

Cell Phone and Male Infertility: An Update

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Abstract

Cell phones are a relatively novel and evolving technology. Mobile communication is now essentially ruling in our daily activities through better connectivity and intelligent, smart phone services. While the potential benefits of this technology continue to emerge, so do the potential health risks. There is increasing concern that the use of mobile phones may be associated with decreased semen quality and infertility. The most sensitive tissues to the damaging effects of cell phones are testicular tissues through increased oxidative stress, heating and radiation. Cell phone radiation may negatively affect sperm quality in men by decreasing the semen volume, sperm concentration, sperm count, motility, and viability, thus impairing male fertility. This should be supported by mass media to raise awareness among people regarding the possible health effects of radiofrequency emissions from mobile phones and to minimize its exposure. This study is a brief review of the recent data about the effect of cell phones in male infertility.

Key words: Cell phones, male infertility, radiofrequency

INTRODUCTION

Sources of radiofrequency exposure

Exposure of the human to radiofrequency (RF) radiation can occur from several sources, including the use of personal devices (cell phones, cordless phones, Wi-Fi, Bluetooth, amateur radios, etc.), occupational sources (high-frequency dielectric and induction heaters, broadcast antennas, high-power pulsed radars, and medical appliances), and environmental sources (cell phone base stations, broadcast antennae).^[1]

One of the most common tools we see these days is that of people with their cell phones next to their ears. Cell phones are low-powered RF transmitters, with frequencies between 450 and 2700 MHz, operating through a network of base stations, with power in the range of 0.1–2 W transmitted through an antenna used close to the user's head.^[2]

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Cell phones use RF fields in the form of electromagnetic waves which are transmitted from the handset to the closest base station to connect calls, text messages, E-mails, pictures, and web downloads to the main telephone network.^[3] These RF waves are unlike ionizing radiation such as X-rays or gamma rays, can neither break chemical bonds nor are powerful enough to damage our deoxyribonucleic acid (DNA). However, they are likely to be absorbed by tissues closest to device exposure site and produce the mild local thermal effect.^[4]

Possible mechanisms of radiofrequency-induced general human health hazards

Tissue heating is the principal mechanism of interaction between RF energy and the human body. At the frequencies which were used by mobile phones, most of the energy is absorbed by the skin and other superficial tissues, resulting in negligible temperature rise in the brain or any other organ of the body and thus, they do not pose any proven health hazard. However, much of public health concern revolves around the possibility of hazards from long-term exposure to levels which do not produce measurable heating.^[5]

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Physicists have analyzed every other conceivable interaction between mobile radiation and biological processes, for example, physical deformations of proteins, activation of signaling pathways, and docking with receptors on cell membranes.^[6]

The World Health Organization (WHO) and government agencies like Federal Communications Commission (FCC) of the United States have laid down specific limitations for human exposure to RF emissions from hand-held mobile phones in terms of specific absorption rate (SAR), a measure of the rate of absorption of RF energy by the body.^[3]

The FCC's exposure guidelines delineate a SAR of 1.6 W/kg, averaged over 1 g of tissue, as the safe limit for a mobile phone user and every handset should comply with this limit before FCC approval is granted for marketing of a phone in the United States. However, less restrictive limits, for example, 2 W/kg averaged over 10 g of tissue, are specified by the International Commission on NonIonizing Radiation Protection guidelines, endorsed by the WHO, and used in Europe and most other countries.^[7]

Exposure of a user to RF falls off rapidly with increasing distance from the handset. A person using a mobile phone 30–40 cm away from the body, i.e., using speaker mode while talking or using a “hands-free” device, for example, bluetooth headsets, will, therefore, have a much lower exposure than someone holding the handset against the head.^[2]

Various devices which claim to increase the safety of mobile phone use, such as shielded cases, earpiece pads/shields, antenna clips/caps, special batteries, and absorbing buttons, reduce exposures by a factor of 10, they have the danger of adversely affecting the phone's antenna, due to which the phone will attempt to transmit more power up to its specified maximum.^[1]

Using the mobile phone in areas of good reception decreases exposure as it allows the phone to transmit at reduced power.^[2] Since time is a key factor in how much exposure a person receives, reducing the time spent on usage by limiting the number and length of calls may reduce RF exposure.^[7]

New changes in mobile phone technology have lowered the RF power emissions from the newer devices like the third-generation (3G) phones where it is two times lowered and Digital Enhanced Cordless Telecommunications where the risk is almost five times lowered than the older versions.^[1]

Patterns of cell phone-induced general human health hazards

A large number of studies have been performed over the past two decades to assess potential health risks of cell phones. The

only established health hazard as cited by an independent expert group on cell phones' use while driving, and the risk of an accident increased with age which was comparable to driving with blood alcohol level of 0.05%. The risk was the same when the phone was used “hands-free” (via a loudspeaker), implying the distraction caused by the conversation.^[8]

The use of cell phone in children is dangerous due to the closer proximity of the mobile phone to their brain compared to adults; the average RF exposure from its use is higher by a factor of 2 in a child's brain and by a factor of 10 in the bone marrow of the skull. Brain and bone marrow have a higher conductivity in children than in adults and receive a higher energy deposition from RF sources. With age, the bone marrow progressively incorporates more fat, and the bone itself increases in thickness, hardens, and loses water over time, thus making the tissues less vulnerable.^[11]

Possible health hazards of cell phones use can be classified into short- and long-term effects *Short-term effects*

Increasing the use of devices for wireless communication and by their respective base stations cause various adverse health effects. The list of such alleged effects is virtually endless which was including sleep disturbances, headaches, tinnitus, high blood pressure, and endocrine disorders.^[9]

However, changes in the permeability of the blood-brain barrier and electroencephalographic activity also have been reported.^[10] Self-reported symptoms such as an earache, and warmth sensation, concentration difficulties, and fatigue have been highlighted by numerous studies.^[11]

Long-term effects

Mobile phone radiations may affect brain function and cause several neurological disorders such as (some changes in neurobehavioral functions and neuropsychiatric problems), especially in whom are inhabitants living near mobile phone towers and chronic exposure to nonionizing microwave radiation may lead to infertility through free radical/oxidative species-mediated pathway.^[12,13]

In a study conducted in Amritsar, Punjab, India, a correlation between mobile phone use (exposure to radio frequency radiations), DNA and chromosomal damage in lymphocytes of mobile phones users was observed. Such damages can have long-term consequences in terms of increased the risk of neoplasia or other age-related changes.^[14]

The results of some international epidemiologic studies have increased popular interest in possible health problems and gliomas and other brain tumors due to the use of mobile

phones.^[15] Furthermore, there is not enough evidence, either epidemiological or experimental, to support whether RF-electromagnetic field (EMF) has a detrimental effect on organisms.^[16]

Possible mechanisms of cell phone-induced male infertility

Thermal effect

The only scientifically-assured biological effect of exposure to RF-EMF in the frequency range of mobile communication is heating. Below the exposure limits, however, potentially damaging temperature increases are prevented: while for whole-body exposure, thermal effects are negligible, local exposure (i.e., by using a mobile phone) leads to temperature increases of $<1^{\circ}\text{C}$ only in close proximity of the antenna, mainly in the ear pinna, the ear canal, the skin and parts of the brain where the temperature increase due to exposure is on the order of 0.1°C .^[17]

One of the common misunderstandings by laymen is the warmth perception at the ear pinna after a long telephone call which is believed to be caused by RF-EMF. Studies have clearly shown that RF-EMF is responsible for only a small fraction of this temperature increase, while the major contribution comes from the insulation (i.e., less heat dissipation by the ear pinna) and heating of the phone's battery and electric circuits during operation.^[18]

On the basis of thermal effects which have to be prevented, maximum exposure levels were defined as basic restrictions in 1998 by the International Commission on non-ionizing radiation protection and had been adopted by most countries as by-laws. These limits are different from whole-body exposure and local exposure and different for the general public and those with occupational exposure. The measure of exposure is the SAR, and the unit is watts per kilogram (W kg^{-1}).^[19]

Radiation

The EMFs emitted by mobile phones and other wireless devices are often called "radiation" which is at least misleading. Radiation is the commonly used term for ionizing radiation, i.e., high-energy photons (e.g., ultraviolet-C, X-rays, γ -rays) or particles (α and β), which can ionize atoms and molecules and can, therefore, lead to mutations and cancer. The energy of the photons in the frequency range is approximately six orders of magnitude lower than the energy required for ionization (approximately 1 MeV). Therefore, from a physical point of view, direct mutagenic effects from exposure to RF-EMF are impossible.^[20]

The testis is one of the tissues most sensitive to the damaging of radiation, which causing considerable functional impairment of the testis.^[21]

Role of oxidative stress

Oxidative stress is a process in which the normal balance between per oxidants and antioxidants changes in such a way that leads to strengthening oxidants and biological damage.^[22] The issue in question is that cell phone waves may cause oxidative stress by enhancing lipid peroxidation and changing antioxidant activities in the body.^[23]

Sperm is sensitive to oxidative stress. The sperm membrane of mammals is full of unsaturated fatty acids and sensitive to oxidation. Abnormal sperm is responsible for the overproduction of reactive oxygen species (ROS) which result in oxidative stress and considered to be one of the causes of male infertility.^[24]

Under normal circumstances, semen plasma contains sufficient antioxidant mechanisms and can neutralize the effect of ROS on sperm. However, if for any reason an imbalance occurs, the sperm goes through changes that negatively influence sperm parameters. Age, environmental factors (e.g., radiation exposure), and nutrition are factors that affect this change.^[25]

Both thermal and nonthermal mechanisms (e.g., increased production of ROS resulting in DNA damage.^[26] As regarding DNA damage, Aitken *et al.*^[27] demonstrated that exposure of mice to RF-EMW, 900 MHz, 12 h/day for 7 days led to damage to the mitochondrial genome and nuclear beta-globin locus of epididymal spermatozoa.

Chronic exposure to RF-EMW can decrease the activity of catalase, superoxidase dismutase (SOD), and glutathione peroxidase, and thus decrease total antioxidant capacity (TAC), but other experimental studies designed to measure malonaldehyde level and SOD activity show conflicting results.^[28]

Effects and patterns of cell phone-induced male infertility

Experimental studies

A study by Kesari *et al.* 2010^[29] found that chronic exposure of male Wistar rats to mobile phone radio-frequencies was associated to decrease in protein kinase C activity and total sperm count along with increased apoptosis and could be related to overproduction of ROS.

Kesari *et al.* 2011^[30] found that chronic exposure of male Wistar rats to mobile phone radio-frequencies was associated (1) decreased glutathione peroxidase and superoxide dismutase, (2) increased in catalase and malondialdehyde, (3) decreased histone kinase, (4) decreased micronuclei, and (5) changed sperm cell cycle.

Al-Damegh 2012^[31] found that the exposure of the rat to electromagnetic radiation from conventional cellular phone was associated with increase in the diameter of the seminiferous tubules with a disorganized seminiferous tubule sperm cycle interruption and serum and testicular tissue conjugated diene, lipid hydroperoxide, and catalase activities increased 3-fold, whereas the total serum and testicular tissue glutathione and glutathione peroxidase levels decreased 3–5-fold in the electromagnetism-exposed animals. The vitamins C and E had a protective role of preventing these detrimental effects.

Kesari and Behari 2012^[32] reported that chronic exposure of Wistar rats to RF EMFs emitted from a mobile phone was associated with a decrease in the level of testosterone and an increase in caspase-3 activity and distortions in sperm head and midpiece of the sperm mitochondrial sheath. These changes could be caused by overproduction of ROS. Oyewopo *et al.* 2017^[33] found that chronic exposure of male Wistar rats to RF electromagnetic radiation of cell phone leads to defective testicular function in the form of degeneration of the germinal epithelial cells that is associated with increased malondialdehyde (MDA) and decreased SOD and decreased gonadotropic hormonal profile (follicle stimulating hormone [FSH], LH and testosterone).

Human studies

Wdowiak *et al.* 2007 reported that there was a decrease in the percentage of sperms in vital progressing motility in the semen was correlated with the frequency of using mobile phones.^[34]

Agarwal *et al.* 2008 found that the usage of cell phones was associated with a decrease in sperm count, motility, viability, and normal morphology and these changes in sperm parameters were dependent on the duration of daily exposure to cell phones and independent of the initial semen quality.^[35]

Agarwal *et al.* 2009 found that RF electromagnetic waves emitted from cell phones showed a decreased in sperm motility and viability, increased in ROS level, decreased in TAC of semen (ROS-TAC score).^[36]

Gutsch *et al.* 2011 found that cell phone usage by male persons was associated with increased abnormal sperm morphology and increased serum free testosterone and decreased LH levels with no changes in FSH, and prolactin.^[37]

Rago *et al.* 2013 found that the use of mobile phone for more than 4 h daily was associated with increased sperm DNA fragmentation.^[38]

Yildirim *et al.* 2015 found that exposure to RF-electromagnetic radiation of mobile phone and wireless Internet was associated

with decreased total motile sperm count, progressively motile sperm.^[39]

Zhang *et al.* 2016 found that cell phone use may negatively affect sperm quality in men by decreasing the semen volume, sperm concentration, or sperm count, thus impairing male fertility.^[40]

CONCLUSION

Cell phone radiation may negatively affect sperm quality in men by decreasing the semen volume, sperm concentration, sperm count, motility, and viability, thus impairing male fertility. This should be supported by mass media to raise awareness among people regarding the possible health effects of RF emissions from mobile phones and to minimize its exposure.

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Conflicts of interest

There are no conflicts of interest.

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