

Interaction of Mobile Telephone Radiation with Biological Systems in Veterinary and Medicine

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Abstract Every day, we're swimming in a sea of electromagnetic radiation produced by electrical appliances, power lines, wiring in buildings, and a group of other technologies that are part of modern life. Cell phones have become a vital part of our lives, and its use is not only restricted to voice conversations but also conveying news, high resolution pictures and internet. During recent years there has been increasing public concern on potential health risks from extremely low frequency electromagnetic fields and radiofrequency/microwave radiation emissions. It is fairly well established that at sufficiently high power levels, radiofrequency and microwave energy can produce deleterious biological effects. Some investigations suggested that these fields may have genotoxic effects and may increase the risk of several cancers and neurological disorders such as Alzheimer's disease. The aim of this review was to evaluate the influence of mobile telephone radiation on biological systems and health. It is concluded that these fields can influence several biological functions of cells and tissues, modulating intracellular reactive oxygen species levels and the cell cycle progression.

Keywords: *electromagnetic waves, radiofrequency waves, biological systems, health*

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1. Introduction

Cell phones emit radiofrequency (RF) energy, which can be absorbed by tissues closest to where the phone is held. The amount of RF energy a cell phone (also known as "wireless" or "mobile" telephones) user is exposed to depends on the technology of the phone, the distance between the phone's antenna and the user, the extent and type of use, and the user's distance from cell phone towers. When speaking into a cell phone, the sound wave from the speaker goes through a transmitter that converts the sound into a sine wave. The transmitter then sends the signal to the antenna, which then sends it out into space in all directions. Our bodies act as antennas that absorb the radiation and convert them into electric and magnetic fields [1]. These electromagnetic fields might alter the cell structure beginning with the plasma membrane and its receptors to the different biomolecules present within the cell which might cause genotoxicity [3]. Concerning about a possible health effect of RF fields energy goes back to the Second World War and before [2]. The widespread use of mobile phones in the last decade has increased the concern about its potential effects on human body.

In this review, the large-scale scientific studies about the impact of cell phones on biological systems are presented. The results are a complex picture; some experimental evidence confirmed that RF fields can affect

human physiology and behavior at field strengths found in the home or environment, whereas another studies do not show effects on the biological systems and health. Continued researches are needed to come to an understanding of how these possible effects can be neutralized, or at least reduced [5].

2. Characteristics of Wireless Communication Systems

An electromagnetic field (EMF) consists of a combination of an electric field and a magnetic field. The electrical part is produced by voltage gradient and is measured in volts/meter. The magnetic part is generated by any flow of current and is measured in tesla. Electromagnetic radiation can be categorized into two types: ionizing (i.e., x-rays, radon, and cosmic rays) and non-ionizing (i.e., RF and extremely low frequency). Table 1 shows frequency ranges of EMFs and typical applications [6]. Key sources of RF fields (100 kHz-300 GHz) include mobile phones, cordless phones, local wireless networks and radio transmission towers. They are also used by medical scanners, radar systems and microwave ovens. The International Agency for Research on Cancer (IARC) has recently classified RF fields as "possibly carcinogenic to humans," based on limited evidence from human studies, limited evidence from studies of RF energy and cancer in rodents [4]. Sun and

thunderstorm activity are two main sources of natural EMF. In the last hundred years this natural EMF background has been altered by man-made energy sources [2]. Exposure to EMFs from both natural and man-made sources and its effects at different frequencies on living beings has been investigated for decades. It's determined that there are two main forms of EMF that all persons are exposed to these: a) RF-EMF radiation and b) extremely low-frequency (ELF)-EMFs [1]. The former at high frequencies in the GHz range are microwaves. The main sources of RF fields are radio, television, radar and wireless devices such as mobile and cordless phones [2]. The later which is commonly generated by power lines, electrical installations, house hold appliances, microwave

ovens, shavers and hair dryers. Wireless technologies are ubiquitous today and the mobile phones are one of the wonderful outputs of this technology [7]. Waves emitted by mobile phones with an average frequency of 900 MHz to 1 GHz [8]. Mentioned radiation is of non-ionizing type as the energy emitted is too low to break chemical bonds in biological systems. In general, the exposure to electromagnetic wave (EMW) from different sources is divided into two categories: "continuous" and "pulsed" according to the characteristics of the emitted waves. The biological effects of pulsed wave exposure are even more harmful than that of continuous variety from other sources [1].

Table 1. Frequency ranges of electromagnetic fields and typical applications [44]

Band name	Frequency range	Common uses	Medical uses
Extremely Low Frequency (ELF)	1–300 Htz	Railway power supply, Household power supply, Household devices (electric blankets or water beds, night storage heaters)	
Low Frequency (LF)	300 Htz–100 KHz	Visual display units	Stimulation currents, Gradient fields (MRI)
High Frequency (HF)	100 KHz–300 GHz	Radio, TV, other radio applications, mobile phones, cordless phones, microwave ovens, WLAN (Wireless Local Area Network), Bluetooth, anti-theft devices radar	1-Diathermy (heat body tissue, which can ease pain, or at higher temperatures, kill cancer cells). 2-MRI (provides three-dimensional images of internal body structures like the brain) [39].

3. Thermal and Non-Thermal Effects

Thermal and non-thermal effects are the main mediators of EMW interaction with biological systems and both the electrical and magnetic properties determine sequel of such effects on human body [9,10]. The tissue temperature increase resulting from exposure to EMW is referred to as "thermal effects". Thermal effects may cause disruption of cell function and development [11]. The increase of tissue temperature in an organ is related to imbalance between heat generation and heat dissipation. In contrast, heat dissipation involves three mechanisms: heat conduction to other tissues, convection through blood perfusion, and radiation to the surroundings. Generally, the two most vulnerable organs to thermal effects are the eyes and testes because of limited capacity of heat dissipation [12]. Non-thermal effects occur when the emitted energy of the RF field does not significantly increase the temperature of a cell, tissue, or an organism, but does bring to some physical or biochemical changes [13]. It is well known that at sufficiently high intensity, RF energy can produce adverse thermal effects on the functioning of the human body [14,15]. There are several hypotheses that non-thermal levels can affect organism. One is that RF radiation can change cell membrane signal transduction. In vitro research reports that membrane structure and functionality may be altered in RF fields. This change can decrease frequency of single-channel openings and it can also affect membrane transport of cations such as Na^+ , K^+ and Ca^{2+} [16]. Another effect of non-thermal RF radiation on the membrane structure may be the formation of free radicals. Non-ionising radiation might induce oxidative stress by generating reactive oxygen species that can lead to a number of diseases [17,18,21]. The third, Fröhlich's hypothesis argues that large molecules in the biological tissue could vibrate at

frequencies that allow for absorption of external energy. He also determined that electromagnetic radiation in the microwave range could create a resonance in the molecules of living organisms. This resonance is one possible non-thermal biological effect [19,20].

4. Effects of Cell Phones on Biological Systems

There has been substantial development into the understanding of how cell phone radiation may alter normal bodily functions. Many studies have looked at various body tissues reaction to the radiation exposure. Animal studies play a critical role in evaluating the reactions of various body systems to irradiation. However, phenomena seen in animals do not necessarily imply a health risk for people [22]. The idea of the Scientific Committee on Emerging and Newly Identified Health Risks (EU-SCENIHR) of exposure to EMF could be summarized as follows; epidemiological, animal and in vitro studies suggest that non-thermal exposure of RF fields is unlikely to lead to an increase in cancer risk, DNA damage or to influence reproductive system, cognitive and sensory functions, structural sensitivity and cellular response in humans and animals. However, this committee believes, as the widespread duration of exposure to RF fields from mobile phones is shorter than the induction time of some cancers, further studies are required to identify whether considerably longer-term human exposure to such phones might pose some cancer risk [22]. Alternations in the central nervous system, cardiovascular system, and localized tissue effects have been analyzed. Extensive increase of microwave producing devices such as mobile phones which produce EMW have drawn biological researchers' attention to study their effects on human health [23]. Nowadays, the hazardous or beneficial biological effects of EMF on

human and animals is the subject of many studies [3]. With the increase use of cell phones, there are possible interactions of electromagnetic radiation hazard on human beings and their offspring [1]. A recent study showed that when people used a cell phone for 50 minutes, brain tissues on the same side of the head as the phone's antenna metabolized more glucose than did tissues on the opposite side of the brain [24]. Inhabitants living near mobile phone base stations suffered from; frequent headaches (23.5%), memory changes (28.2%), dizziness (18.8%), tremors (9.4%), depressive symptoms (21.7%), and sleep disturbance (23.5%) [25]. The fact that RF exposure causes neurological damage has been documented repeatedly. Some effects showed negative alterations of the nervous tissue in the brain and some sensory organs. The studies about the effects of electromagnetic waves on the brain indicated that 700 MHz magnetic field can cause upsetting in electrical activities of hippocampus of mouse brain [26]. In a case control study, long term use of mobile phone on brain tumor was studied. In mentioned study, after ten years follow up, the results in the United State of America (USA) and 5 European countries indicated that constant mobile phone users are not in a higher risk of brain tumor compared to the people who never or rarely use mobile phones [27,28,29]. Another research was conducted to study the effects of mobile phone EMWs on short time memory, concentration and spatial memory of mice and the results indicated that spatial memory decreased in animals [30]. Rapid cellular molecular alterations was seen in the rat brain after exposure to 900 MHz pulsed microwaves for 15-min [31]. Increased blood-brain barrier permeability and oxidative damage, which are associated with brain cancer and neurodegenerative diseases such as Alzheimer, Parkinson and Amyotrophic Lateral Sclerosis (ALS), have been found [32,33,34,35,36]. Another study was conducted to survey the effects of mobile phone on heart rate and blood pressure in rat, but no significant difference in heart rate and blood pressure was observed [37]. In one study, talking through mobile phone caused significant increase of heart rate in both genders in comparison with resting and ringing states of mobile, this increase was considered as a sinus arrhythmia [37]. The thermal effects of mobile phones on the eye induced cataracts, corneal edema, endothelial cells loss and retinal degeneration [38]. Genotoxic effects from RF exposure, including studies of non-thermal levels of exposure, consistently and specifically show chromosomal instability, chromatin breakage, altered gene expression, gene mutations, DNA fragmentation and DNA structural breaks [32,33,34]. Genotoxic effects are documented to occur in neurons, blood lymphocytes, sperm, red blood cells, epithelial cells, hematopoietic tissue, lung cells and bone marrow [32]. Adverse developmental effects due to non-thermal RF exposure have been shown with decreased litter size in mice from RF exposure well below safety standards [39]. In recent years, some studies indicated an association between cancer risk and EMF exposure, especially mobile telephone use. Most of these studies focused on brain tumours as well as other tumours in the head because exposure to EMFs from mobile phones is concentrated in a small part of the head near the handset. However, some studies had found no increased risk of brain tumours among people who had been using

mobile phones for up to 10 years [4]. It is generally accepted that damage to DNA is necessary for cancer to develop. Trošić I et al. investigated the biological potency of the RF/MW field on whole body irradiated rats [22]. RF/MW radiation on bone marrow showed decrease in anuclear cells and erythropoietic precursor cells, increase in micronucleated cells in the bone marrow, and increase in erythrocyte count, blood haemoglobin, and blood haematocrit. Polychromatophilic erythrocytes counts showed no significant differences between RF/MW-exposed and control animals on the final day of our experiment [22]. Some studies have confirmed altered phagocytic and secretory function of peritoneal and alveolar macrophages after MW radiation [40]. Several studies have shown that EM radiation across almost the entire non-ionising electromagnetic spectrum (ELF to RF/MW) lowers melatonin levels both in animals and humans [40]. Male reproductive system is highly compartmentalized and sensitive biological systems that requires the integration of intrinsic and extrinsic factors to properly function. Because the testis is a superficial organ, it may absorb more EMW energy than other organs. Human testis need physiological temperature 2°C lower than body temperature for optimal spermatogenesis and an elevation of testicular temperature may be reversible detrimental factor to sperm production [41]. Some authors have demonstrated that acute EMW exposure can have direct effect on seminiferous tubular epithelium through increase in testicular temperature [1]. EMW radiation may alter leydig and sertoli cell function, leading to decreased hormone secretion which may lead to altered cell proliferation [42]. Additionally, sperm are electrically active cells and their exposure to cell phone electromagnetic waves and currents may affect their motility, morphology and even their counts. Leaky plasma membranes, calcium depletion and oxidative stress are the postulated cellular mechanisms mediating the harmful effects of cell phones radiation on sperm and male fertility potentials [1]. Nephrotoxic effects from RF exposure also have been reported. A dose response effect was observed by Ingole and Ghosh in which RF exposure resulted in mild to extensive degenerative changes in chick embryo kidneys based on duration of RF exposure [43].

5. Conclusion

Our knowledge regarding the biological and health effects of RF waves have been raised because of the gradual increase in usage of cell phones, and there are scientific questions and debates about the safety of those instruments in daily life. There is a wide range of data documenting the ability of non-ionising radiation to affect living organisms and there is also data regarding the biochemical and molecular mechanisms of cells both in vitro and in vivo, with effects independent of thermal phenomenon. As noted earlier, it is fairly well established that at sufficiently high power levels, RF and microwave energy can produce deleterious biological effects such as retardation in development, cancer, neurological disease and etc. Nevertheless, available data do not suggest any immediate cause for concern of an impending threat to the health of the population from acute or short term exposure to low level RF radiation.

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