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EVALUATION OF BIOPHYSICAL PARAMETERS OF THE CARDIOVASCULAR SYSTEM IN THE EXPERIMENT

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ABSTRACT

The aim of this experiment was to evaluate the ways of identifying a number of biophysical quantities in the vessel wall-plasma-erythrocytes system in heart tissues under the action of microwave electromagnetic wave, γ-irradiation, with pressure chamber hypoxia. The level of magnesium, sodium, calcium and potassium ions in erythrocytes, blood plasma, various blood vessels, tissues and organs of animals was determined, and the activity of Na, K-ATPase of erythrocyte membranes, the amount of inter-wall potential difference of the vessel wall, erythrocytes charge and the viscosity of the suspension of erythrocytes were measured both under the action of the these factors in various modes of exposure, and the introduction of Heparin, Neodicumarinum, calcium antagonists Cardil and Phenihidin, Trental and Xantinol nicotinate. The general results of the experimental data and discussion of both characteristics and general changes in the recorded values with the corresponding conclusions are presented. The largest deviations of the detected values were found when γ-irradiation with a decrease in their concentrations in all evaluated tissues and in the blood with a decrease in hematocrit by 2 times.

Disciplinary: Multidisciplinary (Biological Sciences, Medical Sciences, Biotechnology).

1. INTRODUCTION

The significance of evaluating the effects of among others negatively acting drugs and environmental factors on blood vessels, organs, and blood is dictated primarily by the fact that cardiovascular disorders are the main causes of deaths in Russia and many countries of the world. In particular, the number of people exposed to electromagnetic waves of super-high frequency (SHF EMW) and radiation, as well as those suffering from the lack of oxygen supply to the body (hypoxia) is increasing, which requires the development of methods for preventing and correcting deviations from the normal functioning of the body (Zima & Dreval, 2000; Kiryushin & Motalova, 2014;

Terekhov et al., 2016; Afridi et al., 2013; Bi et al., 2018; Choi et al., 2018; Davis et al., 2018; Egami & Hamashima, 2018; Grün et al., 2018; Nan et al., 2018; Panhwar et al., 2014; Ruiter et al., 2018; Shen et al., 2018).

The available results of the study of the blood circulation and the cardiovascular system require a review of established opinions on the main blood vessels and their evaluation when analyzing the effects of various environmental effects on them (e.g. SHF EMW, γ- irradiation and various modes of hypoxia) and the prescribed drugs. In this regard, the expediency of the analysis is dictated at the membrane level as well: how and to what extent the relationships between blood vessels and blood change, to what extent they participate in the mechanisms of action of drugs on the body's functional systems (FS) (Zima & Dreval, 2000; Kazakov et al., 2009; Kashirina et al., 2013; Landyshev et al., 2009; Mamikonyan, 2015; Nikiforov, 2015; Pustovalov et al., 2002; Filipets & Gozhenko, 2014; Afridi et al., 2013; Ahmad et al., 2018; Davis et al., 2018; Panhwar et al., 2014; Ruiter et al., 2018).

In biomedical research, a special direction "membranology" was distinguished according to the analysis of the structure, properties, functioning of biomembranes, their role and importance in the vital activity of the cell, tissue, organ and the whole organism. The theoretical and practical importance of such studies is due to the fact that the system analysis when studying the functions of biological membranes reveals the molecular mechanisms of the development of many diseases in conjunction with biochemical disorders, makes it possible to propose new diagnostic methods and approaches for treating a number of diseases, and investigates the involvement of the membrane factor in drugs effect on the body's FSs (Kashirina et al., 2013; Nikiforov, 2015; Pustovalov et al., 2002; Afridi et al., 2013; Panhwar et al., 2014).

The functional state of bio-membranes is also characterized by the level of ions in tissues, organs, blood, the magnitude of the potential difference of the vessel wall and the charge of the formed elements and the rheological properties of blood (Landyshev et al., 2009; Mamikonyan, 2015; Nikiforov, 2015; Pustovalov et al., 2002; Filipets & Gozhenko, 2014; Afridi et al., 2013; Panhwar et al., 2014). The study of these parameters allows solving the problems of adjusting the functioning of the membranes when exposed, for example, to physical factors, by prescribing drugs for the functional systems of the body.

The aim of this study was to develop methods for analyzing characteristic disorders of various bio-membranes of tissues, organs and blood under the action of SHF EMW, radiation, pressure chamber hypoxia, as well as to develop and substantiate the methods of prescribing drugs for the FS of the human body and animals with the ability to reduce the corresponding functional and pathological disorders caused by a number of physical factors.

2. LITERATURE REVIEW

Bio membranes and ionic homeostasis of the cell. The plasma membrane is a liquid crystal structure, all types of ion transport through which can be divided into passive diffusion, facilitated diffusion and active transport.

Passive transport of ions through bio membranes is carried out in the direction of the electrochemical gradient, which is formed as a combination of the electrical and concentration gradient of the bio membrane. With facilitated diffusion, the transport of ions is carried out using mobile or fixed carriers and channels, and during exchange diffusion, the concentration of these ions on both sides of the bio membrane does not change (Pustovalov et al., 2002; Terekhina et al., 2012;

Filipets & Gozhenko, 2014).

In a bio membrane, as in a liquid crystal structure, the so-called phase transitions are present, i.e. "melting" of lipids when heated and their "crystallization" when decreasing temperature. In this case, the evidence of phase transitions depends both on the genus and the state of bio membranes, which does not exclude their use as a diagnostic test for the analysis of damaging effects, as well as the corrective effect of drugs on the body's FS.

The importance and relevance of studying biomembranes in modern drug is confirmed, for example, by the fact that American scientists Roderick Mac Kinnon (Rockefeller University in New York) and Peter Agr (J. Hopkins University in Baltimore) won the Nobel Prize in chemistry in 2003. Their work was devoted to studying the properties and functioning of ion channels of bio membranes.

1. Endogenous and exogenous factors can modify the permeability of bio membranes for ions. For example, the deviation of cations in the medium can disrupt the membrane structure, which is possibly caused by a deviation of the trans-membrane potential difference, and it is possible that the membrane potential, for example, that of erythrocytes plays a leading role in changing their permeability. At the same time, the change in the concentration of ions in cells contributes to the modification of the transfer of cations in the membrane (Pustovalov et al., 2002; Terekhina et al., 2012; Filipets & Gozhenko, 2014; Afridi et al., 2013; Panhwar et al., 2014).

The wall of blood vessels should be considered in comparison with erythrocytes as a system of biological membranes with different permeability parameters or, as a result, as one multicellular heterogeneous bio membrane, where all transport processes are different combinations and modifications of the known cation transport. The inter-wall transport of cations and metabolites along a concentration gradient (diffusion or facilitated diffusion) in tissues, the smallest blood vessels, or in a combination (blood - wall of a vessel in large vessels) can significantly depend on the distribution of cations and electrical charges, which, in turn, contributes changes in the functioning of blood vessels (Pustovalov et al., 2002; Afridi et al., 2013; Panhwar et al., 2014).

Ca^{2+}, Na^{+}, K^{+} and Mg^{2+} cations are involved in a number of regulatory releasers. The disturbance of these cations distributions inside and outside the cell in a given functional state can cause some corresponding biochemical disturbances.

Achieving a more effective correction of pathological abnormalities in the body, accompanied by electrolyte imbalance, requires an approach that allows you to compare the control processes occurring both at the cellular level and in individual organs. This approach would make it possible to analyze the sequence of disease development more significantly and have more successful medical correction by appropriate effects on the FS of the body.

It should be noted that erythrocytes affect many aspects of the process of hemocirculation, having a significant impact on hemostasis and intravascular thrombosis. The mechanical properties of erythrocytes and their deformability are one of the main factors affecting blood functioning. In addition, the movement of blood and its viscosity are considered to be essential factors in vascular tone regulation (Landyshev et al., 2009; Mamikonyan, 2015; Nikiforov, 2015; Pustovalov et al., 2002).

When considering the functions of blood vessels and blood together, it is necessary to take into account the values of the coefficient of blood viscosity, plasma, erythrocytes and their membranes and the role of erythrocyte deformability.

The study of the blood viscosity, its plasma, a suspension of erythrocytes and their membranes under the action of damaging environmental factors is an essential condition in the practical realization of the possibility of some effective influence on the microcirculation in hemodynamic and metabolic disorders, in achieving the significance of the effect of drugs.

The influence of microwave irradiation, hypoxia, and γ-rays on the cardiovascular system and blood. The influence of microwave irradiation, hypoxia and γ-rays on the cardiovascular system and blood. The interactions of electromagnetic radiation with living organisms are diverse and require various additional studies. The interaction of electromagnetic waves with biological objects depends both on the parameters of the waves (frequency, wavelength, coherence, polarization, intensity, etc.) and on the properties, the state of the bio-system itself (electrical conductivity, dielectric constant, tissue bioelectric activity, etc.). For example, at the cell level, membrane, ionic, non-chemical, and a number of other theories of the interaction of electromagnetic radiation with cell structures are discussed (Kazakov et al., 2009; Kiryushin & Motalova, 2014; Terekhov et al., 2016; Egami et al., 2018; Shen et al., 2018).

Microwave irradiation, for example, can have a direct effect on blood cells with the possible induction of the protein structures metabolism from membranes or a change in their conformational state. The high sensitivity of lipid metabolism under the action of electromagnetic waves of the microwave range seems to be important. A number of effects of microwave irradiation cause ambiguous effects on the transport of sodium and potassium ions through the erythrocyte membrane (Kazakov et al., 2009; Kiryushin & Motalova, 2014; Terekhov et al., 2016; Ruiter et al., 2018).

The concept of the leading significance of bio-membranes in the body's response to microwave irradiation is presented as one of the main methods of microwave radiation exposure on cells. The essence of this concept lies in the fact that bio-membranes are capable of selective absorption of microwave energy, which is ensured by the heterogeneity of the electrical and other physical-chemical properties of the membrane and near-membrane layers. The corresponding absorption of microwaves in the membranes includes both thermal and non-thermal components. The nonthermal absorption of microwave energy is based, in particular, on some resonance phenomena, the manifestation of which depends on both the molecular organization of the microstructures of the irradiated object and on the conditions and modes of study.

The presence of high physiological and possible therapeutic activity of microwaves suggests that microwave radiation has a diverse influence on the action and metabolism of drugs. However, without knowledge of characteristics of the influence of microwaves on the action of drugs with damaging factors, effective treatment is not possible and the forecast of remote consequences is difficult.

In this regard, we studied the effect of SHF EMW on tissues of blood vessels, heart, organs, blood, and the use of anticoagulants Neodicumarinum and Heparin.

The effect of ionizing radiation on biological objects is characterized by a variety of interrelated and interdependent reactions affecting the functioning of almost all body systems, the reactivity of which changes according to factors of the external and internal environment of the body, including pharmacological agents, which significantly complicates the choice of doses and dosage regimens (Zima & Dreval, 2000; Ahmad et al., 2018; Choi et al., 2018; Grün et al., 2018).

The biological effects of radiation on cell membranes, on the human body and animals, depend both on the dose and radiation power, and on the γ-radiation stage (Zima & Dreval, 2000; Ahmad et al., 2018; Choi et al., 2018; Grün et al., 2018).

Ionizing radiation has a direct and indirect effect on the circulatory system, causing damage to the vascular wall itself and blood corpuscles, changes the reactivity of the tone and the blood channels, violating the permeability of bio-membranes (Zima & Dreval, 2000; Ahmad et al., 2018; Choi et al., 2018; Grün et al., 2018).

Despite numerous studies of the effects of radioactive radiation on humans and animals, there is a lack of knowledge about the nature of the processes that develop after irradiation in the structures of the vascular wall at the sub-cellular, cellular and membrane levels. Still, to some extent, there is not enough knowledge to understand the mechanisms of damage to the vascular wall itself, hemodynamic disturbances and their connection with impaired blood clotting at various periods after irradiation. The pathogenetic validity and effectiveness of methods for the prevention and treatment of radiation injuries of the circulatory system are still low. Despite significant advances in radiation medicine, there is a need to study the effects of radioactive radiation on the body's FS and the choice of means to correct the disturbances.

The primary cause of hypoxia is the lack of oxygen in cells, which leads, in particular, to a decrease in the re-synthesis of energy-supplying phosphates. At the same time, the functional activity of erythrocytes reflects their ability to bind, transfer and release oxygen (Bi et al., 2018; Davis et al., 2018; Nan et al., 2018).

Hypoxia is actually the most frequent phenomenon of general pathology. However, it should be noted that this is only one of the possible causes of the energy deficit in the body, and that, considering bio-energy in all its complexity, it is necessary to focus on complex disruption of energy metabolism, the individual stages of which are closely related to each other by cause-effect relations (Bi et al., 2018; Davis et al., 2018; Nan et al., 2018).

The most important element of the vascular system is the microcirculatory bloodstream, in which the exchange of substances and gases between the blood and tissues. There is no doubt that often during hypoxia, along with the use of antihypoxic drugs, it is also necessary to prescribe anti- and hemo-coagulants and vascular agents. However, there exists a task about the necessary study of the features of their controlling influence, in particular, on blood vessels, blood, the structure and functions of bio-membranes, the ratio of cations in them and the functional respiratory system.

3. MATERIALS AND METHODS

To study the vascular wall and blood, we used the following drugs: Phenihidin and Cardil (calcium antagonists), antiaggregants and the ones affecting blood microcirculation - Trental and Xantinol nicotinate, Heparin - an anticoagulant of direct action, and Neodicumarinum - that of indirect action.

Studies were conducted on 150 outbreed white heterosexual rats weighing 0.14-0.18 kg, anesthetized with ether, and on 24 cats using sodium pentobarbital as anesthesia. Each group included six animals.

The methods of prescribing the above-mentioned drugs are selected with the available data from their experimental use and the characteristics of laboratory animals:

- Heparin sodium manufactured by "Belmedpreparaty", Belarus - abdominally for 7 days, 2 times a day at doses of 0.15 U/g or 1.5 U/g.

- Neodicumarinum manufactured by "Health PHFO", Ukraine - orally for 6 days, 2 times a day at doses of 0.003 g / kg or 0.03 g/kg.

- Cardil is a trading name. The active substance is Diltiazem manufactured by Orion Pharma International, Finland - orally for 7 days, 3 times a day and 1 time on the 8thday at a dose of 3.5 mg/kg (daily dose of 10.5 mg/kg).

- Xantinol nicotinate manufactured by "Polipharm", Russia - orally for 7 days, 3 times a day at a dose of 30 mg/kg and 1 time on the 8th day (daily dose of 90 mg/kg).

- Trental - trade name. Active substance

- Pentoxiphyllin manufactured by "Jugoremedija", Yugoslavia - intramuscularly for 7 days, 2 times a day and 1 time on the 8th day at a dose of 10 mg/kg.

- Phenihidin–trade name. The active substance is Nifedipinum manufactured by "Grindex", Latvia - orally for 14 days, 2 times a day and 1 time on the 15th day at a dose of 0.0025 g/kg (daily dose of 0.005 g / kg**).**

To determine the concentration of sodium, potassium, calcium and magnesium ions in erythrocytes, blood plasma, tissues of blood vessels and organs of animals, their mineralization was carried out by burning at high temperature in a muffle furnace and then in test tubes - in nitric acid vapor (Pustovalov et al., 2002). Salt solutions were obtained by adding deionized water.

The levels of magnesium and calcium cations in the materials under study were measured with a fluorimeter and those of potassium and sodium with a flame photometer. Blood viscosity and suspensions of erythrocytes were measured with a capillary viscometer. The viscometer was designed using the capillaries of the Sally hemometer with a diameter of 0.52 ± 0.02 mm, a length of 0.13 m and a height of the liquid column above the capillary of 0.02 m. The shear rate was about 2.5 s^{-1}. The erythrocyte suspension was prepared by washing arterial blood three times with cooled isotonic phosphate buffer with pH=7.4 by centrifuging for an hour at 1500 rpm. A suspension of erythrocytes in isotonic phosphate buffer with pH = 7.4 and hematocrit of 50 % was received. Evaluation of the temperature dependence on the coefficient of viscosity of the suspension of erythrocytes (TDCVSE) was carried out by immersing the tubes in a water thermostat. The temperature varied from 34^{o} C to 46^{o} C via 1^{o} Cwith incubation at each temperature for 9 ± 1 minutes. The temperature was maintained with an accuracy of ± 0.25^{o} C.

For potassium and sodium ions, the active transport through erythrocyte bio-membranes was calculated from the activity of their Na, K-ATPases (in nanomoles of the released orthophosphate per 1 mg of protein per hour). The inter-wall potential difference (IWPD) of the abdominal aorta was measured with metal silver chloride electrodes. Hematocrit was evaluated after centrifuging blood in Panchenkov capillaries for ¼ of an hour at 3,000 rpm. The control of blood clotting was carried out by hemocoagulograph H334. The charge of erythrocytes was estimated by relative changes in the fluorescence intensity of charge-dependent probe 1.8ANS-1-anilinonaphalene-8-sulfonate (ANS).

The research results were processed statistically using the appropriate programs. At the same time, the normalized correlation coefficients (CC) were calculated using the methods of non-parametric statistics (the rank orders of the values obtained from the experimental data were used).

A single microwave irradiation of 36 white rats was carried out using LUCH-58 apparatus in the mode of obtaining blood hyper coagulation. Once for 1/3 hour, 18 rats were irradiated at an energy flux density (EFD) of 40 W/m^2. The first group of 6 rats served as irradiation control, and the second and the third groups also each of 6 rats got heparin abdominally at doses of 0.15 or 1.50 U / g after irradiation. The other 3 series of six rats were exposed for 7 days to 30 minutes daily with EFD of 8 W / m^2. After each irradiation, Neodicumarinum was orally administered to two groups of rats at a dose of 0.003 or 0.030 mg / g. The remaining series of animals served as a control of the course microwave exposure. One group of 6 rats was intact (total control).

The course SHF irradiation of 12 cats weighing 2,900-3,900 g, six animals in each group, was carried out using G3-14A apparatus with horn antenna P6-8 with EFD of 0.4 W / m at a wavelength of 0.03 m in conditions close to the schedule of relevant enterprises (5 days a week during the month every day for 5 hours). The other two groups of cats were irradiated with the help of LUCH-58 microwave therapy apparatus (wavelength 0.125 m) once for 1.5 hours with EFD of 4 W/m^2 (thermal effect is hardly probable) or 30 W / m^2 (thermal non-heating effect in the absence of integral increasing of temperature in tissues).

The total single *γ-irradiation* of 5 groups of rats (one of the series represented the control of γ-irradiation) was performed using LUCH-1 radiotherapy apparatus with a dose of 5 Gy at a dose rate of 1 Gy/min. In this mode of irradiation, radiation sickness does not cause mortality of rats for 2 weeks. The material for the study was taken on the 15th day after γ-irradiation, 1 hour after the end of the seven-day oral administration of Phenihidin to animals 3 times a day at a dose of 0.0035 g / kg (daily dose of 0.0105 g/kg) or for 7 days at a dose of 0.030 g/kg of oral administration of Xantinol nicotinate 3 times a day (daily dose of 0.090 g/kg), or administration of Cardil at a dose of 0.0035 g / kg 3 times a day (daily dose of 0.0105 g/kg) during the last 7 days, or a seven-day intramuscular administration of Trental 2 times a day and 1 time on the 8th day at a dose of 0.010 g/kg.

Acute hypoxia was carried out by a single keeping of 30 rats in the pressure chamber at a “rise height” of 8000 m (atmospheric pressure of 40,000 Pa) for 6 hours. The first group of rats represented the control of acute hypoxia, another group was administered Phenihidin for 7 days (daily dose of 0.0105 g/kg), or Xantinol nicotinate was administered for 7 days at a dose of 0.030 g/kg orally 3 times a day (daily dose of 0.090 g/kg), or Cardil was administered 3 times a day at a dose of 0.0035 g/kg (daily dose of 0.0105 g/kg) for 7 days, or a seven-day intramuscular administration of Trental 2 times a day and 1 time for day 8 at a dose of 0.010 g/kg. In the last case the end of prescribing was the day when the animals were in the pressure chamber.

Chronic hypoxia was caused by the presence of 5 groups of animals in the pressure chamber for 6 hours a day for 14 days at “rise heights” starting from 3.5 km, followed by a daily increase of “height” by 0.5 km to reach 6 km. On the 14th day animals were placed on the “height” of 8 km. The first group of animals was represented by the control of chronic hypoxia, other groups of six animals were orally administered Phenihid in 3 times a day for 7 days at a dose of 0.0035 g/kg (daily dose of 0.0105 g / kg), or Xantinol nicotinate was administered for 7 days at a dose of 0.030 g/kg orally 3 times a day (daily dose of 0.090 g/kg), or Cardil was administered 3 times a day at a dose of 0.0035 g/kg (daily dose of 0.0105 g/kg) for last 7 days, or a seven-day intramuscular administration of Trental 2 times a day and 1 time for day 8 at a dose of 0.010 mg/kg. The last day of prescribing was the day when the animals were in the pressure chamber.

4. RESULTS AND DISCUSSION

Consider the results of an experiment to evaluate the content of ions in the blood, tissues of the *heart, the size of the abdominal aorta and the blood viscosity of white rats under SHF radiation.* The research results represent a huge amount of tabular and graphic material, so this article presents mainly a discussion of the experimental results.

A single SHF irradiation of rats decreased the content of Mg^{2+}, $K^{+}$and Ca^{2+} cations as well as the Ca / Mg ratio when increasing the concentration of Na^{+} ions and the value of Na / K in tissues of the heart. At the same time, in the indicated mode, the content of the named ions in tissues of the abdominal aorta and myocardium changed in a co-directional manner, while in the plasma-erythrocyte system the Na^{+}gradient decreased with increasing K^{+} and Ca^{2+}.

The charge of erythrocytes decreased, possibly, by increasing the degree of binding of calcium ions to the outer surface of the membrane of irradiated animals, which leads to a change in the double electric layer and additional shielding of a part of negative charges.

In the course of SHF irradiation, as in the case of a single one, an increase of Mg^{2+} concentration in plasma was recorded with a more pronounced change in the level of potassium. The concentration of Na^{+} is more significantly increased in erythrocytes, than that of K^{+}, which is apparently due to an increase in the passive transfer of Na^{+}cations through cell membranes.

The disorder of the cationic composition of erythrocytes is probably caused by a change in the structure of their membranes, which indicates the absence of microwaves on the secondary structure of the protein in the erythrocyte membrane and indicates subtler changes in the molecular organization of the membranes due to abnormality of protein and lipid interactions in the membrane.

In the course of SHF irradiation of animals, a more pronounced imbalance of the ions we studied in myocardial tissues was observed, than in a single exposure with a significant decrease in the values of Na / K and Ca / Mg.

The single SHF irradiation influenced greater the blood coagulation process and the course irradiation significantly increased the viscosity of the erythrocyte suspension. This may be due to an increase in the molar coefficient of phospholipids/cholesterol erythrocyte membranes and a drop in the charge of erythrocytes.

The obtained results confirm the assumption of the high sensitivity of bio-membranes to SHF radiation, which is probably one of the mechanisms of the biological action of microwaves.

Thus, an increase in the content of Na^{+}, K^{+} , and Mg^{2+} in erythrocytes was registered both with the course and single exposure of microwaves to animals with a decrease in the Ca^{2+} and the charge of erythrocytes. A decrease in the Na^{+}gradient in the plasma-erythrocyte system and an increase in K^{+} and Ca^{2+} were noted. The content of cognominal ions in the tissues of the abdominal aorta and myocardium changed concurrently with a single SHF irradiation of animals, and the course SHF irradiation caused a decrease in the level of all investigated cations in the tissues of the heart and blood vessel (except for increasing the level of K^{+} in the myocardium).

The values of the correlation coefficients in the case of SHF irradiation allow us to conclude that the content of Mg^{2+} cations is high in all the organs and tissues of animals we studied. In this case, it is possible in some cases to predict the concentration of a number of cations in the tissues of the myocardium and blood vessel according to the level of ions in erythrocytes and blood plasma.

The SHF irradiation has changed the cationic composition in the organs and tissues we studied with a violation of their ratios in the content of these ions, which suggests the presence of common damaging mechanisms in both erythrocyte membranes and in more complex membranes.

The course of heparin to control rats for 3 days 4 times a day at a dose of 0.15 and 1.5 U / g contributed to a slight decrease in the level of the studied cations and their ratios in plasma compared to their values in control animals. The level of Na^+ decreased by 12 % and K^+ by 7 % in erythrocytes with an increase in the value ofK/Nain them at a dose of 0.15 U / g by 1.22 times, which was probably due to a corresponding increase in the activity of Na and K-ATPase by 27 %. The concentration of divalent cations decreased significantly (up to 40 %) with a higher dose of heparin.

More vivid disorders in the level of cations were observed in the tissues of the myocardium and blood vessel, where in a case of heparin the level of Na^+ increased in both doses together with the decline of the level of K^+cations and an increase of Na / K coefficient values in them from 42 to 89 %. However, if the concentration of Mg^{2+} in the myocardium practically did not change, then in the tissues of the blood vessel it increased, when decreasing Ca^{2+} and the value of Ca / Mg by 1.69 times.

There was an increase of Mg^{2+} gradient in erythrocytes in the blood vessel with a slight decrease of K^+.

The study of TDCVSE showed a more significant drop in the viscosity of the erythrocyte suspension at a dose of heparin of 1.5 U / g in the range of all temperatures studied, which to a large extent was probably due to an increase in the negative charge of erythrocytes.

When heparin was administered to animals at a dose of 0.15 U / g after a single SHF irradiation, the imbalance of cations in the myocardium practically did not change, but the Ca / Mg value almost corresponded to its value in control rats.

The rather good effect of heparin, when SHF exposure, is to a certain extent related, apparently, to its ability to lower cholesterol in the blood and regulate the permeability of bio-membranes.

The administration of heparin to animals at a dose of 0.15 U / g for nine days when keeping rats in the pressure chamber was accompanied by the correction of a number of estimated parameters caused by chronic hypoxia. The value of blood coagulation time actually corresponded to its value in control rats, however, the hematocrit remained equal to 58 %. The viscosity of the erythrocyte suspension decreased, however, its values in the area of physiological temperatures were nevertheless higher than in control animals, and the appearance of TDCVSE was closer to that in chronic hypoxia than in intact animals.

The active transport and the magnitude of the charge of erythrocytes with the introduction of heparin after the rats' stay in the pressure chamber were close to their values in the control rats, and the level of cations in the plasma and in the vascular wall leveled out. The concentration of Ca^{2+} in erythrocytes decreased, but the levels of Mg^{2+}, $K^+$and Na^+ in the cells increased even more with a deviation of Mg / Ca in them. However, an increase in K^+ and Na^+ in erythrocytes did not cause a change in their K / Na ratio, and their gradient in erythrocytes and blood plasma did not decrease as the calcium gradient approached its value in intact rats.

Experimental data showed the presence of phase transitions of erythrocytes bio-membranes (as their liquid-crystal structure) in control rats at temperatures of 35° C, 36° C, 39° C, 40° C. With an increase in the temperature of the erythrocyte suspension, their viscosity increased on average, as expected (Fig. 1, curve 1).

A single SHF irradiation of rats for 1/3 hour at an intensity of 0.04 kW / m^2 caused an increase in the viscosity of the erythrocyte suspension with the presence of a single-phase transition at a temperature of 36^o C, which can be considered a characteristic effect of the above-mentioned mode of SHF irradiation. When increasing temperature, the viscosity of the suspension increased synchronously with its value in intact animals. e of 0.15 U / g more significantly contributed to the approximation of the viscosity and TDCVSE to those in intact animals, than when prescribing the drug at a dose of 1.5 U / g.

Analysis of the obtained dependencies of the coefficient of viscosity of the erythrocyte suspension on temperature and the values of the viscosity of blood and its plasma allows us to consider viscometry a valuable informative diagnostic test, especially since changes in the rheological parameters of blood appear in the initial stages of the development of diseases. It should be assumed that the correction of this component of the microcirculation will contribute to a significant reduction in the development of the disease, and its severity can also be assessed according to TDCVSE that we studied.

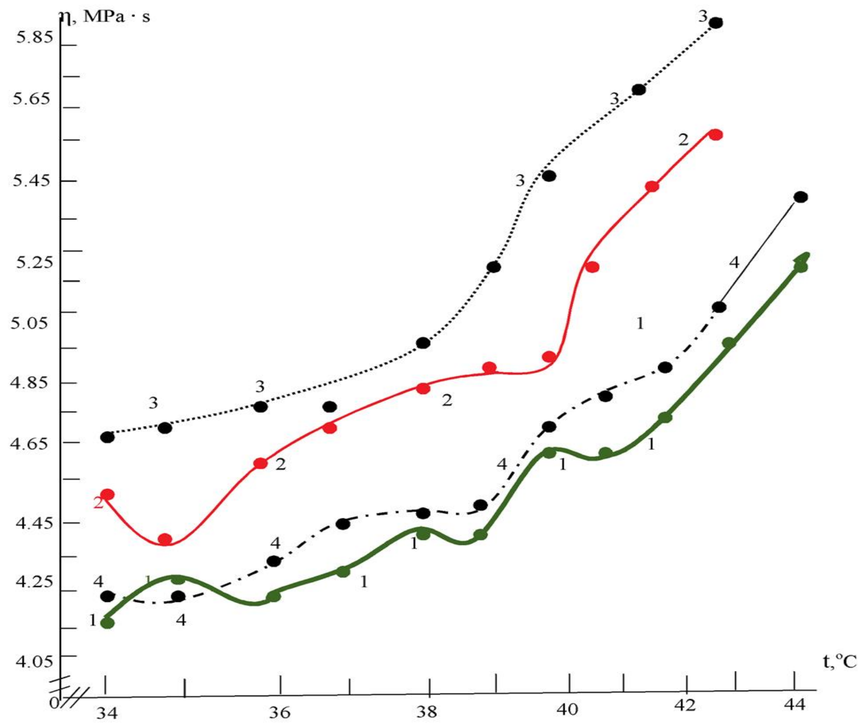

Figure 1. TDCVSE. Curve 1 - intact animals, curve 2 - SHF irradiation, curve 3 - SHF irradiation + Neodicumarinum 3 mg / kg, curve 4 - SHF irradiation + Neodicumarinum 30 mg/kg.

In the course of SHF irradiation, the coefficient of viscosity of a suspension of erythrocytes increased with characteristic phase transitions at temperatures of 35° C and 40° C (curve 2 in Figure 1). At the same time, the administration of Neodicumarinum at a dose of 3 mg/kg did not cause a decrease in the viscosity coefficient, but, contrary to expectations, increased it (curve 3 in Figure 1), which should be assumed as with its effect on blood clotting as a perverse effect. A similar paradoxical effect of Neodicumarinum with different parameters of the action of microwaves is not excluded. However, a tenfold increase in the dose of Neodicumarinum to 0.030 mg / g significantly approximated the appearance of the TDCVSE curve (curve 4 in Fig. 1) to that in control rats (curve 1 in Fig. 1), which gives grounds to consider it appropriate to administer the drug in this dose to correct TDCVSE caused by this mode of action of microwaves.

Analysis of the imbalance of ions in the tissues of blood vessels after irradiation of cats with electromagnetic waves showed that in the tissues of blood vessels of various functional purposes, unidirectional and oppositely directed deviations of the content of Na^{+}, K^{+}, Mg^{2+} and $Ca2^{+}$ ions and their ratios were observed.

In a case of microwaves, the level of Na^+ ions in arteries increased, while in the tissues the aorta it decreased. For K^+ cations, the opposite deviations with an increase in the Na^+ / K^+ value in arteries and a decrease of it in the aorta were observed. If in the anterior vena cava, the content of Na^+cations increased with a decrease in the K^+concentration with an increase in the value of Na^+ / K^+, then in the posterior vena cava their opposite deviations were observed.

Oppositely directed changes in the level of calcium cations were detected both in two different arteries and in various vena cava and aorta. In all the blood vessels studied by us, the level of magnesium decreased significantly with an increase in the ratio of Ca^{2+} / Mg^{2+} in them.

The phase character of the blood vessel response we observe during SHF irradiation requires adequate therapeutic interventions. A number of SHF irradiation effects related to the function of cells can be explained by a change in the enzymatic activity of membrane protein ATPases, as a result of which the concentration profiles of ions contained in the membrane layer can change.

It is not excluded that the indicators of the influence of microwaves we have registered are also due to their direct effect on the tissues of blood vessels with the possible induction of the release of protein structures from the membranes or a change in their conformational state.

Thus, the imbalance of cations in the blood vessels of cats registered by us during SHF irradiation in this mode dictates the need to avoid SHF irradiation, to carry out the necessary therapeutic and other measures.

Our assessment of the imbalance of ions in the tissues of various organs during irradiation of cats with electromagnetic waves showed that under the action of microwaves during the month at an intensity of 0.4 W / m^2, the sodium level in the myocardium, liver and kidney decreased more significantly than in intact animals.

When the organs lost Na^+ cations, the level of potassium ions increased in the tissues: in the kidneys by 4.17 times, in the heart by 1.47 times, in the bladder by 2.04 times, in the liver by 1.42 times and only in the lung and the spleen it remained almost unchanged.

Such violations of the levels of Na^+ and K^+ ions caused an imbalance of Na^+ / K^+ in organs. This ratio decreased in the myocardium by 2.98 times, in the kidneys by 6.72 times, in the bladder by 2.18 times, in the liver by 2.04 times and only in the tissues of the lung and the spleen this ratio practically remained the same.

The study showed that the most serious sharp decrease in the Na / K ratio in the mentioned irradiation regime was observed in the kidney tissues, which necessitates correction of the Na^+ / K^+ value, especially in this organ.

To a much lesser extent, SHF irradiation during a month with an intensity of 0.4 W/m^2 at a wavelength of 0.03 m (with a frequency of 1,010 Hz = 10 GHz) caused an imbalance of Ca^{2+} and Mg^{2+} ions in organs. The Mg^{2+} content increased significantly in the kidney (4.36 times) and in the lungs (1.32 times). At the same time, the content of Ca^{2+} in the tissues of the kidney (131%), the spleen (198 %), and the bladder (156 %) increased, while its level did not actually change in the myocardium, the liver and lungs.

In this regard, the ratio of Ca^{2+} / Mg^{2+} decreased by 1.29 times in the lung tissues and 3.36 times in the kidney tissues, and in the spleen and bladder tissues, on the contrary, increased respectively by 1.81 times and 1.43 times. Consequently, the most significant changes in the levels of Ca^{2+}, Mg^{2+} and their ratios were recorded (as for monovalent sodium and potassium cations) in the kidney.

Irradiation of cats with microwaves at a wavelength of 0.126 m (at a frequency of 2.375 GHz) for 1.5 hours with EFD of 4 W / m^2 caused a decrease in the level of Na^+ cations in the tissues of a number of organs: in the heart by 1.94 times, in the liver by 2.72 times, in the kidneys by 191 % and in the bladder by 167 %. A similar directionality of deviations of the level of Na^+ was noted earlier with other parameters of microwaves.

In this mode of exposure of electromagnetic waves to animals, an increase in K^+concentration was recorded in all the organs we studied. The most significant changes were in the myocardium (by 3.15 times), in the liver (by 2.58 times), in the bladder (by 3.11 times) and more in the kidney. Such violations of potassium and sodium concentrations were accompanied by a significant decrease in the amount of Na^+ / K^+ in the liver (by 8.82 times), in the kidneys by more than 6 times and in the bladder by 4.30 times.

The increase in the concentration of calcium cations in the tissues examined by us in a number of organs was significantly less than that of magnesium, potassium, and sodium ions (in the kidneys - by 1.52 times and in the bladder - by 1.61 times).

An increase in Mg^{2+} content was noted in various organs. It was more significant than that of calcium cations: in the kidneys by 2.61 times, in the heart by 5.62 times, in the liver by 3.18 times and in the bladder by 3.48 times. Accordingly, the ratio of Ca^{2+}/Mg^{2+} decreased in almost all organs, more significantly in the myocardium (by 3.52 times), the liver (by 4.96 times) and in the kidneys (by 175 %).

In comparison with the effect of microwaves on cats with EFD of 0.4 W/m^2, this method of exposure had the imbalance of the studied cations (except for the level of Ca^{2+} cations) and the ratios of Ca^{2+} / Mg^{2+} and Na^+ / K^+.

The phase character of the blood vessel response we have observed during SHF irradiation requires adequate therapeutic interventions. A number of SHF irradiation effects related to the function of cells can be explained by a change in the enzymatic activity of membrane protein ATPases. As a result of it the concentration profiles of the ions, contained in the near-membrane electrolyte layer and forming an electrical double layer, can change (Zima & Dreval, 2000; Kazakov et al., 2009; Panhwar et al., 2014).

We noted general and specific deviations of the experimental results in the regulation of the cardiovascular system and blood functioning *with Xantinol nicotinate during γ-irradiation and hypoxia*.

The administration of Xantinol nicotinate *to control rats* promoted a decrease (by 12-35 %)in the concentration of cations in the tissues of the myocardium, the blood vessel, erythrocytes, and blood plasma, except for an increase in the level of K^+ and Na^+ in the myocardium. However, a significant increase in the activity of Na and K-ATPases of erythrocyte membranes was not accompanied by an adequate increase in the K / Na ratio in them. Therefore, this was facilitated by an increase in the passive transport of K^+ and Na^+ cations across the erythrocyte membrane, which should probably be assumed to have a negative effect on the drug.

The administration of this drug to control rats increased the value of Na / K in the heart by 139 % and decreased the Ca / Mg ratio. These values changed in the tissues of a blood vessel in the opposite way. The K^+ gradient increased in the blood plasma, erythrocytes, the tissues of the blood vessel, while the Na^+ gradient decreased.

The positive results of the action of Xantinol nicotinate should include a decrease in blood viscosity by reducing both plasma viscosity and erythrocytes by 19 % with an increase of 28 % in the VFD of the vascular wall.

The results of the correlation analysis with the administration of Xantinol nicotinate to control rats give an opportunity to estimate the level of magnesium and sodium cations in the tissues of the blood vessel or calcium and sodium in the heart, respectively, according to the content of Ca^{2+} in plasma and sodium in erythrocytes or K^{+} in plasma and erythrocytes.

The administration of Xantinol nicotinate to animals *during acute hypoxia* caused more significant correction of the parameters studied in the work than its administration in the case of chronic hypoxia.

The content of cations in the vascular wall, practically corresponded to its value in control rats with an increase in the frequency of abdominal aorta. Only the content of Ca^{+} decreased in plasma and the concentration of K^{+} and Mg^{2+} in the heart increased by 132 % with decreasing Ca/Mg, but without changing the level of Ca^{2+}. The administration of the drug caused the correlation adjustment of Na^{+}, K^{+}, and Ca^{2+} concentrations in erythrocytes with an increase in K / Na and gradients of K^{+}, Mg^{2+}, Ca^{2+} in plasma, the blood vessel, erythrocytes.

Probably, the passive transfer of Na^{+} and K^{+} cations increased through the erythrocyte bio-membrane, since the administration of the drug to animals during acute hypoxia promoted the growth of active transport of sodium and potassium ions by 172 % (the latter was also observed when it was used in control animals). The increase in energy consumption for an increase in K / Na in erythrocytes can be considered an undesirable factor in the membrane mechanism of the drug action during acute hypoxia. At the same time, the drug significantly reduced the blood viscosity coefficient (by 21 %), both by reducing the plasma viscosity and by lowering the hematocrit to its level in control rats. In this case, the correlation analysis revealed an estimate of the content of Na^{+}, $K^{+,}$ and Ca^{2+} in the tissue of the vascular wall and the heart according to the content of cations in erythrocytes and blood plasma.

Summing up the effect of Xantinol nicotinate on the increase in the active transport of Na^{+} and K^{+}, it should be noted that it can correct the changes in the values we studied caused by acute hypoxia, which allows us to recommend considering its preventive use in medicine in a case of acute hypoxia

When administrating Xantinol nicotinate to animals in a case of chronic hypoxia, the tendency of K^{+}, Mg^{2+} and Na^{+} level changes in plasma was inverse to changes in these values in a case of chronic hypoxia, however, the level of Ca^{2+} increased significantly in erythrocytes and plasma. The imbalance of other cations in erythrocytes was not corrected. The K^{+} cation gradient increased with a decrease of Mg^{2+} and Na^{+} in the blood vessel, erythrocytes, and plasma as compared to their values in both control animals and in chronic pressure chamber hypoxia

In general, the experimental data showed the lack of drug efficacy on the correction of the parameters studied by us in a case of chronic pressure chamber hypoxia. Despite a number of its positive effects, this drug should apparently be considered ineffective in a case of chronic hypoxia for correcting the balance of ions in the heart, blood vessel and blood viscosity, especially due to the increased content of Ca^{2+} in plasma, myocardium, erythrocytes and low correction of blood viscosity.

In a case of radiation injury, the administration of Xantinol nicotinate to animals caused positive deviations of the studied values, but not more significant than its effect was observed during acute hypoxia (Fig. 2). Experimental data allow us to consider possible to administer Xantinol nicotinate to correct the imbalance of a number of these quantities in the tissues and organs of rats that we studied, caused by γ-irradiation.

An analysis of the values we recorded showed that an assessment of the viscosity of biological fluids is a valuable diagnostic test. At the same time, the active transport of cations, which is interconnected with the deviations of the VFD and the electrolyte composition of the vascular wall, correlates with the viscoelastic parameters of erythrocytes. The increase in the viscosity of the erythrocyte suspension is probably due to the increase in the ratio of phospholipids to cholesterol in the bio-membranes of erythrocytes, and peroxide oxidation of lipids in them (Kashirina et al., 2013; Mamikonyan, 2015; Nikiforov, 2015; Pustovalov et al., 2002).

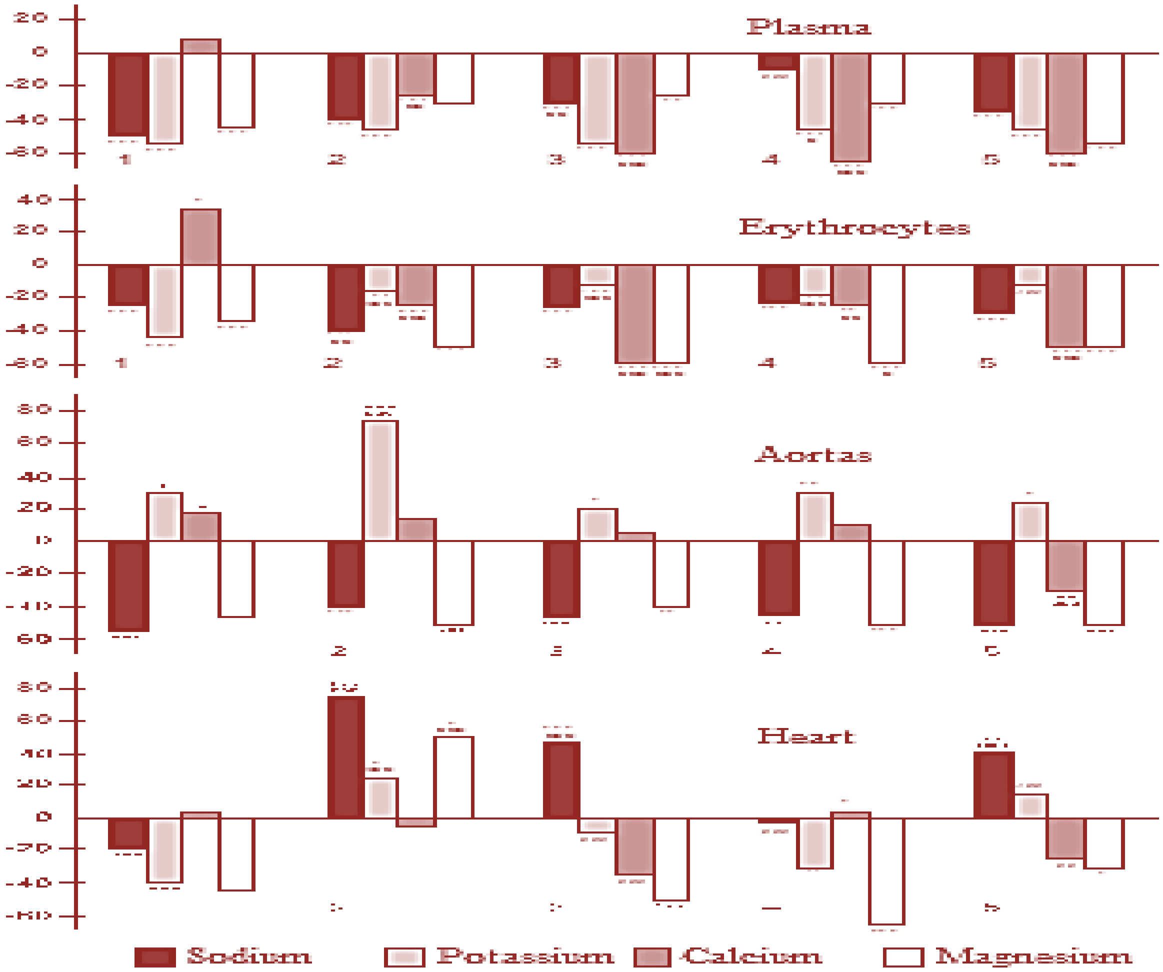

Figure 2: Relative changes (in %) of the cationic composition with γ-irradiation - 1, and the administration of Phenihidin- 2, Cardil - 3, Xantinol nicotinate - 4, Trental – 5.
*, **, *** – significant differences with control animals or o, oo, ooo – with the control of γ-irradiation, respectively, at P ≤ 0.05, P ≤ 0.01 and P ≤ 0.001

The resulting deviations of the studied parameters when administering Xantinol nicotinate on the background of the influence of hypoxia, γ-irradiation are most likely caused by the peculiarities of their controlling effect on the body's FS.

The membrane effects of Phenihidin were investigated when irradiating the animals with γ-rays and during chamber hypoxia. The introduction of Phenihidin to animals contributed to the correction of changes in the balance of recorded values, triggered by both acute and chronic hypoxia, γ-irradiation with a drop in the active transport of potassium and sodium ions during acute pressure chamber hypoxia and γ-irradiation. At the same time, the correction was more significant during chronic hypoxia and, to a lesser extent, during radiation exposure.

The effectiveness of the action of Cardil on the studied values during hypoxia and γ-irradiation of rats was evaluated. The results of the experiment suggest that Cardil should be prescribed to correct the deviations of the quantities we studied in tissues and organs during γ-irradiation of animals, despite the fact that the level of cations in them differed from the concentration of ions in intact animals. The greatest correction of the studied values was observed with γ-irradiation compared with that with chronic pressure chamber hypoxia.

Evaluation of the correlation coefficients revealed the effect of the concentration of magnesium cations on their level in the studied organs and tissues. Therefore, it should be noted that in the biomedical work, in diagnostics, nowadays, more attention has been paid to studies of the parameters of the content of magnesium cations both of the diagnostic test and of the corresponding treatment.

The deviations of the registered parameters noted by us with the introduction of Cardil under hypoxic conditions or radiation damage are probably caused by the significance of their control effect on FS and their characteristic bio-membrane effect.

The following are the concentrations of ions in the vascular wall, in the blood and the heart, as well as the coefficient of blood viscosity when administering Trental to control rats, γ-irradiation, pressure chamber hypoxia. The results we obtained revealed that the administration of Trental to animals contributed to a significant correction of changes in the studied parameters in the organs and tissues caused by acute hypoxia, but less significant than with the administration of Xantinol nicotinate, Phenihidin under conditions of acute hypoxia. However, in chronic pressure chamber hypoxia, the administration of Trental to animals did not cause any significant correction of the recorded parameters in the abdominal aorta, the blood plasma, and erythrocytes.

With γ-irradiation of animals, the introduction of Trental contributed to the correction of Ca / Mg in plasma and erythrocytes, as well as in the vascular wall and in the heart. In the abdominal aorta and in the blood plasma, this was observed by reducing the level of Ca2+ with the unchanged level of other electrolytes. In the heart, the directivity of deviations of K+, Ca2+, and Na+ concentrations was opposite to that of γ-irradiation of animals (Figure 2).

Withγ-irradiation in erythrocytes, the correction of deviations of K^+ and Ca^{2+} was noted without any correction of the content of Mg^{2+} and Na^+ in them. Since the decrease in the active transport of potassium and sodium cations (as compared to their values during γ-irradiation), then the K/Na ratio in erythrocytes and the K^+ gradient in erythrocytes and plasma increased. And the passive transport of Na^+ cations decreased more significantly, than the active transport, and K^+ ions transport was more significant through erythrocyte bio-membranes (Figure 2).

The results of the study revealed that with the introduction of Trental to animals, it is possible to correct a number of violations of the studied parameters in erythrocytes, abdominal aorta, in blood plasma caused by γ-irradiation. A higher corrective effect with the introduction of Trental to animals was observed with γ-irradiation and to a lesser extent with chronic pressure chamber hypoxia.

The results of our work allow us to conclude that the influence of pharmacological preparations on the FS of the body in the conditions of various pathological conditions of the body should also be provided for the correction of electrolyte imbalance in the tissues of organs, blood vessels, and blood.

5. CONCLUSION

The effects of SHF irradiation are due to the parameters of microwaves and the duration of their exposure. In our study, the presence of a co-directional change in the level of cognominal ions in the rat myocardium has been shown with various types of SHF irradiation of animals.

There were less pronounced deviations in the balance of the cations of the blood vessels during the course action of microwaves than during a single one with greater intensity. In all the modes of irradiation we studied, hyper-coagulation of blood was noted.

The reaction of the whole organism can be associated with the direct effect of SHF radiation on blood cells. The induction of the release of protein structures from the membrane by microwaves and conformational changes of proteins in the membrane are possible (Kazakov et al., 2009; Kiryushin & Motalova, 2014; Terekhov et al., 2016; Egami & Hamashima, 2018).

However, hemodynamic shifts occur, probably, not so much because of the direct influence of waves on the cardiovascular system, as due to some violation of the structure and function of the body's regulatory systems, ensuring the constancy of the internal environment of the body. When angiodystonic disorders of the SHF etiology, it is necessary to introduce measures aimed at correcting electrolyte disorders into the medical complex.

The strategy of treating hypoxic states, radioactive injuries and damaging effects of microwaves by influencing the body's PS with leveling out imbalances of cations will help eliminate immediate and long-term negative effects. It is justified to assign traditional and evaluate the significance of new drugs to achieve the desired therapeutic effect and the degree of correction of electrolyte disorders and viscoelastic properties of blood.

The results revealed both general and specific changes in the studied values against the background of the damaging effects on animals that we examined. The severity and direction of their deviations were due to the type of hypoxic state, the modes of microwave action and radioactive damage. We discovered a number of regularities:

- the VFD of the vascular wall decreased, as well as the charge of erythrocytes with an increase in the coefficient of blood and erythrocytes viscosity except for the decrease of blood viscosity during γ-irradiation with a decrease in hematocrit and an increase in the time of blood clotting;

- the concentration of Mg^{2+} in the blood vessel wall decreased mainly with a decrease in the magnitude of Ca^{2+} and Na^{+} in the tissues of the abdominal aorta, blood plasma, and erythrocytes under the action of microwaves and radioactive damage. The similarity of the deviations of the quantities studied by us at various external damaging effects is probably due to the presence of common factors of destabilization of bio-membranes with a violation of their structure and an imbalance of cations in them; general patterns of molecular organization of protein-membrane receptors and protein ATPases; probably the uniformity of membrane damage by channel-forming proteins and the entry of various toxins inside the cell and, probably, the ability of Na, K-ATPase, to "adapt" to the negative influences of the surrounding environment (Kazakov et al., 2009; Kashirina et al., 2013; Pustovalov et al., 2002; Terekhina et al., 2012; Filipets, N.D. & Gozhenko, A.I. (2014; Afridi et al., 2013; Panhwar et al., 2014).

There was a decrease in the level of Mg^{2+} in the heart and plasma with an increase in the level of Ca^{2+} in the myocardium under conditions of acute or chronic pressure chamber hypoxia and γ-irradiation. The concentration of Ca^{2+} increased in erythrocytes with a drop in the level of Na^{+} and K^{+} in the heart against the background of various types of hypoxia, while the level of Ca^{2+} and the value of Ca/Mg in the heart, erythrocytes and blood plasma increased with an increase in the activity of passive Na+ transport during chronic pressure chamber hypoxia, and K^+ cations in a case of acute hypoxia.

With different modes of γ-irradiation the concentration of Na^+, K^+ and Mg^{2+} decreased in the blood plasma together with increasing values of Ca/Mg and the activity of Na^+, K^+-ATPases in erythrocyte membranes and the passive transfer of K^+ cations accompanied with a decrease in the total level of ions both in the heart tissues and the abdominal aorta, and in blood plasma and erythrocytes.

There was a drop in K/Na values in erythrocytes, both under the action of microwaves and radioactive damage, as well as in chronic pressure chamber hypoxia. A decrease in blood clotting time was noted during SHF irradiation and hypoxia, and γ-irradiation contributed to the process of slowing blood coagulation.

Concluding remarks are

1. Under the influence of microwaves on the PS of the organism of animals, a decrease in the VFD of the vascular wall, the charge of erythrocytes with an increase in the viscosity coefficient of erythrocytes and blood were registered. The level of Mg^{2+} in the tissues of the vascular wall was reduced, as well as the magnitude of the Na^+ and K^+ gradient both in the abdominal aorta and in the erythrocytes and blood plasma.

2. The administration of Neodicumarinum at a dose of 0.003 g/kg at the background of the action of microwaves contributes not to an increase, but to a decrease in blood clotting time with an increase in the viscosity of the erythrocyte suspension and an increase in deviations of the content of ions in the tissues of the vascular wall, in the blood plasma and erythrocytes.

3. The introduction of Xantinol nicotinate for 7 days at a dose of 0.003 g/kg three times a day corrects changes in the balance of Na^+, K^+, Mg^{2+} and Ca^{2+} ions in the myocardium, abdominal aorta, and blood viscosity of animals provoked by acute hypoxia with an increase in both active and passive transport of sodium and potassium through the erythrocyte bio-membranes.

4. The imbalance of Na^+, K^+, Mg^{2+} and Ca^{2+} ions and the ratio of their contents in cats' blood vessels studied by us is determined by the parameters of the action of microwaves and is more pronounced at the background of microwaves at a wavelength of 0.125 m for 1.5 hours at an intensity of 30 W/m^2, than during their exposure during a month at EFD of 0.4 W/m^2 for 300 minutes a day five days a week.

5. The course administration of Xantinol nicotinate for 7 days (daily dose of 0.09 g/kg) did not cause any significant correction of the balance of Na^+, Mg^{2+}, K^+ and Ca^{2+} ions in the tissues of the myocardium, blood vessel, and also the blood viscosity of animals caused by chronic pressure chamber hypoxia.

6. With γ-irradiation of animals with a dose of 5 Gray, a correction of the balance of Na^+, Mg^{2+}, K^+ and Ca^{2+} ions and blood viscosity of white rats, as well as the blood viscosity of animals by 7-day administration of Xantinol nicotinate in a daily dose of 0.09 g/kg was registered caused by γ-radiation, but less pronounced than in acute hypoxia.

7. At the background of the acute pressure chamber hypoxia of animals, the effect of Phenihidin, Cardil, Xantinol nicotinate, Trental (in daily doses here and in the following conclusions, respectively, 0.005 g/kg, 0.0105 g/kg, 0.09 g/kg and 0.020 g/kg) on FS of the organism contribute to the growth of K / Na values in erythrocytes and the K^+ gradient values in the vascular wall, blood plasma and erythrocytes with a decrease in active and passive transport of Na^+ and K^+ ions through erythrocyte bio-membranes (except for an increase in active transport and passive transfer of Na^+ ions, K^+ when administration of Xantinol nicotinate).

8. Xantinol nicotinate and Trental at the background of chronic pressure chamber hypoxia in animals causes some correction of the Na^+, Mg^{2+} and K^+ balance in the heart with a decrease in the activity of both Na^+, K^+-ATPase and passive transfer of Na^+ and K^+ through erythrocyte bio-membranes and erythrocyte suspension viscosity, but does not decline hematocrit and blood viscosity index. Cardil against the background of chronic pressure chamber hypoxia corrects the balance of Na^+, K^+ and Ca^{2+} in the vascular wall, erythrocytes and in the blood plasma of animals with some decrease in the activity of both Na^+, K^+-ATPase and passive transfer of Na^+, K^+ through erythrocyte bio-membranes when growing the level of Ca^{2+} in the heart.

9. In a case of administration of Cardil, Xantinol nicotinate, Trental and Phenihidin at the background of γ-irradiation, acute pressure chamber hypoxia the Mg^{2+} level in erythrocytes, the blood plasma, the myocardium, and the vascular wall is less than that in control rats.

10. During hypoxia, exposure to microwaves, and radioactive damage to animals, the same tendencies were revealed: the IWPD of the vascular wall or erythrocytes charge decline when there is some increase in the viscosity of erythrocytes and blood, except for the drop in blood viscosity during γ-irradiation with a decrease in hematocrit and blood coagulation. In a case of microwaves and radioactive irradiation the concentration of Mg^{2+} in the vascular wall, as well as the gradient of Na^+ and Ca^{2+} in the vascular wall, in erythrocytes and blood plasma decreases. Acute chronic hypoxia and γ-irradiation reduce the content of Mg^{2+} in the heart and in the blood plasma with an increase in the level of Ca^{2+} in the myocardium.

11. At the background of microwaves, radioactive damage and pressure chamber hypoxia, the following features of deviations of the studied biophysical parameters of blood functioning, abdominal aorta and the heart of rats:

- the imbalance of ions in the vascular wall, blood plasma and erythrocytes is more significant during microwave irradiation than during chamber hypoxia, and in the myocardium, to a greater extent during hypoxia; the active transport of potassium and sodium is significantly rejected during γ-irradiation than during hypoxia; the viscosity of erythrocytes is to a greater extent increased with pressure chamber hypoxia and γ-irradiation than with microwave irradiation;

- the concentration of Ca^2 and the value of Ca / Mg in the blood plasma, erythrocytes and the heart increase with a decline in the Na / K ratio in the plasma and the vascular wall and an increase in hematocrit during the pressure chamber of chronic and acute hypoxia;

- with γ-irradiation at a dose of 5 Gray, the concentrations of Na^+, Mg^{2+}, Ca^{2+} and K^+ both in the tissues of the heart and the vascular wall have unidirectionally deviated. An increase in the values of Na / K and a decrease in the total content of all the ions studied by us take place in erythrocytes and the blood plasma.

12. The intensities of the correction of the imbalance of ions in the plasma, in erythrocytes, heart tissues and abdominal aorta, the blood viscosity coefficient of drugs are different:

- significant: Trental, Cardil, Phenihidin, Xantinol nicotinate with acute pressure chamber hypoxia and γ-irradiation; Phenihidin, Cardil with chronic hypoxia; Heparin at a dose of 0.150 U/g and Streptase at a dose of 2.5 U/g when pressure chamber hypoxia;

- cause a slight correction: Trental, Xantinol nicotinate - with pressure chamber chronic hypoxia; Vikasol, Protamine Sulphate in the appropriate doses of 0.00025 mg/g and 0.0001 mg/g with γ-irradiation;

- Neodikumarinum at a dose of 0.003 mg/g under the action of microwaves does not cause a slowdown, but rather an acceleration of the blood coagulation process, and also increases the viscosity of erythrocytes and imbalance of ions in erythrocytes, vascular wall and blood plasma.

13. Under the action of microwaves, radiation damage, acute chamber pressure and chronic hypoxia, the effects of the drugs studied by us change (compared to their effects in control rats) as for blood viscosity values and ion levels in erythrocytes, vascular wall and blood of animals:

- acute chamber hypoxia causes an increase in the action of Phenihidin on positive changes in blood viscosity, on the reduction of calcium in erythrocytes and an increase in the level of magnesium in the heart;

- chronic pressure chamber hypoxia reduces the effect of Phenihidin, Cardil, Trental, Xantinol nicotinate on an increase in the IWPD of the vascular wall, reduces the effect of Cardil in myocardial tissues, but increases the effect of Xantinol nicotinate on the blood viscosity;

- radiation damage reduces the effect of Cardil and Xantinol nicotinate on increasing the frequency of the IWPD of the abdominal aorta and reduces the effect of Xantinol nicotinate on the balance of cations in the wall of the abdominal aorta.

14. High correlation coefficients have also been recorded between deviations of the ion content in erythrocytes or blood plasma, impaired concentrations of cations in the tissues of the myocardium or vascular wall, as well as between the concentrations of Mg^{2+} cations in myocardial and vascular tissues and in erythrocytes, blood plasma and Na^{+}, Ca^{2+}, K^{+} in them under microwave irradiation, radiation damage and pressure-chamber hypoxia, and the prescription of the drugs we studied.

6. DATA AND MATERIALS AVAILABILITY

Information relevant to this study is available by contacting the corresponding author.

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