

Review Article

## Effects of Cell Phone EMF Radiations on the Auditory System- A Review

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### ABSTRACT

Cell phones operate with microwaves (450900 MHz in the analog service, and 1,82,2 GHz in the digital service) very close to the user's ear. These are electromagnetic radiations in the radiofrequency range. The skin, inner ear, VIII nerve and the temporal lobe surface absorb the radiofrequency energy.

**Objective:** The objective of this article is to review the recent literature on the effects of exposure to mobile phones on the auditory system.

**Study Design:** Systematic review.

**Methods:** We reviewed papers on the influence of mobile phones on auditory system on databases, published till 2014, and also materials available in the Internet. Searches were made electronically through various search engines and health-related databases, and manually through journals, reports, and conference proceedings, WHO reports and publications.

**Results:** Research articles (epidemiologic, experimental, cellular, and animal studies), systemic or meta-analysis review studies, and reports were included in the review. The reported effects associated with exposure to mobile phones on the auditory system did not show a consistent pattern.

**Discussion:** Despite several publications on the auditory effects of cell phones, yet, at present, there is no uniformity in the data regarding their effects on hearing. Studies concerning cell phone radiation and risk of developing an acoustic neuroma have questionable results.

**Conclusions:** Continued research is recommended to address specific areas of concern, including carcinogenicity, auditory effects in children using cell phones, and the relation between long-term intensive exposure to cell phones and hearing loss.

**Keywords:** Cell phone; radiation; EMF; hearing loss; auditory system; acoustic neuroma.

### INTRODUCTION

There is a phenomenal growth in the number of cell phone users in the world. Any consequent biological effect should be a cause of concern and a high priority health issue. There is lack of knowledge of the biological effects of radiofrequency electromagnetic fields (EMF) transmitted by mobile phones. These are invisible microwaves and reach close to infrared radiation. <sup>[1]</sup>

In India mobile phones operate in the frequency range of:

- 869 - 890 MHz (CDMA)
- 935 - 960 MHz (GSM900)
- 1805 - 1880 MHz (GSM1800)
- 2110 - 2170 MHz (3G). <sup>[2]</sup>

The rate at which the radio frequency energy is absorbed in the body tissue is the Specific Absorption Rate (SAR) which has the unit, Watt/Kg. <sup>[1]</sup> SAR value information of the mobile handsets is normally available on the manufacturer's web site & in the handset's manual. In India, the SAR limit prescribed

for cell phones is 1.6 W/Kg averaged over one gram of human tissue. [2]

Sensations of burning or warmth around the ear, [3] head ache, [4] disturbance of sleep, [5] alteration of cognitive functions and neural activity [6,7] as well as alteration of blood brain barrier and relative decrease in cerebral blood flow have been reported as effects of mobile phone use. [8,9]

Telecommunication systems like radio, television, wireless telephones, pagers, mobile phones, radars and satellites, emit invisible electromagnetic radiation or radiofrequency (RF). The radiation spectrum includes microwaves (frequencies between 300 MHz and 300 GHz) and reaches close to infrared radiation. [1]

RF is also used daily in microwave ovens and diathermy medical devices (thermo-ablation). The latter are used in surgery for tumors and other conditions. [10]

There are concerns about the possibility of lymphatic cancer, central nervous system tumors (including acoustic neuromas), choroidal melanomas, and other disorders in subjects chronically exposed to RF, which have motivated epidemiological and experimental studies. [11-14]

RF is a non-ionizing radiation, and therefore does not have enough energy to destabilize electrons or break chemical bonds in DNA. Nevertheless there are thermal effects which result from water molecule polarization as electromagnetic waves course through tissues and produce heat (temperature variation over 1°C). This is the principle behind microwave ovens and medical diathermy devices. Devices that generate RF between 350 and 500 kHz or microwaves over 2 GHz are used for thermo-ablation surgery. Tissue temperatures reach 50-100°C, resulting in local necrosis and coagulation. Temperatures over 100°C vaporize and carbonize tissues. [10] Telecom workers that

are accidentally exposed to high RF loads absorb this energy, which produces heat. They may have skin burns and injury to heat-sensitive tissues, such as the lens of the eye, the testicles and the brain, leading respectively to cataract, male infertility and seizures. [1,11] Safety guidelines are therefore needed for screening RF/microwave-emitting devices and for protecting workers that may be exposed to this radiation. [1] The power of radio and television transmitters may reach many kilowatts; mobile phone base stations may reach over 100 W. [13]

On the other hand, the power of mobile phone handsets and cordless phone base units is very low, respectively around 0.01-2 W and 0.09W. [13,15]

For this reason mobile phones do not cause thermal effects on a user's organs. It has been calculated that the temperature in the head increases by not more than 0.11°C while using a mobile phone, although a feeling of warmth may be felt in the ear during a telephone call.

The non-thermal effects include electrical force induction and possibly an increase in heat shock protein synthesis in cells. Continuous heat shock protein synthesis may be involved in oncogenesis, by inhibiting cell apoptosis. The potential carcinogenic effect of EMFs is much studied and though there were suggestions of an increased risk of glioma at the highest exposure level, a causal interpretation remains uncertain and subject to debate and further investigation. [16,17]

When the mobile is in use, all the components of the auditory system including the skin, external and middle ear, the inner ear, cochlear nerve and the temporal lobe surface absorb the radiofrequency energy. Also the outer hair cells in the cochlea are known to be highly sensitive to a great variety of exogenous and endogenous agents including externally applied electrical and magnetic fields. [18]

Low-energy EMFs seem to cause structural and functional changes in the cell membrane of different cell types, leading to abnormal cell response. Various studies suggest that EMR directly affects neurons by reducing the neuronal reactivity, increasing the neural membrane conductivity and prolonging their refractory period. Thus, the auditory system, the cochlea and the auditory (VIII) nerve which directly receive EMF during mobile phone use are particularly at risk and therefore should be studied for any changes resulting from the thermal and non-thermal effects of EMF.

**Methods:** Searches were made electronically through various search engines of health related databases and manually through journals, reports and publications.

## RESULTS

### Effects on hearing:

**i) Animal Experiments:** Galloni et al. studied rats exposed to cellular telephone electromagnetic waves two hours a day, five days a week, for four weeks. No significant difference between DPOAE measurements was observed before and after exposure. [19]

Kizilay et al. exposed adults and new-born rats to cellular telephone electromagnetic fields for 1 hour a day, for 30 days, and found no significant differences in pre- versus post-exposure DPOAEs. [20]

Kayabasoglu et al. concluded that exposure to the EMFs emitted by cellular telephones, for 6 hours a day for 30 consecutive days, had no effect on the hearing of new-born or adult rats, at the outer ear, middle ear or cochlear level. [20]

**ii) Short Term Exposure Studies In Humans:** Only limited research data concerning interaction between mobile phone exposure and the inner ear is available in the literature. [15,22,23] Ozturan et al. studied the effects of electromagnetic waves on the hearing of 30 volunteers.

OAEs were compared before and after exposure to 10 minutes of cellular telephone use. The study did not show any effect on hearing of the subjects. [15]

Uloziene et al. conducted a double-blind study to assess the effects of cellular telephone electromagnetic fieldson 30 volunteers. The experimental and control group underwent PTA and TEOAE investigations before and 10 minutes after cellular telephone use. No significant difference was observed between control and experimental groups. [24]

Sievert et al did a study on effects of electromagnetic fields emitted by cellular phone on auditory and vestibular labyrinth by investigating with VNG of 13 subjects, BERA of 24 ears and DPOAE of 20 ears with and without a cell phone in use and concluded that EMFs generated in using the mobile phone do not have an effect on the inner ear and auditory system. [25]

A number of human experimental studies have attempted to assess potential changes in hearing function as a consequence of short-term (10–20 min) exposure to EMFs produced by cell phones, but found no significant effects. [15,24,26] This could be because of their low statistical power, as the number of participants in each study did not exceed 30 volunteers.

A recent large-scale European study [27] reporting results from the EMFnEAR project (Exposure at UMTS Electromagnetic Fields: Study on Potential Adverse Effects on Hearing) concluded that short-term exposure to cell phones, even at the maximum output, does not exert measurable immediate effects on the human auditory system. UMTS is the universal mobile telecommunication system or the third generation of mobile communication systems using frequencies between 1900 and 2170 MHz. This European study, despite involving 134 participants who were tested across different European laboratories,

overlooked cell phones operating at lower frequencies, tested for the effects of short-term exposure only (up to 20 min), and not all participants were subjected to all audio logical tests. In order to reach definitive conclusions, such shortcomings should be avoided in future studies.

Most of these studies have investigated only the short term effect of mobile phone handset EMF radiation on the auditory system and the result obtained did not reveal any information regarding the potential effects of longer exposure or chronic cumulative exposure.

### Studies Involving Long Term Exposures:

The few studies concerned with the long-term effects of chronic use, are retrospective and with a small sample size. [28-32] In addition, the results are not consistent and no attempt has been made to correlate the changes found with the level of exposure as measured by SAR value. [33] Therefore, no safe conclusions can be drawn regarding the potential harmful effects of mobile phone use.

In a Turkish study [28] involving 60 participants, the results revealed no significant difference between the exposure groups, except that the detection thresholds in those who talked approximately 2 h/day were significantly higher than those in moderate users or control participants. This could indicate that a higher degree of hearing loss is associated with a long-term and intensive use of cell phones.

Some of the long term studies summarised in Table 1, show a tendency to hearing loss in the long term intensive users. Almost all recommend further studies in larger population over a longer time.

In their review article Ahmed Ragab, [34] et al (2014) concluded that there is no overall increased risk of hearing problems among short-term cellular phone users, whereas long-term use of mobile phones may lead to high-frequency hearing loss and an increased risk of acoustic neuroma after 10 years of mobile phone use.

**Table 1 Auditory effects of Cell Phone**

Investigators	Sample size	Findings
OktayMF, Dasdag F [28] (2006) Retrospective cohort.	60; 20 (2hr/day for 4 years), 20(10-20 minutes for 4 years) and 20 (never used cell phone)	A higher degree of hearing loss is associated with long term exposure to EMF generated by cell phone.
Panda NK, et al [30] (2010) Retrospective, cross-sectional, randomized, case control study	112 cases using mobile phones >1 year. 50 controls that never used mobile phones.	High-frequency loss and absent DPOAE were observed with an increase in the duration of mobile phone use, excessive use of mobile phones.
C S Ramya, et al [35] (2011) comparative study	50 cell users for > 5 years. 25 <30min/day 25 >30min/day	Significant increase in the hearing threshold in mobile phone users associated with duration of usage.
S Bhagat, S Varshney, et al [33] (2012) Cohort study	75 cell users for > 4 years 2 Groups (<60 min and > 60 min) Also comparison between dominant and non-dominant ear	Prolonged, frequent exposure to EMFs from mobile phones does not cause damage to the inner ear as measured by DPOAE.
Mahesh Chandra Hegde, et al [36] (2013) Prospective study over 3 years	120 users. Group I >1hour for > than 1 year & Group II < 1 hour for < than a year or no usage	No significant difference in the 2 groups but minimal hearing loss of 5-15 dB in those exposed to mobile phone usage of more than 2 hours per day.
Hitesh Patel, Rizwan Qureshi(2013) [37] Retrospective	30 subjects > 1hour per day 30 subjects < 15 mins per day.	Some hearing impairment in long term mobile phone users compared to infrequent users. The dominant ear was affected more than non-dominant ear.
ShilpaKhullar , Archana Sood , Sanjay Sood (2013) [38] Retrospective	60 subjects;20 who never used cell phones,20 men who used for 10–20 min/day for 4 years and 20 men who used frequently ( 2 hrs. per day for 4 years)	Long term exposure to mobile phones may affect conduction in the peripheral portion of the auditory pathway.
P.Velayutham [39], et al (2014) Prospective single blinded study	100 subjects. Dominant ear (study group) compared to non-dominant ear (control)	High frequency hearing loss in the dominant ear (mobile phone used) compared to the non-dominant ear.

**Relation between mobile phone use and central nervous system tumors:** There is very little evidence supporting the influence of mobile phone use on the occurrence of benign or malignant CNS tumors, especially those located in the temporal lobe. [40-42] Results of studies on mobile phone handset radiation and the risk of developing acoustic neuroma have been contradictory (Table 1). Some authors have found no increased probability of tumor development in mobile phone users, [41-44] while other have stated that the use of mobile phones, particularly analog handsets, for 10 years or more is a risk factor for developing tumors. [13,45,46]

In 2010, the results of the international multicentre INTERPHONE study carried out from 2000 to 2004 were published. [17] The INTERPHONE study was initiated as an international set of case-control studies focusing on four types of tumours in tissues that most absorb RF energy emitted by cell phones: tumours of the brain (glioma and meningioma), acoustic nerve (schwannoma), and the parotid gland. The objective was to determine whether mobile phone use increases the risk of these tumours and, specifically, whether the RF emitted by mobile phones is carcinogenic. Sixteen study centres from 13 countries (Australia, Canada, Denmark, Finland, France, Germany, Israel, Italy, Japan, New Zealand, Norway, Sweden, and the United Kingdom) were included; and 2708 glioma and 2409 meningioma cases and matched controls were interviewed. No increase in the risk of glioma or meningioma was observed overall, with the use of cell phones. However, an increased and significant risk of glioma (OR=1.40, 95% CI 1.03-1.89) was observed at the highest exposure levels. Nevertheless, the study group concluded that biases and error prevent a causal interpretation, and recommended further

research to explore the possible effects of long-term heavy use of cell phones.

## DISCUSSION

As a result of the activities of standards and regulatory bodies, there are a significant number of scientific studies underway within both national and international research programmes, on the health implications of exposure to EMFs, in both public and private laboratories. However, the sheer volume of data being generated can result in the misinterpretation of results or in the inappropriate extrapolation of scientific findings. As a result it can be very difficult to provide relevant timely inputs for the development of policies on EMF and health issues.

A review of recent studies on the possible effects of mobile phone signals on the auditory system found that mobile phone use can affect the hearing function of users according to the duration of use. Short-term exposure at the maximum output of consumer mobile phones does not cause measurable immediate effects on the human auditory system, whereas long-term (more than 1 year) and intensive mobile phone use may cause inner-ear damage and can lead to high-frequency hearing loss.

Some epidemiological studies on mobile phone use have hinted at an increased risk of acoustic neuroma, but others have not. Studies to date have been conflicting about its possibility with mobile phone use. The results of the INTERPHONE study, were hailed by the mobile phone industry but was criticized by some researchers, on the grounds that it shares the same limitations as all case-control studies previously carried out on cell phones and cancer, namely that it can investigate only a short period of observation since first exposure to cell phones. [47] The majority of participants in this study were not heavy cell phone users compared to today's practices. The brief

exposure in most of the cases leaves only a limited incubation time for an exposure-related cancer to develop. Thus, the no increase in risk observed is reassuring only to a limited extent. To overcome the problems in the current body of evidence regarding cell phone use and cancer, well-designed prospective cohort studies would be best. Kundi <sup>[48]</sup> summarized this controversy in his review article. He concluded that in most studies, no evidence-based exposure metric was available and the observed duration of cell phone use was generally still too low. These problems precluded the detection of reliable risk estimates. Likewise, in some studies, selection bias, misclassification bias, and effects of the disease on cell phone use could have reduced risk estimates, whereas in other studies, recall bias may have led to dubiously increased risks. He reasoned that the overall evidence was in favour of an increased risk, but its extent cannot be assessed properly at present.

The International Agency for Research on Cancer (IARC), a WHO specialized agency, has reviewed the carcinogenic potential of RF fields from Cell phones in May 2011 and now considers them possibly carcinogenic to humans (Group 2B). The reviewed evidence included exposure data, studies of cancer in humans, studies of cancer in experimental animals, and mechanistic and other relevant data. The press release of the IARC working group indicated that the evidence, while still accumulating, is strong enough to support the 2B classification. This conclusion means that there could be some risk, and that further research is still needed. <sup>[49]</sup> To date, the body of literature indicating no increased risk of cancer in conjunction with cell phone use is larger and more diverse than the results of existing studies indicating an increased risk of cancer.

**Mobile phones and children:** The brain tissue of children is more conductive than

that of adults as it has higher water content and ion concentration. As a result, RF penetration is greater relative to head size. Thus, they have a greater absorption of RF energy in the tissues of the head at mobile telephone frequencies. The greater vulnerability of the developing nervous system of children has raised concerns about their potential susceptibility to RF fields of cell phones. Although anatomically, the development of their nervous system is complete by two years of age, RF fields could hypothetically interfere with the functional development of the nervous system which continues up to adult age.

Considering that the use of cell phones by children and adolescents, has been increasing in recent years and also with the onset of use starting very early in life, children will have a longer lifetime exposure than adults. <sup>[50]</sup> However, only a few relevant epidemiological or laboratory studies have addressed the possible effects of cell phone exposure on children. In 2005, two double-blind experimental studies <sup>[51,52]</sup> were published in which children (10–14 years) were exposed to 902MHz GSM signals, while their cognitive functions were evaluated through a number of cognitive investigations. Neither study reported any significant differences. However, both studies have some experimental weaknesses that restrict their interpretation, such as limited exposure, low statistical power due to the very small number of children involved, and the high variability of the tests of cognitive function.

Although the few studies that have been conducted in children till date do not seem to indicate a substantial increase in risk, a definitive answer to the question of whether children are more at risk from cell phones than adults is not possible and further research is needed.

## CONCLUSION

The widespread use of cell phones has raised the question of possible health effects, mainly effects on auditory system, cognitive function, hearing and various brain diseases including acoustic neuromas.

As regards the epidemiologic evidence on cell phone use and the risk of brain tumors like acoustic neuromas in adults, it is noted that the scientific evidence has grown in volume, geographic diversity of study settings, and the amount of data on longer-term users. However, some key methodological problems remain, mainly the lack of proper exposure metrics, dose–response relationships, and methods to overcome bias and confounding. Case– control studies in particular have selective non response and inaccuracy and bias in the recall of phone use.

Overall, the studies published to date do not establish any increased risk within approximately 10 years of use for any brain tumor. Only a long latency period (more than 10 years) and long-term cell phone use have been significantly associated with glioma in some studies. For slower growing tumors such as acoustic neuroma, the absence of an association reported thus far does not exclude its likelihood, because the observation period has been too short. The best way to address the uncertainties of epidemiological studies so far is to carry out a large prospective cohort study.

As uncertainty prevails concerning the health effects of cell phones, precautionary measures are best adopted by all concerned parties, namely governments, mobile companies, and the public.

**Conflicts of interest:** There are no conflicts of interest.

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