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EFFECTS OF MICROWAVE RADIATION AND MELATONIN ON THE ACTIVITY OF ALKALINE AND ACID DNASE IN THE RAT BRAIN

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The toxic effect of the microwave radiation (MW) on human health usually manifests with the occurrence of various unspecified such as irritability, neurovegetative dystonia and insomnia. In the brain microwave radiation leads to thermal damage, oxidative stress induction and molecular changes in DNA. Melatonin is a neurohormone and a powerful antioxidant that reduces the damage of brain cells. The goal of this research is to analyze DNA fragmentation through the activity of alkaline and acid DNase in conditions of exposure to MW in the brain tissue and to monitor the melatonin effect on the activity of these enzymes. Wister rats were divided into four experimental groups: I(control), II(Mel)-the animals were given melatonin daily (2mg/kg), III(MW) animals were exposed to the MW for 20, 40 and 60 days (4h daily), IV(MW+Mel)-the rats that were given melatonin and were exposed to the MW as well. Animals were sacrificed after 20, 40 and 60 days of the experiment. In the brain of the rats that were exposed to microwave radiation a significant increase in the alkaline DNase activity (after 60 days) ($p < 0.05$) and acid DNase (after 20 days) ($p < 0.001$) were observed when compared to the control group. In animals that were exposed to microwave radiation and that were given melatonin a significant decrease in the acid DNase activity was observed in the brain when compared to the irradiated animals that were not given melatonin. It can be concluded that melatonin exerts significant anti-apoptotic and neuroprotective effect in the brain of animals exposed to the microwave radiation.

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Key words: *Melatonin, Microwave radiation, DNase, Brain*

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Introduction

The toxic effect of the microwave radiation (MW) on human health usually manifests with the occurrence of various unspecified symptoms, such as irritability, neurovegetative dystonia, and insomnia (1). Experimental animals exposed to relatively low microwave radiation intensity show signs of long-term memory and orientation capabilities disorders (2). Frequent exposures to the microwave radiation cause acute diseases and weakening of the immune system. It has been shown that if the person sleeps in the microwave radiation zone the organism recovery is not satisfying, the process of sleeping is superficial and intermittent and the person wakes up tired and unwilling. Usually, these persons complain at exhaustion, depression, nervousness, allergic manifestations, insomnia, a non-refreshing dream, nightmares, headaches, numbness in arms and legs.

Microwave radiation absorbed by the tissue converts into heat and manifests thermal effect. High temperature within tissues and organs leads to the damage of its function. This primarily refers to those tissues and organs with limited circulation and therewith constrained capability of releasing excess heat (usually refers to eyes and testicles) (3).

The non-thermal effects of microwave radiation lead to the induction of oxidative stress, as well as changes in DNA molecules and proteins in the brain tissue of experimental animals (4). Microwave radiation leads to the development of numerous disorders at the cellular level, such as the increased release of calcium ions in the culture of human neuroblastoma cells (5), the reduction in melatonin secretion or the disbalance in the dopamine-opiate system (6).

Numerous studies have shown the ability of microwave radiation to cause DNA damage and thus cause the carcinogenic effect. Lai and Singh (1995) have shown that microwave radiation dosage dependently causes interruptions of one or both DNA chains in brain cells of experimental animals. Later studies confirm that this is a consequence of damage to DNA reparation mechanisms, leading to cell apoptosis (7). It has been found that this DNA damage can be prevented by the use of anti-oxidants, immediately before and after exposure. This suggests that free radicals may play a significant role in the pathogenesis of DNA damage caused by microwave radiation. These effects are particularly expressed in the nerve tissue since neurons have a lower ability to repair DNA molecules.

Numerous studies suggest that long-term damage to DNA molecules by microwave radiation can lead to the formation of various neurodegenerative diseases, such as Alzheimer's and Huntington's disease. Since nerve cells do not show the ability to divide, malignancy is unlikely to occur and is most often the result of DNA damage, a disorder in cell function and/or the occurrence of cell death, which can lead to the development of neurodegenerative diseases or the acceleration of their development. On the other hand, another type of brain cells – glial cells may be malignantly altered due to DNA damage.

Long-term exposure to microwave radiation leads to the apoptosis in the brain tissue. The final result of the apoptosis is the fragmentation of DNA molecules by the endonuclease (DNase), which breaks down DNA chains at precisely defined sites. Endonucleases are enzymes that catalyze the proliferation of inter-nucleotide bonds simultaneously at several sites within the nucleic acid molecule. DNases are hydrolytic enzymes which disrupt both native and denaturated DNA molecules. Recently, DNasees have been increasingly referred to as chief executors of apoptosis responsible for the interleukemal fragmentation of the DNA cell into apoptosis. DNases responsible for the apoptosis may be classified into three groups: 1) alkaline DNase (DNase I), 2) CAD (caspase 3-dependent DNase) and 3) acidic DNase (DNase II) (Counis et Torriglia, 2000).

Melatonin is a neurohormone and is primarily synthesized and released from the pineal gland during the night, as its synthesis and secretion is inhibited by the light. Because its blood concentrations are significantly higher during the night and much lower throughout the day, it is often called "hormone of darkness" (8). It has been proven that this hormone recovers or even prevents the ageing process and the cancer development. In a lesser extent, melatonin is synthesized in extra-pineal tissues such as the retina, lens, brain tissue, thymus, respiratory epithelium, bone marrow, digestive tract epithelium, ovary, testicle, placenta, lymphocytes, and skin. Melatonin shows its effects by activating two G-protein-linked receptors (MT1 and MT2) (9). Melatonin receptors are located on the cell membrane and in the nucleus of CNS cells. However, some effects of melatonin are independent of the receptor, so that it can bind to calmodulin, thereby exhibiting antagonistic effects on the intracellular Ca-binding protein (10).

The Aim of study

This study aims to analyze DNA fragmentation, measuring the activity of alkaline and acidic DNase in conditions of exposure to microwave radiation in the brain tissue, and monitor the effect of melatonin on the activity of these enzymes.

Material and Methods

Experimental model

In the experiment white male rats of Wistar species (aged 8 to 10 weeks) were used, weighing about 200 grams, grown at the Institute for Biomedical Research, Medical School in Niš. The work with experimental animals was in accordance with the decisions of the Ethics Committee of the Medical Faculty in Niš.

For the purpose of the experiment, an experimental model was used for the exposure to microwave radiation, consisting of a mobile test phone and a PC measuring controller. Using this PC measuring device, the mobile phone is brought into a state of emission that corresponds to the normal mode of operation during a telephone conversation. The mobile test phone (Nokia Mobile Phones Ltd.) was located in a plexiglass box that was placed in the middle of the cage at the height of the floor. All animals were in plexiglass cages 30x40x40 cm in size.

Animals were exposed to microwave radiation in all experimental groups 4 hours a day, then moved to a room without sources of the electromagnetic field. Exposure to microwave radiation lasted for 20, 40 and 60 days. The electromagnetic field parameters in the cage were measured using the SPECTRAN HF 6080 instrument, manufactured by AARONIA AG (Germany). The range of the measured values of power, electric and magnetic fields were: E=9,884-18,356 V/m (electric field) and B=4,68-8,69 μT (magnetic field). Based on these parameters, the Specific Absorption Rate (SAR) for the whole body of the rat was calculated from 0.043 to 0.135 W/kg.

Laboratory animals (total 84) were divided into 4 experimental groups: I group (Control) – animals were intraperitoneally (i.p.) daily administered per 1,0 ml of saline; II group (Mel) - animals are given daily melatonin at a dose of 2 mg/kg body weight, intraperitoneally; III group (MW) – the animals were exposed to the microwave radiation of the mobile phone 4 hours a day, and 30 minutes before radiation they were applied to 1.0 ml of saline solution (i.p.); IV group (MW+Mel) – animals that are daily administered melatonin (at a dose of 2 mg/kg) are exposed to microwave radiation every day for 4 hours. Seven animals from each group were successively sacrificed after 20, 40 and 60 days of the experiment.

The animals were sacrificed after the experiment, in Ketamine Anesthesia (2 ml/kg BM), after a starvation period of 15 hours. After sacrificing experimental animals, the brain tissue was washed multiple times in a cold isotonic NaCl solution, immediately frozen at -20 °C and kept until homogenization. A 10% homogenate was then prepared in distilled water at 0 °C (on ice) using a homogenizer (IKA® Works de Brasil Ltd Taquara, RJ 22713-00).

Biochemical methods

Measurement of the activity of DNase (alkaline and acidic). The activity of DNase (alkaline and acidic) was determined by the method of Bartholeynes et al. (1975), using DNA as a substrate (Sigma-Aldrich, St. Louis, MO, USA) (11). This method is based on the spectrophotometric measurement of "acid-soluble nucleotides" extinction of which is read at 260 nm in the UV spectrum. The activity of the alkaline DNase was determined at an optimum pH of 7.4 with the use of TRIS-HCl buffer, with the addition of the Mg^{2+} ion activator, and the acidic DNase activity using the acetate buffer pH 5.0. The unit of activity of these two enzymes is defined by an increase in the absorbance of 0.001/min in a sample containing 0.132 mg of DNA at pH 7.4 or pH 5.0 and 3 ml of the reaction mixture. The DNase activity is expressed in international units per gram protein (U/g protein).

Determination of protein concentration. The amount of total protein in brain tissue was determined by the Lowry method (1951), with bovine serum albumin as standard (12).

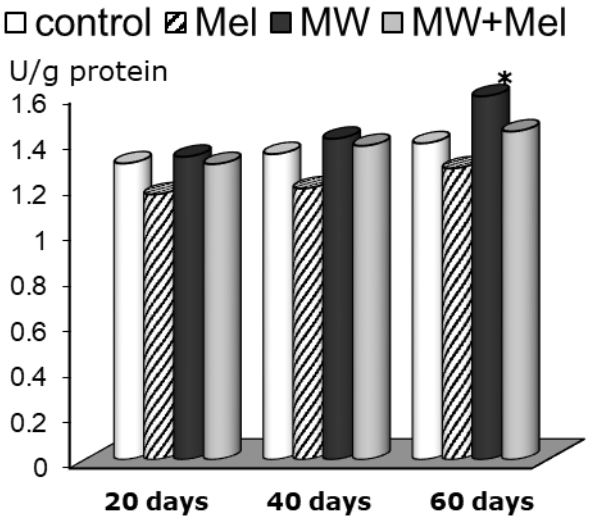
Statistical analysis

Statistical processing was done with Excel 7.0 and SPSS 11.0 in the Windows 2000 environment, with results displayed graphically.

Results

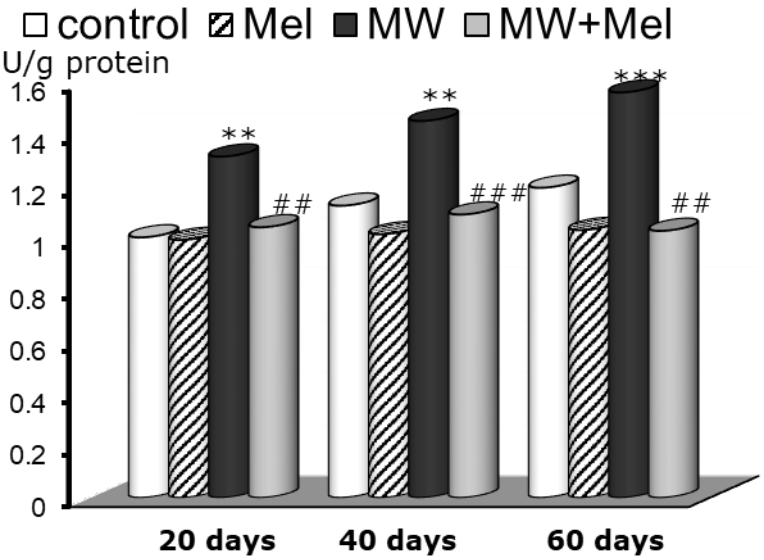
The effects of microwave radiation on the apoptosis process in the brain tissue of rats were being monitored by measuring the activity of alkaline and acidic DNase. The results are shown in Figure 1 and 2.

Alkaline DNase activity in brain tissue of rats exposed to microwaveradiation is shown in Figure 1. There was a significant increase of the enzyme activity in the brain of rats exposed to microwave radiation, after just 60 days of radiation exposure, as compared to the control group and the group to which melatonin was administered ($p < 0.05$). Administration of melatonin in animals that were exposed to microwave radiation caused no statistically significant change in alkaline DNase activity in brain tissue, as compared to animals which were exposed to radiation and not treated with melatonin (Figure 1).



* p<0,05 vs. control and Mel

Figure 1. The effect of melatonin and microwave radiation on the alkaline DNase activity in the rat brain (U/g protein)



***p<0.001 vs. control and Mel; ##p<0,01 vs. MW, ###p<0.001 vs. MW

Figure 2. The effect of melatonin and microwave radiation on the acid DNase activity in the rat brain (U/g protein)

Figure 2 shows the effects of melatonin on acid DNase activity in the brain of rats exposed to microwave radiation. As compared to the control group and the group in which melatonin was administered, there was a significant increase of acid DNase activity in the brain of rats exposed to microwave radiation, after 20, 40 and 60 days of radiation exposure ($p < 0.001$). Daily administration of melatonin to rats exposed to microwave radiation, in doses of 2mg/kg body weight, significantly decreased acid DNase activity in brain tissue, as compared to animals that were radiated and not treated with melatonin ($MW+Mel_{20}$ - 1.04 ± 0.03 vs. 1.31 ± 0.17, $p < 0.01$; $MW+Mel_{40}$ - 1.09 ± 0.06 vs. 1.45 ± 0.07, $p < 0.001$; $MW+Mel_{60}$ - 1.03 ± 0.13 vs. 1.56 ± 0.14 U/g protein, $p < 0.001$).

Discussion

Programmed cell death (apoptosis) in the CNS is a process mediated by various intracellular enzymes, inclucluding endonucleases which have an important place as enzymes that catalyze the internucleosomal fragmentation of DNA molecule (13, 14). Fragmentation of DNA molecule during apoptosis is a multistage process. In the initial stage, chromatin breaks into large fragments 50 to 1000 kb. Such fragmentation is essential for the continuation of apoptosis (15). At a later stage, apoptosis is associated with the internucleosomal DNA degradation, which is characterized by the production of standard fragments. The activity of DNases in the brain tissue is a marker of the apoptosis process since these enzymes are responsible for the hydrolytic internucleosomal fragmentation of DNA molecule.The results of our study show that the activity of alkaline DNase in the brain tissue is slightly increased during exposure to microwave radiation, after 60 days of exposure (Figure 1). The activity of acid DNase during exposure to microwave radiation in the brain was significantly increased after 20 days of exposure. Acid DNase activity is, according to our results, time dependent (Figure 2). Numerous studies have confirmed the significant role of acid DNase in the apoptosis process (16, 17). Otherwise, the acid DNase hydrolyzes native and denatured DNA molecules, by degrading the bond between the carbon in the 5'-pentose position and phosphorus, thereby forming 3'-nucleotides. Its presence in the nucleus, cytosol, and lysosomes has been confirmed. This enzyme breaks down a lower number of internucleotide bonds than alkaline DNase (18). The high activity of the acid DNase after 20 days of exposure in the brain tissue of the irradiated animals, in contrast to the alkaline DNase activity, can be explained by the fact that the pH in the brain apoptotic cells was most likely acidic.

Studies of Lai and Singh from 1995 and 1996 adduce that acute exposure to 2,45 GHz microwave radiation (strength density 2 mW/cm², SAR 1,2 W/kg) leads to a significant increase in single-stranded and double-stranded DNA interruptions in brain cells of experimental animals (7) These damages primarily relate to the tertiary and quaternary chromatin structure. In addition to the direct genotoxic effect of physical and chemical agents, single-stranded DNA interruptions are also an intermediate step during DNA reparation due to DNA-DNA and DNA-protein cross-linking. Single-stranded breaks of DNA also occur during reparation of double-stranded interruptions through recombination (19). The activity of endonucleases can be used as a measure of the reparation intensity, because it has been significantly increased in the brain tissue, during the exposure of animals to microwave radia-

tion. In this way, the phenomenon of DNA fragmentation under the conditions of chronic exposure to MT radiation can be explained.

The first experimental studies on the metabolic effects of melatonin in the brain tissue, following the chronic exposure to the microwave radiation, were published in 1996 by Lai et al. (1996), and they showed that melatonin, as a powerful antioxidant, reduces brain damage and successfully prevents disturbed functions of the central nervous system (19). This effect is also reflected in the prevention of morphologically visible damage to the cells of the central nervous system (20). This effect of melatonin is facilitated by its free passage through the blood-brain barrier, which is impermeable to other antioxidants.

The results of numerous studies indicate that lipid peroxidation caused by free radicals is one of the pathogenetic mechanisms involved in cell damage after exposure to microwave radiation. It has been proven that an elevated level of oxidative stress in brain tissue caused by microwave radiation has been successfully normalized after melatonin administration (21). The evidence for this claim lies in the fact that exposure to microwave species leads to an increase in reactive oxygen radicals (ROS) and a decrease in the concentration of melatonin in the brain. The decline in melatonin concentration is due to its increased take-up by tissues exposed to oxidative stress. It has been shown that treating rats with melatonin prior to exposure to microwave radiation blocks the side effects on the brain tissue (22).

Our research shows that the application of melatonin to irradiated animals significantly reduces the activity of acid DNase in the brain tissue (Figure 2), so this result can be interpreted as an antiapoptotic effect of melatonin by preventing DNA fragmentation. Numerous studies have shown the neuroprotective effect of melatonin, which is reflected in the inhibition of the apoptosis process, increase in the number of viable neurons, reduction of reactive gliosis, reduction of the oxidation of neuronal lipids and oxidative damage to DNA molecules (23, 24). It has been shown that melatonin induces gene expression of proapoptotic Bcl-2 proteins, which improves the survival of neurons (25, 26). Melatonin reduces the level of ROS and the intensity of apoptosis in rat astrocytes during laser radiation (27). Also, this neurohormone prevents the disturbance of the structure of DNA molecules caused by the action of free radicals and expresses an antiapoptotic effect in astrocytes of the rat brain (26).

Conclusion

By analysing the obtained experimental results, it can be concluded that DNA fragmentation in the apoptosis process measured through the activity of the alkaline and acid DNase is increased (in particular, the acid DNase activity) in brain tissue under the condition of exposure to microwave radiation, while the melatonin application has a significant anti-apoptotic and neuroprotective effect.

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EFEKTI MIKROTALASNOG ZRAČENJA I MELATONINA NA AKTIVNOST ALKALNE I KISELE DNAZE U MOZGU PACOVA

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Toksično dejstvo mikrotalasnog zračenja (MW) na zdravlje ljudi najčešće se ispoljava pojavom različitih nespecifičnih simptoma kao što su: razdražljivost, neurovegetativna distonija i nesanica. Mikrotalasno zračenje dovodi do termalnih oštećenja, indukcije oksidativnog stresa, promena na DNK molekulima u moždanom tkivu. Melatonin je neurohormon, koji kao snažan antioksidans smanjuje stepen oštećenja ćelija mozga. Cilj ovog istraživanja bio je da se analizira DNK fragmentacija, kroz aktivnost alkalne i kisele DNaze, u uslovima ekspozicije mikrotalasnom zračenju u tkivu mozga, i prati uticaj melatonina na aktivnost ovih enzima. Wister pacovi su bili podeljeni u četiri eksperimentalne grupe: I (kontrola), II (Mel) – životinjama je svakodnevno davan melatonin (2 mg/kg), III (MW) - životinje su 20, 40 i 60 dana izlagane MW (4h/dnevno), IV (MW+Mel) - pacovi kojima je aplikovan melatonin izlagani su MW. Životinje su žrtvovane nakon 20, 40 i 60 dana eksperimenta. U mozgu pacova koji su izlagani mikrotalasnom zračenju došlo je do značajnog porasta aktivnosti alkalne DNaze (nakon 60 dana) ($p < 0,05$) i kisele DNaze (nakon 20 dana) ($p < 0,001$) u odnosu na kontrolu. Kod životinja koje su izlagane mikrotalasnom zračenju i kojima je aplikovan melatonin došlo je do značajnog sniženja aktivnosti kisele DNaze u moždanom tkivu u odnosu na ozračene životinje koje nisu tretirane melatoninom. Može se zaključiti da aplikovanje melatonina životinjama koje su izlagane mikrotalasnom zračenju ima značajan anti-apoptotički i neuroprotektivni efekat u moždanom tkivu.

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Ključne reči: *melatonin, mikrotalasno zračenje, DNaze, mozak*