

Hemodynamic changes caused by exposure of animals with acute immobilization stress to continuous terahertz radiation

V. F. Kirichuk, V. V. Velikanov, T. S. Velikanova, O. N. Antipova, E. V. Andronov, A. N. Ivanov, S. S. Parshina, N. E. Babichenko, T. S. Kiriyaazi, E. V. Ponukalina, I. V. Smyshlyaeva, L. K. Tokaeva, A. A. Tsymbal

112 Bolshaya Kazachiya ul. , Saratov, Russia

Email address:

andronov-med@rambler.ru (E. V. Andronov)

To cite this article:

V. F. Kirichuk, V. V. Velikanov, T. S. Velikanova, O. N. Antipova, E. V. Andronov, A. N. Ivanov, S. S. Parshina, N. E. Babichenko, T. S. Kiriyaazi, E. V. Ponukalina, I. V. Smyshlyaeva, L. K. Tokaeva, A. A. Tsymbal. Hemodynamic Changes Caused by Exposure of Animals with Acute Immobilization Stress to Continuous Terahertz Radiation. *American Journal of Bioscience and Bioengineering*. Vol. 1, No. 1, 2013, pp. 17-23. doi: 10.11648/j.bio.20130101.13

Abstract: Experimental simulation of hemodynamic disorders during acute immobilization stress has shown that exposure to continuous terahertz radiation with frequencies equal to absorption and emission frequencies of nitrogen oxide (150.176-150.664 GHz) and atmospheric oxygen (129.0 ± 0.75 GHz) for 5, 15 and 30 minutes allows to revert post-stress hemodynamic changes in great vessels. This allows using terahertz electromagnetic radiation with frequencies equal to absorption and emission frequencies of nitrogen oxide (150.176-150.664 GHz) and atmospheric oxygen (129.0 ± 0.75 GHz) to treat hemodynamic disorders accompanying some of pathologic diseases.

Keywords: Hemodynamics, Linear Blood Flow Rate, Terahertz Waves, Nitrogen Oxide, Atmospheric Oxygen

1. Introduction

Hemodynamic disorders can be treated by a wide range of vasodilating agents. However, the optimal results are rather hard to achieve: there is always a risk of undesirable adverse effects and counter indications limiting application of these agents.

That's why, nowadays, development of new drug-free methods of hemodynamic disorder treatment is a subject of intense study. One of such methods is application of low-intensive millimeter and submillimeter radiation [1,2,3,4].

In recent years, a new branch of information therapy has emerged – terahertz therapy [5]. Terahertz frequency band makes for an interesting research subject because molecular absorption and emission spectra (MAES) of various cell metabolites (NO, CO, active forms of oxygen etc.) belong to this band [6].

Of the above mentioned test subjects for electromagnetic radiation effect study, the most interesting are frequencies of absorption and emission spectra of nitrogen oxide (150.176-150.664 GHz) and atmospheric oxygen (129.0 ± 0.75 GHz) as there is evidence of positive effect of the said

frequencies energy deposition on rheological properties of blood and platelet functional activity [7,8], blood clotting and fibrinolytic activity [8], blood gas and electrolyte concentration [10], lipid peroxidation and antioxidative activity [11,12], functional status of thyroid body [13], primary indices of metabolic status [14], concentration of adrenocorticotrophic hormone in blood [15], receptor system of formed blood elements [16], state of vascular endothelium [17] and microcirculation [18].

The lack of data on physiological effects of exposure of albino rats to electromagnetic terahertz radiation with frequencies equal to absorption and emission frequencies of nitrogen oxide (150.176-150.664 GHz) and atmospheric oxygen (129.0 ± 0.75 GHz) during their immobilization stress leading to disrupted blood flow velocity served as a primary reason for studying various modes of terahertz radiation with the said frequencies.

Thus, the purpose of this work is to study the effects of exposure of albino rats to continuous terahertz radiation with frequencies equal to absorption and emission frequencies of nitrogen oxide (150.176-150.664 GHz) and atmospheric oxygen (129.0 ± 0.75 GHz) during their immobilization stress on their blood flow rate.

2. Materials and Methods

In order to find a solution to the aforementioned problem, a group of 120 male non-pedigree albino rats with average weight of 180 – 220 g was chosen as a test subject. Simulation of hemodynamic disorders was achieved by incurring active immobilization stress.

The animals were exposed to electromagnetic terahertz radiation equal to absorption and emission frequencies of nitrogen oxide (150.176-150.664 GHz) and atmospheric oxygen (129.0 ± 0.75 GHz). The exposure was done using Orbita, an extremely-high frequency (EHF) therapy apparatus [19,20]. The animals with acute immobilization stress received a single dose of radiation for 5, 15 and 30 minutes.

Blood flow analysis within abdominal aorta and femoral artery was performed using MM-D-F portable microprocessor-based Doppler ultrasonograph (“Minimax”, Russia) [21] and Doppler ultrasonic transducer with 10 MHz working frequency used for ultrasound probing. During the analysis, the following parameters were registered: average linear blood flow velocity (Vam), average linear systolic blood flow velocity (Vas), average linear diastolic blood flow velocity (Vad) and pressure differential (PG).

The studied animals were divided into 5 groups of 15 rats each: 1st group – control group (noninvolved animals), 2nd group – comparison group (animals with acute immobilization stress), 3rd, 4th and 5th groups were comprised of animals exposed to terahertz radiation equal to absorption and emission frequencies of nitrogen oxide (150.176-150.664 GHz) for 5, 15 and 30 minutes (respectively) while 6th, 7th and 8th were comprised of animals exposed to terahertz radiation equal to absorption and emission frequencies of atmospheric oxygen (129.0 ± 0.75 GHz) for 5, 15 and 30 minutes (respectively).

The obtained data were processed with generally accepted parametric and nonparametric methods of statistical analysis using Statistica for Windows v.6.0 software. As Gaussian law was found to be not applicable to majority of

obtained data, Mann-Whitney U test was used for value comparison instead and Fischer’s z test and certainty factor p were calculated on the basis of Mann-Whitney U test value.

3. Results

According to test results, acute immobilization stress leads to statistically-valid (in comparison to control group) changes of hemodynamic parameters including increase of average linear, average linear systolic and average linear diastolic blood flow velocities as well as pressure differential. I.e., in abdominal aorta linear blood flow velocity increased by 26%, systolic blood flow velocity – by 15%, diastolic blood flow velocity – by 75% and pressure gradient – by 34%, while in femoral artery, linear blood flow velocity increased by 50%, systolic blood flow velocity – by 23%, diastolic blood flow velocity – by 25% and pressure gradient – by 67%.

Maximal efficiency of continuous exposure of male rats with acute immobilization stress to terahertz radiation equal to absorption and emission frequencies of nitrogen oxide (150.176-150.664 GHz) was found to be achieved after 5 minutes exposure to terahertz waves. In this case, exposure of male rats with acute immobilization stress to terahertz radiation led to complete recovery from any systematic hemodynamic disorders of abdominal aorta and femoral artery which was evidenced by absence of statistically-valid differences in such hemodynamic parameters as average linear, average linear systolic and average linear diastolic blood flow velocities as well as pressure differential of animals from the studied group in comparison to animals from control group. Continuous exposure of male rats with acute immobilization stress to terahertz radiation for 15 and 30 minutes also led to complete recovery from any systematic hemodynamic disorders in both of the above-mentioned great vessels (Table 1,2).

Table 1. Hemodynamic parameters of abdominal aorta blood flow in control groups rats, rats with acute immobilization stress, and rats exposed to terahertz 150,176 – 150,664 GHz radiation under immobilization stress.

Group parameters	Control group	Immobilization stress	Time of radiation exposition under stress		
			5 minutes	15 minutes	30 minutes
Vam, cm/s	15,2 (14,04;15,8)	17,7 (17,17;20,6) Z ₁ =4,33 p ₁ =0,000015	16,19 (15,37;17,64) Z ₁ =1,60 p ₁ =0,110288 Z ₂ =2,88 p ₂ =0,003943	15,09 (14,25;15,86) Z ₁ =0,06 p ₁ =0,950390; Z ₂ =4,58; p ₂ =0,000005; Z ₃ =1,76 p ₃ =0,077932	14,77 (14,16;15,74) Z ₁ =0,39 p ₁ =0,693551 Z ₂ =4,67 p ₂ =0,000003 Z ₃ =2,01 p ₃ =0,442543 Z ₄ =0,44 p ₄ =0,663186

Vas, cm/s	34,5 (32,93;37,64)	40,56 (35,28;43,91) Z ₁ =2,65 p ₁ =0,007941	34,45 (30,58; 38,12) Z ₁ =0,10 p ₁ =0,917411 Z ₂ =2,30 p ₁ =0,021334	34,60 (31,36;36,07) Z ₁ =0,62 p ₁ =0,533833 Z ₂ =2,79 p ₂ =0,005114 Z ₃ =0,48 p ₃ =0,633364	34,34 (31,36;38,42) Z ₁ =0,48 p ₁ =0,633364 Z ₂ =2,92 p ₂ =0,003454 Z ₃ =0,37 p ₃ =0,708923 Z ₄ =0,06 p ₄ =0,950390
Vad, cm/s	3,13 (0,78;4,7)	3,92 (3,13;6,27) Z ₁ =2,07 p ₁ =0,038089	2,45 (0,78; 3,92) Z ₁ =0,37 p ₁ =0,708923 Z ₂ =2,57 p ₂ =0,010122	1,46 (0,00;3,13) Z ₁ =1,61 p ₁ =0,105740 Z ₂ =3,38 p ₂ =0,000724 Z ₃ =1,49 p ₃ =0,135383	2,50 (1,56;3,92) Z ₁ =0,35 p ₁ =0,724416 Z ₂ =2,51 p ₂ =0,012093 Z ₃ =0,29 p ₃ =0,771551 Z ₄ =1,68 p ₄ =0,092885
PG, mmHg	0,46 (0,4;0,54)	0,64 (0,49;0,73) Z ₁ =2,63 p ₁ =0,008443	0,46 (0,36; 0,57) Z ₁ =0,12 p ₁ =0,900972 Z ₂ =2,36 p ₂ =0,018067	0,45 (0,38;0,49) Z ₁ =0,87 p ₁ =0,383733 Z ₂ =2,86 p ₂ =0,04210 Z ₃ =0,73 p ₃ =0,467921	0,48 (0,38;0,57) Z ₁ =0,37 p ₁ =0,708923 Z ₂ =2,73 p ₂ =0,006190 Z ₃ =0,33 p ₃ =0,740022 Z ₄ =0,35 p ₄ =0,724416

The data present as median and intercvartiles –Me (Q1-Q3). p1 is p-level of difference from control group. p2 is p-level of difference from group with acute immobilization stress.

Table 2. Hemodynamic parameters of femoral artery blood flow in control groups rats, rats with acute immobilization stress, and rats exposed to terahertz 150,176 – 150,664 GHz radiation under immobilization stress.

Group parameters	Control group	Immobilization stress	Time of radiation exposition under stress		
			5 minutes	15 minutes	30 minutes
Vam, cm/s	9,67 (8,48;10,39)	13,13 (12,01;13,91) Z ₁ =4,46 p ₁ =0,000008	9,21 (8,18;10,24) Z ₁ =0,48 p ₁ =0,633364 Z ₂ =4,17 p ₂ =0,000031	10,08 (8,61;11,96) Z ₁ =0,56 p ₁ =0,575511 Z ₂ =3,50 p ₂ =0,000457 Z ₃ =1,12 p ₃ =0,262754	9,83 (8,87;11,07) Z ₁ =0,62 p ₁ =0,533830 Z ₂ =4,33 p ₂ =0,000015 Z ₃ =1,02 p ₃ =0,309529 Z ₄ =0,10 p ₄ =0,917411
Vas, cm/s	21,17 (19,6;22,74)	24,30 (23,52;28,23) Z ₁ =3,86 p ₁ =0,000115	21,80 (18,82;25,09) Z ₁ =0,08 p ₁ =0,933886 Z ₂ =2,26 p ₁ =0,023788	22,10 (21,17;23,52) Z ₁ =1,76 p ₁ =0,077932 Z ₂ =2,94 p ₂ =0,003230 Z ₃ =0,87 p ₃ =0,383733	21,85 (20,38;22,74) Z ₁ =0,87 p ₁ =0,383733 Z ₂ =3,01 p ₂ =0,002637 Z ₃ =0,73 p ₃ =0,467921 Z ₄ =0,91 p ₄ =0,361497

Vad, cm/s	-1,57 (-2,36;0,78)	1,56 (0,78;3,92) Z ₁ =3,65 p ₁ =0,000262	-0,63 (-3,14;1,56) Z ₁ =0,35 p ₁ =0,724416 Z ₂ =2,90 p ₂ =0,003691	-0,63 (-2,36;2,35) Z ₁ =0,46 p ₁ =0,648204 Z ₂ =2,45 p ₂ =0,014397 Z ₃ =0,21 p ₃ =0,835705	-1,62 (-3,14;0,1) Z ₁ =0,81 p ₁ =0,418618 Z ₂ =3,96 p ₂ =0,000075 Z ₃ =1,24 p ₃ =0,213375 Z ₄ =1,02 p ₄ =0,309529
			0,17 (0,14;0,19)	0,23 (0,21;0,33) Z ₁ =3,795 p ₁ =0,000148	0,18 (0,12;0,25) Z ₁ =0,06 p ₁ =0,950390 Z ₂ =2,38 p ₂ =0,017080

The data present as median and intercvartiles –Me (Q1-Q3). p1 is p-level of difference from control group. p2 is p-level of difference from group with acute immobilization stress.

Continuous exposure of male rats with acute immobilization stress to terahertz radiation equal to absorption and emission frequencies of atmospheric oxygen (129.0 ± 0.75 GHz) for 5 minutes leads to normalization of all studied hemodynamic parameters of abdominal aorta and femoral

artery. Further increase of time of exposure to electromagnetic terahertz radiation equal to absorption and emission frequencies of atmospheric oxygen to 15 and 30 minutes does not appear to increase biological effect of terahertz radiation to hemodynamic parameters (Table 3,4).

Table 3. Hemodynamic parameters of abdominal aorta blood flow in control groups rats, rats with acute immobilization stress, and rats exposed to terahertz 129.0 – 0.75 GHz radiation under immobilization stress.

Parameters	Control group	Immobilization stress	Time of radiation exposition under stress		
			5 minutes	15 minutes	30 minutes
Vam, cm/s	15,2 (14,04-15,8)	17,7 (17,17-20,6) Z ₁ =4,33446 p ₁ =0,000015	15,07 (12,93-15,29) Z ₁ =0,154672 p ₁ =0,87708 Z ₂ =4,025768 p ₂ =0,000001	15,53 (13,93-15,98) Z ₁ =1,80775 p ₁ =0,070646 Z ₂ =4,70016 p ₂ =0,000003	15,57 (14,39-15,86) Z ₁ =1,74574 p ₁ =0,080857 Z ₂ =4,058853 p ₂ =0,000049
			Vas, cm/s	34,5 (32,93-35,64)	40,56 (35,28-43,91) Z ₁ =-2,6546 p ₁ =0,007941
Vad, cm/s	3,13 (0,78-4,7)	3,92 (3,13-6,27) Z ₁ =-2,0739 p ₁ =9,038089			
			PG, mmHg	0,46 (0,4-0,54)	0,64 (0,57-0,73) Z ₁ =-2,63386 p ₁ =0,008443

The data present as median and intercvartiles –Me (Q1-Q3). p1 is p-level of difference from control group. p2 is p-level of difference from group with acute immobilization stress.

Table 4. Hemodynamic parameters of femoral artery blood flow in control groups rats, rats with acute immobilization stress, and rats exposed to terahertz 129.0 – 0.75 GHz radiation under immobilization stress.

Parameters	Control group	Immobilization stress	Time of radiation exposition under stress					
			5 minutes	15 minutes	30 minutes			
Vam, cm/s	9,67 (8,48-10,39)	13,13 (12,01-13,91) Z ₁ =4,45889 p ₁ =0,000008	9,32 (9,08-9,76) Z ₁ =1,11400 p ₁ =0,265280 Z ₂ =3,20983 p ₂ =0,001328	9,36 (9,08-9,84) Z ₁ =1,24434 p ₁ =0,213375 Z ₂ =3,46342 p ₂ =0,000533	9,5 (9,12-9,84) Z ₁ =1,01621 p ₁ =0,309529 Z ₂ =2,5509 p ₂ =0,010745			
			Vas, cm/s	21,17 (19,6-22,74)	24,30 (23,52-28,23) Z ₁ =3,85746 p ₁ =0,000115	22,06 (21,17-22,74) Z ₁ =1,03848 p ₁ =0,299050 Z ₂ =3,37977 p ₂ =0,000726	22,82 (21,17-23,52) Z ₁ =1,63838 p ₁ =0,101343 Z ₂ =1,80430 p ₂ =0,071186	22,34 (21,17-23,52) Z ₁ =0,954 p ₁ =0,340087 Z ₂ =2,44721 p ₂ =0,014397
						Vad, cm/s	-1,57 (-2,36-0,78)	1,56 (0,78-3,92) Z ₁ =3,65007 p ₁ =0,000262
PG, mmHg	0,17 (0,14-0,19)	0,23 (0,21-0,33) Z ₁ =3,79524 p ₁ =0,000148						

The data present as median and intercvartiles –Me (Q1-Q3). p₁ is p-level of difference from control group. p₂ is p-level of difference from group with acute immobilization stress.

4. Results Discussion

Active forms of oxygen acts as intermediate agents for positive effect of electromagnetic terahertz radiation equal to absorption and emission frequencies of nitrogen oxide and atmospheric oxygen in cells and body fluids [22]. The said active forms are generated as a result of enzyme-caused changes in hydration of protein molecules and increase of nicotinamide adenine dinucleotide phosphate oxydase, cyclooxygenase and xanthine oxydase activity while concentration of the said enzymes is kept on stationary level. In their turn, active forms of oxygen together with Ca²⁺ stimulate soluble guanylate cyclase, accumulation of cyclic guanosine monophosphate in endothelial vessel cells and increase of NO-synthase activity which leads to increase of NO generation. This may be one of possible mechanisms of both anti-stress and vasodilating effect of terahertz radiation equal to absorption and emission frequencies of nitrogen oxide and atmospheric oxygen. Synthesized nitrogen oxide has the ability to form complex compound which can act as a sort of repository in vessel endothelium which is capable of releasing NO, if necessary [23,24].

Nitrogen oxide is a natural regulator of vascular tone,

thus causing vasodilating effect [25]. Activation of NO-ergic system also restricts excessive secretion of pituitary-hypothalamic stress hormones (adrenocorticotrophic hormone, adrenocorticotrophic hormone releasing hormone etc.), blocks secretion of catecholamines by adrenal glands and nerve terminals [26]. Nitrogen oxide also supports stress limiting effect of GABA(gamma-aminobutyric acid)-ergic and opioidergic systems [27] by decreasing concentration of stress-inducing hormones (including adrenaline and adrenocorticotrophic hormone), which leads to recovery of platelet aggregation ability disrupted by acute immobilization stress.

Mechanism of terahertz waves' activity always includes NO-synthase [28,29]. NO-synthase can influence formation of active forms of oxygen in endothelial cells by activating nicotinamide adenine dinucleotide phosphate oxydase, thus causing vascular relaxation. I.e. hydrogen peroxide causes endothelium-dependent vessel vasodilation which is mediated by prostaglandins E₂ and I₂ [30].

It is known that electromagnetic terahertz radiation equal to absorption and emission frequencies of nitrogen oxide and atmospheric oxygen can replenish decreased nitrite concentration in blood plasma during stress [31,32] which can serve as a indirect indication of normalization of nitrogen oxide generation process and provides an opportunity

to normalize endothelial functions.

5. Conclusion

The results of this study has shown that according to experimental simulation of hemodynamic disorders during acute immobilization stress, exposure to continuous terahertz radiation with frequencies equal to absorption and emission frequencies of nitrogen oxide (150.176-150.664 GHz) and atmospheric oxygen (129.0 ± 0.75 GHz) for 5, 15 and 30 minutes allows to revert post-stress hemodynamic changes in great vessels. This allows using terahertz electromagnetic radiation with frequencies equal to absorption and emission frequencies of nitrogen oxide (150.176-150.664 GHz) and atmospheric oxygen (129.0 ± 0.75 GHz) to treat hemodynamic disorders accompanying some of pathologic diseases.

Reference

- [1] Betsky O.V., Lebedeva N.N. Application of Low-Intensive Millimeter Waves in Biology and Medicine // *Biomeditsynskaya radioelektronika* (Biomedical Radioelectronics), 2007, No. 8-9, pp. 6-25.
- [2] Kirichuk V.F. Physiological Effects of Extremely High-Frequency and Terahertz Electromagnetic Waves: The Discoveries of Saratov Medical Scientists // *Biomeditsynskaya radioelektronika* (Biomedical Radioelectronics), 2007, No. 2-4, pp. 98-126.
- [3] Kirichuk V.F. Achievements of Saratov Scientists in Studying the Influence of Extremely High-Frequency and Terahertz Electromagnetic Waves on Humans and Animals // *Millimetrovye Volny v Biologii i Meditsyne* (Millimeter Waves in Biology and Medicine), 2007, No. 3, pp. 5-71.
- [4] Kirichuk V.F. Results and Perspectives of Experimental Validation of Application of Terahertz Electromagnetic Waves with Frequencies Equal to Frequencies of Molecular Absorption and Emission Spectra (MAES) of Various Cell Metabolites in Clinical Practice // *Millimetrovye Volny v Biologii i Meditsyne* (Millimeter Waves in Biology and Medicine), 2012, No. 1, pp. 5-24.
- [5] Kirichuk V.F., Golovacheva T.V., Parshina S.S., et.al. Application of NO-therapy in Clinical Practice // *Millimetrovye Volny v Biologii i Meditsyne* (Millimeter Waves in Biology and Medicine), 2009, No. 1-2, pp. 5-21.
- [6] Rothman Y.S., Gordon J.E., Barbe A., et al. The HITRAL Molecular Spectroscopic Database 2008 // *Journal of Quantitative Spectroscopy and Radioactive Transfer*, 2009, No. 110, pp. 533-572.
- [7] Kirichuk V.F., Sukhova C.V., Antipova O.N. Influence of Exposure to Terahertz Electromagnetic Waves with Frequencies Equal to Absorption and Emission Frequencies of Atmospheric Oxygen on Functional Activity of Platelets of Albino Rats with Immobilization Stress // *Biomeditsynskaya radioelektronika* (Biomedical Radioelectronics), 2008, No. 12, pp. 41-48.
- [8] Kirichuk V.F., Ivanov A.N., Antipova O.N. Electromagnetic radiation of the terahertz range at the nitric oxide frequency in correction and prophylaxis of functional activity disorders in thrombocytes of white rats under long-term stress // *Tsytologiya* (Cytology), 2007, Volume 49, No. 6, pp. 484-490.
- [9] Kirichuk V.F., Tsymbal A.A., Krenitsky A.P. et. al. Application of Terahertz Electromagnetic Waves with 129.0 GHz Frequency of Atmospheric Oxygen for Blood Clotting and Fibrinolytic Disorder Treatment // *Biomeditsynskaya radioelektronika* (Biomedical Radioelectronics), 2009, No. 9, pp. 11-16.
- [10] Tsymbal A.A., Kirichuk V.F. Changes in Blood Gas and Electrolyte Concentration Caused by Exposure to Terahertz Radiation with Frequencies of 150.176 – 150.64 GHz During Stress // *Patologicheskaya Fiziologiya i Eksperimentalnaya Terapiya* (Pathologic Physiology and Experimental Therapy) – 2011, No. 1, pp. 49-51.
- [11] Kirichuk V.F., Tsymbal A.A. Effects of terahertz irradiation at nitric oxide frequencies on intensity of lipoperoxidation and antioxidant properties of the blood under stress conditions // *Bull Exp Biol Med.* 2009 Aug;148(2):200-3.
- [12] Kirichuk V.F., Tsymbal A.A. Application of Terahertz Electromagnetic Waves with Frequencies of Nitrogen Oxide for Correction of Antioxidant Blood Activity and Lipid Peroxidation During Stress // *Russian Journal of Physiology named after N.M. Sechenov*, 2010, No. 2, pp. 121 – 127.
- [13] Kirichuk V.F., Tsymbal A.A. Application of Terahertz Electromagnetic Waves with Frequencies of Nitrogen Oxide for Correction of Functional Status of Thyroid Body During Stress // *Vestnik RAMN* (Bulletin of Russian Academy of Medical Sciences), 2010, No. 4, pp. 37-40.
- [14] Tsymbal A.A., Kirichuk V.F., Krenitsky A.P. Recovery of Primary Indices of Metabolic Status by Exposure to Terahertz Electromagnetic Waves with Frequencies of Nitrogen Oxide (150.176 – 150.64 GHz) as a Result of Expiration // *Biomeditsynskaya radioelektronika* (Biomedical Radioelectronics), 2011, No. 1, pp. 30-35.
- [15] Tsymbal A.A., Kirichuk V.F., Antipova O.N. Changes of Concentration of Adrenocorticotrophic Hormone in Blood of Experimental Animals as a Result of Exposure to Terahertz Electromagnetic Waves with 129.0 GHz Frequency of Atmospheric Oxygen During Acute and Continuous Stress // *Biomeditsynskaya radioelektronika* (Biomedical Radioelectronics), 2011, No. 8, pp. 23-29.
- [16] Kirichuk V.F., Ivanov A.N., Andronov E.V. Influence of Terahertz Electromagnetic Waves with Frequencies of Nitrogen Oxide on Post Stress Disorders of Carbohydrate Component and Activity of Platelet Glycoprotein Receptors // *Biomeditsynskaya radioelektronika* (Biomedical Radioelectronics), 2010, No. 5, pp. 39-46.
- [17] Kirichuk V.F., Ivanov A.N., Kiriyaizi T.S. Changes in Functional State of Endothelium and Peripheral Perfusion of Albino Rats with Acute Immobilization Stress as a Result of Exposure to Terahertz Electromagnetic Waves with Frequencies of Nitrogen Oxide // *Biomeditsynskaya radioelektronika* (Biomedical Radioelectronics), 2010, No. 12, pp. 30-37.
- [18] Kirichuk V.F., Ivanov A.N., Kiriyaizi T.S. Correction of microcirculatory disturbances with terahertz electromagnetic radiation at nitric oxide frequencies in albino rats under conditions of acute stress. // *Byulleten Eksperimentalnoi Bi-*

ologii i Meditsyny (Bulletin of Experimental Biology and Medicine). – 2011, Volume 151, No. 3, pp. 259-262.

- [19] Tsymbal A.A., Kirichuk V.F. Apparatus for Extremely-high Frequency (EHF) Electromagnetic Wave Therapy // *Med Tekh.* 2011, (3):42-46.
- [20] Kirichuk V.F., Tsymbal A.A. Use of terahertz electromagnetic waves for correcting the hemostasis functions / *Med Tekh.* 2010 Jan-Feb;(1):12-6.
- [21] Domashenko R.A., Andozhskaya Yu. S., Plotkin G. L. Assessing the impact on Clexane microcirculation in patients with Doppler device Minimax // *Regionarnoe Krovoobrashchenie i Mikrotsirkulyatsya (Regional Circulation and Microcirculation)*, 2002, no. 4, pp. 76-78.
- [22] Potselueva M.M., Pustovidko A.V., Evtodienko Yu.V. The formation of reactive oxygen species in aqueous solution under the influence of electromagnetic radiation EHF // *Doklady Akademii Nauk*, 1998, № 3, pp. 415-418.
- [23] Pshennikova M.G., Smirin B.V., Bondarenko O.N. Deposition of nitrogen oxide in rats of different genetic lines and its role in the anti-stress effect of adaptation to hypoxia // *Russian Journal of Physiology named after N.M. Sechenov*, 2000, Volume 86, No. 2, pp. 174 – 181.
- [24] Kirichuk V.F., Velikanova T.S., Ivanov A.N. Hemodynamic Changes Induced by Preventive Exposure of Terahertz Radiation at a Frequency Range Corresponding to Molecular Emission and Absorption Spectrum of Nitric Oxide in Animals under Conditions of Acute Stress // *Byulleten Experimentalnoi Biologii i Meditsyny (Bulletin of Experimental Biology and Medicine)*. – 2010, Volume 151, No. 2, pp. 186-189.
- [25] Tsymbal A.A., Kirichuk V.F. Effect of terahertz radiation at a frequency of 129 GHz atmospheric oxygen concentration of nitrite in the blood in different types of experimental stress on the background of the non-selective inhibitor of constitutive NO synthase isoforms // *Byulleten Experimentalnoi Biologii i Meditsyny (Bulletin of Experimental Biology and Medicine)*. – 2011, No. 10, pp. 416-419.
- [26] Kirichuk V.F., Ivanov A.N., Kulapina E.G. et.al. Effect of Terahertz Electromagnetic Irradiation at Nitric Oxide Frequencies on Concentration of Nitrites in Blood Serum of Albino Rats under Conditions of Immobilization Stress // *Byulleten Experimentalnoi Biologii i Meditsyny (Bulletin of Experimental Biology and Medicine)*. – 2011, Volume 149, No. 12, pp. 132-134.
- [27] Kirichuk V.F., Ivanov A.N., Velikanova T.S. et.al. Influence of endothelial NO synthase inhibitor L-Name and influence of electromagnetic terahertz waves at frequency of molecular spectrum of radiation and absorption of nitric oxide 150,176-150,664 GHz on system hemodynamic in mail rats subjected in conditions of immobilization stress// *Biomeditsynskaya radioelektronika (Biomedical Radioelectronics)*, 2011, №. 1, pp. 19-24.
- [28] V.F. Kirichuk, A.N. Ivanov, T.S. Kiriyazi The role of NO-synthase in the reaction of endothelium and changes in peripheral perfusion under the influence of electromagnetic terahertz waves at frequencies of nitric oxide in albino rats in a state of acute stress // *Biomeditsynskaya radioelektronika (Biomedical Radioelectronics)*, 2011, №. 8, pp. 12-18.
- [29] Ignarro L.J. Nitric oxide as a signaling molecule in the vascular system: an overview / L.J. Ignarro, G.Cirino, A.Casino // *J. Cardiovasc. Pharmacol.* – 1999. – 34. – p. 879-886.
- [30] Addicks K. Nitric oxide modulates sympathetic neurotransmission at the prejunctional level / K. Addicks, W. Bloch, M. Feelisch // *Microsc. Res. Technique.* – 1994. - №29. – P. 161 – 168.
- [31] Armstead W.M. Nitric oxide contributes to opioid release from glia during hypoxia / W.M. Armstead // *Brain Res.* – 1998. – V.813. – P. 398 – 401.
- [32] Naesh O. Platelet activation in mental stress / O. Naesh, C. Haedersdal, J. Hindberg // *Clin. Physiol.* – 1993. – V.13. – P. 299 – 307.