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ESTIMATION OF ADAPTABLE ABILITIES OF CHILDREN OF THE EARLY NEONATAL PERIOD WITH THE HELP OF INTEGRAL CRITERION ON THE BASIS OF INTELLECTUAL BIOMEDICAL SYSTEM

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One of the perspective approaches to an estimation of a state of health of children in the early neonatal period based on integral information criterion, in intellectual biomedical system is considered. The urgency of research of adaptation processes at children in the early neonatal period is shown. Structure, possibilities and features of realization of the biomedical system developed in C ++ Builder medium are described.

Introduction

Recently the problem of health of the population draws attention of the increasing number of researchers in different areas that is connected with significant deterioration of health of the all population. And the adaptation approach to studying of health is considered as the most productive [1–5].

For the first time classification of types of physiological adaptation by the functional – time principle has been offered by V.P. Kaznacheev [3]. It is established, that two basic types of adaptation strategy of an adult person organism exists. In the first type the organism possesses ability of powerful physiological reactions in reply to external action. However the level of physiological reactions can be supported relatively short time. In the second type of adaptation strategy the organism is less resistant short-term significant actions, but more resistive against long uniform loadings. Studying of various variants of adaptation strategy has allowed to establish, that the same diseases are expressed differently at people with various types of adaptation strategy and demand various approaches in diagnostics, treatment and prophylaxis. However data about investigations allowing not only adequate, with a high degree of reliability to estimate changes in a functional state of a children organism on the basis of analysis of adaptation processes, but also to predict them authentically for the nearest and remote time taking into account changes and consequences are practically absent in the literature.

The seven basic periods of development of a child organism (intra-uterine, the new-born period, chest, early, preschool age, adolescence and pubertate period) are noted in pediatrics [6]. Each period is characterized by perfection of the certain vital functions. However one of the important periods is the chest age in which special value is given to development of the child in the early neonatal period (from 0 till 10 days). A sharp change of an inhabitancy medium and processes of functioning of organism systems (pulmonary breath, change of circles of blood circulation) takes place in this time and the child life outside of a mother organism itself presents process of the adaptation to the changed environment (adaptation process). Further the child organism only is arranged to changing conditions of an environment. In this connection the problem of express – estimation of adaptation characteristics of an child organism in the early neonatal period is actual.

The description of the generalized integral criterion and the basic stages of software designing for estimation and forecasting of a child health level are given in the article on the basis of the analysis of adaptation processes.

The basic concepts. The generalized integral criterion

The large attention to problem of adaptation of children is paid by B.A. Kobrinsky, which has proposed classification of types of child adaptation («norm», «boundary states», «desadaptation», «decompensation») [4]. Shortage of B.A. Kobrinsky`s idea is in our opinion absence of mathematical presentation of adaptation process. Therefore, construction of some integral characteristic determining dynamics of adaptation processes which allows to reveal the latent laws in the complex processes, caused by influence of external factors on a functional state of an organism is of interest.

Construction of integral characteristics assumes a choice of measured parameters being significant for an estimation of a children state in the early neonatal period. Clinical anamnesis parameters, parameters of cardiovascular system and blood are frequently used for this. But when the question is an estimation of a child health state in the early neonatal period it is necessary to remember, that the child organism in this age has the increased sensitivity, therefore many approaches for estimation of a functioning level of a child organism appear unacceptable. In particular, blood parameters for children in the early neonatal period cannot be used, as the given method is based on invasive methods demanding a fence of blood that is connected to the certain technical, organizational and objective difficulties. The anthopometrical parameters read at the child at a birth, change in the first days of a life slowly and do not allow to estimate occuring changes operatively. In the given research the cardiovascular system has been chosen as the indicator of a functional state of a child organism and the integral characteristic for an operative estimation of a child health state is proposed on the basis of the analysis of change of *R-R* intervals distribution at carrying out of a wedge orthostatic tests (WOT).

The wedge orthostatic test (loading) is an experimental revealing of an organism reaction on transition from horizontal position in vertical one and keeping of this position [7]. Vertical position of a body is designated by the term «orthostaz», and horizontal one by the term «wedge

position», reaction of an organism on active or passive transition from horizontal position in vertical one is called the wedge orthostatic reaction, and from vertical position in horizontal one is called the wedge static reaction. A number of organism functions is changed at change of a body position in space. In this connection to maintain an optimum mode of vital activity it is necessary a high coordinated activity of all elements of cardiovascular system. Thus, carrying out of WOT gives very important information about a functional state of cardiovascular system and a range of its adaptation to loadings.

The integral estimation of the current state of an organism is proposed in the work. At this we proceeded from the following positions: if measured parameters change casually, and no law tendency is observed the system practically does not change its state, and integral parameters do not exceed the given level. If influence of an environment result in change of the state, integral parameters will exceed the accepted initial level the more, the stronger are changes of the system state.

Let's designate parameters of a child organism, as the state vector $X(x_1,...,x_n)$, input influence – environmental parameters as $V(v_1,...,v_m)$, and parameters of biosystem outputs – controllable organism parameters as $Y(y_1,...,y_z)$. In work biosystem «output» is informative parameters of cardiovascular system («essential» variables) at carrying out of wedge orthostatic tests which bear the information about tension degree of regulatory mechanisms directed on maintenance of a time homeostasis.

Comparison of changes in organism activity with a certain reference state can be carried out by methods of the theory of information.

For the analysis of change of an organism state on the data the wedge orthostatic tests it is possible to use the information criterion I [8] presented in the following form:

$$I = \int \rho_1(x) \cdot \ln \frac{\rho_1(x)}{\rho_2(x)} dx, \qquad (1)$$

Where $\rho_1(x)$, $\rho_2(x)$ are distribution densities of the variable x in a the states 1 and 2.

Let's rewrite the formula (1) as a difference of two integrals, and receive:

$$I = \int \rho_1(x) \ln \frac{\rho_1(x)}{\rho_2(x)} dx =$$

$$= \int \rho_1(x) \ln \rho_1(x) dx - \int \rho_1(x) \ln \rho_2(x) dx.$$

Let's image continuous values $\rho_1(x)$ and $\rho_2(x)$ as discrete values (fig. 1), being constant on equal intervals of a segment $[a, b]$.

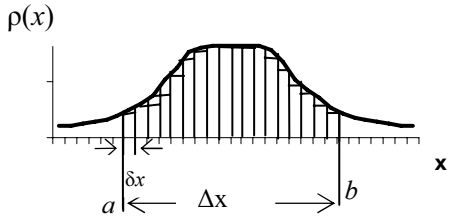

Fig. 1. *Representation of distribution density of of a variable x as discrete values*

Let's receive:

$$I = \sum_j \rho_1(x_j)\delta x \ln \rho_1(x_j)\delta x -$$

$$-\sum_j \rho_1(x_j)\delta x \ln \rho_2(x_j)\delta x, \qquad (2)$$

Where $x_j \in [a, b]$.

Taking into account that $\rho(x_j)\delta x = P(x_j)$, on each interval δx expression (2) can be presented as:

$$I = \sum_j P_1(x_j) \ln P_1(x_j) - \sum_j P_1(x_j) \ln P_2(x_j) =$$

$$= \sum_j P_1(x_j) \ln \frac{P_1(x_j)}{P_2(x_j)}. \qquad (3)$$

As the given criterion is supposed to be used for an estimation of the type of reaction of child organism on the wedge orthostatic test, let's designate I in expression (3) as I_{WOT} and write expression (3) in the following form:

$$I_{\text{КОП}} = \sum_{j=1}^{m} P_1(x_j) \ln \frac{P_1(x_j)}{P_2(x_j)}, \qquad (4)$$

Where m is number of orders of histogram received on the segment $[a, b]$; $P_1(x_j)$, $P_2(x_j)$ are probabilities of hit of the value x in the *j-th* order of the histogram before and after loading, Fig. 2, *a*.

The wedge orthostatic test is carried out in 5 stages (a background, wedge orthostaz, 1st ort, 2nd ort, wedge position). Hence, $P_2(x_j)$ is probability of hit of value of *R-R* intervals in *j-th* order of the histogram for each site of test accordingly. The histogram of distribution *R-R* of intervals in the wedge orthostaz state is shown on Fig. 2, *b*.

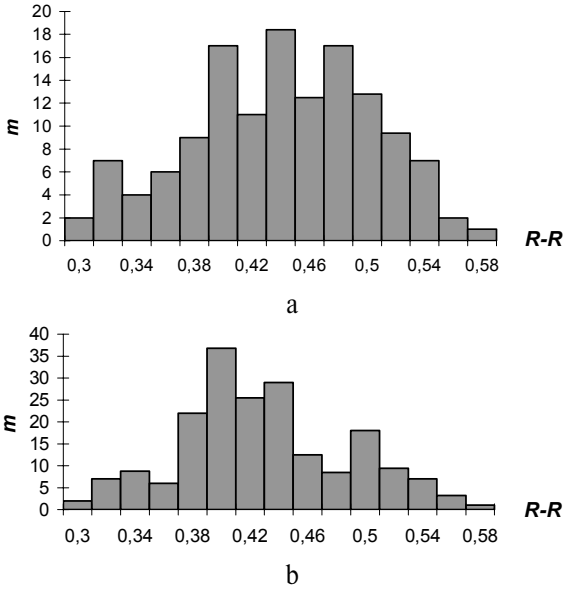

Fig. 2. *The histogram of distribution of intervals R-R in the state: a) rest; b) wedge orthostaz*

Application of integral criterion for an estimation of a bioobject state (in this case state of a child organism) assumes existence of threshold values which excess corresponds to transition in a new state. At introduction of threshold values we used the following way of allocation

of gradation for quantitative changes of a researched variable of the state [5] accepted in biocybernetics:

- Absence of authentic changes: $|x-\overline{x}|<\pm 0{,}5\sigma$;
- a slight degree of reduction (increase) x: $|x-\overline{x}|<\pm\sigma$;
- a moderate degree of change: $|x-\overline{x}|<\pm 1{,}5\sigma$;
- a pronounced degree of change: $|x-\overline{x}|<\pm 2\sigma$;
- the sharply pronounced degree of change: $|x-\overline{x}|<\pm 2{,}5\sigma$;

According to these points 4 conventional states of biosystem are allocated and threshold values for criterion I_{WOT} (Tabl. 1) are received.

Table 1. *Threshold values of criterion I_{WOT} and states of biosystem corresponding to them*

Threshold values	The state of biosystem
$I_{кр}$= 0,69	The state of satisfactory adaptation: absence of action of the influencing factor on the condition of biosystem
$I_{утом}$= 2,01	The state corresponding to a slight degree of reduction (increase) of state variables
$I_{tension}$= 3,09	The tension of functional systems
$I_{failure}$= 4,39	Failure of adaptation

The analysis of types of curves I_{WOT} obtained with the help of criterion (4) using the cluster analysis, allowed to allocate 5 reference types of adaptation curves.

For a quantitative estimation of deviation of state variables x_j ($j\in[1,...,m]$) from the normal level the integral parameter of a form:

$$S=S_1/S_0,$$

where $S_0=\int_t I_{КОП}(t)dt$; $S_1=\int_t I_{КОП}(t)dt$, for $I_{КОП}(t)>I_{кр.}$

has been entered.

Integral parameter S can be used as an estimation of a tension degree of a child organism.

In opinion of number of authors [9, 10], for an estimation of adaptation potential of any organism subsystem (for example, cardiovascular system, breath or blood circulation) it is expedient to use relation of a functioning level (FL) of this system, its functional reserve (FR) and tension degrees (TD) of regulation mechanisms. And it is considered, that FR has a direct communication with a functioning level and feedback with the tension degree of regulation systems.

Let's accept as a functioning level of biosystem the value of function $I_{WOT}(t)$, and as a tension degree integral parameter S. At this

$$\text{ФР}=\frac{\text{УФ}}{\text{СН}}.$$

The gradations for TD and FR change, have been introduced on the basis of the analysis of experimental data (Tabl. 2).

The information about reserve possibilities of a child organism in the early neonatal period obtained during research taking into account the tension degree of regulation systems and functioning level for various types of reaction on loading is presented in Tabl. 3.

Table 2. *Gradation of changes of a tension degree and a functional reserve of an organism*

For a tension degree	For a functional reserve
СН<0,2 – «tension» is absent	ФР>6 – high
0,2<СН≤0,4 – a low tension degree	3≤ФР≤6 – medium
0,4<СН≤0,6 – a medium tension degree	ФР<3 – low
СН>0,6 – high	

Table 3. *A level of values of the tension degree and a functional reserve of a child organism in the early neonatal period for various types of reaction*

Type of the adaptation curve	The characteristic of adaptation process	A functional reserve	A tension degree
Type I Subcompensated	Satisfactory adaptation	ФР>6	СН<0,2; 0,2<СН≤0,4
Type II Compensated	Satisfactory adaptation at a new functioning level	3≤ФР≤6	0,2<СН≤0,4; 0,4<СН≤0,6
Type III Decompensated	Gradual transition from satisfactory adaptation in the tension state	3≤ФР≤6; ФР<3	0,4<СН≤0,6; СН>0,6
Type IV Desadaptive	The tension state – destabilization of all investigated systems of an organism	ФР<3	СН>0,6
Type V Hypercompensated	The tension state is replaced gradually by satisfactory adaptation	3≤ФР≤6	СН>0,6

For the automated definition of the type of an adaptation curve the problem of the choice of the most suitable kind of approximating dependence for function I_{WOT} was solved. With the help of the least squares method the efficiency of approximation by (linear, power, logarithmic, exponential, polynomial of 2-nd and 3-rd orders) functions was investigated.

Realization of the generalized integral criterion in intellectual biomedical system

The developed intellectual biomedical system consists of the whole complex of program components which are realized with use of language C ++ in the medium of fast development of application C ++ Builder. The choice of the programming language is caused by presence of wide possibilities, support of address arithmetics and rich library of functions. Medium C ++ Builder belongs to the RAD (Rapid Application Development) systems possesses the convenient interface, and the integrated library of visual component VCL (Visual Component Library) allows to reduce time of development of applications essentially. The special library of the C ++ classes, supporting functional basis of system has been developed for realization of the basic functions of the mathematical device.

The created software is oriented on work in family of operational systems of Microsoft Windows that enables to carry out interaction of the user with system in the form of the multiwindow dialogue interface with the advanced system of the screen help, supporting the basic

agreements of GUI (Graphic User Interface) of the Windows media.

At designing the program complex intended for an estimation of adaptation possibility of a child organism, the method of nods [11] was used. It allows to work with the diverse information on an input and has some outputs. The expediency of use of the given nods for solution of the set problems is caused by the fact that there is a necessity of processing of the polytypic diagnostic information and an possibility of an estimation and comparison of the results obtained by in various units of system. Two units are realized in the intellectual biomedical system.

The developed complex of programs laying in the basis of the first unit has an ability to classify type of reaction of an organism on external influences, to predict changes of its state and to anticipate complications by formation of the adjusting program of treatment. The algorithms in which basis the method of construction of adaptation function on the basis of information criteria lays are realized by program way. Results obtained an output of the 1-st unit enter on an input of the second unit. However, already at the first stage, the certain conclusions about a health state are formed and in case of an error (failure) in the program, it can be detected at the first stage of investigation that will not entail statement of the incorrect diagnosis in following.

The complex of the programs laying in the basis of the second unit of biomedical system, allows to solve a problem of differential diagnostics. With this purpose algorithms of indistinct logic are realized.

Each unit of system is built by a modular principle that enables expansions and additions of system with other algorithms and programs. The structure of units of system includes the following basic modules (functional components):

1. Formations of base of knowledge of biomedical intellectual system. It is intended for: formations of base of the knowledge including description of structure of knowledge and set of descriptions of objects on the basis of experimental data; realizations of the basic functions of work with knowledge (sample, sorting, information search); supports of system of reference values of adaptation curves; protection of the information in base of knowledge from incorrect actions of users and the non-authorized access;
2. Estimations of adaptation abilities of an organism on the basis of the mathematical analysis of dynamics of separate parameters of heart rhythm structure (the module of revealing of adaptation strategy);
3. Estimations of adaptation abilities of an organism at reaction on the wedge orthostatic test. It is intended to estimate: adaptation strategy on the basis of information criteria taking into account dynamics of parameters under influence of external actions; reactions of an organism on the wedge orthostatic test. The results obtained by the given module, are used to form an operative estimation of a health state and development of the adjusting program of treatment;
4. Differential diagnostics and forecasting of a health level of a human organism: recognition of severity of a state; diagnostics of the most widespread diseases; definitions of a degree (kind) of disease. It realizes the mathematical device of decision-making on the basis of indistinct logic algorithms. The module of differential diagnostics is connected in case of adverse course of adaptation process;
5. Visualization of research results (building of approximating curves). It is intended for evident display of information structures for: revealing of the latent laws in a heart rhythm structure; a visual estimation of adaptation abilities of a human organism; formations of the final decision, output on the screen and, if necessary, printing of a firm copy.

Modification of the complex with the purpose to wide the functional abilities can be made by modification of separate modules or by addition of a new program component.

The program modules in which the algorithms allowing to make of the decision of diagnostic and forecast character are incorporated should be used in medical-diagnostic establishments. The further researches are connected with perfection of: ways of setting of the description of research objects; the intellectual interface; cognitive means of intellectual biomedical system.

Conclusion

Presented in the article the approach to an estimation of the health state of children in the early neonatal period, based on integral information criterion, is universal and allows to reveal law of an adaptation state formation being common for various stressing factors. Quantitative characteristics of integral information criterion allow to estimate with high reliability a functional reserve and a tension degree of all organism as a whole, separate systems or separate parameters.

Application of information integral criterion for estimation and forecasting of a health state of a human organism is expedient in transition periods when the life represents adaptation process: for the person in the postoperative period; for children of the early neonatal period; for pregnant women.

Approbation of intellectual biomedical system on the special test problems and on the problems of revealing of deviations in a health state of children in the early neonatal period has shown, that quality of the solutions on algorithms in which basis the method of construction of adaptation function lays on the basis of information criteria, meets the requirements of the practical doctor.

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