New Investigation Technologies of the Cardiovascular System and of the Vegetative Nervous System

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***Abstract* – Protecting and enhancing the health of the population is an important task for our country. Also financial resources targeted to medicine are insufficient to organize the effective functioning of medical institutions. In these circumstances is particularly important to equip the medical personnel with devices that have high possibilities of early diagnosis, which would allow family doctors to establish a correct diagnosis of health from the patient's first visit. On the other hand this will save human and financial resources by optimizing the treatment process and the exclusion of laboratory and instrumental investigations which repeats the information obtained by other methods.**

***Key Words* – photoplethysmography, cardiovascular system, vegetative nervous system,**

I. INTRODUCTION

Computerization and automation of various diagnostic methods in recent years does not surprise anybody, and allows ease of early diagnosis and improves doctor's work efficiency. In our opinion, such as automated methods of diagnosis as **cardiointervalography** (allows to establish and to study the nature of links that exist between the heart and the vegetative nervous system, the assessment of sinus node rhythm and function, assessment of various arrhythmias) **photoplethysmography** (allows to obtain information about the status of blood vessels and some parameters of central hemodynamics) should be materialized in a portable diagnostic device. And usage of this device while performing physiological maneuvers should allow assessment of adaptive-compensatory reactions occurring in the human body.

The offer comes from a group of researchers, doctors, engineers, programmers united in a team in the Department of Microelectronics, led by Professor Victor Şontea allows a qualitative increase of the diagnosis by specialist doctor, family physician. The same device can be used with success by sports medicine physicians during trainings, in scientific laboratories that are concerned with investigations of health of humans with special working regimen, of pupils and students. It is proposed to the scientific opinion an original device that allows rapid, noninvasive assessment of the cardiovascular system and vegetative nervous system, to the abilities to

to adapt to physical and psycho-emotional limited efforts and, based on these data, to establish the correct diagnosis.

The methodology of operation of this device is based on a theoretical and clinical foundation based on investigations of the heart rate. The device is designed to record and to measure the pulse wave allowing diagnosis of the condition of the patient's blood vessels, tracking and recording in real time the pulse heart rate and thus appreciation of the sinuous structure of the heart rate. The device was tested at the Department of Functional Diagnostics of the Republican Hospital, and Republican Medico-Social Rehabilitation Centre.

Fundamental investigations of the heart rate in healthy volunteers and in high performance athletes, at cosmonauts, performed by scientists V. Parin and R. Baevsky (1964-2009), A. Dembo (1984) E. Zemţovski (1984-2003), A . Korkuşko (1987-2005), later continued by V. Scripnic and A. Saulea (1983-2010) showed that one and the same values of RR intervals can be interpreted as a result of the oscillations of the length intervals between ventricular contractions of the heart, different depending of it's physiological or pathological nature.

This means that formal assessment of the value of frequency of contraction (FCC) and its deviation $\Delta RR = RRmax-RRmin$, without taking into account the sinuous structure of the heart rate and the set degree of periodic and aperiodic fluctuations, can lead to erroneous conclusions and serious mistakes [1,4,5]. This means that without knowledge of the spectrum of frequencies that belongs to the heart rate, spectral forces of waves, also called respiratory waves, slow waves (LF), very slow waves (VLF), the physician cannot assess correctly the state of the vegetative system, the sympathetic and parasympathetic activity and, ultimately, cannot correctly assess the adaptive capacities of the investigated patient which means that one cannot choose the correct direction of therapy [1, 2, 6]. General knowledge about self-organization of complex systems has been formulated by Ilya Prigogine and Hermann Haken, who first described the operation of complex systems with feedback. Proceeding from the principle formulated by N. Moiseev (1987) and based on the analysis of mechanisms of development of living nature reveals that: if there is more than one state of a system (or process), i.e. a number of coordinated states, subject to the laws of storage, energy accumulation and existing links in the system, then in the human body is achieved that state, which corresponds to minimum energy dissipation or minimum increase of entropy. Living organisms are subject to this principle [1, 2, 3, and 7].

Also we must remember the principle of minimal constraint of any system, which was discovered by Le Chatelie-Braun, that allows anticipation of human body's

reaction to an external trigger, by obtaining a certain effect (the minimum time or minimum dynamic deviation) due to effective change of the feedback signal (amplitude, or power) but also the characteristics of the object are kept [8.9]. These principles provided by synergistic can be used successfully during treatment.

For the specialist, but especially for the family doctor, who is forced to go to the patient's home, it is very important to establish the status of the vegetative nervous system and cardiovascular system. The proposed device can help establish more easily the state of the nervous system functional during the hyperventilation test, a procedure that takes only a minute

The hyperventilation test provides performing of deep breaths with a frequency of
6 osc/min (5sec. inspires; 5sec. exhale) in supine position.
Also the pulsogram is recorded.

Thus, a maximum and stable variation of the FCC is obtained in healthy humans. This variation of the FCC is a normal reaction, called respiratory sinus arrhythmia, which gives rise to respiratory waves in the spectrum of frequencies of the heart rate and is caused by vagus nerve activity (increased activity of the vague during expiration and a decreased during inspiration, due to excitation and inhibition of the vague nucleus, which transmits signals through nerve pathways to the sinus node). In pathological cases associated with vegetative dysfunction, this reaction with deviations of the gaps between heart contractions changes.

The developed device allows rapid and safe recording of the respiratory deviations of heart rate, by several methods: intervalography, correlative ritmography (scatterography). It should be noted that the respiratory method can not be used if the pulse is followed by palpation or auscultation.

This device not only allows assessment of vegetative status, but also of the sympathetic and parasympathetic activity of the vegetative nervous system during execution of test with hyperventilation. The doctor can assess and ensure vegetative reactions in the physiological limits of the test given, a very important thing for athletes, convalescents with sedentary lifestyle and elderly.

During the test with hyperventilation an increased parasympathetic activity occurs during exhalation compared with normal breathing and as a result FCC decreases (RR interval increases), and during inspiration cute the sympathetic prevails, FCC increases and RR intervals decrease. Depending on the increase and decrease in RR intervals we can talk about the activity of sympathetic and parasympathetic systems and their functional status [5, 6, 7].

II. MATERIALS AND METHODS

The study of the possibilities offered by the new VRC1 device proposed by the team of researchers from the Department of Bioelectronic was made in the Functional Diagnosis Department of the Republican Hospital, Head of Department, MD, Phd, Dr. I. Zatuşevski. Investigations were conducted on 186 persons of both sexes, aged 18-68 years, with various pathologies of the cardiovascular system and 32 practically healthy people, between November 2010 - April 2011.

With the help of HCV, a last generation portable device, one can obtain biological information to diagnose function of the vegetative and cardiovascular system by plethysmographic method.

The operating principle is based on pulse wave propagation and reflection, which is captured by a phootopletismographic transducer and processed by an original microprocessor using its own program developed by the engineers of the Department of Microelectronics.

This device allows obtaining the following parameters:

Statistical parameters of heart rate:

FCC – Frequency of cardiac contractions;

RR med, Mo (mode) - the value of the RR interval is most often encountered in a exract of RR intervals; Amo (mode amplitude) or the frequency of tracing the length of RR interval that coincides with the Mo value calculated from an extract of RR intervals; RR min, HR max, dX, CV,%, SDNN, RMSSD, NN 50count, pNN50%

Spectral parameters of heart rate:

HF; LF; VLF; spectral sum Σ; LF/HF; LF%; HF%.

The largest spread between the integral parameters has the blood pressure index (IT) by R. Baevsky. The essence of the above-listed parameters was demonstrated by R. Baevsky (1997) using his own mathematical model of adjusting the activity sinus node. After R. Baevsky, Mo characterizes the activity of the humoral chanel of rhythm regulation, AMo characterizes the sympathetic activity and ΔRR – the activity of the parasympathetic channel of the nervous system.

In order to study the state of vegetative control of heart rate in patients and volunteers were used rhythmographic methods, including corellative rhythmography (scatterography) and intervalography.The research was performed based on VRC1 device.

Hemodynamic parameters:

AUD - Amplitude of the Anacrote Wave;

IUD - Dicrote Wave Index ;

TRU - Time to Wave Reflection (dicrotic notch)

IUC - Ascending Wave Index.

III. THE RESULTS OF INVESTIGATIONS AND DISCUSSIONS:

Investigations made in the department of functional diagnosis of Republican Clinical Hospital, in the Department of Physiology and in the Republican Center of Medical-Social Rehabilitation have shown that normal activation of the parasympathetic system during the test with hyperventilation occurs by increasing the duration of RRmax interval (0, 05 sec. ≤ RRmax ≤ 0.1 sec.), while the sympathetic system's - within the ranges of decrease of RRmin interval (0.05 sec. ≤ RRmin ≤ 0.09 sec.). Increasing the value RRmax> 0.1 sec. and decreasing RRmin> 0.09 sec. confirms the prevalence of parasympathetic activity and sympathetic avegetative system, while lowering RRmax <0.05 sec. and increasing RRmin <0.05 sec. show reduction of their activity.

Investigations carried out on healthy people and on sick people with heart diseases has allowed us to emphasize the physiological and pathological responses that characterize the activity of sympathetic and parasympathetic systems from the the vegetative system. Pathological reactions are due to vegetative dysfunction.

Depending on the sympathetic and parasympathetic activity report nine types of reactions were highlighted, of which 7 physiological and 2 types of pre -pathological reactions. The first 3 types of physiological reactions are characterized by normal parasympathetic activity, within physiological limits (0.05 sec. ≤ RRmax ≤ 0.1 sec.).

In the first case sympathetic activity is decreased, in the second – it is normal and in the third - is increased. Vegetative activity in the first case is made predominantly by the parasympathetic system, in the second – due to the both rings: sympathetic, parasympathetic and in the third - mainly due to the sympathetic system.

The fourth, fifth and sixth case are characterized by high parasympathetic activity (increased value RRmax> 0.1 sec.). Sympathetic activity is low (RRmin is <0.05 sec.) for case four, in the fifth case is normal (0.05 sec. ≤ RRmin ≤ 0.09 sec.), in the sixth case is high (RRmin> 0 , 09 sec.).

In case four and five the vegetative activity is due predominantly to the parasympathetic system, and in case six – due to both systems: sympathetic and parasympathetic. The two types (the fourth and fifth) of heart rate are cases where vegetative regulation is within the physiological limits, but in case 6 there is a form of adjustment in which a pronounced sinus arrhythmia appears and extrasystoles may occur, supra-ventricular migration of rhythm leader and replacement impulses. So, high activity of both systems: the sympathetic and parasympathetic leads to an arrhythmogen effect, that is why this kind of adjustment may be called pre-pathological.

The seventh, eighth and ninth type is characterized by low parasympathetic activity (increased RRmax <0.05 sec). The seventh type is characterized by low sympathetic activity, the eighth type is characterized by normal sympathetic activity and ninth type is characterized by high sympathetic activity. The seventh can be characterized as a type in which the human body has very low adaptive capacities of both systems: sympathetic and parasympathetic. This type of reaction can be called pre-pathological. Types eight and nine are characterized by physiological reactions, more due to sympathetic regulation.

Usually, in case of normal regulation, physiological, ensuring the execution of the test, to say, with hyperventilation, or some other tests depends on the type of vegetative regulation listed above. For example, in case of vagotonic regulation (when the vague activity is predominant), the vegetative activity is performed due to sympathetic system and in the case of the sympathetic regulation - by the parasympathetic system and if normotonic, they are equally active -sympathetic and parasympathetic - then adjustment is performed by both systems: the sympathetic and parasympathetic.

So, we can establish that between sympathetic and parasympathetic system there is a close interconnection and interdependence, which provides an adaptation to a wide range of changes that come from outside and inside the body and the doctor can easily determine and distinguish the body's physiological functioning of the pathological. In vegetative dysfunctions pathological reactions appear during hyperventilation test, and we can establish which of the segments of the vegetative nervous system is unable to react adequately and therefore do not provide cardiac adaptation to changes in external environment.

In addition to the types of physiological, pre-pathological there are also pathological. There are three types of pathological reactions:

1) paradoxical reaction of sympathetic system (RRmin during the hyperventilation test increases instead of gradually declining);

2) paradoxical reaction of the parasympathetic system (RRmax during the hyperventilation test decreases instead of increasing);

3) paradoxical reaction of both sympathetic and parasympathetic systems (RRmax - decreases and RRmin - increases).

Pathological reactions of the vegetative nervous system at the test with hyperventilation reveals the presence of the vegetative dysfunction, and early diagnosis will allow starting of appropriate treatment.

During the investigation of the objective status at sick persons and healthy volunteers we have found different versions of the sympathetic and parasympathetic activity, which subsequently, during the statistical processing, allowed the split the investigated in samples according to the types of rhythm disturbances which allowed to optimize the patient's stay in the hospital and increase of the efficiency of treatment.

IV. CONCLUSIONS:

The algorithms used in the device VRC1 allows computerised processing , facilitating the diagnosis of various cardiac rhythm disorders in patients and assessing vegetative disturbances (predominance or inhibition of parasympathetic or sympathetic) and the correct choice of treatment

The advantages of this device ensures reduction of diagnostic time and significantly increase its objectivity, and also assessment of disorders in blood circulation, the changes taking place in the kinetic capacities of the heart and blood vessel tonic capabilities should ensure a certain flow of blood.

The results of the investigations confirm the need to apply the hyperventilation test, that allows objectivity of various arrhythmias and their division into three samples: functional , intermediate and pathological, which allows to optimize treatment and follow-up treatment in the dispensary system.

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