Changes of the arteries vertebrobasilar pool hemodynamics under the influence of low intensity millimetre radiation

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Abstract. It has been shown that low-intensity millimetre radiation (wavelength - 7.1 mm, power flux density - 0.1 mW / cm²) changes the hemodynamics of vertebrovascular pool in healthy subjects. The low-intensity millimeter radiation increases the velocity characteristics of vertebrobasilar pool arteries (blood flow velocity in systole, blood flow velocity in diastole), increases pulsating index, decreases the arterial resistance (decrease of resistance index), and also normalizes cerebrovascular reactivity in functional tests with hyperventilation and breath holding. These data indicate that millimetre waves decrease the arterial tone. Different mechanisms of these changes were observed. Changes in the hemodynamics indices of the arteries vertebrobasilar pool were noted after 5 sessions after the action of millimetric waves. The changes in the velocity characteristics of the blood flow and cerebrovascular reactivity hemodynamics of vertebrobasilar pool are observed with prolonged exposure of low-intensity millimetre radiation. The low-intensity factor has a mild modulating effect on hemodynamic, without going beyond the standard values.

1. Introduction

There are numerous biological and therapeutic effects of low-intensity millimeter (mm) radiation (power flux density - 0.1 mW/cm²). Reviews on therapeutic efficacy are collected in Betsky's monograph [1]. There are many studies devoted to the beneficial effects of mm waves on the cardiovascular system. A possible mechanism of the mm-waves biotropic action is a resonant effect on the biochemical and biophysical processes that trigger a cascade of subsequent physiological changes. There is an assumption that the specific interaction of living structures with electromagnetic radiation mm-range is due to the existence of a natural generator of this type radiation. This determines the functioning of living structures and controls their homeostasis.

At the same time, the biological effect is detected with a significant deviation from normal functioning. That is why there is a high biological effectiveness in diseases. However, studies on healthy subjects can help to understand the mechanism of this type radiation exposure. Therefore, it is urgent to study the response of cerebral vessels to the action of mm-waves in healthy subjects. Thus, the aim of this study was to assess the effect of low-intensity millimeter radiation (wavelength - 7.1 mm, power flux density – 0.1 mVt/cm²) on the cerebral arteries functioning in healthy people.
2. Materials and methods
The study was carried out on a basis of the Laboratory for assessing functional state of a person at the Department of Human and Animal Physiology and Biophysics of the Taurida Academy, V. I. Vernadsky Crimean Federal University.

The study involved 15 healthy student volunteers, aged 20-25 years. All subjects gave their voluntary consent to participate in the study.

The experimental action of EMR EHF was carried out using a single-channel therapeutic generator "EHF. RAMED. EXPERT-01" (wavelength - 7.1 mm, power flux density - 0.1 mW / cm²) every day, for 10 days, with an exposure of 30 minutes on the area of a shoulder joint right hand. The affected area has many biologically active points, receptive to millimeter radiation.

The hemodynamics of vertebrobasilar pool arteries was researched before the exposure of low-intensity factor, on 5th and 10th days of the physical factor impact.

The hemodynamics of vertebral arteries and basilar arteries was researched on the doppler apparatus «Sonomed 300» by the sensor at frequency 2 MHz.

Doppler ultrasonography of the vertebrobasilar pool arteries was performed before the exposure of the low-intensity factor, on 5th and 10th days of the low-intensity factor exposure.

The following indicators were assessed:
- \( V_s \) is the maximum systole blood flow velocity;
- \( V_d \) is the diastole blood flow velocity;
- \( V_{aver} \) is an average blood flow velocity for the cardiac cycle;
- \( R_i \) is the index of circulatory resistance (resistivity) (Purcelo index), i.e. the ratio of difference between the maximum systole and final diastole velocities to the maximum systolic velocity, reflects the state of resistance to blood flow distal to the measurement site.

\[
R_i = \frac{(V_s - V_d)}{V_s}
\]  

(1)

\( P_i \) is the pulsation index (Gosling index), i.e. the ratio of difference between the maximum systole and diastole velocities to the average velocity, reflects the resilient-elastic properties of the arteries and decreases with age.

\[
P_i = \frac{(V_s - V_d)}{V_{aver}}
\]  

(2)

To evaluate the arteries reactivity functional tests were performed: hyperventilation and hypercapnia tests for the basilar artery.

In hypercapnia test there are changes in registrations of speed indicators during the period of breath holding (\( V_s \text{ CO}_2 \)). In hyperventilation test there are registered changes of blood velocity indicators during the period of deep respiratory excursions (\( V_s \text{ O}_2 \)).

Based on the results of functional tests there were calculations of cerebrovascular reactivity (CVR). This index was evaluated according to the following formula:

\[
\text{CRV} (\%) = \frac{V_s(CO_2) - V_s O_2}{V_s} \times 100,
\]  

(3)

where \( V_s \) is the initial values of velocity blood flow in the systole before the functional test.

The CRV index makes it possible to judge the severity of adaptive reactions.

Statistic data processing was carried out using the nonparametric Mann-Whitney test in the Statistica 8.0 software package. The average and its error were calculated.

3. Results and discussion
As the study results show, the indicators of velocity blood flow for the basilar artery and vertebral arteries, registered before the low-intensity factor exposure are standard values. So, for the basilar artery the velocity indices were: \( V_s \) was 68.44 ± 5.15 cm/s, \( V_d \) - 33.2 ± 3.30 cm / s, \( R_i \) - 0.51 ± 0.03, \( P_i \) - 0.69 ± 0.062.

The data for the vertebral arteries are the following: on the right vertebral artery \( V_s \) was 75.05 ± 3.58 cm / s (76 ± 9 cm / s), \( V_d \) - 33.54 ± 2.24 cm / s, \( R_i \) - 0.55 ± 0.04, \( P_i \) - 0.76 ± 0.08;
on the left vertebral artery $V_s$ was $72.17 \pm 5.65$ cm / s, $V_d$ - $34.53 \pm 2.97$ cm / s ($35 \pm 6$ cm / s), $R_i$ - $0.52 \pm 0.04$, $P_i$ - $0.7 \pm 0.08$.

The course of MM-waves action contributed to the change in the parameters of cerebral hemodynamics. The low-intensity factor action on 5th day led to the increase of $P_i$ index by the basilar artery by 6.91% ($p \leq 0.05$), which was $0.74 \pm 0.05$. These changes indicate a decrease in the vessel resistance proximal to the place of application of the sensor.

At the same time, a 5-fold exposure of the low-intensity factor contributed to the increase in $V_d$ for the left vertebral artery by 6.79% ($p \leq 0.05$). After MM-exposure, this indicator was $36.88 \pm 2.96$ cm /s.

More significant changes in cerebral blood flow were observed after 10 days exposure of MM radiation. So, the 10-days of MM-waves course impact contributed to the increase in $V_s$ for the basilar artery by 6.31% ($p \leq 0.05$), after which this indicator was $72.76 \pm 3.30$ cm / s.

Similar changes were induced in vertebral arteries in both sides under the action of MM-radiation: increase in $V_s$ on the right by 5.48% ($p \leq 0.001$) and on the left by 6.54% ($p \leq 0.001$), respectively, an increase in $V_d$ on the right by 11.17% ($p \leq 0.001$), on the left - by 5.88% ($p \leq 0.05$). Thus, $V_s$ for vertebral arteries on the right was $79.16 \pm 3.76$ cm / s and on the left - $76.9 \pm 4.33$ cm / s, $V_d$ for vertebral arteries was $37.29 \pm 2.39$ cm / s on the right and $37.57 \pm 2.88$cm / s left (Figure 1).

![Changes in doppler ultrasound indices along the vertebral arteries when exposed to millimeter radiation.](image)

Note: significance of differences according to Wilcoxon test at* - $p \leq 0.05$. 

Figure 1. Changes in doppler ultrasound indices along the vertebral arteries when exposed to millimeter radiation.
These changes, received in this study, indicate to unidirectional changes: increase in Vs for basilar artery and for vertebral arteries on both sides under the influence of 10-fold exposure to MM-waves and Vd for vertebral arteries. These changes indicate the decrease in peripheral resistance.

In addition, the changes, concerning the calculated indices, were noted: increase in Pi for basilar artery was noted not only after 5-fold, but also after 10-fold exposure to MM-waves, maximum by 8.83% (p≤0.001) and Pi was 0.76 ± 0.05 (Figure 2).

An increase in the pulsation index is accompanied by a decrease in resistance in the areas where the basilar artery is more proximal to the application of the sensor.

At the same time, according to the vertebral arteries on the right, a decrease in Ri was recorded, after a 10-day course of low-intensity exposure factor by 4.25% (p≤0.05) and this indicator after a course of MM waves was 0.53 ± 0.03. A decrease in this indicator is accompanied by a decrease in resistance to blood flow distal to the measurement site, probably due to both vasodilation and activation of the shunt blood flow.

It is important to note that the changes observed during MM-waves exposure did not go beyond the normative values. This fact indicates a mild modulating effect on cerebral blood flow, expressed in an increase in the speed indicators of blood flow, and those indices characterizing elastic properties of the vessels.

An important aspect of the functioning of blood vessels is their adequate response to influencing factors. At the same time, the vascular response is determined by the initial state of the vascular tone. The cerebral vessels are of high sensitivity to the changes in blood gases. One of the simplest and at the same time informative methods for recording of the vascular reactivity is functional tests with breath holding and hyperventilation; and the determination defines a cerebrovascular reactivity index (CVR).

Thus, before the impact of MM-waves, the CRV level was 78.58%, which is slightly below the norm (> 80%), which indicates initial disturbances in adaptive vascular reactions in response to changes in the gas composition of the blood. After 10-fold exposure the level of CRV increased by 5.82% (p≤0.05) and amounted to 84.4%, and it was normalized (Figure 3).

Thus, in this study it was shown that the course of MM-waves increases in speed indicators and the level of pulsation, against the background of a decrease in vessels resistance. These changes can be associated with the change in the elastic properties of the arteriolar wall under the influence of MM waves.
Figure 3. Dynamics of the coefficient of cerebrovascular reactivity (CVR) by the action of the low-intensity millimetric radiation course.
Note: significance of differences according to Wilcoxon test at* - p<0.05. Figure with short caption (caption centred).

Probably, the changes under the action of low-intensity MM-radiation on the vertebrobasilar arteries tone may be due to the following reasons. It is known that cerebral vessels have pure innervations. For the greatest extent, the arteries tone can be determined by local factors, as well as by substances circulating in the blood. Thus, catecholamines, circulating in the blood, contribute to the formation of the arterial tone. For example, the previous studies have shown that MM-radiation changes the activity of the sympathoadrenal system [2].

The nervous regulation can be mediated by the changes in the activity and synthesis of neuropeptides that have a vasotropic effect: substance P, vasoactive intestinal peptide (VIP) and neuropeptide Y, calcitonin-gene-related peptide (CGRP). These peptides have been identified in many animals and humans by immunohistochemical, radiometric, and biochemical methods. In rat cerebral arteries, 40% of nerve terminals contain VIP, 35% - neuropeptide Y and 5% - substance P. According to the generally accepted hypothesis, VIP is a cofactor for cholinergic axons, and neuropeptide Y - adrenergic; substance P is located in afferent nerve fibers and endings with electron-dense vesicles 120 nm in diameter [3]. It has been shown that the substance P has the ability to relax smooth muscle cells, presumably using an axon reflex accompanied by vasodilation.

VIP induces cholinergic-independent relaxation of intracranial arteries and arterioles. The peptides are contained in the vesicles of nerve terminals, often together with acetylcholine.

Neuropeptide Y is a typical vasoconstrictor by properties; in the experiment, it causes a decrease in the lumen of intracerebral arterioles to 81% of their diameter. It is assumed that neuropeptide Y is a modulator that increases the constrictor effect of biogenic monoamines. At the same time, it is possible that neuropeptides Y and VIP can act as mediators if their content in the axon is predominant (or exclusive) over catecholamines or acetylcholine.

The previous studies have shown an increase in antidromic releasing of vasoactive peptides under the influence of mm radiation course [4], which was accompanied by an increase in the severity of the response (increase in perfusion) of microvessels with subsequent stimulation of peptidergic vasmotors. The effect is mediated, presumably, by VIP and substance R.

Possibly, in the present study, the increase in the rate parameters and the pulsation index, among other things, may be due to the release of vasoactive peptides.

The reception of the MM radiation can be carried out by the venous wall, since its tissues belong to type B tissues according to Labori (1970), equipped with metabolic blocks of the pentose phosphate cycle, glycolysis and the tricarboxylic acid cycle, and therefore sensitive, according to N.P. Zalyubovskaya [5], to low-intensity mm-radiation. The metabolic effect of mm-impact on these
formations consists in the intensification of the pentose phosphate cycle, which leads to the activation of the potassium pump. This circumstance is accompanied by the change in the level of potassium in the environment surrounding the cell, causing excitation of peptidergic nerve fibers of the skin, secreting substance P, CGRP, VIP, neurotensin, modulating vascular tone by peptidergic innervation of microvessels. These data are consistent with the physiological concept of I.V. Rodshtat [6], where the primary target of EMR MM-range is water molecules associated with the protein structures of skin collagen, through which excitation is carried out in skin receptors - Ruffini's bodies. Next, the preganglionic synaptic neurons of the lateral horns of the spinal cord and the small intensely fluorescent neurons located in the autonomic ganglia are excited. The biologically active substances (biogenic amines, neuropeptides, prostaglandins, alpha2-macroglobulin) are released into the blood and tissue fluid. These substances initiate a chain reaction, causing further changes in the body and forming the therapeutic effect of microwave radiation.

In addition, a decrease in arterial tone may be due by change in the activity / synthesis / transport of humoral substances, including NO, in response to the acetylcholine action. Thus, it has been previously shown that the concentration and activity of metabolites of nitric oxide, which is the main paracrine vasodilator [7], increases under the influence of MM-waves. This possibly also contributes to the increase in velocity parameters under the influence of MM-waves in this study. In addition, NO synthesis can also be caused by the effect of substance P on the vascular endothelium, an increase in the activity of which, among other things, is also noted under the influence of MM waves.

4. Conclusions
1. Low-intensity millimeter radiation (wavelength – 7.1 mm, power flux density – 0.1 mW / cm²) contributes to an increase in the velocity parameters of the vertebrobasilar pool arteries: increase in the velocity blood flow in systole and velocity blood flow in diastole.
2. Millimeter radiation promotes the normalization of cerebrovascular reactivity of the basilar artery in response to changes in the gas composition of the blood.

5. References
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