Hemodynamic Changes Induced by Preventive Exposure to Terahertz Radiation at a Frequency Range Corresponding to Molecular Emission and Absorption Spectrum of Nitric Oxide in Animals under Conditions of Acute Stress

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We studied the influence of preventive irradiation with terahertz electromagnetic waves at frequencies corresponding to nitric oxide emission and absorption molecular spectrum (150,176-150,664 GHz) on hemodynamic parameters in arteries of albino rats upon acute immobilization stress. We showed that exposure to the specified frequencies can produce adaptogenic effect manifesting in the absence of post-stress changes in the linear, systolic, and diastolic blood flow velocities and pressure gradient in various blood vessels of experimental animals.

Key Words: *hemodynamics; linear blood flow velocity; terahertz waves, nitric oxide*

Disturbances in systemic hemodynamics leading to inappropriate oxygen and nutrient supply to organs and tissues play an important role in the pathogenesis of cardiovascular diseases. Powerful central and peripheral stress-limiting systems, *e.g.* NO system [9-11] can prevent the development of adaptation diseases. NO acts as a neurotransmitter, endogenous vasodilator, and antiaggregant [13].

Modern approaches to pharmacological regulation of NO often lead to undesirable and even harmful side effects. The search for new non-drug and non-invasive methods of NO synthesis regulation are now in progress. Application of low-intensity irradiation of millimeter and submillimeter frequency ranges, or THF-therapy [2,4,7], is one of such techniques. THF-band of electromagnetic waves is challenging first of all because it contains molecular spectra of emission and absorption (MSEA) of important cell metabolites, such as NO, CO_2, and O_2 [14].

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Here we studied the effect of preventive THF irradiation on NO MSEA frequencies 150,176-150,664 GHz on hemodynamic parameters in albino rats under conditions of acute immobilization stress (AIS).

MATERIALS AND METHODS

The study was conducted on 75 male random-bred albino rats weighing 180-220 g. Control (n=15) and reference (AIS; n=15) groups underwent the same irradiation-related manipulations, as animals of experimental groups. Experiments were carried out in adherence Order of Ministry of Public Health issued on August 12, 1977 (as of October 20, 2006), Federal Law On Prevention of Cruelty to Animals issued on December 1, 1999, Geneva Convention (1990) and World Medical Association Declaration of Helsinki.

We used AIS as the model of hemodynamic parameters impairment [8].

Before AIS, the animals were exposed to THF waves on a KVCh-NO-Orbita generator on a frequency range of NO MSEA 150,176-150,664 GHz for 5, 15, or 30 min (15 animals per group).

Blood flow in the carotid artery, abdominal aorta, and femoral artery was analyzed by Dopplerography using a MM-D-F ultrasound portative microprocessor device (Minimax) [3,5]. An ultrasound Doppler transducer with working frequency of ultrasonography 10 MHz [6] was used. The following parameters of hemodynamics were recorded: mean linear blood flow velocity, systolic blood flow velocity, diastolic blood flow velocity, and pressure gradient.

For statistical analysis of experimental data, the hypotheses on the distribution types were analyzed using Shapiro-Wilk test. Since most data were not normally distributed, we used Mann-Whitney *U* test.

RESULTS

Under conditions of AIS, hemodynamic parameters were altered, which was accompanied by statistically significant increase in linear, systolic, and diastolic blood flow velocities and pressure gradient compared to the corresponding parameters in the control group (Tables 1 and 2). Thus, linear, systolic, and diastolic blood flow velocities in the abdominal aorta increased by 26, 15, and 77%, respectively, and the pressure gradient increased by 34%. In the femoral artery, the linear, systolic, and diastolic blood flow velocities increased by 50, 23, and, 25%, respectively, and the pressure gradient increased by 67%. Changes in the carotid artery hemodynamic indices were insufficient compared to stress (3-4%), which

TABLE 1. Effect of AIS and Preventive THF Irradiation on Hemodynamic Indices in the Abdominal Aorta of Male Rats

Index	Control	AIS	THF irradiation		
			5 min	15 min	30 min
Mean linear velocity, cm/sec	15.2 (14.04-15.8)	17.7 (17.17-20.6) *Z*1=-4.33446 *P*1=0.000015	15.05 (14.35-15.72) *Z*1=0.154672 *P*1=0.87708 *Z*2=4.025768 *P*2=0.000001	15.85 (5.19-16.43) *Z*1=-1.80775 *P*1=0.070646 *Z*2=4.70016 *P*2=0.000003	15.94 (15.39-16.66) *Z*1=-1.74574 *P*1=0.080857 *Z*2=4.058853 *P*2=0.000049
Mean systolic velocity, cm/sec	34.5 (32.93-37.64)	40.56 (35.28-43.91) *Z*1=-2.6546 *P*1=0.007941	32.54 (29.79-36.85) *Z*1=1.361114 *P*1=0.173479 *Z*2=3.511056 *P*2=0.000446	34.5 (29.79-36.85) *Z*1=0.66887 *P*1=0.503580 *Z*2=3.109337 *P*2=0.001875	32.54 (28.23-34.5) *Z*1=2.02943 *P*1=0.042416 *Z*2=3.666061 *P*2=0.000246
Mean diastolic velocity, cm/sec	3.13 (0.78-4.7)	3.92 (3.13-6.27) *Z*1=-2.0739 *P*1=9.038089	1.56 (0.78-3.13) Z1=1.562188 *P*1=0.118245 *Z*2=3.743064 *P*2=0.000182	2.35 (0.78-4.7) *Z*1=-0.054237 *P*1=0.95675 *Z*2=2.07897 *P*2=0.037626	2.35 (0.78-3.92) *Z*1=0.63283 *P*1=0.526844 *Z*2=2.531328 *P*2=0.011364
Pressure gradient, mm Hg	0.46 (0.40-0.54)	0.64 (0.49-0.73) *Z*1=-2.63386 *P*1=0.008443	0.4 (0.36-0.51) *Z*1=1.05177 *P*1=0.292906 *Z*2=3.232646 *P*2=0.001227	0.46 (0.33-0.51) *Z*1=0.37963 *P*1=0.704222 *Z*2=2.964716 *P*2=0.00303	0.4 (0.31-0.46) *Z*1=1.96396 *P*1=0.049535 *Z*2=3.513308 *P*2=0.000443

Note. Here and in Tables 2 and 3: in each case mean value (median), upper and lower quartiles of 15 measurements are shown. *Z*1, *P*1: compared to control; *Z*2, *P*2: compared to AIS.

TABLE 2. Effect of AIS and Preventive THF Irradiation on Hemodynamic Indices in the Femoral Artery of Male Rats

Index	Control	AIS	THF irradiation		
			5 min	15 min	30 min
Mean linear velocity, cm/sec	9.67 (8.48-10.39)	13.13 (12.01-13.91) *Z*1=-4.45889 *P*1=0.000008	10.15 (8.89-12.58) *Z*1=-1.11400 *P*1=0.265280 *Z*2=3.20983 *P*2=0.001328	10.46 (7.78-11.95) *Z*1=-1.24434 *P*1=0.213375 *Z*2=3.46342 *P*2=0.000533	11.02 (8.09-13.22) *Z*1=-1.01621 *P*1=0.309529 *Z*2=2.5509 *P*2=0.010745
Mean systolic velocity, cm/sec	21.17 (19.6-22.74)	24.30 (23.52-28.23) *Z*1=-3.85746 *P*1=0.000115	21.95 (20.38-22.74) *Z*1=-1.03848 *P*1=0.299050 *Z*2=3.37977 *P*2=0.000726	22.74 (19.60-25.09) *Z*1=-1.63838 *P*1=0.101343 *Z*2=1.80430 *P*2=0.071186	21.95 (18.82-24.3) *Z*1=-0.954 *P*1=0.340087 *Z*2=2.44721 *P*2=0.014397
Mean diastolic velocity, cm/sec	-1.57 (-2.36-0.78)	1.56 (0.78-3.92) *Z*1=-3.65007 *P*1=0.000262	0.00 (-2.36-0.78) *Z*1=-0.45315 *P*1=0.650439 *Z*2=3.34200 *P*2=0.000832	-0.79 (-2.36-1.56) *Z*1=-0.477 *P*1=0.633364 *Z*2=2.46795 *P*2=0.01359	0.00 (-0.79-1.56) *Z*1=-1.63838 *P*1=0.101343 *Z*2=2.38499 *P*2=0.01708
Pressure gradient, mm Hg	0.17 (0.14-0.19)	0.23 (0.21-0.33) *Z*1=-3.79524 *P*1=0.000148	0.17 (0.16-0.19) *Z*1=-0.92519 *P*1=0.354869 *Z*2=3.39865 *P*2=0.000677	0.19 (0.14-0.25) *Z*1=-1.61764 *P*1=0.105740 *Z*2=1.82503 *P*2=0.067997	0.17 (0.12-0.23) *Z*1=-0.82956 *P*1=0.406787 *Z*2=2.57104 *P*2=0.010122

attests to maintenance of cerebral perfusion at a constant level (Table 3).

THF irradiation of male rats at a frequency range of NO MSEA 150,176-150,664 GHz for 5 min before AIS was followed by adaptive response to stressor in the abdominal aorta, because all studied hemodynamic indices remained within normal and stable ranges typical of control animals. Further increase in exposure time to 15 and 30 min did not lead to potentiation of the biological effect of THF irradiation on hemodynamic indices as well (Table 1).

Under the effect of THF irradiation at the specified frequencies for 5 min, the studied hemodynamic indices in the femoral artery also remained at the level of control values, which is indicative of the adaptogenic effect of THF irradiation. Increasing irradiation time to 15 and 30 min did not change its biological effect on hemodynamic indices (Table 2).

In the carotid artery, no significant changes of the studied parameters of hemodynamics were observed under the influence of THF irradiation for 5, 15, or 30 min as compared to control, which is indicative of maintenance of cerebral perfusion at a constant level (Table 3).

These findings suggest that preventive THF irradiation with NO frequencies 150,176-150,664 GHz can prevent post-stress changes of hemodynamic indices on the experimental model of hemodynamic disturbances caused by AIS. This allows using THF waves with frequencies corresponding to NO molecular emission and absorption spectra (150,176—150,664 GHz) for prevention of hemodynamic disturbances in some pathological states.

REFERENCES

1. O. V. Betsky, A. P. Krenitsky, A. V. Mayborodin, and V. D. Tupikin, *Apparatus for Patient Treatment with Electromagnetic Waves of Extremely High Frequencies*, Useful model patent No. 50835, issued on 27.01.2006.
2. O. V. Betsky, A. P. Krenitsky, A. V. Mayborodin, and V. D. Tupikin, *Biomed. Tekhnol. I Radioelektron*, No. 12, 3-6 (2003).
3. T. D. Vlasov, D. E. Korgevsky, M. B. Guirina, *et al.*, *Regionarnoe Krovoobraschenie i Mikrotsirkuliatsia,* No. 1, 66-71 (2002).

TABLE 3. Effect of AIS and Preventive THF Irradiation on Hemodynamic Indices in the Carotid Artery of Male Rats

Index	Control	AIS	THF irradiation		
			5 min	15 min	30 min
Mean linear velocity, cm/sec	13.44 (12.92-13.70)	13.79 (13.13-14.01)	13.73 (13.40-14.16)	13.86 (13.62-14.04)	13.67 (13.30-14.35)
		*Z*1=-1.80430	*Z*1=-1.69929	*Z*1=-1.91171	*Z*1=-1.54346
		*P*1=0.071186	*P*1=0.089266	*P*1=0.055914	*P*1=0.122721
			*Z*2=-0.16270	*Z*2=-0.27639	*Z*2=0.086711
			*P*2=0.870756	*P*2=0.782247	*P*2=0.930901
Mean systolic velocity, cm/sec	29.01 (25.87-32.93)	29.79 (29.01-32.93)	27.84 (25.87-31.36)	25.87 (25.09-29.01)	26.66 (25.09-29.79)
		*Z*1=-0.78808	*Z*1=0.59656	*Z*1=1.68139	*Z*1=1.63017
		*P*1=0.430649	*P*1=0.550802	*P*1=0.092689	*P*1=0.103067
			*Z*2=1.77160	*Z*2=2.671790	*Z*2=2.826779
			*P*2=0.076462	*P*2=0.007545	*P*2=0.004702
Mean diastolic velocity, cm/sec	1.56 (0.78-2.35)	3.13 (1.56-3.13)	3.13 (1.56-3.92)	2.35 (2.35-3.92)	2.35 (1.56-3.13)
		*Z*1=-1.24434	*Z*1=-2.07892	*Z*1=-1.93474	*Z*1=0.068618
		*P*1=0.213375	*P*1=0.037626	*P*1=0.053023	*P*1=1.85394
			*Z*2=-1.03042	*Z*2=-0.43762	*Z*2=0.017342
			*P*2=0.302814	*P*2=0.661662	*P*2=0.986164
Pressure gradient, mm Hg	0.33 (0.25-0.40)	0.33 (0.33-0.40)	0.30 (0.25-0.38)	0.25 (0.25-0.33)	0.29 (0.25-0.33)
		*Z*1=-0.80882	*Z*1=0.61464	*Z*1=1.58925	*Z*1=1.49143
		*P*1=0.418618	*P*1=0.62031	*P*1=0.112004	*P*1=0.135850
			*Z*2=1.73544	*Z*2=2.510561	*Z*2=2.930832
			*P*2=0.082663	*P*2=0.012054	*P*2=0.003381

4. T. V. Golovacheva, V. D. Petrova, and S. S. Parshina, *Millimetrovye Volny v Biol. i Med.*, No.1, 18-25 (2000).
5. R. A. Domashenko, Yu. S. Andogskaya, G. L. Plotkin, and M. B. Guirina, *Regionarnoe Krovoobraschenie i Mikrotsirkuliatsia*, No. 4, 76-78 (2002).
6. T. A. Zelenina, N. V. Vorokhobina, O. F. Malygina, and Ya. O. Papp, *Regionarnoe Krovoobraschenie i Mikrotsirkuliatsia*, No 2, 53-59 (2005).
7. V. F. Kirichuck, T. V. Golovacheva, and A. G. Chige, *EHF-Therapy* [in Russian], Saratov (1999).
8. V. F. Kirichuck, A. N. Ivanov, O. N. Antipova, *et al.*, *Tsitologiya*, **47**, No. 1, 64-70 (2005).
9. I. Yu. Malyshev and E. B. Manukhina, *Biokhimiya*, **63**, No. 7, 992-1006 (1998).
10. E. B. Manukhina and I. Yu. Malyshev, *Ross. Fiziol. Zh.*, **86**, No. 10, 1283-1292 (2000).
11. F. Z. Meerson, *Adaptation Medicine: Mechanisms and Protective Effects* [in Russian], Moscow (1993).
12. R. G. Oganov and G. Ya. Maslennikova, *Kardiologiya*, **40**, No. 6, 4-8 (2000).
13. L. J. Ignarro, G. Cirino, A. Casino, and C. Napoli, *J. Cardiovasc. Pharmacol.*, **34**, No. 6, 879-886 (1999).
14. L. S. Rothman, A. Barbe, D. C. Benner, *et al.*, *J. Quant. Spectroscopy & Radiative Transfer.*, No. 82, 5-44 (2003).