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OVERVIEW OF CELLULAR DAMAGE IN ABNORMAL ABSORPTION OF MAGNETIC AND RADIO WAVES: IMPLICATIONS AMONG CELL-PHONE USERS

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Abstract

In the recent years, the use of mobile phones has soared and fast evolving across the nations of the world. However, a great debate exists about the possible damage that the radiofrequency-electromagnetic radiation (RF-EMR) emitted by mobile phones exerts on living systems which includes damage to brain cells, impairment of metabolic activities in tissues and ultimately, damage to the hereditary materials - DNA, which serves as the underlying molecular chaperon of diverse metabolic activities that takes place in living systems. It also suggests that increased reactive oxygen species (ROS) play an important role by enhancing the effect of radiations which may cause neurodegenerative diseases however, some plant have been suggested to prevent these effects. This has necessitated the need for more research on risks that are likely to occur as a result of exposure to existing and newer technologies that are emerging rapidly to meet the perceived needs of end users/consumers. Nevertheless, several works has been done and put forward by erudite scholars on this same issue. As a result of these speculations, diverse countries of the world have enacted policies such as specific absorbance ratio (SAR) limits on manufactured phones and precaution in the use of these products by users. Therefore, it is imperative to design researches that would assess the speculated and reported risks of exposure especially among the end users by disseminating precautionary health warnings that promote safer cell-phone use, ensure the development and adoption of best practices in using these technologies in order to reduce exposure and risk of health hazards for the enhancement of a healthier population in the world. In this review, chromosomal damage in abnormal absorption of magnetic and radio waves and implications among cell-phone users was assessed.

Keywords: Radiation, Mobile phone, chromosomal damage, cancer formation.

Introduction

Our environment is mostly subjected to exposure in form of microwaves and electromagnetic (radio) irradiations as a result of widespread use of wireless telecommunication; this yields a massive increase in electromagnetic pollution [1]. Living organisms are perpetually exposed to some amount of radiation originating from a variety of sources in nature as well as from nuclear weapons testing, occupations, consumer products and medical procedures [2, 3]. Usage of cellular phones and long term exposure to electromagnetic radiation are associated with alterations in various body systems including the central nervous system, cardiovascular system, and male reproductive system, Alzheimer's disease [4], Immune system disorders [5], Hormonal imbalance [6], Sleep disorders and insomnia [7], Lowered sperm count, Increased blood pressure etc. However, there is an increasing report of sensitivity to cell phone radiation with symptoms which may include ringing in their ears, headaches, dizziness, an irregular heartbeat, and memory and sleep problems which has been termed as a condition known as electromagnetic hypersensitive syndrome (EHS) and these has been closely linked to relative amount of exposure i.e. extended duration of exposure to radiofrequency radiation (RF) [8].

This phenomenon can be traced to the circulation rate of high technology cell phones that are mostly powered at a higher radiofrequency and 3G networks for better and faster internet connectivity when compared to the conventional landlines and the alternative mobile telecommunication service known as the code division multiple access (CDMA) phones which is operated via 2G technologies for voice communication, which emit less radiation on the average than GSM phones is mostly used in the United States which is fast eroding in the face of the newer/emerging telecommunication technologies [9, 10]. Electromagnetic radiation is classified into several different forms of radiations according to the frequency at which they are released; generally, RF covers the frequency ranges from 100 kHz to 300 GHz. RF radiation is further specified as microwaves, if the frequency of the radiation is between 300 MHz and 300 GHz. Mobile phones operate on wireless technology using a 900 to 1800 MHz (GSM) frequency and 2200 (UMTS/3G) signals [11].

Previous studies on the effects of electromagnetic field (EMF) emission

The potential risk of electromagnetic field (EMF) emitted by the mobile phones on living systems has been intensively studied and many other studies had been conducted on the effects on genetic materials [12] and biological system at large [13], a number of studies have also been carried out to investigate whether mobile communication devices are safe for their users and these studies mostly were focused on human health [14, 15]. Paulraj and Behari reported an increase in single strand DNA breaks in the developing brain cells of rats that were exposed for 35 days to 2.45 and 16.5 GHz fields at 1 and 2.01 W/kg [16]. Gandhi *et al* reported DNA and chromosomal damage in the form of significant increase in micronucleated cells in the peripheral blood lymphocytes of individuals using mobile phones (exposed to 800 to 2000 MHz MWR). Correlation between mobile phone use (exposure to MWR) and genetic damage was observed [17]. Several studies confirmed that exposure to electromagnetic fields may increase the incidence of cancer and DNA damage of sperm and brain cells [16, 17, 18, 19]. Chauhan *et al*., reported significant elevated expression of HSP27, HSP70, OS and UN proteins in Human Lymphoblastoma cell line exposed to EMR, showing stress response [20].

Studies have also shown that these electromagnetic fields (magnetic and radio waves) might alter the cell structure beginning with the plasma membrane and its receptors to the different biomolecules present within the cell with a vital genotoxic potential [21]. Some experimental proofs 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 abridged [22].

Epidemiological studies

This fast expanding use of mobile communication has aroused public concern about the possible health effects of exposure to the radiofrequency (RF) radiation utilized in cell phones. Reports have shown that, the number of mobile communication subscribers all over the world was on the increase markedly and the figure continues to increase by 850 connections per minute [23]. Chromosomal damage (CD) is one of the important biological genotoxic consequences of human exposure to ionizing radiation and other environmental pollutants which must be attended to with utmost consideration [24]. It has been shown that people with elevated frequencies of chromosomal aberration (CA) in their

peripheral blood lymphocytes have a significantly elevated risk of developing cancer [25, 26]. Many types of cancers are associated with specific types of CD which are etiologic for a specific type of cancer [27]. The human genome is constantly subjected to chromosomal damage derived from endogenous and exogenous sources. Normal cellular metabolism can give raise to DNA damage through free radicals production and replication errors [25], whereas environmental agents, such as magnetic, radio waves, ultraviolet (UV) and ionizing radiation (IR), induce specific types of lesions. DNA damage can ultimately lead to genomic instability and carcinogenesis if unattended to [28], therefore, an elaborate system of proteins has evolved in cells to maintain genome integrity through a pathway termed the DNA-damage response (DDR) and some medicinal plants can prevent chromosomal damage within the living system. Genotoxicity, a property of a substance that makes it harmful to the cellular genetic material of living organisms, this property can be modulated by different factors. In particular, it is accepted that many dietary constituents markedly influence or alter the adverse effects of genotoxic agents [29, 30]. While there are many different factors that can affect DNA, RNA, and other accessory proteins of nucleic acid replication and repair, the genotoxicity implies structural damage to the genetic material [31]. Cell phone radiations are radiofrequency radiations that fall under non-ionizing radiation. These radiations being non-ionizing in nature do not have the thermal effect that can break the chemical bonds in a molecule but due to high vibration it increases the randomness; i.e. entropy of the molecule and hence causes bond breakage [32]. Hence, the study was undertaken to assess the effect of exposure to radiofrequency waves of cell phone on the systemic tissue in terms of *in vitro* chromosomal breakage.

Health issues in children exposed to radio frequency's from cell phone usage

Countries such as Austria, Belgium, Germany, Russia and the United Kingdom have issued counteractive guide in the use of phone by children by stipulating the specific absorption rate (SAR) limits of phones owned by kids while some have out rightly proscribed the use of phones by this age brackets as children have been reportedly diagnosed with brain tumor and a host of other health issues [9]. Also, the increased risks of developing attention deficit hyperactivity disorder (ADHD) in children wide-open to technologies that emit RF radiation have been linked to their early or prolonged exposure [33]. This is on the basis that, their brain tissues, with high content of water and ions; absorb more RF radiation at mobile phone frequencies [34]. Therefore, increased intensity and extended duration of exposure to RF radiation during these stages may lead to inherited disorders by altering the conformation of molecular chaperons. Also, the international agency for research on cancer (IARC); which has earned acceptance to the review by WHO's published scientific literature regarding cancers affecting cell-phone users and has classified radiofrequency radiation as a 2B, carcinogenic agent possibly in humans. Hence, the need for caution by pregnant women and parents to reduce their exposure or children's to radiofrequency/microwave emissions as much as possible to avoid possible consequence (s).

Mechanisms of Radiofrequency-Electromagnetic field genotoxicity (RF-EMF)

Cells are abnormally sensitive to electromagnetic fields [35]. Weak fields may accelerate electron transfer and thereby destabilize the H-bond of cellular macromolecules [13]. This could explain the stimulation of transcription and protein translation, which has been observed after RF-EMF exposure [36]. Conversely, the energy of weak EM fields is not sufficient directly to break a chemical bond in DNA. Therefore, it can be resolved, that genotoxic effects are mediated by indirect mechanisms and afterwards, generation of oxygen radicals (ROS) or a disturbance of DNA-repair processes.

Exposure to RF-EMW can induce alteration in plasma membrane potential and calcium efflux with resultant calcium diminution which leads to decrease in the activity of protein kinase C (PKC). This decrease leads to alteration in many enzymes, ion pumps, channels and proteins as well as inducing apoptosis. RF-EMW induces reactive oxygen species (ROS) production through effect on mitochondrial membrane bound NADH oxidase. ROS has impact on PKC, histone kinase, chaperons e.g hsp, DNA and apoptosis. Heat shock protein (hsp) increases in response to electromagnetic radiation (EMR) and ROS [37].

Implication of Oxygen radicals in Cellular degeneration

Several scientists have provided evidence that RF-EMF may stimulate the formation of reactive oxygen species (ROS) when cell are exposed both *in vivo* and *in vitro* [38, 39, 40]. Free oxygen radicals may form base adducts in DNA, the most important lesion being 8- OHdG, and oxidize also other cellular

components, such as lipids leaving behind reactive species, that in turn can couple to DNA bases [41]. The first step in the generation of ROS by microwaves is mediated in the plasma membrane by NADH oxidase [42]. Subsequently ROS activates matrix metalloproteases (MMP), thereby initiating intracellular signalling cascades. It's remarkable to note that these processes start within some few minutes of irradiation even at very low field intensity of 0.005 W/cm2. This is in agreement with *in vitro* genotoxicity studies using the comet assay [12, 43].

Radiofrequency and DNA damage/Sperm motility

A non-thermal effect reported in RF's exposure in humans is double-strand DNA breaks and damage to sperm which has been implicated in increased male infertility. It has been shown that, hsp increases in response to EMR exposure and it decreases metabolism of sperm and impairs the testis blood barrier also, it interferes with apoptosis of damaged and transformed sperm [37, 44]. However, some have refuted the claim on the basis that RF's insufficient energy level to affect the macromolecular bonds [45]. However, the findings by Bystander effect in radiobiology clarifies that direct quantum energy is not indispensable to induce DNA strand breaks [46, 47]. Radio frequency wave (RFW) generated by base trans-receiver station (BTS) has been reported to make deleterious effects on reproduction, possibly through oxidative stress induced by ROS produced [48]. Also, effects has been shown on rat testes exposed to radiofrequency radiation emitted from indoor Wi-Fi Internet access devices using 802.11 g wireless standards have been found to have harmful effects [37]. Also, results from a study by Vignera *et al.,* (2012), has shown that human spermatogametes exposed to RF-EMR have decreased motility, morphometric abnormalities, and increased oxidative stress, whereas men using mobile phones have been evidenced in the decreased sperm concentration, decreased motility, normal morphology, and decreased viability abnormalities seem to be directly related to the duration of mobile phone use [49]. Furthermore, several new, independent studies confirm previous research that pulsed digital signals from cell phones disrupt DNA, impair brain function and damage sperm [10]. Fejes *et al*., 2005, from their cell phone usage and sperm motility study with figures described increasing cell phone usage per minutes has inverse correlation with the percentage of rapid progressive motile sperm and also, that increasing cell phone usage per minutes is correlated with an increase in slow progressive motile sperm [50].

Implication of cell-phone in brain tumor generation

Previous studies have shown a reliable and proven association between long-term use of mobile and cordless phones and diverse forms of carcinogenesis in the brain. Glioma and acoustic neuroma have been linked to RF exposure. However, further studies to confirm the relationship between meningioma and telephone use was inconclusively ascertained [51, 52]. It has been argued that the RF-EMFs emitted from the handheld device targets the brain since it is mostly placed around the head region and this play a role both in the initiation and promotion stages of carcinogenesis. Furthermore, electro-hypersensitivity have been reported in cell phone users which is as a result of reduced calcium ion levels in the blood which arises eventually from the parathyroid gland malfunction that is found in the neck just inches from where one regularly holds a cell phone. Reduction in the level of Melatonin has also been implicated in RF/microwave irradiation which serves a basis in cancer formation [18, 53]. In their studies, Hardell *et al.,* (2012) examined the effects of long term use of wireless phone on brain tumor risk [54]. Overall, the research found that people who used wireless phones for more than a year were at 70% greater risk of brain cancer as compared to those who used wireless phones for a year or less. Those who used wireless phones for more than 25 years were at greatest risk—300% greater risk of brain cancer than those who used wireless phones for a year or less.

Cell-phone and Radio wave safety standards

The International Agency for Research on Cancer (IARC) of the World Health Organization (WHO) issued a press release on May 31, 2011 labeling cell phone radiation as "possibly carcinogenic to humans" and added it to the list to the list of other group 2B agents [55]. Electromagnetic and radio wave (radiation) traverses through space at the speed of light and the direction of propagation is perpendicular to time changing electric and magnetic fields. EMR from mobile phones and their base stations is non-ionizing and thus lacks sufficient energy to add or remove electrons from molecules. The cell phones emit 1-2 W of peak radiation. The handset antenna radiates microwave power equally in all directions. Every communication channel has 8 slots. Hence the average power emitted by the handset is 0.125-0.25 W/cm2 [56]. There is an increased exposure to cell phone radiation today

when compared to several years ago when test models are being used to certify new cell phones. There are possible non thermal risks that are yet to be identified as only thermal effects (heating tissue) were stated by most countries FCC standards prior to the research discoveries of deleterious non-thermal effects (increased glucose metabolism in the brain, generation of heat shock proteins, free radicals, and double-strand DNA breaks; penetration of the blood-brain barrier, damage to sperm and increased male infertility) of RF's exposure from cell phones [10, 57]. Hence, the adoption and dissemination of precautionary health warnings that promote safer cell phone use and to protect cell phone users. Although the FCC web site provides some simple steps to reduce exposure to cell phone radiation. Moscowitz (2013) also reiterated that it is time for all nations to review their cell phone regulatory standards and testing procedures in order to protect their citizens from preventable risks [9]. Also, it is critical that governments provide ample warnings to cell phone users how to use their phones safely like in Belgium where children are banned from using phones and other phone users are advised to select phones with lesser specific absorption rate (SAR) and several other countries strict SAR limits including the fact that phone provider must state SAR on every mobile phone at the point of sale. It should be noted that, the long-term exposure to low intensity electromagnetic microwaves as emitted continuously by mobile phones may provoke ill health effects which may further lead to cancer development.

The specific absorption rate (SAR) defines the amount of energy deposited per kilogram of body weight and is a measure for assessing thermal effects. International Commission for Non-ionizing Radiation Protection (ICNIRP) and the FDA safety standards of USA limit the spatial peak radio wave exposure to 2 W/Kg and 1.6 W/Kg SAR values respectively, averaged over 10g of tissue for 6 minutes. Many people in Nigeria are ignorant of these limits and use mobile phones for long durations as well as making extra cool calls [58].

Standard limit of exposure

In the year 1982, ANSI published the first exposure standard incorporating 10 fold safety factors for humans exposed to electromagnetic fields between 300 kHz and 100 GHz frequencies. The standard adopted for whole body exposure was 0.4 W/kg averaged over 6 minutes and a 20-fold greater spatial peak SAR exposure over any 1 gram of tissue of 8 W/kg averaged over 6 minutes [17]. The initial safety guidelines for radio frequency and microwave radiation (RFR and MWR) were set by American National Standards Institute (ANSI) in 1982 and the US Federal Communications Commission (FCC) on Feb. 26, 1985 based on " thermal effects" [59]. The FCC guidelines in 1996 for cell phone radiation restricted exposure to a maximum SAR of 1.6 watts of energy absorbed per kilogram of body weight per cell phone call that averages 30 mins when the cell phone is held at the ear [60].

Recommendations

As long as there is no concrete evidence on the mechanism by which cell phones causes chromosomal damage leading to cancer, it is therefore advised to avoid the prolong use of phones, Wi-Fi networks, and Bluetooth transfer and to avoid spending time or over exposure in the vicinity of mobile phone base station. Cell phone use should be minimized in children, adolescents and pregnant women as a child's brain absorbs twice as much radiation as an adult brain. Cell phones should not be used when the signal is weak like in a moving vehicle or in a lift as the phone increases its signal strength to compensate. We cannot at the same time turn deaf ear to the beneficial effects of cell phones as it has helped in communication, ease stress, managed time and saved lives during emergency. Meanwhile, a strict precaution is advised.

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