Biophysical approach to the correction of supporting tissue microcirculation impairments

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Abstract. By experimental and histological methods it was estimated that application of terahertz –frequency electro-magnetic radiation at 150,176 – 150,664 GHz frequency at the background of acute and chronic immobilization stress contributes to the decrease of occurrence incidence of microcirculation impairments in the bone tissue and red bone marrow. The presented findings give the grounds to assume that terahertz – frequency electro-magnetic radiation at the frequency of molecular spectrum absorption and radiation of nitrogen oxide may be recommended as a valid and effective method in the complex treatment of patients with orthopedo-traumatological pathology.

Keywords: electromagnetic radiation, terahertz range, nitric oxide, bone tissue, microcirculation, immobilization stress, skeletal trauma, orthopedics pathology.

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1 Introduction

In traumas of the supportive-locomotive system hemostasis is impaired at macro- and microlevels due to the effect of an extreme factor. One of the basic pathogenetic units determining the markedness of catabolic processes in the bone tissue during the nearest post-traumatic period, is the impairment of microcirculation [4,7]. Recently, the most commonly used medicamentous correction of microcirculation impairments includes treatment with anticoagulants, non-steroid anti-inflammation agents and desaggregants [5]. The presence of contraindications to the use of these preparations or the lack of the desired effect of their usage [5] prove the necessity to search for new methods

(including non-medicamentous ones) of microcirculation impairments' correction.

One of effective methods aimed to improve microcirculation in the damaged tissues is short-wave-frequency (SWF) therapy widely used in orthopedo-traumatological practice [2,3]. According to the opinion of a number of researchers, the study of the effect of terahertz –frequency (THF) radiation on microcirculation at the frequency of molecular spectrum absorption and radiation of nitrogen oxide (MSARNO) – a neurotransmitter, powerful hemostasis factor, thrombocyte aggregation inhibitor, endogenic vasodilator, - is, at the moment, of great scientific and practical interest [1,2,3,6,8]. Some investigations present the findings which prove the positive effect of electro-magnetic radiation (EMR) of THF range at MSARNO frequency on rheological properties of blood [1].

The aim of the present investigation is to study EMR THF MSARNO application effectiveness for correction of microcirculation impairments in the bone tissue.

2 Methods of the investigation

This work was based on the experimental method of investigation. The experiments were carried out on 135 white non-bred male rats of 180 – 220 g of weight. The animals were kept in standard vivarium conditions. Experimental studies were performed according to the principles of laboratory practice of the Russian Federation, and according to the requirements of Geneva Convention «International Guiding Principles for Biomedical Research Involving Animals» (Geneva, 1990). The experiments were carried out in a separate laboratory excluding outside effects, dietary errors, at constant air temperature of 18 – 22 0C, with standard levels of light and moisture, unification of seasonal and daily cycles.

Microcirculation impairments were modelled by means of immobilization stress: in acute stress variant – maximum fixation of the rats on the back for 3 hours, in chronic stress variant - maximum fixation of the rats on the back during 5 days for 3 hours a day.

The study consisted of 9 series of experiments, each including 15 animals. In the 1-st series acute immobilization stress without additional outside effects was modelled. In the next 3 series the animals were radiated with EMR THF MSARNO (150,176 – 150,66 GHz) at the background of acute immobilization stress. The source of radiation was placed at the distance of 1,5 cm from the skin surface of 3 cm² area above the sternal region (power density was 0,2 mWt/ cm²). In the 2-nd series the duration of radiation was 5 minutes, in the 3-d - 15 minutes, in the 4-th – 30 minutes. In the 5-th series chronic immobilization stress without additional outside effects was modelled. In the 6-th – 8-th series the animals were radiated with EMR THF MSARNO at the background of chronic immobilization stress. The duration of radiation was 5, 15, 30 minutes in the 6-th, 7-th and 8-th series respectively. The 9-th series of the experiment was intact control. At the end of the experiment the animals were decapitated in accordance to the basic principles of euthanasia. Series of cytological and histological samples of blood, red bone marrow (RBM), breastbone, femoral bones were prepared. The serial samples were stained with hematoxylin and eosine, according to Romanovsky – Gimse technique, with toluidine blue solution.

When studying the obtained preparations the presence and markedness of various signs, characterizing impairments in the vascular, intravascular and extravascular units of the microcirculation channel of the bone tissue and red bone marrow, were taken into consideration.

3 Results and discussion

It was established that in immobilization stress (to greater extent – in chronic, to lesser extent – in acute) the most significant changes occurred in capillaries and post-capillaries, where the signs of stasis, aggregation and sludge of the blood formed elements were noted. Leucocyte adhesion, high edgt position of the laminar vessels' surface with migration to the perivascular region were observed in the venules. In the system of the microcirculation channel the picture of amorphic – type sludge (according to V.V.Kuprianov, 1969) was formed. Parietal areas contained thrombocytic groups which gave the evidence of the tendency to thromboformation. All the above mentioned changes caused stasis in post-capillary-venular section, reduction of a significant amount of capillaries, which lost their functional properties. All units of the microcirculation channel were subjected to pathological transformation. Changes in smooth muscular and endothelial cells of the vessels aggravated and were accompanied by metachromasia, masaic hyperchromasia; signs of dystrophy of all cellular elements, connective tissue fibers and perivascular structures became more pronounced, - all these changes were accompanied by intensification of deformation of the vessels' contours. Alongside the passage of the vessels of metabolic and refluence units of the microcirculation channel all the objects of the investigation (the bone tissue and red bone marrow) showed aggravated perivascular edema, cell infiltration, which were caused by the increase of the vascular wall permeability. The number of the network capillaries with the formation of loop-shaped capillary complexes and extensive avascular regions was significantly reduced. The red bone marrow in the animals of the 5-th group looked like that consisting predominantly of cells, hemopoietic cells were arranged into islands, stroma elements were poorly differentiated. There were revealed the signs of dystrophy; a significant amount of stroma cells; the number of hemopoietic activity foci was significantly reduced; the number of cells in some islands was decreased, in other islands the reduction of the red bone marrow was observed. In the animals subjected to the effect of acute immobilization stress the incidence of impairments in intravascular and vascular microcirculation units was significantly close to the analogous indices observed in

chronic stress modelling. In particular, vascular dystonia occurred in all the animals in both acute and chronic stress. Under the influence of acute immobilization stress extravascular microcirculation impairments of the bone tissue and red bone marrow occurred 1,5 – 1,7 times more rarely as compared to the effect of chronic stress. In acute stress intravascular microcirculation impairments also occurred 1,2 – 1,4 times more rarely as compared to chronic stress. In particular, erythrocyte hemolysis in acute stress modelling was noted in 1/3 of the experimental animals, while in chronic stress it was observed in almost half of the cases (Table 1).

Table 1 Relative incidence (%) of occurrence of the signs of microcirculation impairments in the bone tissue and red bone marrow of experimental animals at acute and chronic immobilization stress modelling.

Unit of microcirculation channel (number of the signs analyzed)	**Acute immobilization stress (n=15)**	**Chronic immobilization stress (n=15)**
Vascular unit (8 signs)	76,6%	91,6%
Intravascular unit (8 signs)	75%	93,3%
Extravascular unit (5 signs)	70,6%	97,3%

There was noted practically equal decrease of the incidence of the impairments' occurrence in all three units of the microcirculation channel in the bone tissue and red bone marrow in the animals subjected to the influence of acute immobilization stress at the background of radiation during 5 minutes and 30 minutes as compared to the effect of acute stress without radiation (Table 2).

Table 2 Relative incidence (%) of occurrence of the signs of microcirculation impairments in the bone tissue and red bone marrow of experimental animals at the modelling of acute immobilization stress at the background of radiation with EMR THF 150,176-150,664 GHz.

Unit of microcirculation channel (number of the signs analyzed)	**Duration of radiation with EMR THF 150,176-150,664 GHz**		
	5 minutes (n=15)	**15 minutes (n=15)**	**30 minutes (n=15)**
Vascular unit 8 signs)	55%	7,5%	46,6%
Intravascular unit (8 signs)	44,2%	2,5%	35,8%
Extravascular unit (5 signs)	41,3%	4%	32%

Besides, the incidence of occurrence of the majority of the signs of microcirculation impairments at 30 – minute radiation was less as compared to 5 – minute radiation regimen (Table 2). In the animals subjected to the influence of acute immobilization stress at the background of 15 – minute radiation, practically complete normalization of the bone tissue and red bone marrow microcirculation conditions was noted in accordance with zero indices of the incidence of occurrence of the majority of the corresponding signs. Moreover, the incidence of occurrence of some signs of microcirculation impairments (dystonia and swelling of the vascular wall, focal perivascular edema, interstitial edema, poikilocytosis) in the animals of that experimental series did not exceed 1/5.

The analysis of the impairments' incidence in intravascular, vascular and extravascular units of the bone tissue and red bone marrow microcirculation channel in the animals subjected to the effect of chronic immobilization stress made it possible to establish significantly equal decrease of that index at the background of 5 – minute and 30 – minute radiation. Besides, when comparing the corresponding indices between the above mentioned experimental series of the animals, there was noted the tendency to more pronounced decrease of the incidence of occurrence of the majority of signs of microcirculation impairments at 30 – minute radiation as compared to 5 – minute radiation (Table 3).

Table 3 Relative incidence (%) of occurrence of the signs of microcirculation impairments in the bone tissue and red bone marrow of experimental animals at the modelling of chronic immobilization stress at the background of radiation with EMR THF 150,176-150,664 GHz.

Unit of microcirculation channel (number of the signs analyzed)	**Duration of radiation with EMR THF 150,176-150,664 GHz**		
	5 minutes (n=15)	**15 minutes (n=15)**	**30 minutes (n=15)**
Vascular unit (8 signs)	50%	26,6%	45%
Intravascular unit (8 signs)	45%	17,5%	38,3%
Extravascular unit (5 signs)	62,6%	30,6%	52%

The animals under chronic immobilization stress at the background of 15 – minute radiation, as compared to other experimental series of chronic stress modelling, demonstrated maximum degree of correction of microcirculation impairments in the bone tissue and red bone marrow, in accordance to the minimal incidence indices of the majority of corresponding signs. The incidence of occurrence some signs of microcirculation impairments (dystonia and swelling of the vascular wall, focal perivascular edema, capillary network reduction; metachromasia of Haversian canals' elements; bone matrix acidophilia) in the animals of that experimental series did not exceed 1/3, the signs of erythrocyte hemolysis were noted in none of the cases.

4 Conclusion

Application of radiation with EMR THF at 150,176-150,664 GHz frequency at the background of acute and chronic immobilization stress contributes to the decrease of occurrence incidence of microcirculation impairments in the bone tissue and red bone marrow. It has been established that in experimental conditions the effect of EMR THF at the frequency of molecular spectrum of absorption and radiation of nitrogen oxide (150,176-150,664 GHz) on microcirculation impairments in the supporting tissues under immobilization stress depends on the radiation duration. The highest degree of correction of the supporting tissue microcirculation impairments is reached by application of 15-minute radiation duration.

The presented findings give the grounds to assume that EMR THF MSARNO may be recommended as a valid and effective method in the complex treatment of patients with orthopedo-traumatological pathology.