DOI: 10.7860/JCDR/2015/13831.5976

Original Article

Physiology Section

Effect of Prolonged Use of Mobile Phone on Brainstem Auditory Evoked Potentials

NAVEENTA GUPTA[1], DARSHAN GOYAL[2], RAJIV SHARMA[3], KHUSHDEEP SINGH ARORA[4]

ABSTRACT

Objectives: Mobile phones are being widely used throughout the world. Electromagnetic waves generated from mobile phones have raised concerns as these may have adverse effects on human auditory system owing to the daily use of mobile phones. The purpose of current study was to evaluate the effects of long term mobile phone usage on auditory brainstem evoked responses (ABR).

Materials and Methods: A retrospective, cross-sectional, case control study was carried out in a tertiary care hospital. Total 100 healthy subjects aged 18 to 30 years of both the genders were selected, out of which 67 subjects were long-term GSM mobile phone users (using mobile phone for more than 1 year) and 33 were controls who were mobile phone non users. Both the groups were investigated for ABR and changes were studied in both the ears of cases and controls to ascertain the effects of electromagnetic exposure.

Results: No significant difference ($p>0.05$) was found in latencies, interpeak latencies and amplitudes of ABR waves between cases and controls.

Conclusion: Our study shows that long term usage of mobile phones does not affect propagation of electrical stimuli along the auditory nerve to auditory brainstem centres.

Keywords: Auditory brainstem-evoked responses, Mobile phones

INTRODUCTION

Mobile phones have become an indispensable communication tools and have transformed from a status symbol to a necessity because of countless perks that a mobile phone provides. In the last 20 years, worldwide mobile phone subscriptions have increased from 12.4 million to over 5.6 billion, involving about 70% of the global population [1].

The mobile phones transmit and receive microwave radiations at frequencies of about 900 MHz and 1,800 MHz respectively and these frequencies excite rotation of water molecules and some organic molecules [2]. There are two direct ways by which exposure to radio frequency radiations can affect health. These are thermal effects caused by holding mobile phones close to the body and possible non-thermal effects. Electromagnetic field (EMF) radiations may cause adverse health problems such as headache, sleep disorders, impairment of memory, lack of concentration, dizziness, increased frequency of seizures in epileptic children, brain tumours and high blood pressure [3].

EMF power intensity is measured in units of mW/cm^2 but this provides little information about the biological consequences unless the amount of energy absorbed is known. Exposure limits relevant to mobile telephones are expressed as the specific absorption rate (SAR) with units of W/kg which is the amount of energy absorbed by a unit mass of the object [4]. The mobile phone is used by bringing it close to the ear which increases the specific absorption rate (SAR) of EMFs by the brain which may affect the auditory system. The absorption of mobile phone's radiofrequency (RF) output power energy in the users head may be as high as 40–55% [5].

The auditory brainstem-evoked responses (ABR) may allow quantifying the activity and functions of auditory organ, including the auditory nerve and subcortical centers. These are potentials recorded from ear and vertex in response to brief auditory stimulation to assess conduction through the auditory pathway upto the level of midbrain. Numerous studies have investigated the electrophysiological effects of EMF to human body. One such study was conducted by exposing the head to EMFs emitted by a GSM mobile phone for 15 min and a delay in the latency of the fifth wave (V) of the ABR was observed [6]. Conversely, a different study found no effects on ABR (I,II and III) waves after a 30 minute mobile phone irradiation [7]. The aim of the current study was to investigate the effects of mobile phones on human auditory brainstem responses (ABR) in long term GSM mobile phone users.

MATERIALS AND METHODS

The present study was conducted in the Department of Physiology in collaboration with the Department of ENT at Guru Gobind Singh Medical college, Faridkot from June 2014 to January 2015 in a period of 8 months. The protocol of the study was approved by the Institutional Ethics Committee. All the subjects gave their written informed consent after the nature of the experiment had been fully explained.

Study design

The present study was conducted on 100 normal healthy volunteers (69 women and 31 men) aged 18-30 years with no clinical evidence of hearing disorder. The subjects were divided into 2 groups i.e. cases and controls, depending upon their mobile phone usage. Cases comprised of 67 subjects who were using mobile phones for duration of more than one year. Controls were 33 subjects who had never used any mobile phone.

Inclusion criteria for cases

1. Apparently healthy subjects with normal hearing.
2. No past/present history of any ear disease or deafness.
3. Chronic mobile phone users using GSM mobile phones for more than 1 year.

The cases (n=67) were further categorized into two categories according to the total duration of mobile phone use:

Category A: Subjects using mobile phone for 1 to 5 years.

Category B: Subjects using mobile phone for more than 5 years.

In each category, the users were further divided into two groups according to daily use of mobile phones as follows:

Group 1: Users with cumulative mobile phone use for less than 60 minutes/day.

Group 2: Users with cumulative mobile phone use for more than 60 minutes/day.

Exclusion criteria

Subjects with a history of any ear problem such as discharge, hearing loss, ear surgery, ototoxic medication, or any systemic disease that would affect hearing were excluded. Subjects with history of alcohol and substance abuse or those suffering from any disease known to affect the study such as diabetes mellitus, hypertension, epilepsy, brain injury or hormonal imbalance as acromegaly were excluded from the study. Diseases were excluded by taking their history, general physical examination and audiological examination.

Controls

Subjects (n=33) who had never used a mobile phone.

The recording procedure: The auditory brainstem response was recorded in a shielded room by using Digital data acquisition and analysis system model Neurostim (NS4) by Medicaid systems, Chandigarh, India.

The subjects were allowed to sit comfortably in a fully relaxed state and were instructed not to sleep during the procedure.

Three disc electrodes were placed as follows

i. **Ground electrode:** At the forehead in the midline.

ii. **Active electrode:** At the mastoid process ipsilateral to the acoustic stimuli.

iii. **Reference electrode:** At the vertex of the skull.

Both the ears of all the subjects were tested (one ear at a time). The contralateral ear was always masked with white noise 40dB below the ipsilateral click stimuli in order to get a correct response.

Brief click acoustic stimuli (square wave pulse of 0.1ms duration) alternating in polarity were presented by an earphone on the ear with 40 and 70 dB intensities. With a filter setting of 100 Hz (low filter) to 3000 Hz (high filter), 2000 sweeps were averaged [8]. Sweep speed was 1ms/div and sensitivity was set at 0.5μv/ div. Skin to electrode impedance was kept below 5kohm.

Peak ABR latencies (I, II, III, IV and V), interpeak latencies (I-III, III-V and I-V) and amplitudes (I-Ia, V-Va) of waves were measured. The results were expressed as mean ± SD. ABR waves latencies, interpeak latencies and amplitudes of different groups were compared and analysed statistically.

STATISTICAL ANALYSIS

One-way analysis of variance (ANOVA) was performed [9] using SPSS software version 16.0. p-value less than 0.05 was considered as statistically significant.

RESULTS

In the present study, the mean value of age among users of mobile phone was 23±3.45 years and that of controls was 21±4.43 years. Statistical analysis of ABR findings demonstrated no statistically significant differences (p>0.05) in latencies, interpeak latencies and amplitudes of waves among the controls and cases in right ear [Table/Fig-1] and left ear [Table/Fig-2].

The results indicate that auditory pathways from cochlear nerve to auditory brainstem are not affected by mobile phones. In the mobile phone user group (cases), 30 subjects said they used both ears equally, 17 used mostly their left ears, and 20 used mostly their right ears while calling. Thus, comparison of lateralization of mobile phone use for each group was not possible statistically.

DISCUSSION

The use of mobile phones is becoming increasingly popular and almost indispensable in modern day life. This is one of the fastest growing technological developments of our times. However, there is an increasing amount of public concern over possible health risks of electromagnetic field (EMF) exposure from mobile phones. Radio frequency electromagnetic radiations are emitted from mobile phone antennae. These can penetrate organic tissue and be absorbed and converted into heat. The close proximity of a mobile telephone antenna to the user's ear may lead to the deposition of a large amount of EMF energy in the ear [2].

Waves	Controls (n=33)	Cases				p-value
		1-5 y		>5 y		
		<60 min/d (n=24)	>60 min/d (n=16)	<60 min/d (n=10)	>60 min/d (n=17)	
I(msec)	1.20±0.31	1.25±0.41	1.86±0.35	1.12±0.33	1.22±0.35	0.90*
II(msec)	2.52±0.41	2.49±0.49	2.48±0.37	2.47±0.39	2.68±0.40	0.60*
III(msec)	3.36±0.39	3.35±0.37	3.43±0.29	3.43±0.43	3.35±0.33	0.93*
IV(msec)	4.29±0.47	4.25±0.53	4.46±0.45	4.52±0.59	4.53±0.44	0.24*
V(msec)	5.19±0.38	5.06±0.44	5.31±0.38	5.45±0.54	5.17±0.52	0.16*
I-III(msec)	2.15±0.44	2.12±0.46	2.24±0.41	2.30±0.55	2.12±0.33	0.76*
I-V(msec)	3.99±0.48	3.81±0.53	4.12±0.52	4.32±0.64	3.94±0.49	0.09*
III-V(msec)	1.83±0.45	1.69±0.36	1.88±0.45	2.02±0.29	1.81±0.35	0.26*
I-Ia(μV)	0.56±0.38	0.45±0.23	0.47±0.36	0.34±0.23	0.41±0.19	0.27*
V-Va(μV)	0.77±0.27	0.82±0.20	0.76±0.39	0.69±0.26	0.88±0.34	0.51*

[Table/Fig-1]: Comparison of latencies, interpeak latencies and amplitudes of ABR waves in right ear
*p>0.05- not significant

Waves	Controls (n=33)	Cases				p-value
		1-5 yr		>5 yr		
		<60 min/d (n=24)	>60 min/d (n=16)	<60 min/d (n=10)	>60 min/d (n=17)	
I(msec)	1.26±0.28	1.35±0.26	1.22±0.32	1.29±0.33	1.24±0.27	0.63*
II(msec)	2.56±0.46	2.62±0.21	2.60±0.35	2.75±0.42	2.57±0.32	0.70*
III(msec)	3.46±0.50	3.48±0.24	3.37±0.28	3.66±0.26	3.40±0.30	0.36*
IV(msec)	4.39±0.53	4.40±0.40	4.48±0.44	4.47±0.35	4.46±0.31	0.95*
V(msec)	5.21±0.37	5.17±0.47	5.28±0.24	5.25±0.47	5.33±0.34	0.72*
I-III(msec)	2.19±0.45	2.12±0.30	2.15±0.40	2.37±0.23	2.16±0.34	0.51*
I-V(msec)	3.91±0.48	3.81±0.51	4.05±0.41	3.96±0.40	4.08±0.53	0.40*
III-V(msec)	1.75±0.53	1.68±0.44	1.89±0.30	1.58±0.37	1.92±0.46	0.22*
I-Ia(μV)	0.61±0.28	0.44±0.22	0.54±0.22	0.43±0.39	0.46±0.31	0.15*
V-Va(μV)	0.90±0.31	0.85±0.32	0.72±0.23	0.70±0.47	1.01±0.34	0.06*

[Table/Fig-2]: Comparison of latencies, interpeak latencies and amplitudes of ABR waves in left ear
*p>0.05- not significant

A study carried out in USA, UK, New Zealand, and Australia showed that the major complaints of mobile phone users include headache, fatigue, general ill-being, muscular pains, and nausea. The EMF of the microwave frequency as well as the frequency emitted by mobile phones may be responsible for various biological effects [10]. The degree of adverse biological effects of the mobile phone microwave radiation depends on many factors: the duration of the irradiation, individual characteristics of the central nervous system and immune systems, and other factors like the rate of absorption and the distribution of EMF energy by different tissues of the body [11,12]. Despite public concerns regarding the safety of mobile phones and their base stations, little research specifically relevant to these emissions has been published which may be due to the fact that mobile phones have been widely used by the public only recently and there has been little opportunity for all the health effects to manifest. Moreover, populations as a whole are not genetically homogenous and people can vary in their susceptibility to the environmental hazards, such as the EMF from mobile phones [13].

Mobile phone microwave radiations can induce reversible, nonspecific adaptive responses when the duration of exposure is short and the affected organism is sensitive to radiations. The results of some studies of the biologic effects of low-intensity modulated microwave radiation, including that generated by mobile phones,

have led investigators to conclude that such radiation does not exert any lasting pathologic effects on the body [11].

Although the acute effects of mobile phones on hearing have been studied, but very less data regarding chronic effects of EMFs created by mobile phones is available. Cochlear nerves and temporal lobes are the neural structures most exposed to the pulsed EMF emitted by mobile phones. Mobile phones are ideally positioned to affect the auditory system. Such fields have been shown to have some adverse effects on the brain [14].

The present study was designed to investigate possible effects of frequent and long term repeated exposure to EMF of mobile phones on the hearing of adult users, as measured by changes in latencies, interpeak latencies and amplitudes of ABR waves which represents the electrical activity of the distal portion of the auditory pathway from cochlear nerve to auditory brainstem and lateral lemniscus of mid brain with five waveforms. We compared absolute latencies, interpeak latencies and amplitudes of ABR waves. Our study revealed that EMF causes no significant alteration in the latencies, interpeak latencies and amplitudes of these ABR waves. The lack of effect of mobile phone on BERA in this study suggests that the fundamental pathways mediating an auditory stimulus, from cochlear nerve to midbrain, are not affected by exposure to EMF emitted by mobile phones.

While some authors [15,16] have presented positive findings but our results are consistent with results reported by other investigators [12,17-20] on otoacoustic emissions and ABR.

The energy radiated by a mobile telephone is low. GSM mobile phones always emit maximum power for a few seconds during the initiation of a call. The telephone rings only after it has received this powerful transmission and the power then decreases to a level which is just sufficient to sustain the connection [2]. This safety feature of GSM mobile telephones may be one reason for the negative results obtained in this study.

Another possible cause of our results may be that heating of biological tissue is a consequence of microwave energy absorption by the tissue's water content. The amount of heat produced in the body depends on the intensity of the radiation after it has entered the body, on some electrical properties of the biomatter and on the capability of the body's thermoregulation mechanism. The temperature homoeostasis is not maintained above a certain intensity of the microwaves, and adverse effects on health develop once the temperature rise exceeds about 1°C. Safety guidelines on mobile phones impose upper limits on the radiation intensity to ensure that this does not happen [21]. The power of mobile phone handsets and cordless phone base units is very low so mobile phones do not cause thermal effects on user organisms. Prolonged use of mobile phones can cause only 0.1°C increase in temperature of deep tissues like brain [22]. Such minor increase in temperature cannot cause any adverse effect on the body. The telephones with low SAR values and use of hands-free devices can further reduce the levels of SAR exposure [4].

CONCLUSION

It was concluded that the long term use of mobile phones is not the cause of adverse effects on the auditory system as far as brainstem auditory evoked responses (ABR) are concerned. The results of the present study may appear comforting in terms of the effects of mobile telephones on hearing. However, it is not reasonable to conclude that exposure to EMFs during mobile telephone use does not lead to any hazardous health effects. Therefore, we propose the prudent use of mobile telephones. Mobile telephones should be used only for short periods, and that too for essential purpose. The health impact of mobile phone on each individual is variable as the population is genetically heterogenous. Therefore a further population based study should be planned for future open end research.

REFERENCES

[1] World Health Organization. Electromagnetic fields and public health: mobile phones. 2011; Fact sheet No.193.
[2] Szentpali B. Human exposure to electromagnetic fields from mobile phones. In: Proceedings of the 4th International conference on telecommunications in modern satellite, cable and broadcasting services. 1999;1:222–31.
[3] Michael M, Colin B, Mika K. The health hazards of mobile phones. *Br Med J*. 2000;320:1288-89.
[4] International Commission on Non-Ionizing Radiation Protection. Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz). *Health Phys*. 1998;74(4):494-522.
[5] Gandhi OP. Electromagnetic fields: human safety issues. *Annu Rev Biomed Eng*. 2002;4:211-34.
[6] Kellényi L, Thuróczy G, Faludi B, Lénárd L. Effects of mobile GSM radiotelephone exposure on the auditory brainstem response (ABR). *Neurobiology*. 1999;7:79-81.
[7] Arai N, Enomoto H, Okabe S, Yuasa K, Kamimura Y, Ugawa Y. Thirty minutes mobile phone use has no short-term adverse effects on central auditory pathways. *Clin Neurophysiol*. 2003;114:1390-94.
[8] Misra UK, Kalitha J. Clinical neurophysiology. 2nd ed. New Delhi: Reed Elsevier *India Private Ltd*. 2006; 330-34.
[9] Oktay MF, Dasdag S. Effects of Intensive and Moderate Cellular Phone Use on Hearing Function. *Electromagn Biol Med*. 2006;25:13–21.
[10] Bortkiewicz A. A study on the biological effects of exposure mobile-phone frequency EMF. *Med Pr*. 2001;52(2):101-06.
[11] Galeev AL. The effects of microwave radiation from mobile telephones on humans and animals. *Neurosci Behav Physiol*. 2000;30:187-94.
[12] Ozturan O, Erden T, Miman MC, Kalcioglu MT, Oncel S. Effects of the electromagnetic field of mobile telephones on hearing. *Acta Otolaryngol*. 2002;122(3):289-93.
[13] Independent Expert Group on Mobile Phones. Mobile phones and health. (The Stewart report). Didcot, Oxon, United Kingdom: National Radiological Protection Board. 2000: 159.
[14] Lonn S, Ahlbom A, Hall P, Feychting M. Mobile phone use and the risk of acoustic neuroma. *Epidemiology*. 2004;15(6):653-59.
[15] Khullar S, Sood A, Sood S. Auditory Brainstem Responses and EMFs Generated by Mobile Phones. *Indian J Otolaryngol Head Neck Surg*. 2013;65(Suppl 3):645-49.
[16] Liburdy RP, Vanek PF. Microwaves and the cell membrane. II. Temperature, plasma, and oxygen mediate microwave induced membrane permeability in the erythrocyte. *Radiat Res*. 1985;102(2):190-205.
[17] Panda NK, Jain R, Bakshi J, Munjal S. Audiologic Disturbances in Long-Term Mobile Phone Users. *J Otolaryngol Head Neck Surg*. 2010;39(1):5–11.
[18] Parazzini M, Lutman ME, Moulin A, Barnel C, Sliwinska-Kowalska M, Zmyslony M, et al. Absence of short-term effects of UMTS exposure on the human auditory system. *Radiat Res*. 2010;173(1):91-97.
[19] Parazzini M, Sibella F, Lutman ME, Mishra S, Moulin A, Sliwinska-Kowalska M, et al. Effects of UMTS Cellular Phones on Human Hearing: Results of the European Project "EMFnEAR". *Radiat Res*. 2009;172(2):244-51.
[20] Kwon MS, Jääskeläinen SK, Toivo T, Hämäläinen H. No effects of mobile phone electromagnetic field on auditory brainstem response. *Bioelectromagnetics*. 2010;31(1):48-55.
[21] Hyland GJ. Physics and biology of mobile telephony. *Lancet*. 2000;356(9244):-1833-36.
[22] Van Leeuwen GM, Lagendijk JJ, Van Leersum BJ, Zwamborn AP, Hornsleth SN, Kotte AN. Calculation of change in brain temperatures due to exposure to a mobile phone. *Phys Med Biol*. 1999;44(10):2367-79.

PARTICULARS OF CONTRIBUTORS:
1. Associate Professor, Department of Physiology, Guru Gobind Singh Medical College, Faridkot, Punjab, India.
2. Associate Professor, Department of E.N.T, Guru Gobind Singh Medical College, Faridkot, Punjab, India.
3. Professor, Department of Physiology, Guru Gobind Singh Medical College, Faridkot, Punjab, India.
4. Professor, Department of Physiology, Adesh Institute of Medical Sciences and Research, Bathinda, Punjab, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Naveenta Gupta,
Associate Professor, Department of Physiology, Guru Gobind Singh Medical College, Faridkot, Punjab - 151203, India.
E-mail : drnaveenta@gmail.com

FINANCIAL OR OTHER COMPETING INTERESTS: None.

Date of Submission: **Mar 04, 2015**
Date of Peer Review: **Apr 13, 2015**
Date of Acceptance: **Apr 21, 2015**
Date of Publishing: **May 01, 2015**