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CLINICAL RESEARCH

The Influence of Radiofrequency Electromagnetic Radiation on the Platelet Aggregation

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Abstract

The purpose of this study was to examine the impact of radiofrequency electromagnetic fields (RF-EMFs) on platelet aggregation (PA) in individuals working for a long time under a direct and continuous RF-EMF exposure. We examined 119 persons aged from 22 to 65 years. In individuals working under the direct and constant exposure to RF-EMFs, the various changes of PA with a predominance of hyperaggregation are detected. The dependence of the changes in the indicators of PA on length of work in conditions of RF-EMF exposure is determined.

Keywords: *platelet aggregation; radiofrequency electromagnetic fields.*

Introduction

Exposure to electromagnetic fields (EMF) is not a new phenomenon. However, during the 20th century, environmental exposure to man-made EMF has been steadily increasing as growing electricity demand, ever-advancing technologies and changes in social behavior have created more and more artificial sources. Over the course of the past decade, numerous EMF sources have become the focus of health concerns, and the problem of electromagnetic safety has become extremely important.

There are two main forms of EMF: radiofrequency (RF)-EMFs and extremely low-frequency (ELF)-EMFs. The frequencies of RF-EMFs are ranging from 3 kHz to 300 GHz. EMI from different artificial sources irradiating in different frequency diapasons has a pronounced effect on living organisms. The two known actions of RF-EMFs on living matter are assessed: thermal (due to dielectric heating of molecules); and non-thermal (mechanisms not due to local or whole body increases in temperature). The mainstream view is that the only potential danger from RF-EMFs stems from their heating effects on tissue. However, there is strong evidence to suggest that the athermal effects of RF-EMFs also contribute to various health problems. Recently, it has been shown that RF-EMFs with extremely high frequencies may influence practically all known types of cells in systems of arbitrary organization levels of living material [1-3]. Changes in blood–brain barrier have been reported after exposure to RF-EMFs of 915, 1200, 1300, 2450, and 2800 MHz, and effects on calcium metabolism have been reported at 50, 147, 450, and 915 MHz [4-8]. RF-EMFs have been given a 2B classification – possibly carcinogenic – by the International Agency for Research on Cancer (IARC) [9].

It is known that in extreme conditions adaptation processes are initiated in organism: mobilization of reserve possibilities, reconstruction of homeostatic mechanisms, plastic and energetic exchange intensity change. The majority of the biological studies on RFR have been conducted with short-term exposures, i.e., a few minutes to several hours. Little is known about the effects of long-term exposure. An important question regarding the biological effects of RF-EMFs is whether the effects are cumulative, i.e., after repeated exposure, will a biological system adapt to the perturbation and, with continued exposure, when will homeostasis break down leading to irreparable damage [10]?

Among "*diseases of adaptation*" [11], the cardiovascular diseases (CVDs) are crucial. CVDs include a number of clinical entities, among which hypertension and coronary heart disease are the most important. CVDs continue to occupy a leading position in the causes of death and disability. A disturbance of microcirculation plays a leading role in the pathogenesis of CVDs [12-14]. A microcirculatory bed is a place where the transport function of the cardiovascular system is eventually realized and provides the transcapillary exchange, creating the need for living tissue homeostasis. In the functioning of the intravascular component of microcirculation, the vascular-

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platelet component of hemostasis is of great importance. Platelets play an important role in the development of pathological processes such as thrombosis and atherosclerosis. Data on platelet function in terms of the whole organism in individuals working for a long time under the influence of RF-EMF is absent.

The purpose of this study was to examine the impact of RF-EMFs on platelet aggregation (PA) in individuals working for a long time under a direct and continuous RF-EMF exposure.

Material and methods

We have studied the effects of RF-EMFs on PA in persons working under the direct and continuous RF-EMF exposure. We examined 119 persons aged from 22 to 65 years. Informed consent was obtained from each patient. The study was approved by the Tashkent Institute of Postgraduate Medical Education.

Depending on the duration of RF-EMF exposure, the examinees were divided into six main groups: Group I (n=15) worked under conditions of systematic prolonged RF-EMF exposure (up to 6:00 per day) for 5 years, Group II (n=17) for 6–10 years, Group III (n=25) for 11–15 years, Group IV (n=24) for 16–20 years, Group V (n=18) for 21–25 years, and Group VI (n=20) over 25 years. The control group included 15 healthy volunteers.

The observed persons had higher or secondary technical education and held various positions—engineers, electrician mechanics, electrical steeplejacks—who were in the same operating conditions. The power density (PD) on the ground-commissioning works was 24μW/cm^2 (norm -16.724 μW/cm^2), which exceeds the maximum allowable level of PD by 43.71%. The range of electromagnetic radiation was 650-800MHz. The labor schedule was based on a 12-hour shift.

We used a comprehensive health assessment based on consideration of the general biological background in statistical analysis of morbidity. This assessment provides constant monitoring of the health team for at least three years. To assess the health status we used three key indicators: primary attendance, the results of periodic examinations in the form of a confirmed diagnosis, and data on the functional state of the body (blood pressure, electrocardiography, radiography, and laboratory tests).

Platelet aggregation activity was studied between 09:00 and 11:00. The change in light transmission of platelet-rich plasma was used to evaluate in vitro platelet aggregation and was measured in an aggregation analyzer PEC-56 (Russia) at 37°C according to the method of M.A. Howard (1986). The venous blood was taken after overnight fasting and stabilized by 3.8% trisodium citrate (in a ratio 9:1). Citrated blood was centrifuged at 200g for 10 minutes to obtain platelet-rich plasma and for 20 minutes to obtain platelet- poor plasma.

Platelet-rich plasma (1.2-1.5 mL) were added to a PEC cuvette with optical path length of 3 mm and the absorbance was measured at a wavelength of 500-560 nm (green filter) against distilled water. After 1 min, ADP (5 μM) was added, optical density of the platelet-rich plasma, *as well as* platelet-poor plasma, was *determined* after 1,3,5 and 10 minutes of incubation. The intensity (IPA,%) and the rate (RPA,%/min) of PA were determined [15].

Results were statistically processed using the *software* package Statistica 6.1. The mean (M) and standard error of the mean (m) were calculated. Analysis of the distribution of values obtained was performed using the Kolmogorov-Smirnov test. For data with normal distribution, inter-group comparisons were performed using Student's t-test. The Mann-Whitney (U Test) was used to compare the differences between the two independent groups (for nonparametric data). A value of $P<0.05$ was considered statistically significant.

Results and Discussion

In surveyed individuals, working in conditions of RF-EMF exposure, the various changes in PA curves toward hyperaggregation were identified (Fig.1), while in the control group, hyperaggregation was detected in 58.5% of patients. Hyperaggregation of platelets was observed in 60% of Group I patients, in 62.6% of Group II, in 68.4% of Group III, in 76.6% of Group IV, in 78.4% of Group V and 84.2% of Group VI patients. Therefore, there has been an increase of ADP-induced PA with increased length of work. Along with the increase of hyperaggregation, a decrease of hypoaggregation and normoaggregation was detected.

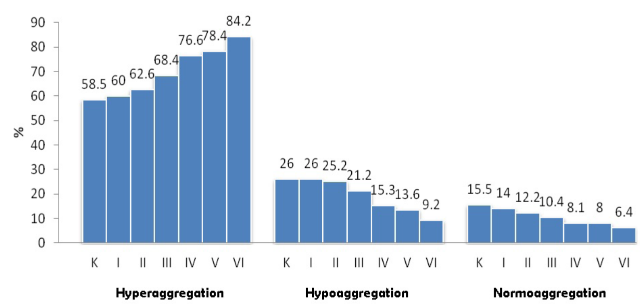

Figure 1. *Features of platelet aggregation*

We have noted significant differences in the parameters of the intensity and the rate of PA in the persons working under the influence of RF-EMF compared with healthy volunteers (Table 1). The rate of PA in Groups III-VI was significantly different from the control values, i.e. in persons working for over 11 years under the influence of RF-EMF. The highest percentage of platelet hypoaggregation and platelet hyperaggregation was observed in the group with the length of work over 25 years: 8.0±0.71%/min and 16.4±1.44% /min, respectively. That was 45% and 57% below the reference values.

Analysis of the intensity of PA in the surveyed individuals revealed similar dynamics in normoaggregation and hypoaggregation in Groups V and VI. Thus, in individuals with normoaggregation, the intensity of PA was 61.2±3.03% in the control group and 52.1±4.51% in Group VI ($P<0.05$), which was 15% below control values. In patients with platelet hyperaggregation, the intensity of PA was 25.1±2.13% in the control group and 20.1±1.03% and 19.8±0.78% in Groups V and VI, which were lower by 20% and 21%, respectively.

Table 1.

Platelet aggregation (agg) in individuals, working in conditions of RF-EMF exposure

Group		Normo-agg	Hyper-agg	Hypo-agg
Control	IPA, %	61.2±3.03	79.2±4.01	25.1±2.13
	RPA, %/min	28.0±1.96	37.8±2.14	14.6±1.12
Croup I	IPA, %	62.6±5.86	80.4±7.64	25.1±2.01
	RPA, %/min	27.3±2.13	35.4±2.76	13.8±1.56
Croup II	IPA, %	60.4±4.51	79.6±5.84	24.6±2.08
	RPA, %/min	26.0±1.78	33.2±2.18	13.1±1.02
Croup III	IPA, %	58.1±4.53	79.4±6.01	24.0±2.11
	RPA, %/min	23.2±1.56*	27.8±1.72*	10.2±1.01*
Croup IV	IPA, %	54.2±4.02	79.0±6.21	22.6±2.13
	C_KA % min	19.6±1.56*	26.0±1.64*	9.8±0.87*
Croup V	IPA, %	53.6±4.50	78.6±6.44	20.1±1.03*
	RPA, %/min	18.5±1.46*	19.6±1.71*	9.1±0.78*
Croup VI	IPA, %	52.1±4.51*	78.4±6.01	19.8±1.33*
	RPA, %/min	15.7±1.55*	16.4±1.44*	8.0±0.71*

** - p<0.05 vs control group.*

It is known that the cell generates EMF of a wide range during one's lifetime. The millimeter and submillimeter ranges were used by the cells for information exchange, which is necessary for the regulation of intracellular functions and cell-cell interactions. This is supported by the appearance of a number of effects, both in individual cells and the whole organism, in response to RF-EMF. Under the RF-EMF exposure, the directed displacement of ions, the redistribution of electric charges, and polarization take place. Oscillatory motion of the charged corpuscles lead to different intramolecular physicochemical and structural adjustments, promoting change in the functional activity of cells, including platelets. As a result, the nonspecific metabolic reactions (phosphorylation of proteins, receptor activation) determining the hyperactivity of platelets consistently occur in platelets, which are lined up in the form of the "sludge" chain in parallel to the force lines of the electrical field. Thus, the structure of the cell membrane is changed: the membrane is destroyed and intermolecular bonds are ruptured. Platelet-derived factors, such as adenosine diphosphate, thromboxane A2, serotonin and others, are activated. Changes in the structure of the platelet membrane lead to the activation of the receptor complex GPIIβ/IIIα, which mediates PA. The emergence of a large number of circulating platelet aggregates impairs blood rheology and microcirculation. The blockage of microcirculation is accompanied by impaired functioning of organs and systems.

It is also known there are low-frequency bio-currents in the human body. The heart generates electrical oscillations with frequencies from 30 to 700Hz and the brain from 200 to 500Hz. If the frequency of bio-currents coincides with the frequency of the EMF, the bio-currents are distorted, which leads to disruption of normal functioning of the body. Microcirculatory disorders and hyperactivity of platelets further exacerbate this situation.

Conclusion

The results of our study confirm the deleterious effect RF-EMF both on the blood cells and on blood rheology. In individuals working under the direct and constant exposure to RF-EMFs, the various changes of PA with a predominance of hyperaggregation are detected. The dependence of the changes in the indicators of PA on length of work in conditions of RF-EMF exposure is determined.

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