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Public health implications of wireless technologies

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Abstract

Global exposures to emerging wireless technologies from applications including mobile phones, cordless phones, DECT phones, WI-FI, WLAN, WiMAX, wireless internet, baby monitors, and others may present serious public health consequences. Evidence supporting a public health risk is documented in the BioInitiative Report. New, biologically based public exposure standards for chronic exposure to low-intensity exposures are warranted. Existing safety standards are obsolete because they are based solely on thermal effects from acute exposures. The rapidly expanding development of new wireless technologies and the long latency for the development of such serious diseases as brain cancers means that failure to take immediate action to reduce risks may result in an epidemic of potentially fatal diseases in the future. Regardless of whether or not the associations are causal, the strengths of the associations are sufficiently strong that in the opinion of the authors, taking action to reduce exposures is imperative, especially for the fetus and children. Such action is fully compatible with the precautionary principle, as enunciated by the Rio Declaration, the European Constitution Principle on Health (Section 3.1) and the European Union Treaties Article 174.

Keywords: Wireless technology; Brain cancer; Radiofrequency; Cell phones; Wireless antenna facilities; Childrens' health

1. Introduction and background

Exposure to electromagnetic fields (EMF) has been linked to a variety of adverse health outcomes that may have significant public health consequences [1–13]. The most serious health endpoints that have been reported to be associated with extremely low frequency (ELF) and/or RF include childhood and adult leukemia, childhood and adult brain tumors, and increased risk of the neurodegenerative diseases, Alzheimer's and amyotrophic lateral sclerosis (ALS). In addition, there are reports of increased risk of breast cancer in both men and women, genotoxic effects (DNA damage and micronucleation), pathological leakage of the blood–brain barrier, altered immune function including increased allergic and inflammatory responses, miscarriage and some cardiovascular effects [1–13]. Insomnia (sleep disruption) is reported in studies of people living in very low-intensity RF environments with WI-FI and cell tower-level exposures [85–93]. Short-term effects on cognition, memory and learning, behavior, reaction time, attention and concentration, and altered brainwave activity (altered EEG) are also reported in the scientific literature [94–107]. Biophysical mechanisms that may account for such effects can be found in various articles and reviews [136–144].

The public health implications of emerging wireless technologies are enormous because there has been a very rapid global deployment of both old and new forms in the last 15 years. In the United States, the deployment of wireless infrastructure has accelerated greatly in the last few years with 220,500 cell sites in 2008 [14–16]. Eighty-four percent of the population of the US own cell phones [16]. Annualized wireless revenues in 2008 will reach $144 billion and US spending on wireless communications will reach $212 billion by 2008. Based on the current 15% annual growth rate enjoyed by the wireless industry, in the next 5 years wireless will become a larger sector of the US economy than both the agriculture and automobile sectors. The annualized use of cell phones in the US is estimated to be 2.23 trillion minutes in 2008 [16]. There are 2.2 billion users of cell phones worldwide in 2008 [17] and many million more users of cordless phones.

Over 75 billion text messages were sent in the United States, compared with 7.2 billion in June 2005, according to

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Preface

There is an old joke with a well-known punch line about a man who has just fallen from the 86th floor of the Empire State Building in New York. As he passes the 30th floor, he is heard saying to himself 'so far, so good'. . .

Most of us laugh because we know where the man is headed, and that he must know too. But, our laughter usually has a guilty edge. We know that many of us are guilty of occasionally displaying a 'so far, so good' attitude in our own lives. We think of the smoker who says that about the possibility of getting lung cancer or heart disease and who counts on beating the odds because he feels healthy at the moment. That smoker will not find out if he won the bet until many years later, and by then it is often too late. The 'so far, so good' attitude to health is so common that people even kid themselves about it. One smoker told me that smoking would only cut a few years off his life, and that he did not mind losing the last few years because they are usually not much fun anyway.

Unlike the optimist in the joke, whose end is virtually certain, many of us live like the smoker, playing the odds and reassuring ourselves 'so far, so good'. Diseases like cancer usually take many years to develop, and we try not to think how some of the things we do casually can affect the long-term odds by compromising the natural processes that protect us. We rely on our bodies to be strong and resilient all the time. Yet, we know there are limits to the body's natural ability to reverse damage to cells. We also know that there may be gaps in the ability of our genetic endowment to cope with damage. At some level, we all know it is just common sense to try to minimize damage to our bodies and maximize the ability to repair.

These opening paragraphs provide a quick introduction to the theme of this issue of Pathophysiology and a summary of the point of view of its authors. The public is currently interested in possible hazards from radio frequency (RF) due to cellphones, towers, WiFi, etc. The concern is certainly warranted, but we are surrounded by electromagnetic fields (EMFs) of many frequencies, and there are also significant biological effects and known risks from low frequency EMF. The scientific problem is to determine the nature of EMF interaction with biological systems and develop ways of coping with harmful effects in all frequency ranges, as well as their cumulative effects. The practical problem is to minimize the harmful biological effects of all EMF.

The technical papers in this issue are devoted to an examination and an evaluation of evidence gathered by scientists regarding the effects of EMF, especially RF radiation, on living cells and on the health of human populations. The laboratory studies point to significant interactions of both power frequency and RF with cellular components, especially DNA. The epidemiological studies point to increased risk of developing certain cancers associated with long-term exposure to RF. Overall, the scientific evidence shows that the risk to health is significant, and that to deny it is like being in free-fall and thinking 'so far, so good'. We must recognize that there is a potential health problem, and that we must begin to deal with it responsibly as individuals and as a society.

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EMF effects on DNA

M. Blank and R. Goodman (USA): Electromagnetic Fields Stress Living Cells

Abbreviations: EMF, electromagnetic fields; Hz, hertz (cycles/s the unit of frequency); ELF, extremely low frequency (3–3 × 10^3 Hz) power frequency is 50–60 Hz; RF, radio frequency (band width 3 × 10^3 to 3 × 10^{11} Hz); UHF, ultrahigh frequency band the RF sub-division used for cell phones (3 × 10^8 to 3 × 10^9 Hz).

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Neoplasm

Cell phones and brain tumors: a review including the long-term epidemiologic data☆

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Abstract

Background: The debate regarding the health effects of low-intensity electromagnetic radiation from sources such as power lines, base stations, and cell phones has recently been reignited. In the present review, the authors attempt to address the following question: is there epidemiologic evidence for an association between long-term cell phone usage and the risk of developing a brain tumor? Included with this meta-analysis of the long-term epidemiologic data are a brief overview of cell phone technology and discussion of laboratory data, biological mechanisms, and brain tumor incidence.

Methods: In order to be included in the present meta-analysis, studies were required to have met all of the following criteria: (i) publication in a peer-reviewed journal; (ii) inclusion of participants using cell phones for ≥10 years (ie, minimum 10-year "latency"); and (iii) incorporation of a "laterality" analysis of long-term users (ie, analysis of the side of the brain tumor relative to the side of the head preferred for cell phone usage). This is a meta-analysis incorporating all 11 long-term epidemiologic studies in this field.

Results: The results indicate that using a cell phone for ≥10 years approximately doubles the risk of being diagnosed with a brain tumor on the same ("ipsilateral") side of the head as that preferred for cell phone use. The data achieve statistical significance for glioma and acoustic neuroma but not for meningioma.

Conclusion: The authors conclude that there is adequate epidemiologic evidence to suggest a link between prolonged cell phone usage and the development of an ipsilateral brain tumor.

Keywords: Acoustic neuroma; Brain tumor; Cell phone; Electromagnetic radiation; Glioma; Incidence; Mechanism; Meningioma; Radiofrequency fields

Abbreviations: CBTRUS, Central Brain Tumor Registry of the United States; CDMA, code division multiple access; CI, confidence interval; CNS, central nervous system; EMF, electromagnetic field; EMR, electromagnetic radiation; FCC, Federal Communications Commission; GSM, global system for mobile communication; IARC, International Agency for Research on Cancer; MRI, magnetic resonance imaging; NHL, non-Hodgkin lymphoma; OR, odds ratio; SAR, specific absorption rate; TDMA, time division multiple access; WHO, World Health Organization.

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Mobile phones, cordless phones and the risk for brain tumours

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Abstract. The Hardell-group conducted during 1997-2003 two case control studies on brain tumours including assessment of use of mobile phones and cordless phones. The questionnaire was answered by 905 (90%) cases with malignant brain tumours, 1,254 (88%) cases with benign tumours and 2,162 (89%) population-based controls. Cases were reported from the Swedish Cancer Registries. Anatomical area in the brain for the tumour was assessed and related to side of the head used for both types of wireless phones. In the current analysis we defined ipsilateral use (same side as the tumour) as ≥50% of the use and contralateral use (opposite side) as <50% of the calling time. We report now further results for use of mobile and cordless phones. Regarding astrocytoma we found highest risk for ipsilateral mobile phone use in the >10 year latency group, OR=3.3, 95% CI=2.0-5.4 and for cordless phone use OR=5.0, 95% CI=2.3-11. In total, the risk was highest for cases with first use <20 years age, for mobile phone OR=5.2, 95% CI=2.2-12 and for cordless phone OR=4.4, 95% CI=1.9-10. For acoustic neuroma, the highest OR was found for ipsilateral use and >10 year latency, for mobile phone OR=3.0, 95% CI=1.4-6.2 and cordless phone OR=2.3, 95% CI=0.6-8.8. Overall highest OR for mobile phone use was found in subjects with first use at age <20 years, OR=5.0, 95% CI 1.5-16 whereas no association was found for cordless phone in that group, but based on only one exposed case. The annual age-adjusted incidence of astrocytoma for the age group >19 years increased significantly by +2.16%, 95% CI +0.25 to +4.10 during 2000-2007 in Sweden in spite of seemingly underreporting of cases to the Swedish Cancer Registry. A decreasing incidence was found for acoustic neuroma during the same period. However, the medical diagnosis and treatment of this tumour type has changed during recent years and underreporting from a single center would have a large impact for such a rare tumour.

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Key words: astrocytoma, acoustic neuroma, meningioma, age groups, incidence, wireless phones, survival, attributable fraction

Introduction

During the last decade there was a rapid increase in the use of wireless phones and the prevalence has reached 100% in many countries. Concerns about different health risks have been raised, particularly an increased risk for brain tumours (1). The ipsilateral brain (same side as the mobile phone has predominantly been used) is most exposed, whereas the contralateral side (opposite side to the mobile phone) is much less exposed (2). It is thus of vital importance to have information on the localisation of the tumour in the brain and which side of the head that has predominantly been used during phone calls.

Studies in this area have been hampered by rather short latencies for the different types of wireless phones. In general carcinogenesis usually takes decades from first exposure to manifest cancer, although shorter latencies have been implicated for promoters and certain types of diseases, e.g. ionising radiation and leukemia (3-5). Sweden was one of the first countries in the world to adopt this new technology so studies with longer latencies are possible and health effects from the wireless technology may be especially pertinent in our country for early warnings. Analogue phones (NMT, Nordic Mobile Telephone System) were introduced on the market in the early 1980s using both 450 and 900 Megahertz (MHz) fields. NMT 450 was used in Sweden beginning in 1981 and ending in December 31, 2007, whereas NMT 900 operated from 1986 to 2000.

The market is now dominated by the digital system (GSM, Global System for Mobile Communication) that started in 1991 and uses dual band, 900 and 1,800 MHz. The third generation of mobile phones, 3G or UMTS (Universal Mobile Telecommunication System), using 1,900 MHz RF fields has been introduced around the world more recently, in Sweden since 2003. The desktop cordless phones (Digital Enhanced Cordless Telecommunication, cordless phone) have been used in Sweden since 1988, first analogue 800-900 MHz RF fields, but since early 1990s the digital 1,900 MHz system has been used.

Results from the Hardell-group have been published previously on the association between use of mobile or cordless phones and brain tumours. All studies were approved by the local Ethics Committee. These studies are briefly discussed in the following and additional results are presented on e.g. age-dependent brain tumour risk. The aim of this presentation is not to give a review of this area, since such publications can be found elsewhere (6,7). In addition to our studies only a few publications from the so-called Interphone group give results

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Original Contribution

Cellular Phone Use and Risk of Benign and Malignant Parotid Gland Tumors—A Nationwide Case-Control Study

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The objective of this nationwide study was to assess the association between cellular phone use and development of parotid gland tumors (PGTs). The methods were based on the international INTERPHONE study that aimed to evaluate possible adverse effects of cellular phone use. The study included 402 benign and 58 malignant incident cases of PGTs diagnosed in Israel at age 18 years or more, in 2001–2003, and 1,266 population individually matched controls. For the entire group, no increased risk of PGTs was observed for ever having been a regular cellular phone user (odds ratio = 0.87; $p = 0.3$) or for any other measure of exposure investigated. However, analysis restricted to regular users or to conditions that may yield higher levels of exposure (e.g., heavy use in rural areas) showed consistently elevated risks. For ipsilateral use, the odds ratios in the highest category of cumulative number of calls and call time without use of hands-free devices were 1.58 (95% confidence interval: 1.11, 2.24) and 1.49 (95% confidence interval: 1.05, 2.13), respectively. The risk for contralateral use was not significantly different from 1. A positive dose-response trend was found for these measurements. Based on the largest number of benign PGT patients reported to date, our results suggest an association between cellular phone use and PGTs.

case-control studies; cellular phone; head and neck neoplasms; Israel; parotid gland

Abbreviations: CI, confidence interval; OR, odds ratio; PGT, parotid gland tumor; UICC, Union Internationale Contre le Cancer.

Since the mid-1990s when cellular phones became widespread in most Western countries, there has been concern about the possible carcinogenic effects of the electromagnetic radiofrequency fields thereby emitted (1, 2). Numerous studies addressing this issue have been published recently (3–14). Most focused on brain tumors that occur in an anatomic location where a substantial amount of the power is absorbed. The vast majority did not show an association between cellular phone use and the development of such tumors. Most studies, however, included few long-term users, reducing the chance of finding any association if one exists because of an assumed long latency time.

In accordance with the recommendations of several expert committees, an international series of case-control studies (known as the INTERPHONE study) on the relation between cellular phone use and several types of head tumors was conducted in 13 countries, including Israel (15). Several individual reports from this collaboration have been published, each reporting on part of the collaborative study population (8–14).

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Epidemiological Evidence for a Health Risk from Mobile Phone Base Stations

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Human populations are increasingly exposed to microwave/radiofrequency (RF) emissions from wireless communication technology, including mobile phones and their base stations. By searching PubMed, we identified a total of 10 epidemiological studies that assessed for putative health effects of mobile phone base stations. Seven of these studies explored the association between base station proximity and neurobehavioral effects and three investigated cancer. We found that eight of the 10 studies reported increased prevalence of adverse neurobehavioral symptoms or cancer in populations living at distances < 500 meters from base stations. None of the studies reported exposure above accepted international guidelines, suggesting that current guidelines may be inadequate in protecting the health of human populations. We believe that comprehensive epidemiological studies of long-term mobile phone base station exposure are urgently required to more definitively understand its health impact. *Key words*: base stations; electromagnetic field (EMF); epidemiology; health effects; mobile phone; radiofrequency (RF); electromagnetic radiation.

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INTRODUCTION

Mobile phone base stations are now found ubiquitously in communities worldwide. They are frequently found near or on shops, homes, schools, daycare centers, and hospitals (Figure 1). The radiofrequency (RF) electromagnetic radiation from these base stations is regarded as being low power; however, their output is continuous.[1] This raises the question as to whether the health of people residing or working in close proximity to base stations is at any risk.

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Disclosures: The authors declare no conflicts of interest.

METHODS

By searching PubMed and using keywords such as base station, mast, electromagnetic field (EMF), radiofrequency (RF), epidemiology, health effects, mobile phone, and cell phone, and by searching the references of primary sources, we were able to find only 10 human population studies from seven countries that examined the health effects of mobile phone base stations. Seven of the studies explored the association between base station proximity and neurobehavioral symptoms via population-based questionnaires; the other three retrospectively explored the association between base station proximity and cancer via medical records. A meta-analysis based on this literature is not possible due to differences in study design, statistical measures/risk estimates, exposure categories, and endpoints/outcomes. The 10 studies are therefore summarized in chronological order (Table 1).

RESULTS AND DISCUSSION

We found epidemiological studies pertaining to the health effects of mobile phone base station RF emissions to be quite consistent in pointing to a possible adverse health impact. Eight of the 10 studies reported increased prevalence of adverse neurobehavioral symptoms or cancer in populations living at distances < 500 meters from base stations. The studies by Navarro et al.,[2] Santini et al.,[3] Gadzicka et al.,[4] and Hutter et al.[5] reported differences in the distance-dependent prevalence of symptoms such as headache, impaired concentration, and irritability, while Abdel-Rassoul et al.[6] also found lower cognitive performance in individuals living ≤ 10 meters from base stations compared with the more distant control group. The studies by Eger et al.[7] and Wolf and Wolf[8] reported increased incidence of cancer in persons living for several years < 400 meters from base stations. By contrast, the large retrospective study by Meyer et al.[9] found no increased incidence of cancer near base stations in Bavaria. Blettner et al.[10] reported in Phase 1 of their study that more health problems were found closer to base stations, but in Phase 2[11] concluded that measured EMF emissions were not related to adverse health effects (Table 1).

Each of the 10 studies reviewed by us had various strengths and limitations as summarized in Table 1. Per-

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Genotoxic effects of radiofrequency electromagnetic fields

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Abstract

101 publications are exploited which have studied genotoxicity of radiofrequency electromagnetic fields (RF-EMF) *in vivo* and *in vitro*. Of these 49 report a genotoxic effect and 42 do not. In addition, 8 studies failed to detect an influence on the genetic material, but showed that RF-EMF enhanced the genotoxic action of other chemical or physical agents. The controversial results may in part be explained by the different cellular systems. Moreover, inconsistencies may depend from the variety of analytical methods being used, which differ considerably with respect to sensitivity and specificity. Taking altogether there is ample evidence that RF-EMF can alter the genetic material of exposed cells i*n vivo* and *in vitro* and in more than one way. This genotoxic action may be mediated by microthermal effects in cellular structures, formation of free radicals, or an interaction with DNA-repair mechanisms.

Keywords: Gene mutations; Cytogenetic effects; DNA fragmentation; Mechanisms of genotoxicity

1. Introduction

Alterations of genetic information in somatic cells are the key event in the process of carcinogenesis [1,2]. Consequently any agent, which has a genotoxic attribute is suspected also to be cancerogenic. This is the driving force behind the multitude of studies on genotoxicity of radiofrequency electromagnetic fields (RF-EMF), conducted so far. A total of 101 publications on genotoxicity studies of RF-EMF are exploited here, of which 49 report genotoxic effects, subsequently marked as GT(+) (Table 1), 43 do not (Table 2), and 9 find, that RF-EMF do not induce genotoxic events by itself but enhance the genotoxic action of other physical or chemical agents (Table 3). Thus, in contrast to several reviews in the past [3–6], it now became evident that non-thermal genotoxic effects of RF-EMF is convincingly demonstrated by a substantial number of published studies. The studies have been performed with a variety of different test systems – some studies used more than one test system – which will be assigned here to the three principle endpoints of a genotoxic action: (1) effect on chromosomes, (2) DNA fragmentation, and (3) gene mutations.

2. Effect on chromosomes

This group comprises the analysis of numerical or structural anomalies of metaphase chromosomes (CA), sister-chromatid-exchanges (SCEs), and formation of micronuclei (MN). Of the 21 studies using CA, 9 are CA-positive, 11 CA-negative, and 1 reports an RF-induced enhancement of genotoxicity by X-rays. In general proliferating cells are required for the study of chromosomal effects, however, micronuclei have also been analysed in polychromatic erythrocytes and in exfoliated cells, for instance from buccal smears [7,8]. Moreover, aneuploidy rates of distinct chromosomes as well as chromosomal translocations can also be studied in interphase nuclei using fluorescence in situ hybridization (FISH). While structural aberrations detected by conventional CA are mainly lethal to the cell, translocations are persistent and may be passed to the cellular progeny. Using FISH increased levels of aneuploidy of chromosome 1, 10, 11, and 17 have been reported in human blood lymphocytes after RF-EMF exposure [9]. In metaphase chromosomes FISH may increase the sensitivity of chromosomal analysis [10] but this has only once been used for RF-EMF studies [11].

CA brings about to detect a variety of chromosomal aberrations. In contrast, micronuclei originate only from acentric

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Original Communication

Genetic damage in mobile phone users: some preliminary findings

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BACKGROUND : The impact of microwave (MW)/radio frequency radiation (RFR) on important biological parameters is probably more than a simply thermal one. Exposure to radio frequency (RF) signals generated by the use of cellular telephones have increased dramatically and reported to affect physiological, neurological, cognitive and behavioural changes and to induce, initiate and promote carcinogenesis. Genotoxicity of RFR has also been reported in various test systems after *in vitro* and/or *in vivo* exposure but none in mobile phone users.
AIMS : In the present study, DNA and chromosomal damage investigations were carried out on the peripheral blood lymphocytes of individuals using mobile phones, being exposed to MW frequency ranging from 800 to 2000 MHz.
METHODS : DNA damage was assessed using the single cell gel electrophoresis assay and aneugenic and clastogenic damage by the *in vivo* capillary blood micronucleus test (MNT) in a total of 24 mobile phone users.
RESULTS : Mean comet tail length (26.76 ± 0.054 μm; 39.75% of cells damaged) in mobile phone users was highly significant from that in the control group. The *in vivo* capillary blood MNT also revealed highly significant (0.25) frequency of micronucleated (MNd) cells.
CONCLUSIONS : These results highlight a correlation between mobile phone use (exposure to RFR) and genetic damage and require interim public health actions in the wake of widespread use of mobile telephony.

Key words: DNA damage; micronuclei; microwaves;

The continued spread of mobile telephony is of serious concerns since a relationship between electromagnetic fields radio frequency (RF) and microwave (MW) radiation and adverse health effects at low intensity exposures exists. The cell (mobile) phone is an appliance that requires that it be held close to or touching the head, which is the most sensitive organ of the body. This has initiated a spate of studies to enquire for effects on user health and explore mechanisms of interaction responsible for reported biological sequel on humans, animals and organic cells from acute and chronic exposures from mobile phone frequencies. Generally, the higher the frequency the less able electromagnetic radiation is to penetrate materials. However, even millimetre waves penetrate irradiated skin to a depth of 1 mm, while the microcirculatory system of the skin functions at 150 μm and so is fully accessible to EHF exposure. Lower frequencies can however penetrate further. The mode of interaction between nonionising electromagnetic radiation and tissue is also highly dependent on the dielectric behaviour of water and dissolved ions at RF and MW frequencies.

Wireless communication systems operate in the 400–2000 MHz range, differing in respect to frequency usage in different countries and on different continents. In fact, the use of the digital communication system that transmits radio frequency radiations (RFR) at higher frequencies in this range has increased dramatically. The Indian mobile phone market has also shown dramatic ascent and has 40.6 million users with the global system of mobile communication (GSM) service having 32.02 million registered users and the code division multiple access (CDMA) subscribers with 8.6 million (www.Indianews.com, October 2004). The potential for health effects from low intensity RF/MW

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Mobile Phone Radiation Induces Reactive Oxygen Species Production and DNA Damage in Human Spermatozoa *In Vitro*

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Abstract

Background: In recent times there has been some controversy over the impact of electromagnetic radiation on human health. The significance of mobile phone radiation on male reproduction is a key element of this debate since several studies have suggested a relationship between mobile phone use and semen quality. The potential mechanisms involved have not been established, however, human spermatozoa are known to be particularly vulnerable to oxidative stress by virtue of the abundant availability of substrates for free radical attack and the lack of cytoplasmic space to accommodate antioxidant enzymes. Moreover, the induction of oxidative stress in these cells not only perturbs their capacity for fertilization but also contributes to sperm DNA damage. The latter has, in turn, been linked with poor fertility, an increased incidence of miscarriage and morbidity in the offspring, including childhood cancer. In light of these associations, we have analyzed the influence of RF-EMR on the cell biology of human spermatozoa in vitro.

Principal Findings: Purified human spermatozoa were exposed to radio-frequency electromagnetic radiation (RF-EMR) tuned to 1.8 GHz and covering a range of specific absorption rates (SAR) from 0.4 W/kg to 27.5 W/kg. In step with increasing SAR, motility and vitality were significantly reduced after RF-EMR exposure, while the mitochondrial generation of reactive oxygen species and DNA fragmentation were significantly elevated ($P<0.001$). Furthermore, we also observed highly significant relationships between SAR, the oxidative DNA damage bio-marker, 8-OH-dG, and DNA fragmentation after RF-EMR exposure.

Conclusions: RF-EMR in both the power density and frequency range of mobile phones enhances mitochondrial reactive oxygen species generation by human spermatozoa, decreasing the motility and vitality of these cells while stimulating DNA base adduct formation and, ultimately DNA fragmentation. These findings have clear implications for the safety of extensive mobile phone use by males of reproductive age, potentially affecting both their fertility and the health and wellbeing of their offspring.

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Introduction

Male infertility is a distressingly common condition affecting about 1 in 20 of the male population [1]. In a majority of cases, the male partner produces sufficient numbers of spermatozoa to achieve fertilization but there are functional defects in these cells that prevent conception from occurring [2]. Despite several decades of research, the causes of such functional deficiencies in human spermatozoa remain largely unresolved. However, one contributory factor that has recently emerged is the quality of the sperm DNA delivered to the oocyte at the moment of fertilization [3]. Fragmentation of DNA in the male germ line has been associated with impaired fertilization, poor embryonic development, high rates of miscarriage and an increased incidence of morbidity in the offspring, including childhood cancer [3,4]. In view of the seriousness of these clinical outcomes, attention has recently focused on the environmental and genetic factors that might be involved in the aetiology of DNA damage in the male germ line.

These investigations have suggested that one of the environmental factors potentially involved in the etiology of DNA damage in human spermatozoa is an increased exposure to radio-frequency electromagnetic radiation (RF-EMR) emitted from mobile phones. This association was initially suggested by an epidemiological study which found negative correlations between mobile phone usage and various attributes of semen quality, particularly motility [5]. This was immediately followed by an experimental study involving exposure of male mice to RF-EMR, which revealed a significant impact on the integrity of both the mitochondrial and nuclear genomes [6]. Recently, the negative impact of mobile phone usage on semen quality in human males was confirmed in a study that found the duration of exposure to be

Effects of radiofrequency electromagnetic waves (RF-EMW) from cellular phones on human ejaculated semen: an in vitro pilot study

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Objective: To evaluate effects of cellular phone radiofrequency electromagnetic waves (RF-EMW) during talk mode on unprocessed (neat) ejaculated human semen.
Design: Prospective pilot study.
Setting: Center for reproductive medicine laboratory in tertiary hospital setting.
Samples: Neat semen samples from normal healthy donors (n = 23) and infertile patients (n = 9).
Intervention(s): After liquefaction, neat semen samples were divided into two aliquots. One aliquot (experimental) from each patient was exposed to cellular phone radiation (in talk mode) for 1 h, and the second aliquot (unexposed) served as the control sample under identical conditions.
Main Outcome Measure(s): Evaluation of sperm parameters (motility, viability), reactive oxygen species (ROS), total antioxidant capacity (TAC) of semen, ROS-TAC score, and sperm DNA damage.
Result(s): Samples exposed to RF-EMW showed a significant decrease in sperm motility and viability, increase in ROS level, and decrease in ROS-TAC score. Levels of TAC and DNA damage showed no significant differences from the unexposed group.
Conclusion(s): Radiofrequency electromagnetic waves emitted from cell phones may lead to oxidative stress in human semen. We speculate that keeping the cell phone in a trouser pocket in talk mode may negatively affect spermatozoa and impair male fertility. (Fertil Steril® 2008;■:■–■. ©2008 by American Society for Reproductive Medicine.)

Key Words: Cell phone radiation, radiofrequency electromagnetic waves, sperm, fertility, reactive oxygen species, oxidative stress, EMW

The tremendous development and use of mobile telecommunication services in the last decade has drastically increased the amount of radiofrequency electromagnetic wave (RF-EMW) exposure in our daily lives. As the use of cell phones has increased, so have concerns regarding the harmful effects of cell phone exposure on human health. As part of its charter to protect public health, the World Health Organization (WHO) established the International EMF Project in 1996 to assess the scientific evidence of possible health effects of electromagnetic frequencies in the range of 30 Hz to 300 GHz (1). Despite more than a decade of research in this field, the potential harmful effects of cell phone radiation remain controversial.

Recent epidemiologic (cross-sectional or prospective) studies have highlighted the role of cell phone exposure on sperm motility, morphology, and viability, suggesting a reduction in male fertilization potential (2–6). These studies examined the relationship of cell phone use and its effect on semen parameters and concluded that mobile phone use may cause a decrease in fertility (2–6). To conduct a scientifically robust epidemiologic study, a control group of people who are not using and have not used cell phones in the past is a necessity. However, enrolling a pool of such control subjects in today's culture is extremely difficult. An in vivo human exposure study to investigate the effects of cell phone radiation on semen parameters is not feasible, owing to ethical issues.

Various in vitro studies using animal models have consistently demonstrated oxidative stress in different tissues (kidney, endometrium, eye, testis, brain, myocardial tissue, and so on) in response to cell phone radiation (7–13). Studies have also shown potential beneficial effects of antioxidants, such as melatonin, vitamin C, and vitamin E, on oxidative stress status induced by RF-EMW in animals (7, 8, 12, 13). However, results of animal studies related to the effects of cell phone radiation on reproductive functions are conflicting (14–19). An animal model is not preferable for study purposes for several reasons, including the smaller dimensions of the testes, the nonpendulous scrotum, the free migration

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Archives of Medical Research

ORIGINAL ARTICLE

Effects of Electromagnetic Radiation from a Cellular Phone on Human Sperm Motility: An *In Vitro* Study

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Background. There has been growing public concern on the effects of electromagnetic radiation (EMR) emitted by cellular phones on human health. Many studies have recently been published on this topic. However, possible consequences of the cellular phone usage on human sperm parameters have not been investigated adequately.

Methods. A total number of 27 males were enrolled in the study. The semen sample obtained from each participant was divided equally into two parts. One of the specimens was exposed to EMR emitted by an activated 900 MHz cellular phone, whereas the other was not. The concentration and motility of the specimens were compared to analyze the effects of EMR. Assessment of sperm movement in all specimens was performed using four criteria: (A) rapid progressive, (B) slow progressive, (C) nonprogressive, (D) no motility.

Results. Statistically significant changes were observed in the rapid progressive, slow progressive and no-motility categories of sperm movement. EMR exposure caused a subtle decrease in the rapid progressive and slow progressive sperm movement. It also caused an increase in the no-motility category of sperm movement. There was no statistically significant difference in the sperm concentration between two groups.

Conclusions. These data suggest that EMR emitted by cellular phone influences human sperm motility. In addition to these acute adverse effects of EMR on sperm motility, long-term EMR exposure may lead to behavioral or structural changes of the male germ cell. These effects may be observed later in life, and they are to be investigated more seriously.

Key Words: Mobile phone, Cellular, Electromagnetic field, Human, Sperm, Motility.

Introduction

Use of cellular phones has increased exponentially and become an important part of everyday life throughout the world. A growing concern for their possible adverse effects on human health evokes a flurry of scientific activity to evaluate this dilemma. Despite the increasing number of reports on the effects of electromagnetic radiation (EMR) in various biological systems, no satisfactory mechanism has been proposed to explain the effects of this radiation (1).

Radiofrequency (RF) energy is a type of nonionizing radiation, including EMR produced by cellular phone, and is not strong enough to cause ionization of atoms and molecules. Cellular phones emit low levels of RF in the microwave range while being used. Although high levels of RF can produce health effects (by heating tissue), exposure to low-level RF may not produce heating effects and causes no known adverse health effects. Several experimental studies demonstrated that exposure to electromagnetic or static magnetic fields had adverse effects on the reproductive system (2–10). However, it is likely that these effects were due to heating.

Recent epidemiological studies investigated the possible effects that EMR have comparing cell phone use and sperm

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[O-249] LAPTOP EXPOSITIONS AFFECT MOTILITY AND INDUCE DNA FRAGMENTATION IN HUMAN SPERMATOZOA IN VITRO BY A NON-THERMAL EFFECT: A PRELIMINARY REPORT.

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OBJECTIVE: The use of laptops has drastically increased in the last years. These devices are commonly used on the lap near the groin area and may expose the human testes to radio frequency electromagnetic waves (Wi-Fi mode) as well as to high temperatures. There is weak scientific information about the possible impact of exposition to laptops on male reproduction. Therefore, we have assessed the sperm exposure to laptops in an in vitro study.
DESIGN: An in vitro prospective study.
MATERIALS AND METHODS: Semen samples from 15 men were evaluated. Semen parameters (concentration, motility, morphology and vitality) were assessed. Motile sperm were selected by swim up and separated in two fractions and incubated 4 hours at controlled temperature (25°C). The first aliquot was exposed to the laptop during the incubation times. The second fraction was incubated without exposition (control group). Motility, vitality and sperm DNA fragmentation (TUNEL) was evaluated after incubation in all samples. Comparisons between groups were performed by Student's t test. Data is expressed as mean ± SD.
RESULTS: Our results showed decrease progressive sperm motility (73,5 ± 8,2 vs 63,6 ± 7,3; $p < 0,05$), increase sperm immotility (18,8 ± 6,9 vs 28,3 ± 7,3; $p < 0,05$) and increase of sperm DNA fragmentation (6,3 ± 8,1 vs 13,1 ± 9,2; $p < 0,05$) in the exposed vs non exposed group. Levels of non progressive sperm motility and vitality did not show significant difference between the two groups.
CONCLUSION: To the best of our knowledge, this is the first study to evaluate the impact of laptops on human spermatozoa. We have demonstrated that exposure to laptops decrease progressive motility and induce DNA fragmentation in human spermatozoa in vitro by a non-thermal effect. We speculate that keeping the laptops (Wi-Fi mode) on the lap near the testes may result in decreased male fertility. Further studies are needed to test this hypothesis and identify the causes why sperm quality is affected by laptops exposition.
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ORIGINAL ARTICLE

The effects of microwave emitted by cellular phones on ovarian follicles in rats

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Abstract
Objective The aim of this study was to investigate whether there were any toxic effects of microwaves of cellular phones on ovaries in rats.
Methods In this study, 82 female pups of rats, aged 21 days (43 in the study group and 39 in the control group) were used. Pregnant rats in the study group were exposed to mobile phones that were placed beneath the polypropylene cages during the whole period of pregnancy. The cage was free from all kinds of materials, which could affect electromagnetic fields. A mobile phone in a standby position for 11 h and 45 min was turned on to speech position for 15 min every 12 h and the battery was charged continuously. On the 21st day after the delivery, the female rat pups were killed and the right ovaries were removed. The volumes of the ovaries were measured and the number of follicles in every tenth section was counted.
Results The analysis revealed that in the study group, the number of follicles was lower than that in the control group. The decreased number of follicles in pups exposed to mobile phone microwaves suggest that intrauterine exposure has toxic effects on ovaries.
Conclusion We suggest that the microwaves of mobile phones might decrease the number of follicles in rats by several known and, no doubt, countless unknown mechanisms.

Keywords Follicles · Microwave of cellular phones · Rat

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Introduction

The expansive growth in mobile communication in recent years has resulted in an increasing exposure of the environment to weak radiofrequency (RF) electromagnetic fields (EMF). This has aroused a general interest in the possible effects of RF and microwave radiation (MWR) on human health. During the last decade, association has been suggested between chronic or long-term exposure to EMF and its toxic effects on reproduction [1, 2]. Calculation of the maximum temperature rise in the head from RF exposure during mobile phone use suggests that an increase of no more than about 0.10°C would be expected [3]. Thus, if there are some hard effects of low-level RF exposure on health, they are likely due to an increase in temperature [3, 4]. It was concluded that, although hazards from exposure to high RF fields were established, there have been no identified health hazards caused by low RF sources emitting fields, due to a significant temperature rise in tissues [5].

The misconception still persists that RF and MWR effects are solely the results of an increase in heat, contrary to the fact that a number of reported studies have demonstrated significant effects on various cellular activities in experimental systems under isothermal conditions [6]. An increased damage to macromolecules, by an increase in free radicals in cells, such as DNA, might be caused indirectly. EMF expositions may also modify the amount of cell

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Effects of pulsed electromagnetic fields on cognitive processes – a pilot study on pulsed field interference with cognitive regeneration

Maier R, Greter S-E, Maier N. Effects of pulsed electromagnetic fields on cognitive processes – a pilot study on pulsed field interference with cognitive regeneration.
Acta Neurol Scand 2004: 110: 46–52. © Blackwell Munksgaard 2004.

Background – Due to the ubiquitous use of cellular phones much has been speculated on secondary effects of electromagnetic irradiation emitted by those. Additionally, several studies have reported vegetative alterations as well as effects on the neuronal and molecular levels in humans. Here, using a psycho–physiological test paradigm, we examined effects of exposure to pulsed electromagnetic fields on cognitive performance. *Materials and methods* – In 11 volunteers, we tested cognitive processing under field exposure (GSM standard) and under field-free conditions. To examine the hypothesized effect of pulsed fields, we applied an auditory discrimination task and determined the participant's current 'Order Threshold' value. Following a first test cycle, the volunteers had to relax for 50 min while being, or not, exposed to pulsed electromagnetic fields. Subsequently, the test was repeated. Data acquired before and after the resting phase were compared from both experimental conditions. *Results* – We found that nine of the 11 test participants (81.8%) showed worse results in their auditory discrimination performance upon field exposure as compared with control conditions. Group data comparison revealed a statistical significance of $P = 0.0105$. *Conclusion* – We could show that the participants' cognitive performance was impaired after exposure to pulsed electromagnetic fields. With regard to this finding, we recommend that the use of cellular phones should be restricted generally and in particular in respect of physical hazard of high-risk groups, e.g. elderly, children and ill people.

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Key words: cognitive processes; pulsed electromagnetic fields; order threshold; psycho–physiological test

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Effects of electromagnetic (EM) fields on organisms are discussed ambivalently in the literature. Especially during the last years, the discussion has been of lively interest because of the booming use of cellular phones (1, 2). Particularly maximum exposure limits for the transmitting intensity of the base stations have come in for criticism, as the immission limit values have been determined according to thermal pollution of human circulation. Furthermore, the legally recommended maximum tolerable irradiance differs considerably in different European countries (e.g. $S = 4.5$ W/m^2 in Germany compared with $S = 0.1$ W/m^2 in Italy or $S = 0.04$ W/m^2 in Switzerland). A vegetative impairment of man by thermal effects of electromagnetic fields has been proved (3, 4), but additionally there are also findings hinting at effects in the non-thermal area, with low field strengths, on both the neuronal (5) and the molecular level (6).

Another point of criticism focuses on the transmission technology of pulsed radio frequencies (RF) according to the standard of the Global System of Mobile Communications (GSM standard; 902 MHz/pulsed at 217 Hz). Especially these pulsed fields are considered to be a health hazard. Possible patho–physiological influences on the organism brought about by these pulses including

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Whole body exposure with GSM 900 MHz affects spatial memory in mice

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Abstract

Extended work has been performed worldwide on the effects of mobile phone radiation upon rats' cognitive functions, however there is great controversy to the existence or not of deficits. The present work has been designed in order to test the effects of mobile phone radiation on spatial learning and memory in mice *Mus musculus* Balb/c using the Morris water maze (a hippocampal-dependent spatial memory task), since there is just one other study on mice with very low SAR level (0.05 W/kg) showing no effects. We have applied a 2 h daily dose of pulsed GSM 900 MHz radiation from commercially available mobile phone for 4 days at SAR values ranging from 0.41 to 0.98 W/kg. Statistical analysis revealed that during learning, exposed animals showed a deficit in transferring the acquired spatial information across training days (increased escape latency and distance swam, compared to the sham-exposed animals, on the first trial of training days 2–4). Moreover, during the memory probe-trial sham-exposed animals showed the expected preference for the target quadrant, while the exposed animals showed no preference, indicating that the exposed mice had deficits in consolidation and/or retrieval of the learned spatial information. Our results provide a basis for more thorough investigations considering reports on non-thermal effects of electromagnetic fields (EMFs).

Keywords: Electromagnetic fields; Morris water maze; Spatial memory

1. Introduction

The tremendous increase in the number of users of mobile phone technology in relation to possible health effects raised by several studies has forced a large number of scientists to get involved in the investigation of the biological and health effects [1]. Since the usual, without protective measures (hands free or blue tooth), use of the mobile phone (MP) takes place near the user's head, the elucidation of the cellular, molecular and behavioral effects are of utmost importance, especially since the majority of life-time MP users will be the current teenagers. The key question therefore is, do living organisms in general react upon their exposure to man-made electromagnetic fields (EMFs) of non-ionizing electromagnetic radiation? To have this question answered extensive research is being performed in various laboratories as thoroughly presented in a recent review article [2]. The so far literature regarding the issue of risk assessment of EMFs reveals that the biological effects of EMF have been and are being investigated at different levels [3], starting downwards from the level of human population with epidemiological studies. At the immediate lower level of the individuals, human, animal and plant *in vivo* experiments are carried out. Consequently, at the level of organs, tissues and cells *in vitro* experiments are performed. At last but not least, at the sub-cellular level, biochemical, biophysical and molecular techniques are utilized:

Epidemiological–statistical studies have been successfully correlated exposure conditions to defects, primarily of brain tumors [4,5]. In some cases minor health symptoms have been reported [6], as well as behavioral problems in children exposed prenatally to mobile phone radiation [7]. Clinical studies in humans, mainly involving volunteers, have shown possible effects on sleeping conditions and memory function [8]. At the same, individual's level, lab animal studies are very extensive and have been using sophisticated techniques including gene and protein expression studies, proteomics, development and reproduction following EMF exposure. Many animal models have been used, including

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Cognitive Impairment in Rats After Long-Term Exposure to GSM-900 Mobile Phone Radiation

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Considering the frequent use of mobile phones, we have directed attention to possible implications on cognitive functions. In this study we investigated in a rat model the long-term effects of protracted exposure to Global System for Mobile Communication-900 MHz (GSM-900) radiation. Out of a total of 56 rats, 32 were exposed for 2 h each week for 55 weeks to radio-frequency electromagnetic radiation at different SAR levels (0.6 and 60 mW/kg at the initiation of the experimental period) emitted by a (GSM-900) test phone. Sixteen animals were sham exposed and eight animals were cage controls, which never left the animal house. After this protracted exposure, GSM-900 exposed rats were compared to sham exposed controls. Effects on exploratory behaviour were evaluated in the open-field test, in which no difference was seen. Effects on cognitive functions were evaluated in the episodic-like memory test. In our study, GSM exposed rats had impaired memory for objects and their temporal order of presentation, compared to sham exposed controls ($P = 0.02$). Detecting the place in which an object was presented was not affected by GSM exposure. Our results suggest significantly reduced memory functions in rats after GSM microwave exposure ($P = 0.02$). Bioelectromagnetics 29:219–232, 2008.

Key words: microwaves; episodic-like memory test; memory; open-field-test; learning; exploratory behaviour; anxiety

INTRODUCTION

The worldwide use of Global System for Mobile Communication (GSM) mobile phones raises concerns about possible implications to human health. Since the introduction of the GSM network for mobile communication in 1992 in Western Europe, the use of this kind of phone has increased tremendously. Today one-third of the world's population relies on mobile phones for daily communication. For the foreseeable future, the use of mobile phones and related technologies will continue to increase [Stewart, 2000]. Keeping this vast and constantly increasing exposure of humans to mobile phones in mind, designating the use of mobile phones as the world's largest biological experiment ever [Salford et al., 2001] is indeed appropriate.

The close proximity of the mobile phone to the user's head leads to absorption of about 50% of the electromagnetic field (EMF) energy from the mobile in the brain [Dimbylow and Mann, 1994]. The question of whether the deliberate and passive exposure to radio frequency (RF) EMF from mobile phones might affect cognitive functions is of great importance. Reports of impairment [Maier et al., 2004; Keetley et al., 2006] or improvement [Preece et al., 1999; Koivisto et al., 2000]

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BASIC RESEARCH

SPATIAL MEMORY PERFOMANCE OF WISTAR RATS EXPOSED TO MOBILE PHONE

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Sareesh N N, Kumar RS, Potu BK, Nayak S, Maneesh M. Spatial memory perfomance of wistar rats exposed to mobile phone. Clinics. 2009;64(3):231-4.

INTRODUCTION: With the tremendous increase in number of mobile phone users world wide, the possible risks of this technology have become a serious concern.
OBJECTIVE: We tested the effects of mobile phone exposure on spatial memory performance.
MATERIALS AND METHODS: Male Wistar rats (10-12 weeks old) were exposed to 50 missed calls/day for 4 weeks from a GSM (900/1800MHz) mobile phone in vibratory mode (no ring tone). After the experimental period, the animals were tested for spatial memory performance using the Morris water maze test.
RESULTS: Both phone exposed and control animals showed a significant decrease in escape time with training. Phone exposed animals had significantly (~3 times) higher mean latency to reach the target quadrant and spent significantly (~2 times) less time in the target quadrant than age- and sex-matched controls.
CONCLUSION: Mobile phone exposure affected the acquisition of learned responses in Wistar rats. This in turn points to the poor spatial navigation and the object place configurations of the phone-exposed animals.

KEYWORDS: Mobile phone; Rats; Memory; Learning; Water maze.

INTRODUCTION

The recent enormous increase in the use of wireless mobile devices has motivated a large body of research, both epidemiological and experimental. This voluntary exposure to microwaves has been called the largest human biological experiment ever performed. The possible risks of these microwaves are of growing concern in our society. Exposure to an electromagnetic field (EMF) at 1.8 GHz increases the permeability of the blood-brain barrier to sucrose[1]. The combined exposure to radiofrequency (RF) EMFs and pulsed and static magnetic fields results in significant pinocytotic transport of albumin from the capillaries into the brain[2]. Our recent study (Kumar et al., submitted) has shown that mobile phone exposure in Wistar rats results in high anxiety, demonstrated by deficient open arm exploration on an elevated plus-maze apparatus and by a fear induced increase in parasympathetic activity.

In the present work we studied the spatial memory performance of Wistar rats exposed to mobile phones using the Morris water maze (MWM), the bench mark test for spatial memory performance. Because teenagers are the heaviest users of wireless technology and are of special concern, we exposed 8-10 weeks old Wistar rats, which are developmentally comparable to human teenagers, to EMFs from a GSM mobile phone.

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Mobile phone emission modulates interhemispheric functional coupling of EEG alpha rhythms

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Abstract

We tested the working hypothesis that electromagnetic fields from mobile phones (EMFs) affect interhemispheric synchronization of cerebral rhythms, an important physiological feature of information transfer into the brain. Ten subjects underwent two electroencephalographic (EEG) recordings, separated by 1 week, following a crossover double-blind paradigm in which they were exposed to a mobile phone signal (global system for mobile communications; GSM). The mobile phone was held on the left side of the subject head by a modified helmet, and orientated in the normal position for use over the ear. The microphone was orientated towards the corner of the mouth, and the antenna was near the head in the parietotemporal area. In addition, we positioned another similar phone (but without battery) on the right side of the helmet, to balance the weight and to prevent the subject localizing the side of GSM stimulation (and consequently lateralizing attention). In one session the exposure was real (GSM) while in the other it was Sham; both sessions lasted 45 min. Functional interhemispheric connectivity was modelled using the analysis of EEG spectral coherence between frontal, central and parietal electrode pairs. Individual EEG rhythms of interest were delta (about 2–4 Hz), theta (about 4–6 Hz), alpha 1 (about 6–8 Hz), alpha 2 (about 8–10 Hz) and alpha 3 (about 10–12 Hz). Results showed that, compared to Sham stimulation, GSM stimulation modulated the interhemispheric frontal and temporal coherence at alpha 2 and alpha 3 bands. The present results suggest that prolonged mobile phone emission affects not only the cortical activity but also the spread of neural synchronization conveyed by interhemispherical functional coupling of EEG rhythms.

Introduction

The increasing number of telecommunication devices available and the length of time spent using mobile telephones has aroused interest for possible interactions between human brain and radio-frequency radiation, due to their proximity during phone communications and the increasing amount of mobile phone use by the general population of all ages and health conditions (Repacholi, 1998; Hyland, 2000).

The bulk of the evidence points to the effects of electromagnetic fields from mobile phones (EMFs) on the power of resting electroencephalographic (EEG) activity as a sign of interference with neural activity due to physiological effects of EMFs (Cook *et al*., 2002; Hamblin & Wood, 2002). It has been shown the influence of EMFs on the power of resting EEG rhythms, especially in the alpha band (defined as 8–13 Hz by Reiser *et al*., 1995; Croft *et al*., 2002). This result has been confirmed and extended by a recent EEG study (Curcio *et al*., 2005). Furthermore, the effects of EMFs have been observed in the spectral content of EEG recorded both prior to sleep onset (Huber *et al*., 2002) and during sleep (Borbély *et al*., 1999). In contrast, other studies have detected no effect of EMFs on the power of resting EEG rhythms (Röschke & Mann, 1997; Hietanen *et al*., 2000).

The influence of EMFs on cerebral (EEG) rhythms raises several issues, including whether they affect functional coupling of cerebral rhythms, which roughly reflect operative binding between coupled brain regions and relative information transfer. Linear components of that coupling are nicely modelled by the interhemispheric spectral coherence of EEG rhythms. Indeed, significant coherence between EEG electrodes has been previously interpreted as evidence of functional coupling (Thatcher *et al*., 1986; Gerloff *et al*., 1998), mutual information exchange (Rappelsberger & Petsche, 1988), functional co-ordination (Gevins *et al*., 1998) and integrity of corticocortical connecting pathways between two brain regions (Locatelli *et al*., 1998). In the light of these findings, and taking into account that transient synchronization of neuronal firing rhythms as reflected by functional coupling is often the basis of information processing, the study of functional coupling could reveal any possible effect of EMF interference on the synchronization of cerebral rhythms and on relative information transfer and processing.

Information processing in human cognition is highly reflected by brain EEG alpha (~ 8–12 Hz in the following references) rhythms

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Prenatal and Postnatal Exposure to Cell Phone Use and Behavioral Problems in Children

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Background: The World Health Organization has emphasized the need for research into the possible effects of radiofrequency fields in children. We examined the association between prenatal and postnatal exposure to cell phones and behavioral problems in young children.

Methods: Mothers were recruited to the Danish National Birth Cohort early in pregnancy. When the children of those pregnancies reached 7 years of age in 2005 and 2006, mothers were asked to complete a questionnaire regarding the current health and behavioral status of children, as well as past exposure to cell phone use. Mothers evaluated the child's behavior problems using the Strength and Difficulties Questionnaire.

Results: Mothers of 13,159 children completed the follow-up questionnaire reporting their use of cell phones during pregnancy as well as current cell phone use by the child. Greater odds ratios for behavioral problems were observed for children who had possible prenatal or postnatal exposure to cell phone use. After adjustment for potential confounders, the odds ratio for a higher overall behavioral problems score was 1.80 (95% confidence interval = 1.45–2.23) in children with both prenatal and postnatal exposure to cell phones.

Conclusions: Exposure to cell phones prenatally—and, to a lesser degree, postnatally—was associated with behavioral difficulties such as emotional and hyperactivity problems around the age of school entry. These associations may be noncausal and may be due to unmeasured confounding. If real, they would be of public health concern given the widespread use of this technology.

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Exposure to radiofrequency fields is increasingly common, but the potential influence on health has not been thoroughly investigated, especially in children. Between 2003 and 2008, there were more than 900 million new cell phone subscribers worldwide, with a total of more than 2 billion subscribers.[1] Fetuses and children may be more vulnerable than adults to external exposures in general.[2] In 2000, the Stewart Report recommended a precautionary approach to the use of cell phones until more detailed and scientifically robust information became available, especially for children.[3] Numerous reviews, including 1 by the World Health Organization,[4] stress the need for studies in children and on cognitive effects, because of the importance of cognitive abilities and learning in early development.

Most epidemiologic studies of exposure to radiofrequency fields have focused on brain and acoustic cancers as outcomes[5–11] or on subjective symptoms such as headaches.[12,13] A number of laboratory studies have examined physiologic effects after short-term exposure,[14–18] but a variety of other outcomes are yet to be investigated, and none has included potentially susceptible populations such as fetuses and very young children.

Children are potentially exposed during fetal life by maternal use of cell phones and then later in childhood when they themselves become users of cell phones. Exposures early in life may have particular importance because this is during vulnerable stages of brain development.

There is limited information on the association between radiofrequency field exposure during pregnancy and reproductive outcomes (spontaneous abortions, birth weight, sex ratio, and congenital malformations), mostly from occupational studies. Occupational exposures are typically much higher than exposures from cell phone use. Some studies have reported increased risk of spontaneous abortions and congenital malformations, although these results come from poorly designed studies.[19]

Since no established mechanism is known for radiofrequency exposure—except for what may be caused by an increased temperature in the exposed regions—it is impossible to exclude any health outcomes from consideration. Experimental research indicates exposure might affect nonspecific neurologic performance such as attention. In a preliminary cross-sectional analysis of 13 year-olds in the MoRPhEUs study, differences in certain cognitive abilities related to cell phone use were observed (Rodney Croft personal communication, 16 December 2007).

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BRAIN RESEARCH

Research Report

Effects of prenatal exposure to a 900 MHz electromagnetic field on the dentate gyrus of rats: a stereological and histopathological study☆

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ABSTRACT

Electromagnetic fields (EMFs) inhibit the formation and differentiation of neural stem cells during embryonic development. In this study, the effects of prenatal exposure to EMF on the number of granule cells in the dentate gyrus of 4-week-old rats were investigated. This experiment used a control (Cont) group and an EMF exposed (EMF) group (three pregnant rats each group). The EMF group consisted of six offspring ($n=6$) of pregnant rats that were exposed to an EMF of up to 900 megahertz (MHz) for 60 min/day between the first and last days of gestation. The control group consisted of five offspring ($n=5$) of pregnant rats that were not treated at all. The offspring were sacrificed when they were 4 weeks old. The numbers of granule cells in the dentate gyrus were analyzed using the optical fractionator technique. The results showed that prenatal EMF exposure caused a decrease in the number of granule cells in the dentate gyrus of the rats ($P<0.01$). This suggests that prenatal exposure to a 900 MHz EMF affects the development of the dentate gyrus granule cells in the rat hippocampus. Cell loss might be caused by an inhibition of granule cell neurogenesis in the dentate gyrus.

1. Introduction

Neurons in most regions of the brain are formed during gestation and the process of neurogenesis is completed before birth (Guidi et al., 2005). Because of this developmental pattern, the adult brain is unable to replace nerve cells lost as a result of aging or pathological conditions, except for the dentate gyrus (DG) in the hippocampus and the subventricular zone of the lateral ventricle in several mammals' brains (Contestabile, 2002; Guidi et al., 2005). In these regions, neurogenesis begins during gestation, continues during the early postnatal period and, at a slower rate, through into adulthood. This is true for all species, including humans (Eriksson et al., 1998; Snyder et al., 2001; Magavi and Macklis, 2002; Guidi et al., 2005).The principle neuron type of the DG is granule cells, the production of which begins in the prenatal period and continues throughout postnatal life. However, many of these cells are formed by the third-week after birth (Rodier, 1980). Therefore, deleterious events during gestation may induce neurobiological or behavioral defects in offspring, including hippocampal formation, because this region is vulnerable to disruptive events (Lemaire et al., 2000).

☆ This study was presented at the 9th National Congress of Histology and Embryology, Turkey, Adana, May 20-23, 2008.

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Provocation study using heart rate variability shows microwave radiation from 2.4 GHz cordless phone affects autonomic nervous system

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Abstract

Aim: **The effect of pulsed (100 Hz) microwave (MW) radiation on heart rate variability (HRV) was tested in a double blind study.** ***Materials and Methods:*** **Twenty-five subjects in Colorado between the ages of 37 to 79 completed an electrohypersensitivity (EHS) questionnaire. After recording their orthostatic HRV, we did continuous real-time monitoring of HRV in a provocation study, where supine subjects were exposed for 3-minute intervals to radiation generated by a cordless phone at 2.4 GHz or to sham exposure.** ***Results:*** **Questionnaire: Based on self-assessments, participants classified themselves as extremely electrically sensitive (24%), moderately (16%), slightly (16%), not sensitive (8%) or with no opinion (36%) about their sensitivity. The top 10 symptoms experienced by those claiming to be sensitive include memory problems, difficulty concentrating, eye problems, sleep disorder, feeling unwell, headache, dizziness, tinnitus, chronic fatigue, and heart palpitations. The five most common objects allegedly causing sensitivity were fluorescent lights, antennas, cell phones, Wi-Fi, and cordless phones. Provocation Experiment: Forty percent of the subjects experienced some changes in their HRV attributable to digitally pulsed (100 Hz) MW radiation. For some the response was extreme (tachycardia), for others moderate to mild (changes in sympathetic nervous system and/or parasympathetic nervous system). and for some there was no observable reaction either because of high adaptive capacity or because of systemic neurovegetative exhaustion.** ***Conclusions:*** **Orthostatic HRV combined with provocation testing may provide a diagnostic test for some EHS sufferers when they are exposed to electromagnetic emitting devices. This is the first study that documents immediate and dramatic changes in both Hearth Rate (HR) and HR variability (HRV) associated with MW exposure at levels**

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Effects of mobile phone radiofrequency on the structure and function of the normal human hemoglobin

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ABSTRACT

Widespread use of mobile phones has increased the human exposure to electromagnetic fields (EMFs). It is required to investigate the effect of EMFs on the biological systems. In this paper the effect of mobile phone RF (910 MHz and 940 MHz) on structure and function of HbA was investigated. Oxygen affinity was measured by sodium dithionite with UV–vis spectrophotometer. Structural changes were studied by circular dichroism and fluorescence spectroscopy. The results indicated that mobile phone EMFs altered oxygen affinity and tertiary structure of HbA. Furthermore, the decrease of oxygen affinity of HbA corresponded to the EMFs intensity and time of exposure.

1. Introduction

Nowadays, more than 2.5 billion people utilize cell phones and base stations constituting the cell network. The global system for mobile communication (GSM) which being used in most of the countries has a frequency of either 900 or 1800 MHz (pulsed at 217 Hz, band width of 200 kHz). The spectrum of 900 MHz has two bands: 890–915 MHz which is specific for handset, and 935–960 MHz which is specific for base station antenna. The development of mobile communication has aroused a deep interest in people and has stimulated wide and often controversial discussions in the scientific community about potential damages induced by exposure to low-level radiation emitted in the microwave (MW) region [1].

There are several works on the effect of electromagnetic fields (EMFs) on proteins. The possibility that RF radiation may cause changes in protein conformation and hence biological properties has been reported in Refs. [2–9]. George et al. [10] studied citrate synthase unfolding by the effect of EMFS, and concluded that microwaves have effect on protein conformation that could take the form of a direct interaction of the electromagnetic fields with the protein or its water of hydration. In another work Mancinelli et al. [11] also showed the same result, exploring a potential role of MW-EMFs exposure in affecting folding process and/or determining the misfolding of polypeptide chains. Exposure to cell phone radiation up-regulates apoptosis of genes in primary cultures of neurons and astrocytes [12], and in human endothelial cell lines [13]. Also expression of Hsp70 [14,15]; early gene, c-fos [16]; G1 phase-regulating proteins [17]; tumor suppressor p53 [18]; up-regulating P27Kip1 [19] affected by microwave irradiation.

It has reported the change in the activity of enzymes upon exposure by microwave EMFs, e.g., extracellular-signal-regulated kinase [20]; antioxidative enzyme activities [21]; trichoderma reesei cellulase [22]; Na, K-ATPase [23]; acetylcholinesterase [24,25]; soluble and insoluble peroxidase [26]; cerebral cytochrome *c* oxidase [27].

Schirmacher et al. [28] reported the influence of high frequency EMFs on the permeability of an in vitro model of the blood–brain barrier (BBB). They concluded that on exposure to EMFs the permeability of ^{14}C-sucrose increased significantly compared to that of the unexposed samples.

In light of what happen to biological systems by exposing to the EMFs, there are some evidences for possible effects of EMF via involving in electron transfer reactions. These were extensively

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Disturbance of the immune system by electromagnetic fields—A potentially underlying cause for cellular damage and tissue repair reduction which could lead to disease and impairment

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Abstract

A number of papers dealing with the effects of modern, man-made electromagnetic fields (EMFs) on the immune system are summarized in the present review. EMFs disturb immune function through stimulation of various allergic and inflammatory responses, as well as effects on tissue repair processes. Such disturbances increase the risks for various diseases, including cancer. These and the EMF effects on other biological processes (e.g. DNA damage, neurological effects, etc.) are now widely reported to occur at exposure levels significantly below most current national and international safety limits. Obviously, biologically based exposure standards are needed to prevent disruption of normal body processes and potential adverse health effects of chronic exposure.

Based on this review, as well as the reviews in the recent Bioinitiative Report [http://www.bioinitiative.org/] [C.F. Blackman, M. Blank, M. Kundi, C. Sage, D.O. Carpenter, Z. Davanipour, D. Gee, L. Hardell, O. Johansson, H. Lai, K.H. Mild, A. Sage, E.L. Sobel, Z. Xu, G. Chen, The Bioinitiative Report—A Rationale for a Biologically-based Public Exposure Standard for Electromagnetic Fields (ELF and RF), 2007)], it must be concluded that the existing public safety limits are inadequate to protect public health, and that new public safety limits, as well as limits on further deployment of untested technologies, are warranted.

Keywords: Immunology; Radiofrequency fields; Magnetic fields; Power-frequency

1. Introduction

Around the world, for a number of years, there has been an active debate involving the general public, scientists, journalists, politicians, and people from the electric power and telecom companies, all trying to answer the basic question: Is biology compatible with the ever-increasing levels of electromagnetic fields (EMFs)? Or, to put it in more layman's terms: Can we, as human beings, survive all the radiation? Are we built for a 24-h, whole-body irradiation life? Are we immune to these signals, or are we actually playing with our planet's future, putting life at stake? The answers appear to be: *No, we are not designed for such EMF exposure loads. We are not immune. We are gambling with our future.*

Very often the biggest threat from EMF exposure is said to be cancer. However, this is not the most horrifying scenario. Just imagine if some basic *and general* molecular and/or cellular mechanism were altered. For instance, imagine if one morning the nitrogen-binding bacteria in the soil or the honey bees in the air had been destroyed beyond repair. Or, as this paper will indicate, imagine if our immune system, trying to cope with the ever-increasing electromagnetic signals, finally could not do so any longer!

Is the immune system designed to deal with "allergens" never present before, but now being invented, manufactured and used? Is it likely that our immune system, by some enormously intelligent 'glitch' in the evolutionary process has that capacity? Is that even remotely likely? *Of course, not.*

The recommended safe exposure levels have not taken this into account, since the existing standards are only based on the immediate heating of cells and tissues [most often evaluated in fluid-filled plastic dolls!]. They certainly do not take into consideration long-term effects or non-thermal effects that occur before heating can be detected. Furthermore, the recommendations do not take into account all available sci-

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Electromagnetic pollution from phone masts. Effects on wildlife

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Abstract

A review on the impact of radiofrequency radiation from wireless telecommunications on wildlife is presented. Electromagnetic radiation is a form of environmental pollution which may hurt wildlife. Phone masts located in their living areas are irradiating continuously some species that could suffer long-term effects, like reduction of their natural defenses, deterioration of their health, problems in reproduction and reduction of their useful territory through habitat deterioration. Electromagnetic radiation can exert an aversive behavioral response in rats, bats and birds such as sparrows. Therefore microwave and radiofrequency pollution constitutes a potential cause for the decline of animal populations and deterioration of health of plants living near phone masts. To measure these effects urgent specific studies are necessary.

Keywords: Effects on wildlife; Effects on birds; Electromagnetic radiation; Mammals; Microwaves; Mobile telecommunications; Non-thermal effects; Phone masts; Radiofrequencies

1. Introduction

Life has evolved under the influence of two omnipresent forces: gravity and electromagnetism. It should be expected that both play important roles in the functional activities of organisms [1]. Before the 1990's radiofrequencies were mainly from a few radio and television transmitters, located in remote areas and/or very high places. Since the introduction of wireless telecommunication in the 1990's the rollout of phone networks has caused a massive increase in electromagnetic pollution in cities and the countryside [2,3].

Multiple sources of mobile communication result in chronic exposure of a significant part of the wildlife (and man) to microwaves at non-thermal levels [4]. In recent years, wildlife has been chronically exposed to microwaves and RFR (Radiofrequency radiation) signals from various sources, including GSM and UMTS/3G wireless phones and base stations, WLAN (Wireless Local Area Networks), WPAN (Wireless Personal Area Networks such as Bluetooth), and DECT (Digital Enhanced (former European) Cordless Telecommunications) that are erected indiscriminately without studies of environmental impact measuring long-term effects. These exposures are characterized by low intensities, varieties of signals, and long-term durations. The greater portion of this exposure is from mobile telecommunications (geometric mean in Vienna: 73% [5]). In Germany the GSM cellular phone tower radiation is the dominating high frequency source in residential areas [6]. Also GSM is the dominating high frequency source in the wilderness of Spain (personal observation).

Numerous experimental data have provided strong evidence of athermal microwave effects and have also indicated several regularities in these effects: dependence of frequency within specific frequency windows of "resonance-type"; dependence on modulation and polarization; dependence on intensity within specific intensity windows, including super-low power density comparable with intensities from base stations/masts [4,7–9]. Some studies have demonstrated different microwave effects depending on wavelength in the range of mm, cm or m [10,11]. Duration of exposure may be as important as power density. Biological effects resulting from electromagnetic field radiation might depend on dose, which indicates long-term accumulative effects [3,9,12]. Modulated and pulsed radiofrequencies seem to be more effective in producing effects [4,9]. Pulsed waves (in blasts), as well as certain low frequency modulations exert greater

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