Effect of High Power Terahertz Irradiation on Platelet Aggregation and Behavioral Reactions of Albino Rats

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Intensive terahertz irradiation at the nitric oxide emission and absorption spectrum frequencies (150.176-150.664 GHz) applied for 60 min to male albino rats subjected to acute immobilization stress enhanced platelet aggregation and induced signs of depression.

Key Words: *extremely high frequencies*; *terahertz irradiation; platelet aggregation*

Rapid development of electronic communication system, broadcasting, and television actualizes the problem of long-term effects of electromagnetic radiation (EMR) on human health. The study of the influence of EMR on human and animal behavior revealed the role of receptors in the realization of biological effects of electromagnetic irradiation, its direct action on the brain, cerebral glial cells, neuronal membrane, memory, conditioned reflex activity, and the blood-brain barrier [10,11]. Moreover, EMR enhances motor activity and provokes epileptic discharges revealed by EEG, stimulates the pituitary—adrenal system, increases blood epinephrine level, and activates blood coagulation.

EMR at extremely high frequencies (EHF) is widely used in medical practice; it proved to be an efficient tool in the treatment of various diseases due to normalizing and recovery action on the basic mechanisms of general pathological processes [1,2,4-7]. Numerous studies revealed a favorable effect of EHF EMR on the dynamics of hemostasis and fibrinolysis. This plays an important role in the treatment of the disturbances at various stages of the hemostatic system in patients with myocardial infarction, angina pectoris [9], and vascular disorders in the spinal cord and brain [8].

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The therapeutic effect of EMR at EHF and at the terahertz frequencies (THF) that correspond to molecular emission and absorption spectra (MEAS) of various cell metabolites (specifically, NO) was observed only at small power of irradiation [4-7]. The effects of high-power terahertz electromagnetic waves on biological objects are little studied.

Our aim was to study the effects of pulsed terahertz irradiation at frequencies of 150.176-150.664 GHz on behavioral reactions and aggregation activity of the platelets of albino rats subjected to acute immobilization stress.

MATERIALS AND METHODS

The experiments were carried out on 75 male randombred albino rats weighing 180-220 g: 15 control (intact) and 60 experimental (acute immobilization stress) animals [10].

Behavioral reactions were examined in a Small maze. A hungry animal could get feed only after it escaped from the intricate maze with numerous blind alleys. The following indices were used to assess behavioral reactions: the total time of maze passage, the number of visited blind alleys, and the total grooming (washing) time.

Platelet aggregation was measured on a 230LA Platelet Aggregation Analyzer (Biola) [3]. ADP in a final concentration of 2.5 μM was applied as aggregation inductor. To examine the effect of THF irradiation on behavioral reaction and functional activity of plate-

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lets, we used a G4-161/1 High-Frequency Programmable Signal Generator.

For evaluation of the effect of EMR on aggregation properties of platelets, it was directed to a shaved skin (3 cm^2) over the xiphoid process of the sternum. To assess the effect of EMR on rat behavior in a Small maze, the exposed site was a shaven skin locus (3 cm^2) located on the head. In both cases, the irradiator was

TABLE 1. Changes in Platelet Aggregation Indices in Male Albino Rats Induced by Terahertz Irradiation at 150.176-150.664 GHz with Various Exposure Time

Index	Control (*n*=15)	Acute stress (*n*=15)	Irradiation		
			15 min (*n*=15)	30 min (*n*=15)	60 min (*n*=15)
Maximum size of platelet aggregate, arb. units	2.23 (1.91;2.39)	6.85 (6.15;7.13) P_1=0.000003 Z_1=4.66	6.46 (6.11;6.8) P_2=0.319507 Z_2=0.99	6.99 (6.2;7.1) P_3=0.506915 Z_3=0.66	8.05 (6.94;9.21) P_4=0.003943 Z_4=2.88
Time to form the greatest platelet aggregate, sec	41.26 (39;45)	59.6 (50;75) P_1=0.000019 Z_1=4.27	52.2 (39;54) P_2=0.158466 Z_2=1.41	52.46 (39;54) P_3=0.205843 Z_3=1.26	52.66 (50;57) P_4=0.271695 Z_4=1.09
Maximum rate of formation of the greatest platelet aggregate, arb. units	2.72 (1.98;3.19)	12.13 (10.4;13.1) P_1=0.000003 Z_1=4.66	11.44 (10.4;11.7) P_2=0.693551 Z_2=0.39	12.48 (11.1;13.1) P_3=0.533830 Z_3=0.62	14.9 (11.7;17.4) P_4=0.006592 Z_4=2.71
Time to maximum aggregation rate in developing the greatest platelet aggregate, sec	33.13 (31;36)	40.4 (36;42) P_1=0.000391 Z_1=3.54	39.06 (36;42) P_2=0.755736 Z_2=0.31	38.46 (36;39) P_3=0.493731 Z_3=0.68	39.66 (34;42) P_4=0.708923 Z_4=0.37
Maximum degree of aggregation, %	43.62 (35.4;50.3)	64.62 (57;69.7) P_1=0.000004 Z_1=4.62	61.77 (53;68) P_2=0.430649 Z_2=0.78	62.73 (53;69.7) P_3=0.520283 Z_3=0.64	68.5 (57;85.7) P_4=0.633364 Z_4=0.47
Time to the maximum degree of aggregation, sec	205.2 (186;216)	231.2 (207;258) P_1=0.036204 Z_1=2.09	226.33 (189;258) P_2=0.755736 Z_2=0.31	218.2 (189;243) P_3=0.229030 Z_3=1.2	212.06 (202;213) P_4=0.101343 Z_4=1.63
Maximum aggregation rate, %	63.47 (51.3;71.6)	86.11 (75.1;93.2) P_1=0.000048 Z_1=4.06	82.72 (75.1;97.9) P_2=0.983454 Z_2=0.02	85.26 (75.3;85.6) P_3=0.868226 Z_3=0.16	94.32 (75.4;112) P_4=0.205843 Z_4=1.26
Time to maximum aggregation rate, sec	48.06 (43;52)	55.73 (48;66) P_1=0.009532 Z_1=2.59	52.93 (48;57) P_2=0.280843 Z_2=1.07	51.2 (45;57) P_3=0.046488 Z_3=1.99	61.13 (58;68) P_4=0.031017 Z_4=2.15

Note. Here and in Table 2: shown are the mean values (*Me*, median) and the lower and upper quartiles (25%, 75%). P_1 and Z_1 are confidence levels for the differences between the control and stressed rats; P_2 and Z_2 are the corresponding values for stressed rats and stressed rats exposed to EMR irradiation for 15 min; P_3 and Z_3 the same for stressed rats and stressed rats exposed to EMR irradiation for 30 min; P_4 and Z_4 the same for stressed rats and stressed rats exposed to EMR irradiation for 60 min.

TABLE 2. Effect of Terahertz Irradiation at 150.176-150.664 GHz and Various Exposure Time on Behavior of Male Albino Rats in Small Maze

Index	Control (n=15)	Acute stress (n=15)	Irradiation		
			15 min (n=15)	30 min (n=15)	60 min (n=15)
Total time of maze passage, min	1.54 (1.38;1.7)	2.57 (2.4;2.7) P_1=0.000003 Z_1=4.66	2.63 (2.4;2.9) P_2=0.724416 Z_2=0.35	2.8 (2.5;3) P_3=0.038089 Z_3=2.02	6.52 (4.9;7.9) P_4=0.000003 Z_4=4.66
Number of visits to blind alleys	0.2 (0;0)	1.06 (0;2) P_1=0.005114 Z_1=3.09	1.13 (1;2) P_2=0.835705 Z_2=0.22	1.2 (1;2) P_3=0.533830 Z_3=0.68	3.66 (3;4) P_4=0.000003 Z_4=4.75
Total grooming time, min	0.25 (0.16; 0.33)	0.83 (0.7;0.92) P_1=0.000003 Z_1=4.66	0.81 (0.76;0.95) P_2=0.787462 Z_2=0.27	1.02 (0.88;1.2) P_3=0.019104 Z_3=2.34	2.22 (1.7;2.7) P_4=0.000003 Z_4=4.66

placed at a distance of 1.5 cm over the skin. The radiation power was 4 mW and power flow 3 mW/cm^2.

The experiments on animals were carried out in strict adherence to USSR Ministry of Health Directive No. 755 (August 12, 1977) "Measures to further improve the institutional framework in the studies involving experimental animals" (by the state to October 20, 2006), Federal Law "On protection of animals against cruel treatment" (December 1, 2006), Geneva Convention "International Guiding Principles for Biomedical Research Involving Animals" (Geneva, 1990), and World Medical Association Declaration of Helsinki on Human Treatment of experimental animals (Helsinki, 2000).

The data were statistically processed using Statistica 6.0 software.

RESULTS

Acute immobilization stress increased all indices of aggregation activity of platelets, which reflected disturbance of intravascular component of microcirculation (Table 1). The total time of maze passage, the number of visited blind alleys, and total grooming time significantly increased (Table 2).

Irradiation of animals subjected to acute immobilization stress by high-power terahertz waves at NO MEAS frequencies of 150.176-150.664 GHz for 15 min did not normalize indices characterizing aggregation properties of the platelets and behavioral reactions (Tables 1 and 2). Similarly, irradiation for 30 min produced no significant changes in indices of aggregation capacity of platelets in comparison with the data obtained during acute immobilization stress before irradiation. However, the total time of maze passage and total grooming time significantly increased. Irradiation for 60 min further increased functional activity of platelets previously enhanced by the stress. In addition, irradiation significantly increased the maximum size of platelet aggregate, the maximum rate of the formation of the greatest platelet aggregates, and the time to maximum aggregation rate in comparison with the stressed but non-irradiated rats. Examination of the behavioral reactions revealed signs of depression in irradiated rats: the total time of maze passage, total grooming time, and the number of visited blind alleys increased.

It can be hypothesized that long-term high-power irradiation at the NO MEAS frequencies of 150.176-150.664 GHz stimulates production of NO molecules, enhances their reaction activity, and promotes transformation of NO into peroxynitrites producing a toxic effect on brain structures responsible for behavioral reaction and elevates the aggregation ability of platelets. In addition, the external electromagnetic field interacts with intrinsic electrical behavior of neurons, which can diminish membrane permeability and disturb the excitation-inhibition balance in favor of the inhibitory processes in the cerebral cortex and in the brainstem.

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