Peculiarities of the Effect of Terahertz Radiation at Nitric Oxide Frequencies on Gaseous and Electrolyte Composition of the Blood in Different Types of Stress

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We studied the effect of terahertz radiation at NO frequencies 150.176-150.664 GHz on gaseous and electrolyte composition of the blood in albino rats during stress. Partial or complete recovery of the studied parameters of blood gases and electrolytes in stressed animals was observed after 15- and 30-min terahertz irradiation at NO frequencies, respectively.

Key Words: *blood gases; electrolytes; terahertz radiation; nitric oxide*

The problem of stress, adaptation, and prevention of stress-induced damage is now one of the most urgent problems of modern biology and medicine. Stress is associated with blood redistribution in the organism and centralization of the blood flow. This impairs blood supply to organs and tissues and leads to hypoxemia and a complex of secondary nonspecific metabolic and functional disturbances [7]. Hence, correction of blood gasses, in particular, oxygenation level is pathogenetically substantiated.

Electromagnetic waves in frequency range of 10^2-10^4 GHz (or wavelengths from 3 mm to 30 μ) are called terahertz waves [2]. Biological effects of terahertz waves (THz) open prospects for the development of innovation trends in biomedical technologies: terahertz therapy and terahertz diagnostics [2]. Electromagnetic THz waves with frequencies of 150.176-150.664 GHz corresponding to NO molecular emission and absorption spectrum are of particular interest, because NO is a universal regulator of physiological, pathophysiological, and biochemical processes in the cell and in the whole organism [8].

Here we studied the effect of THz waves at frequencies of NO molecular spectrum 150.176-150.664 GHz on post-stress disturbances in the gaseous and electrolyte composition of the blood in albino rats.

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MATERIALS AND METHODS

Blood samples from 84 outbred albino male rats weighing 180-220 g were examined. Immobilization stress was used for modeling disturbances in gaseous and electrolyte composition of the blood. Single 3-h fixation in the supine position was used as the model of acute stress (AS). Daily 3-h immobilization in the supine position for 5 days was used as the model of chronic stress (CS) [4].

The animals were divided into 7 groups (12 rats per group). Group 1 (control) comprised intact rats, groups 2 and 3 consisted of rats subjected to AS and CS, groups 4 and 5 included experimental animals irradiated for 15 and 30 min, respectively, against the background of AS, and groups 6 and 7 included experimental animals irradiated for 15 and 30 min, respectively, against the background of AS.

Skin area (3 cm^2) above the xiphoid processus of the sternum was irradiated with electromagtetic waves at a frequency of 150.176-150.664 GHz corresponding to NO molecular radiation and absorption spectrum using a KVCh-NO apparatus. The radiator was positioned at a distance of 1.5 cm above the skin. The radiation power was 0.7 mW and power density

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0.2 mW/cm² [5]. During the experiments all animals were maintained under the same conditions.

The gaseous and electrolyte composition of the blood (pH, Pco_2, Po_2, concentration of bicarbonate HCO_3, Na^+, and K^+ ions) was studied using a Rapidlab 348 analyzer (Bayer diagnostics).

The animal experiments were performed in accordance to the principles of the Declaration of Helsinki (October 2000). The data were processed statistically using Statistica 6.0 software. The differences were significant at $p<0.05$.

RESULTS

Changes in blood gases were revealed in rats subjected to AS. This manifested in a decrease in pH, Pco_2, and concentrations of bicarbonate, and pronounced decrease in Po_2. Some changes in electrolyte composition of the blood were also observed in stressed animals: the concentration of potassium ions increased, while concentration of sodium salts was little changed (Table 1).

In rats subjected to CS, more pronounced and significant changes in gaseous and electrolyte composition of the blood were revealed. This manifested in more marked pH drop, decrease in bicarbonate and Pco_2 concentration, and in more pronounced decrease in Po_2. Under conditions of CS we observed a more pronounced and significant increase in the concentration of potassium ions compared to the control, but the concentration of sodium ions remained unchanged (Table 2).

Thus, changes in gaseous and electrolyte composition of the blood are the effector elements of AS and CS. The most pronounced changes in the studied parameters were detected under conditions of CS. This can be explained by activation of the sympathoadrenal system and enhanced release of epinephrine, epinephrine, and glucocorticoids into circulation, which leads to spasm of peripheral vessels, blood flow impairment, and development of ischemia and hypoxia accompanied by a complex of secondary metabolic and functional disorders. On the other hand, oxygen deficit in tissues is aggravated due to activation of glycolysis, lipolysis, and proteolysis under the effect of catecholamines and glucocorticoids, which leads to excessive accumulation of acid metabolites (lactate, piruvate, ketoacids, and suboxidized products) and appearance of signs of metabolic acidosis. In turn, pH drop via central chemoreceptors stimulates pulmonary ventilation. The decrease in Pco_2 in response to pH drop observed in our experiments is a sign of respiratory compensation. An increase in K^+ concentration in blood plasma is a result of the release of intracellular potassium to the extracellular space.

Exposure of male rats subjected to AS to THz radiation at NO frequencies of 150.176-150.664 GHz for 15 min partially normalized the parameters of gaseous and electrolyte parameters of the blood. This mani-

TABLE 1. Changes in Gaseous and Electrolytic Composition of the Blood in Albino Rats in AS against the Background of Exposure to Electromagnetic THz Radiation at NO Frequencies 150.176-150.664 GHz

Parameter	Intact animals (*n*=12)	AS (*n*=12)	Irradiation against the background of AS	
			15 min (*n*=12)	30 min (*n*=12)
pH (active reaction of the blood)	7.37	7.30*	7.32*	7.34^{+o}
	(7.24; 7.42)	(7.20; 7.34)	(7.30; 7.37)	(7.21; 7.39)
Pco_2, mm Hg	45.0	42.4*	44.1^{+}	45.9^{+}
	(42.3; 49.3)	(39.7; 47.2)	(41.0; 47.8)	(42.1; 50.3)
Po_2, mm Hg	40.6	32.1**	36.2^{*+}	47.9^{*++oo}
	(37.1; 47.2)	(30.1; 37.2)	(31.1; 40.2)	(42.3; 54.2)
HCO_3, mmol/liter	24.6	21.1*	22.2*	25.1^{+o}
	(20.8; 27.3)	(19.0; 24.3)	(19.4; 25.1)	(20.0; 28.1)
Concentration of sodium ions, mmol/liter	137.3	135.0	134.5	136.0
	(130.8; 144.3)	(131.0; 141.5)	(130.1; 146.1)	(130.4; 141.1)
Concentration of potassium ions, mmol/liter	4.0	5.2*	4.4^{+}	4.3^{+}
	(3.2; 5.1)	(4.0; 6.0)	(3.0; 5.0)	(3.1; 5.4)

Note. Here and in Table 2: medians and the lower and upper quartiles (25%, 75%) are presented for the corresponding number of measurements. One symbol: $p<0.05$, two symbols: $p<0.01$ compared to: *intact, ⁺AS, °15-min irradiation.

TABLE 2. Changes in Gaseous and Electrolytic Composition of the Blood in Albino Rats in CS against the Background of Exposure to Electromagnetic THz Radiation at NO Frequencies 150.176-150.664 GHz

Parameter	Intact animals (n=12)	CS (n=12)	Irradiation against the background of CS	
			15 min (n=12)	30 min (n=12)
pH (active reaction of the blood)	7.37 (7.24; 7.42)	7.28* (7.18; 7.31)	7.30* (7.26; 7.38)	7.35^{+o} (7.20; 7.41)
Pco_2, mm Hg	45.0 (42.3; 49.3)	40.4* (37.5; 44.2)	45.7^{+} (42.1; 48.9)	46.2^{+} (42.0; 51.9)
Po_2, mm Hg	40.6 (37.1; 47.2)	30.0** (28.1; 34.2)	32.1* (30.1; 35.1)	46.0^{*++oo} (41.4; 52.3)
HCO_3, mmol/liter	24.6 (20.8; 27.3)	20.0* (18.0; 23.2)	23.0^{+} (20.5; 27.4)	24.0^{+} (21.0; 26.9)
Concentration of sodium ions, mmol/liter	137.3 (130.8; 144.3)	139.0 (131.1; 142.4)	138.5 (131.5; 145.1)	139.3 (131.2; 146.2)
Concentration of potassium ions, mmol/liter	4.0 (3.2; 5.1)	5.5* (4.0; 6.3)	4.5^{+} (3.7; 5.3)	4.2^{+} (3.0; 5.0)

Note. One symbol: p<0.05, two symbols: p<0.01 compared to: *intact, $^{+}$CS, ^{o}15-min irradiation.

fested in significant normalization of Pco_2 and increase in O_2 content in the blood. Blood concentration of potassium ions significantly normalized compared to stressed animals. No significant effects of THz in the specified regimen on other studied parameters were revealed (Table 1).

Exposure of male rats subjected to CS to THz radiation for 15 min also partially normalized the parameters of gaseous and electrolyte parameters of the blood. For instance, we observed normalization of Pco_2 and bicarbonate and potassium concentrations compared to immobilized animals. At the same time, Pco_2, pH, and concentration of sodium ions did not significantly differ from those in rats subjected to AS (Table 2).

Exposure of male rats subjected to both AS and to THz radiation at NO frequencies for 30 min completely normalized gaseous and electrolyte parameters of the blood. Other studied parameters in this group did not statistically differ from the control. After 30-min irradiation at THz frequencies corresponding to NO molecular spectrum, Po_2 of the blood was even higher than in the control group (Table 1, 2).

Thus, 30-min irradiation with electromagnetic THz waves at NO frequencies 150.176-150.664 GHz was most effective for normalization of the parameters of gaseous and electrolyte composition of the blood.

It is known that NO plays a role of a stress-limiting factor reducing the release of pituitary stress hormones and catecholamines in synaptic structures and from the adrenals [8].

It was demonstrated that irradiation with THz waves at NO frequencies during the exposure to the stress factor prevented the development of stress-dependent shifts of the parameters of gaseous and electrolyte composition of the blood. This can be related to increased reaction capacity of free endogenous NO or to its accumulation due to the action of THz radiation on NO synthases [1,4-6]. On the other hand, NO can promote hemoprotein activation and increase hemoglobin content to oxygen thus increasing blood oxygenation [3].

It should be also noted that electromagnetic THz radiation at NO frequencies 150.176-150.664 Hz also produced a pronounced stress-limiting effect [4-6].

Our experimental findings suggest that THz radiation at NO frequencies can be used for correction of shifts in gaseous blood composition accompanying some pathological states.

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