines methods using in the space medicine and clinics. The system can be used to examine as in the rest, as in the functional tests.

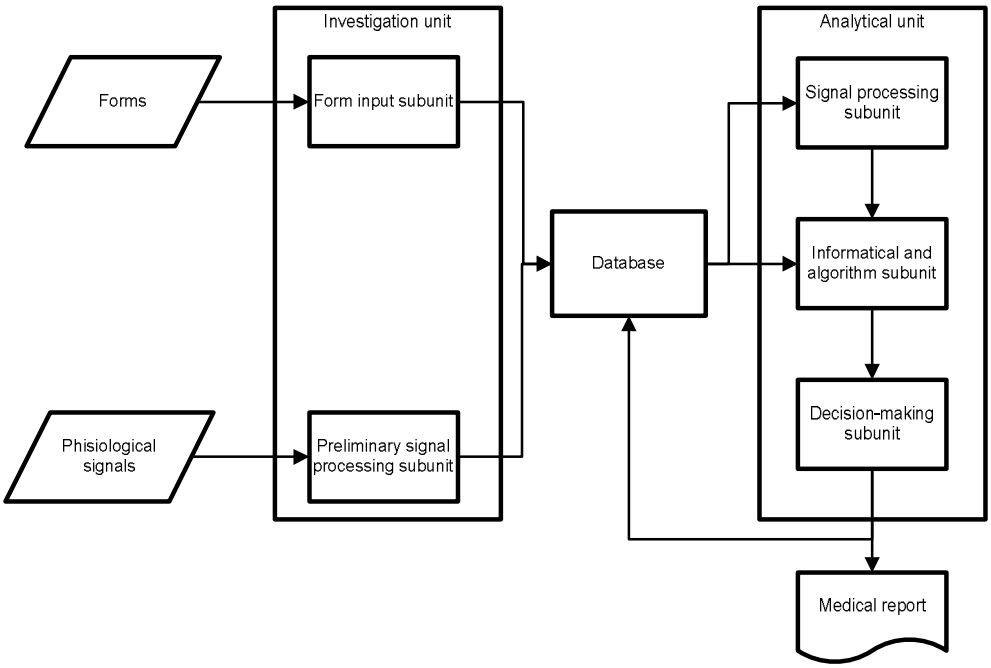

Figure 3: Scheme of the system "Reserve" software.

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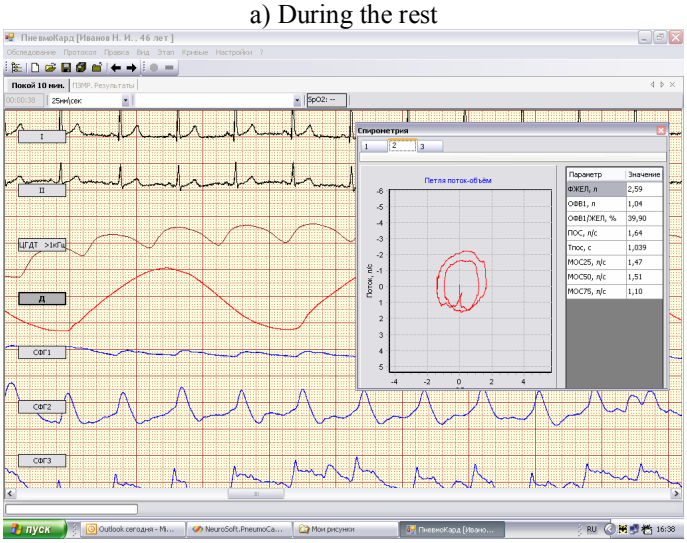
a) During the rest



b) During the test

Figure 4: Screen-shorts of software “Reserve”.

Table 2: Functional tests are realized in the system “Reserve”.

Test	Pneumocard	Reserve
Orthostatic test	+	+
Fix respiration test	+	+
Random respiration test	+	+
Breath taking tests (on in/exhalation)	+	+
Isometric load test		+
Simple optic-motor test		+
Attention test		+
Noise immunity test		+
Discrimination task		+
Discrimination task with time deficient		+
Optic discrimination task		+
Red-black table test		+
Quiet Breathing		+
Inhalation Tests		+
Forced expiration test		+
Maximum Pulmonary Breathing Capacity		+

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Discussion

The system "Reserve" is based on approaches of both space medicine and clinical medicine. Traditional methods (electrocardiogrma, balistocardiogram, phonocardiogram and so on) for clinical medicine and methods of space medicine are realized in the system. Beside traditional methods, the new methods for prediction arrhythmia and ischemic are presented (high resolution electrocardiogram, dispersion mapping electrocardiogram). It is possible to evaluate a current functional state and forecast a possible overstrain and depletion of adaptation processes, that may cause pathological changes in cardio-respiratory system.

The estimation of future functional state is based on a decision making rules, which contain individual mathematical models of functional state. The functional reserves, overstrain of regulatory systems and current state of cardiorespiratory system are considered in the individual mathematical models. The special functional tests are for direct estimation of functional reserves.

The use of commercial devices as a hardware base of the "Reserve" reduces a total cost of work and a period of development. There are ease modification and enhancement, because the system "Reserve" has the same hardware as the commercial devices.

The developed system "Reserve" can save compatibility between experiments on the International Space Station and pre- post flight examinations. Full examinations of cosmonauts on the Earth may be performed by the system for changes caused by microgravity to be revealed.

Conclusions

The system "Reserve" has been developed for full examination of cardio-vascular and respiratory systems in pre and post space flight periods. It is possible to estimate a cosmonaut's readiness for a space flight, functional reserves, stress stability, risk of regulation system disorders and to predict adaptation reactions. From this point of view, the "Reserve" is a modern system for diagnostic and prognosis of the state of cardiorespiratory system.

The presence of traditional clinical methods permits to use the "Reserve" in different fields of physiology and clinical medicine. Especially, the system is useful to investigate states between norm and pathology ("prenosological diagnostic"). For example, the system may be applied in mass examination, regular medical check-ups and so on. Unit design provides easy and quickly modification and modernization for any kind of tasks.

References

[1] BAEVSKY R.M. (1997): 'Noninvasive methods in space cardiology', *J. Cardiovasc. Diagn. a. Proced.*, Vol. 14, N 3, pp. 1-11.

[2] BAEVSKY R.M., BARANOV V.M, BOGOMOLOV V.V. et al (2003): 'Experiments "Pulse" on board the International Space Station', Proc. of 54-th International astronaut congress, Bremen, 2003, p. 17.

[3] BARANOV V.M., BAEVSKY R.M., DRESKER J. et al (2002): 'Investigation of the cardiovascular system and respiratory system on board International Space Station', 53-th International astronaut congress, Houston, 2002, p. 12.

[4] GRIGORIEV A.I., BAEVSKY R.M. (2001): 'Conception of the health and problem of norm in the space medicine', Slovo, Moscow, p. 96.

[5] PARIN V.V., BAEVSKY R.M., GAZENKO O.G. (1965): 'Heart and circulation under space conditions', *Cor et Vasa*, Vol. 7, N. 3, pp.165-182.

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