SHORT REVIEW

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Cybernetic Approach to Health Assessment

In memory of Professor R.M. Baevsky (03.08.1928-30.05.2020), who was a permanent author and member of the editorial board of the journal «Cardiometry»

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Abstract

The exploration of orbital space served as a prerequisite for the creation of a new direction of medical science in relation to the very extreme conditions of life of spacecraft crews. Space medicine, relying on the most modern research methods and approaches, thanks to the development of new medical devices and the use of unique data analysis algorithms, has made a significant contribution to the development of telemedicine, medical cybernetics, and prenosological principles for assessing the state of human health. The review reflects the main stages in the development of medical cybernetics and prenosological diagnostics based on the assessment of the regulatory components of the cardiovascular system. Discussed the aspects of the application of the method of mathematical analysis of the heart rhythm in relation to the assessment and forecast of the working capacity of cosmonauts, at the simulating model of microgravity and confinement. Shown the useful methodically apply for the healthcare of manufacture teams at the plants, passenger bus driver's employments. As the part of appliance of the new advance tools of children and adolescents public health during the educating process at schools. The created system for analyzing the current functional state of human health and mathematical models that make it possible to predict its negative changes make it possible to predetermine the vector of development of medicine in the future. The foundations of knowledge gained over the period of more than 70 years of scientific activity of Professor R.M. Bavsky are reflected in promising areas of cardiology research using computer technologies - such as Cardiometry technologies.

Keywords

Cardiometry, Heart Rate Variability, Medical Cybernetics, Donosology

Imprint

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Introduction

A modern scientific approach to the creation of the theoretical and practical foundations of medicine is impossible without the use of advances in computer technology. "Cardiometry" can be considered as one of the interdisciplinary scientific and practical areas in cardiology, combining innovative approaches to non-invasive measurements of the work of the heart and a detailed analysis of the functional characteristics of the cardiovascular system using the postulates of medical cybernetics.

The founder of the scientific direction "Medical Cybernetics" in the USSR and Russia is Anatoly I. Kitov - the creator of the theoretical foundations of national medical cybernetics and automated control systems (ACS) in healthcare. In the period from 1976 to 1983, he published three monographs in which he formulated the main provisions for the automation of the processing of medical information, the use of equipment and technologies for obtaining and preserving medical data.

However, 10 years before the first edition the book of Vorob`yov E.I. and Kitov A.I. [1] the monography by Vasily V. Parin and Roman M. Baevsky "Introduction to Medical Cybernetics" (1966) was published [2]. In this book, in contrast to the technical problems successfully solved by A.I. Kitov, a presentation of the main problems of medical cybernetics is given. The theory of information, the theory of automatic control, the theory of algorithms, etc. are presented. General questions of biocybernetics are considered. Cybernetics of cellular and subcellular structures, cybernetics of physiological systems, problems of neurocybernetics, features and principles of interaction in a "man-machine"-type system. Much attention is paid to the use of cybernetic methods in diagnostics. The cybernetic aspects of medical electronics are covered. The problems of biological control, the main problems of medical cybernetics, are considered.

Back in 1959, the Scientific Council on Cybernetics was organized under the Presidium of the USSR Academy of Sciences. As part of the Council, a biomedical section was created, headed by Academician V.V. Parin is known for his fundamental works in the field of physiology and pathology of blood circulation, clinical physiology, space biology and medicine, medical electronics and biological cybernetics [3]. Without belittling the merits of A.I. Kitov, it can be argued that the first steps in the field of medical cybernetics in the Soviet Union were made by Academician V.V. Parin, and his student R. M. Baevsky, who organized the laboratory of medical cybernetics (in 1964) within the structure of the Institute of Biomedical Problems, which he led for more than 60 years. During its existence, the laboratory under the direction of R.M. Baevsky, for the first time in the world, important problems of cybernetics were posed and successfully solved in relation to space and Earth medicine.

Since the creation of space medicine in the 60s of the last centuries, the most important task of monitoring the health of cosmonauts and crew members of manned objects has been formed. The solution to this problem was found using the method of mathematical analysis of heart rate variability (HRV) based on a two-loop model of heart rate control. The beginning of the creation of the method was experiments on dogs with a transplanted heart. Under the leadership of the first director of the IBMP, Academician A.V. Lebedinsky, R.M. Baevsky in 1960 together with the outstanding surgeon V.P. Demikhov, who in those years performed the world's first heart transplants in dogs, organized and conducted an experiment consisting in recording an electrocardiogram (ECG) in a dog with a second (transplanted) heart and examining changes in their heart rhythm at rest and during physical load. It turned out that during exercise the rhythm of the dog's own heart rapidly increased, while the rhythm of contractions of the transplanted heart, devoid of nerve connections with the body, changed with a large delay [4]. As a result of the experiment, one of the most important conclusions was made, which is now well known in physiology textbooks about the two-level regulation of cardiac activity [5].

This discovery was the basis for substantiating the use of the parameters of the circulatory system when creating a program of medical and physiological measurements starting from the first animal flights and in all subsequent human flights. The study of the regulatory mechanisms of the heart, blood vessels and the respiratory system is considered as an indicator of the adaptive reactions of the whole organism.

Application in Space Medicine

During the first flights, there were no technical capabilities to register and conduct complex biological experiments. Ways to increase the information content of physiological research in space began to be obtained by extracting from the minimum set of physiological signals the maximum information about the functional state of a person. One of the ways to increase the information content of the data obtained was the development of mathematical methods for processing and analyzing the parameters of heart rate variability (HRV) and the creation of appropriate algorithms, sensors, instruments, and programs based on the obtained materials for their use as one of the most important methods of medical cybernetics.

In those years, there was an active collection and analysis of data received from the Cosmos. The influence of space flight factors on the human body the effect of weightlessness on the cardiovascular system were regularly reported. General information in the form of an article by V.V. Parin, R.M. Baevsky and O.G. Gazenko "Heart and blood circulation in conditions of weightlessness" was published in 1965 simultaneously in several reputable journals, in particular: "Cardiology"[6], and in English in the journal "Cor et Vasa" [7]. To improve the algorithm for assessing the regulation of HRV, the laboratory staff, led by R.M. conducted studies of HRV parameters not only in space, but also on Earth in people in various conditions of life:

during physical exertion, in physical inactivity, during the restructuring of the work and rest regime (in works related to the flights of athletes along the Moscow-Khabarovsk-Sakhalin route), with psychoemotional influences. At that time, ECG signals recorded on paper tape were manually processed to construct a heart rate histogram. With the help of a ruler, the distance between adjacent R-R teeth was measured, their values were then stuffed onto a punched card. The computer, which occupied the space of the whole room, processed these punched cards, and drew a histogram.

In the 1980s, continuous recording of an electrocardiogram for 24 hours (the Holter monitoring method) was carried out for the first time onboard the Mir orbital station. The method made it possible to obtain new scientific information about the functional state of astronauts in terms of their vegetative regulation at different stages of the flight and, most importantly, in the post-flight period [8-9]. Later, based on the generalization of data on HRV obtained in manned flights on the Mir orbital station, in model experiments and in the examination of groups of people with different functional states, a mathematical model was developed that makes it possible to identify various transitional health states for practically healthy people. In the space of these states, four zones are distinguished corresponding to the *physiological norm, prenosological, premorbid and pathological conditions* [10-11]. The model makes it possible to determine the degree of stress (ST – System Tension) and Functional Reserves (FR) of the body using the selected HRV indicators and to construct the space of functional states in the coordinates of these two variables. The individual dynamics of the functional state of cosmonauts during a long space flight depends primarily on the type of autonomic regulation. This can be seen from Fig. 1, which shows the "trajectories" of the functional state of the ISS crew members - A, B, C, D, E and F. The indicators of cosmonauts A and B during the entire flight do not go beyond the boundaries of the conditional zone of the physiological norm. Cosmonauts C and D begin their flight in the zone of physiological norm but end it in the zone of prenosological states. Finally, before the flight and during the entire flight, cosmonauts E and F are in the zone of prenosological states, and cosmonaut F ends the flight in the zone of premorbid states. Thus, during studies of ISS crew members, new scientific data were obtained on the relationship between the nature of the body's adaptive reaction to the action of flight factors and the individual type of autonomic regulation. It is shown that stay in weightlessness is associated with reconfiguration of regulatory systems and transition to the zone of prenosological states. It becomes clear that the practice of medical control needs methods for predicting premorbid conditions and various pathological abnormalities, the beginning of which is an overstrain of regulatory mechanisms and a decrease in their functional reserve.

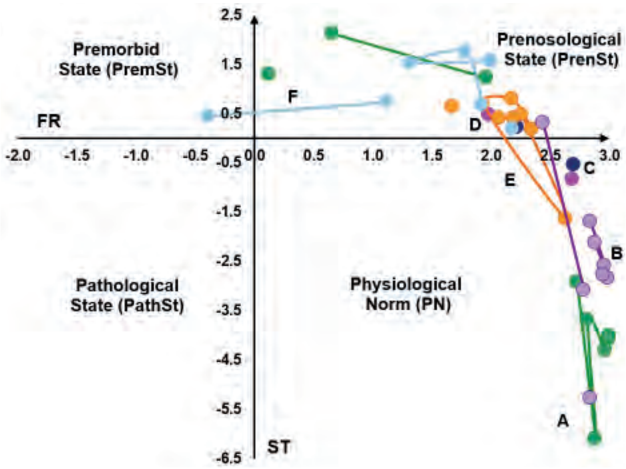

Figure 1. Trajectories of the functional state during a long-term space flight for ISS crew members - A, B, C, D, E and F

The success of space medicine in the field of HRV analysis was one of the stimuli for the further development of this method. In 1966, the first symposium on the mathematical analysis of heart rate variability was held (Chairmen: Parin V.V. and Baevsky R.M.). The maximum activity of researchers working in the field of HRV analysis in the USSR was noted in the 70s and 80s (Zhemaityte D.I., 1965, 1970; Niedekker I.G., 1968; Vlasov Yu.A. et al., 1971; Kudryavtseva V.I., 1974; Voskresensky A.D., Wentzel M.D., 1974; Nikulina G.A., 1974; Baevsky R.M., 1972, 1976, 1979; Vorobyov V.I., 1978, Kletskin S.Z., 1980, Bezrukikh M.M., 1981; Gabinsky Ya.L., 1982). The experience of many of these studies was summarized in a monograph published in 1984 [5]. Since the late 1970s, there has also been an increase in the number of studies on HRV abroad, in Western Europe and the USA. Currently, up to several hundred papers on the use of HRV analysis in cardiology, surgery, labor and sports physiology, and experimental physiology are published annually in the world. Space cardiology, in which the HRV analysis methodology arose and gave its first practical results, still retains its leading position.

At present, the scientific and applied significance of HRV analysis methods is generally recognized. Continuous improvement of HRV study methodology is associated with the rapid development of computer technology. HRV analysis is currently one of the most popular methods for studying autonomic regulation and stress levels. Its use in the clinic and in physiology is largely determined by the European-American HRV standards (1996) [12] and the Russian guidelines for HRV (2001) [13]. These fundamental methodological documents over the past 10-15 years have been significantly supplemented by new experimental and clinical data. The general approach to evaluating the results of HRV analysis is to look for the relationship of each of the separately calculated indicators with specific functional changes observed in the examined. The non-specificity of HRV changes is also taken into consideration; this approach opens great opportunities for applying this method in a wide variety of areas. The rapid development of microelectronics and programming tools has made it possible to create numerous new, much more advanced instruments and devices for HRV analysis.

In recent years, a comprehensive assessment of the results of HRV analysis has been used more often. An example of such an approach is the indicator of the activity of regulatory systems (IARS), which has gained wide popularity [5]. This is explained by the fact that PARS brings the researcher and practitioner to the use of the principles of prenosological diagnostics, which makes it possible to classify functional states according to the degree of tension of regulatory systems. That is why HRV analysis occupies a leading place in prenosological studies aimed at assessing the functional states of the body, borderline between the norm and pathology.

If we represent the continuum of the functional states of the body as a space of states, where each current state is determined by the coordinates: the degree of stress by the ST and the FR, then the problem arises of developing a procedure (method) for calculating these indicators. To solve this problem, stepwise discriminant analysis was used [14], because of which decision rules were obtained in the form of equations of a discriminant function with independent canonical variables. Canonical variables are generalizing indicators that characterize different aspects of the analyzed process. As a result of the analysis of a large array of data of persons with different functional states, two canonical variables were developed, reflecting HF in one case, and FR in the other [14]. The presented two equations of the discriminant function can be considered as a mathematical model of the functional states of a person during transitions from the physiological norm to premorbid and pathological states.

Evaluation of HRV analysis results by the discriminant analysis method has several important advantages. First, the functional state is characterized in the form of quantitative values of FR and ST. Secondly, a visual graphical interpretation of functional states is possible in the form of points on the phase plane. Thirdly, changes in functional state during repeated studies or when performing functional tests can be visually assessed and quantified by a vector connecting two points in the state space. Fourth, the dynamics of the functional state can be characterized by a trajectory, which in turn can be described mathematically. Finally, fifthly, the phase plane perfectly reflects the group distribution of functional states when examining various groups of patients or healthy people.

With a probabilistic approach, a quantitative measure of the presence of a certain functional state can be considered its probability. The higher the probability of a particular functional state, the greater its severity. High risk means a high probability of a particular event occurring. We are talking here about the development of prenosological, premorbid or pathological conditions. Already with the appearance of prenosological conditions, the risk of developing pathology increases compared to the state of the physiological norm, and in the case of premorbid conditions, the risk of pathology becomes apparent. Ten conditional risk categories for the development of pathology were introduced. On Fig. Figure 2 shows a conditional scheme for determining the risk of developing pathology for persons with different functional states who are in space flight conditions [14].

The probabilistic approach opens a fundamentally new possibility for predicting changes in the functional state and assessing the risk of developing pathology. Here, in addition to determining functional reserves, the individual type of autonomic regulation is considered, which makes it possible to judge the probable speed and intensity of the process of mobilization of functional reserves during the body's response to stress.

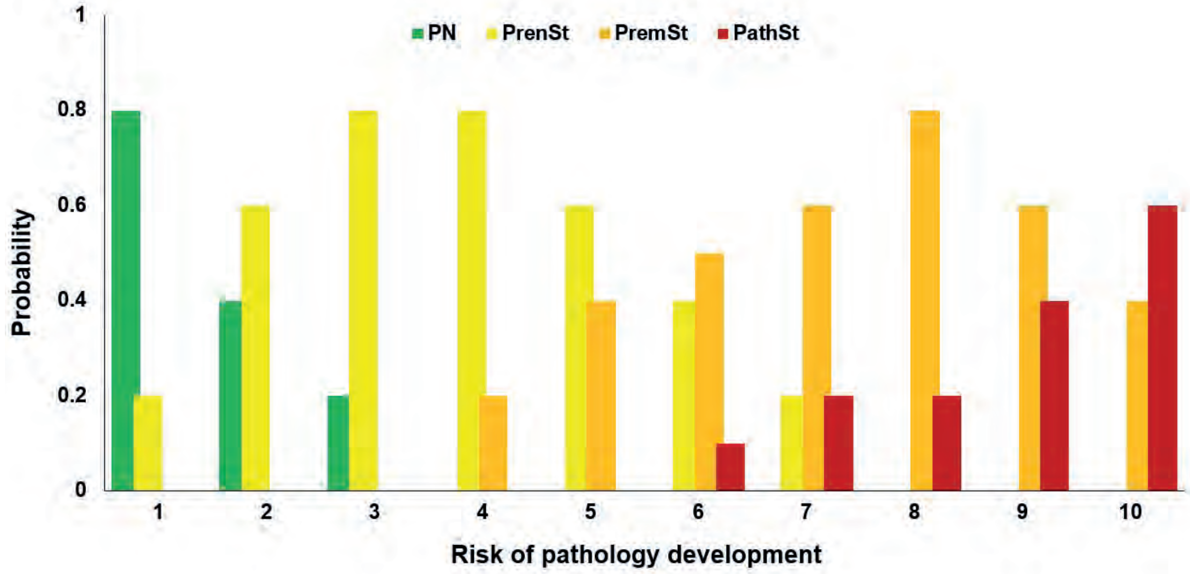

Figure 2. Probability of various functional states and risk of pathology development

Application in ground-based model experiments

Simulation of space flight conditions is an integral part of the development of orbital astronautics in studies of the possibility of a long stay of a person in weightlessness, in a confined space, for great potential for scientific discovery and modernization of available countermeasure systems in response to simulated weightlessness and spaceflight environment. Technological advancements enable effective modeling of extreme environmental conditions in terrestrial facilities. To date, a vast amount of knowledge has been accumulated in space medicine and gravitational physiology, a wealth of research has been accumulated carried out in experiments with the participation of a healthy person, subjected, with his voluntary consent, to various environmental factors, including experiments with significant in duration, but weak in intensity effects. These are experiments with long-term confinement in a hermetic facility or bed rest in an anti-orthostatic position of the body (with a 6 degree negative inclination, known as "bed rest") and one of the more strong microgravitation model called "dry immersion" (DI) [15].

One of the largest experiments in recent years (2010 - 2011), simulating the flight of 6 members of the international crew to the planet Mars, was the MARS-500 Project. As part of this experiment, along with a direct study of the behavior of the crew in an artificial habitat, closed, limited volumes and performing a serious cognitive load, studies were carried out in parallel groups in different regions of the country, as well as in the Czech Republic, Germany and Canada [16-17]. It was shown that, on the one hand, the human body (crew members) sensitively reacts to the conditions of closed volumes, and on the other hand, in the absence of climatic markers of the change of seasons, the human body, and in particular the regulatory components of heart rate control and microalternation electrocardiographic characteristics (dispersion mapping), have own endogenous rhythms of fluctuations with a period of several (60-70 days), as well as characteristic seasonal changes [18]. Shorter experiments of recent years ("LUNA-2015", "SIRIUS-2019") made it possible to work out monitoring technologies - studies conducted for a long time or constantly, and while all study participants remained within the boundaries of physiological norm or just on the verge of prenosological states, there has been a significant variation in the levels of experienced ST [19]. As such, this approach has demonstrated great potential to support early detection monitoring and understanding of physiological and psychological responses that occur as a result of specific tasks or activities [19]. In recent years, progress has been made in assessing the influence of magnetosphere and ionosphere factors on the humans [20].

Studies under DI conditions have shown that adaptation to microgravity conditions occurs in several stages and is accompanied by an increase in ST, when, against the background of a decrease in heart rate, activation of the sympathetic link in the regulation of the cardiovascular system increases, which ultimately affects blood pressure and changes in the duration of the night sleep stages [21]. In shorter experiments with DI (5-7 days), the characteristics of motor activity, body position, respiration frequency and heart rate regulation were studied. A specific growth of ST associated with pain that occurs in the vertebral region, accompanied by an increase in the space of the intervertebral discs or in the abdomen, due to compression of the abdominal region due to the forced “embryo” position in the immersion bath, was revealed. By the third or fourth day, complaints of pain decrease and ST falls, however, the process of adaptation to microgravity conditions is accompanied by a decrease in the need to change body position, even during night sleep, a decrease in HRV with a decrease in heart rate.

Using new methods at public health: into working and school medicine implementation

In the late 1970s - 80s, in space medicine, for the first time, a fundamentally new approach to health assessment was developed, based on modern concepts of the theory of adaptation and the doctrine of homeostasis [23]. The essence of this approach is that health is considered as a process of continuous adaptation of the body to environmental conditions, and the measure of health is the adaptive (adaptive) capabilities of the body. The transition from health to illness is associated with a decrease in the adaptive capacity of the body, with a decrease in the ability to adequately respond not only to social and labor, but also to ordinary daily stress. The method of expert assessments was used as a decision-making algorithm. In the period from 1975 to 1978, the IBMP together with the Institute of Physiology of the Siberian Branch of the USSR Academy of Medical Sciences under the guidance of Professor R. M. Baevsky and Academician V.P. Kaznacheev, mass preventive examinations were organized for about five thousand workers and employees of the “Sibselmash” plant in Novosibirsk. The work was organized and conducted by A.P. Berseneva later in 1981 became the head of the world’s first laboratory of methods for mass prognostic prenosological examinations of the population at the Moscow Regional Scientific Research Clinical Institute (MONIKI). The result of this work was the selection of representative groups of healthy people who are in states bordering between the norm and pathology.

These conditions were called prenosological and the corresponding definition of these conditions was included in the Great Medical Encyclopedia [23]. And in 1981, a monograph by V.P. Kaznacheeva, R.M. Baevsky and A.P. Berseneva “Prenosological diagnostics in the practice of mass surveys of the population” [24]. Thus, the need that arose in space medicine for a more detailed assessment of the level of health and its changes in space flight conditions was an incentive for the emergence of a new scientific direction - “Prenosological diagnostics”.

The theoretical justification for such an assessment of the level of health, based on the concept of V.P. Kaznacheev and R.M. Baevsky was based on the ability of the adaptive mechanism to provide sustainable adaptation to environmental conditions, which depends on the FR of the body. High functional reserves allow maintaining the required level of functioning (FL) of the main body systems without increasing the degree of ST of regulatory mechanisms. There is a relationship between FR, FL, and ST, which can be expressed by a simple equation [12]:

$$FL = ST \times FR$$

The equation FL = SN × RF is the basis of the prenosological approach to assessing the level of health. The technology of prenosological studies is based on the measurement of all three components of the equation. But the key place in this technology is occupied by the measurement of the degree of ST systems by the HRV values. This indicator most dynamically reflects the various levels of adaptation of the organism to environmental conditions, while the values of the other indicators are more stable.

To characterize risk factors and assess their intensity, as well as to assess the presence of pathology profiles, the results of a questionnaire survey are used, where each symptom is expressed in conditional scores. Since the practice of prenosological research is focused on the study of the cardiovascular system and the main metabolic and energy indicators: height, body weight, frequency and depth of respiration, homeostasis can be characterized by measuring the parameters of the functioning of these systems. However, this still does not give an integral picture that reflects the cardiovascular and metabolic-energy homeostasis of the body. In this regard, A.P. Berseneva [26] developed an index of functional changes (IFC), which can be used to obtain a generalized characteristic of homeostasis.

The values of IFC reflect the result of adaptive responses of the body and make it possible to distinguish 4 groups of individuals with different levels of health (in points) or according to the degree of adaptation to environmental conditions [26]. Evaluation of the level of functioning according to the IFC, for all its simplicity, provides a systematic approach to solving the problem of quantitative measurement of the level of health. This is determined by the fact that the IFC, as a complex, integral indicator, reflects a complex structure of functional relationships that characterize the levels of functioning of the cardiovascular system, metabolic and energy systems. Usually, doctors focus only on clinically significant deviations of these measured parameters (pulse rate and blood pressure), which does not allow differentiating different stages of prenosological and premorbid conditions, therefore, it is justified to introduce a complex IFC indicator, which makes it possible to visually and accurately assess the functional state of the body.

However, IFC is not an exhaustive characteristic of homeostasis. This is just one of its components, which is used for practical purposes. Usually there are 4 components of the conclusion with the corresponding values for each of the functional states. FL - estimated by IFC values. CH - is determined by IARS. To assess the RF - any functional test should be used. For example, an active orthostatic test (AOP) can be used, the results of which are expressed in points. Since changes in the values of the indicators do not always go in parallel, for example, IFC corresponds to the physiological norm, and IARS to the prenosological state, the decision is made on most of the 4 components of the conclusion. At the same time, a detailed explanation is given in the text of the conclusion for each of these components. The conclusion about the level of stress (according to the analysis of heart rate variability) is specially highlighted. The conclusion also notes the main deviations that require the attention by the physicians.

Pre-nosological conditions that occur during a long-term space flight can be conditionally divided into three groups and are the result of: 1) Processes of reconfiguring regulatory mechanisms to a new level of functioning, which requires the expenditure of functional reserves and manifests itself in the form of functional stress; 2) A short-term increase in the "price of adaptation" of the organism to flight conditions, which may be caused by previous increased loads, for example, work in outer space; 3) Prolonged stress on the regulatory systems of the body, which is caused either by an increased level of various loads during the flight, or by a discrepancy between the individual adaptive capabilities of the body and the real loads of space flight, or by the presence of hidden disturbances in the operation of individual organs and systems that were not detected before the flight. It is the prenosological conditions of the third group that pose a real danger of the development of pathological abnormalities and diseases in flight. The risk of developing such deviations is higher, the more pronounced and prolonged the prenosological condition is.

The laboratory at "MONIKI" took part in the creation, together with SSC IBMP RAS, of the mobile automated laboratory "Avtosan-82" for express health assessment. In essence, it was a bus equipped with onboard cybernetic medical equipment and a computer, in which the principle of health assessment was implemented cosmonauts in relation to the tasks of mass preventive examinations of the population. Later, based on the experience of working with Avtosan-82, a number of automated systems such as Vita 82, Vita 97, Vita 2007 and the like were developed. With the use of these systems for the period from 1977 to 2008, more than 25 thousand workers and employees in different cities and various industrial and agricultural enterprises of the country were examined. The level of both individual and "collective health" was determined in the form of an indicator of the "health structure" or the percentage distribution of people with different levels of health among the total number of those surveyed. The following four groups were distinguished corresponding to the traffic light system: physiological norm (green zone), prenosological and premorbid states (yellow and orange zone, respectively) and states with adaptation failure (red zone). Comparing the health structures of different enterprises or different workshops of the same enterprise, it was possible to judge the impact of production and environmental conditions on the health of employees. The number of persons with satisfactory adaptation varied in different contingents, examined from 5 to 55%. Persons with functional stresses (W1) from 25 to 40%. The total number of healthy and practically healthy persons (H + W1) at all enterprises is quite significant - 50-70%. The number of persons with unsatisfactory adaptation (W2) varied within 11-40%. And persons with a breakdown in adaptation (K) - from 3 to 13%. In general, the number of people in need of an in-depth medical examination was about 20-30% of all those examined, and they, as a rule, had already applied for medical help or were registered with a dispensary, but were considered "practically healthy people", since they actively worked hard. But the attention of medical services in terms of rehabilitation should have been directed to these individuals. All this made it possible to assess the need for medical care.

Separately, it is worth dwelling on two areas of research work, which were carried out with the direct support and guidance of Prof. Baevsky. We conducted a double study at a large passenger car company, as a result of which, at the first stage, groups and individuals were identified who were in dire need of specific health or treatment procedures. Note that the survey was conducted during business hours. Drivers taking part in the flight on urban passenger routes. When conducting a second study, six months later, we were unable to track the health status of the critically disadvantaged drivers who were in a premorbid state, in particular due to the fact that during this time 2 people died due to cardiovascular pathology and several more were forced to have to leave work for health reasons [27].

Finally, the direction supported and developed by Prof. Baevsky is the health of children and adolescents. Under his scientific guidance, for several years, studies were consistently carried out on groups of student youth in Moscow, Zelenograd, and several cities in the Moscow region. At the same time, when using HRV methods: in addition to revealing hidden disorders of the disease, such as psychiatric deviations that do not allow a student to carry out educational activities in a team, stressful influence on a team of students by an authoritarian teacher or curator, psychotrauma in individual students as a result of psychological pressure, identification of "unusual" regulatory patterns, which, with in-depth diagnostics, confirmed the presence of tumor processes, excessive mental stress in high school students that provoked the development of hypertension earlier - this is a far from complete list of the application of methods and technologies of prenosological diagnostics using computer multi-patient complexes [28].

Conclusion

Medical Cybernetics was formed because of the penetration of the ideas of methods and technical means of cybernetics into medicine. Questions of diagnostics and treatment, processing, and analysis of experimental materials, planning of scientific research, organization of health care, and even the construction of new scientific hypotheses - all this becomes the object of application of cybernetics. Therefore, it is very important that the main provisions of cybernetics, especially in terms of its biological problems, be known to a wide range of doctors and physiologists working both in research and medical institutions. The main element of the system for assessing and predicting the state of health, apparently, will be information and analytical complexes - computer systems containing programs for analyzing information, a data bank, artificial intelligence systems involved in expert evaluation of data, a knowledge base, and a help system. In these complexes, conclusions about the state of health, risk factors and forecasts for the development of diseases will be formed. And the first successful steps towards the development and justification of their methodology and technology have been developed over the past 50 years under the leadership of R.M. Bayevsky.

R.M. Baevsky was the first in the world to pose and successfully solve important problems of cybernetics in relation to space and terrestrial medicine. A system for assessing the adaptive, functional capabilities of the body in terms of HRV was created, new concepts and methods first arose and began to be applied in space, and R.M. Baevsky was the founder of one of the important methods of medical cybernetics - the mathematical analysis of HRV, which received worldwide recognition and found application both in applied physiology and in extensive scientific research around the world.

Creating an appropriate methodology, hardware, and software for both space and terrestrial medicine is a complex task and work should be started on its solution as soon as possible. As an initial version of the system, it is possible to use the established methodologies, algorithms and programs, then improve this system in the development of plans for a phased examination with the allocation of contingents according to the principle of need for a more complete and in-depth examination using special algorithms of both the autonomic regulation system and its RF and all other systems according to as needed. Assessments and forecasting of health conditions, in our opinion, should be carried out by a multi-purpose clinical diagnostic complex with a powerful system of expert assessments built on the principles of cybernetics. Such a complex should include blocks of a questionnaire survey, psychological testing, assessment of mental and physical performance, examination of the state of all major vital systems and organs, biochemical analysis of biological body fluids (blood, urine and saliva). It is possible to use a few non-traditional methods, for example study of biologically active points, or methods, the development of which is still at an early stage today, and in particular, we can talk about the method of segmental-spatial projection of organs and systems.

Donozology is a science-based practical area that could unite doctors, physiologists, biologists and hygienists with ecologists, economists, engineers, and technologists. It could involve politicians and cultural figures, government officials and businessmen in health issues. It is required to start active actions in order for "donosology" to become what it could be. The first steps in this direction have already been taken. The journal "Donozology" was created in St. Petersburg. Until 2019, annual conferences on problems of donosology were held. But most of the reports at conferences and articles in the journal were devoted to general and industrial hygiene, not related to donosology. Only the measurement of the level of health is the starting point and the main point for solving many other problems of hygiene and preventive medicine. It is necessary to have information about the amount of health of an individual person, at each individual enterprise, in each city, district, region, in each country, as well as an assessment of "collective health". And only on this basis it is possible to build forecasts regarding the further prospects for the development of mankind and civilization. Moreover, health assessments should be based on the methods of space medicine, which has created a reliable scientific and theoretical basis for the formation and further development of the methodology of donosology.

There is great potential for this approach (Big Data Analytic and Online Analytics) to health risk assessment to be used both in model experiments, at space mission and Earth medicine as new cybernetic methods to support proactive prognostics, diagnostics and health management [29]. Today we can say with confidence that the methods of "Cardiometry" - the modern direction of cardiological research are directly related to medical cybernetics, with the assessment of the status of pre-illness and are largely consistent with the postulates developed by Professor Roman M. Baevsky during 70 years of his scientific activity.

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References

1. Vorobyov EI, Kitov AI Introduction to medical cybernetics. M.: Medicine, 1977.
2. Parin VV, Baevsky RM Introduction to medical cybernetics. M.: Medicine, 1966.
3. Reznik S. E. Facing a man: Approaches to the biography of V. V. Parin. (Creators of science and technology) - M .: Knowledge, 1981
4. Demikhov V.P., Baevsky R.M., Sharovskaya A.M. "On the Problem of the Reliability of the Heart". Collection of proceedings of the IBMP conference, 1966.
5. Baevsky RM, Kirillov OI, Kletskin SZ Mathematical analysis of changes in the heart rate during stress; Rep. ed. EI Sokolov. - M.: Nauka, 1984.
6. Baevsky R.M. Achievements and problems of space cardiology, Cardiology, 1965, 5
7. Parin V.V., Baevsky R.M., Gazenko O.G. Heart and circulation under space conditions. Cor et Vasa, 1965,7 (3), p. 165-184
8. Baevsky R.M., Nikulina G.A., Tazetdinov I.G. Mathematical analysis of the heart rhythm in assessing the characteristics of the body's adaptation to the conditions of space flight. Bulletin of the USSR Academy of Medical Sciences, 1984, N4
9. Baevsky R.M., Nikulina G.A. Holter monitoring in space medicine. Bulletin of arrhythmology. 2000, no. 16
10. Baevsky R.M. Chernikova A.G. To problem of the physiological norm: a mathematical model of functional states based on heart rate variability analysis. Aerospace and environmental medicine, 2002, No. 5
11. Chernikova A. Heart rate variability in evaluation of functional state and types of autonomic regulation under conditions of space flight. 26-th Annual International Gravitational Physiology Meeting. 26 June -1 July 2005. Cologne, Germany, p. 60.
12. Heart rate variability. Standards of measurement, physiological interpretation and clinical use. Circulation. – 1996. – Vol. 93. – P. 1043-1065
13. Baevsky R.M. Ivanov G.G., Chireykin L.V. et al. Analysis of heart rate variability using various electro-

cardiographic systems. (Guidelines). Bulletin of Arrhythmology, 2001; 24, 67-95 p
14. Method of estimating risk of developing pre-nosological, pre-morbid and pathological condition in space flight. Patent RU2448644C127.04.2012
15. Navasiolava, N., Custaud, M., Tomilovskaya, E., Larina, I., Mano, T., Gauquelin-Koch, G., Gharib, C. and I. Kozlovskaya, Long-term dry immersion: review and prospects, European Journal of Applied Physiology, vol. 111, no. 7, pp. 1235-1260, 2010.
16. Baevsky R.M., Bersenev E.Y., Rusanov V.B., Chernikova A.G.Issues of health evaluation during simulated space mission to Mars. Part 1. Research methodology and methods used in experiment Mars-500 Cardiometry;No.2; May 2013; p.7-18; doi: 10.12710/cardiometry.2013.2.718
17. Bersenev E.Y., Rusanov V.B., Chernikova A.G. Report Issues of health evaluation during simulated space mission to Mars. Part 2. Vegetative regulation of blood circulation in the Martian crew individuals in the Mars 500 project Cardiometry; No.2; May 2013; p.62-73;doi: 10.12710/cardiometry.2013.2.6273
18. Vigo DE, Teurlinckx, Originz F, Wan L, Simonelli G, Bersenev E, Van De Berg O, Aubert AE. Circadian rhythm of autonomic cardiovascular control during Mars500 simulated mission to Mars. AviatSpace Environ Med 2013; 84:1 – 6.
19. McGregor, C., Orlov, O., Baevsky, R., Chernikova, A., Rusanov V. Big Data Analytics for Continuous Assessment of Astronaut Health Risk and Its Application to Human-in-the-Loop (HITL) Related Aerospace Missions, AIAA SciTech Conference, Grapevine, Texas, Jan 2017, 7 pages.
20. Tzetlin V.V., Bersenev E.Yu., Stepanova G.P., Degterenkova N.V., Anikeev D.A. Monitoringof the effect of isolation factors on human physiological functions within the SIRIUS-19 project Aviakosmicheskaya i Ekologicheskaya Meditsina (Russia). 2021. V. 55. № 3. P. 36–44.
21. Bersenev E.Yu., Ukraintseva Y.V., Kovrov G.V. et al. Sleep in 21-Day Dry Immersion. Are Cardiovascular Adjustments Rapid Eye Movement Sleep-Dependent? Front. Physiol. 12:749773.doi: 10.3389/fphys.2021.
22. Slonov, A., Baevsky, R., Rukavishnikov, I., Amirova, L., McGregor, C., Zhmurchak, A. and E. Bersenev, "Analysis of body posture changing, painfulness, regulation of the heart and breath during night sleep in experiment with a 5-day dry immersion." in The 9th International Symposium on Neurocardiology \ The 8th International Symposium on Noninvasive Electrocardiology, 2018, p. 82.
23. Baevsky RM Forecasting states on the verge of norm and pathology. M.: Medicine. 1979.
24. Baevsky R.M., Kaznacheev V.P. Prenosological diagnosis. BME vol. 7, 1978, p. 254-255
25. Kaznacheev VP, Baevsky RM, Berseneva AP Prenosological diagnostics in the practice of mass surveys of the population. Leningrad: Medicine, 1980.
26. Baevsky RM, Berseneva AP Assessment of the adaptive capacity of the body and the risk of developing diseases. M., Medicine, 1997
27. Baevskii, R.M., Berseneva, A.P., Bersenev, E.Y. et al. Use of principles of prenosological diagnosis for assessing the functional state of the body under stress conditions as exemplified by bus drivers. Hum Physiol 35, 34–42 (2009). https://doi.org/10.1134/S0362119709010071
28. Grigoriev AI, Baevsky RM The concept of health and space medicine. M., Slovo, 2007
29. McGregor, C. A Framework for Online Health Analytics for Advanced Prognostics and Health Management of Astronauts, in IEEE Aerospace 2015, pp. 1–7, 2015.