ORIGINAL ARTICLE

A Study to Evaluate the Effects of Mobile Phone Generated EMF in Auditory Brainstem Responses

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Abstract

Mobile phones are being widely used throughout the world resulting in progressive exposure to electromagnetic frequency generated by them. The purpose of the current study is to evaluate the adverse effect of long-term mobile phone usage on auditory brainstem response (ABR). This prospective, cross-sectional study was conducted in a tertiary care hospital, in the Departments of Physiology and ENT, Government Medical College, Jammu. The study involved 60 subjects, divided into three groups of 20 each, based on the usage of mobile phone - Group A: Control subjects, Group B: Subjects using mobile phone for 30 minutes/day for 4 years; and Group C: Subjects using mobile phone for 30 minutes/day for 4-8 years. Their ABR was recorded and analyzed for latency of waves I to V, as well as interpeak latencies of I-III, III-V and I-V in milliseconds. There was statistically no significant difference in ABR parameters i.e. latencies of waves and interpeak latencies among groups A, B and C. Similar to earlier studies done, no significant delay in ABR parameters was observed in long-term mobile phone users as compared to Control subjects. The present study suggests that long-term exposure to EMF generated by commercial mobile phones does not produce measurable effect on ABR parameters.

Key Words

Auditory Brainstem Response, Electromagnetic Frequency, Mobile Phone

Introduction

The everincreasing possession and usage of mobile phones has produced a revolution in communication system, thereby also in social and environmental domain and has modified lifestyle in a dramatic way. Mobile phones have raised public concern over possible harmful physiological effects. Effects and possible health outcomes of exposure to radiofrequency fields from mobile phones and its radiation waves consist of oscillating electric and magnetic field emitted from these wireless devices (1).

Numerous studies have shown that usage of mobile phones may cause adverse health effects such as headache, sleep disturbance, impairment of short-term memory, lack of concentration, brain tumors and high blood pressure (2,3). There are two direct ways by which exposure to radiofrequency radiation can affect health. These are thermal effects caused by holding mobile phones close to the body and include headache, sensation of warmth or burning around the ear, burning sensation on the facial skin and alteration of the blood-brain barrier, while the non-thermal effects at tissue, cellular and sub-cellular levels are possibly induced by magnetic field rather than the electric field of EMF (electromagnetic frequency) because of its ability to penetrate human bodies. The non-thermal effects have been implicated in disturbance of sleep patterns, increase in blood pressure, effect on cognitive functions and potential carcinogenic effect of mobile phone particularly acoustic neuroma (4).Increased permeability of the blood-brain barrier or changes in activation of endogenous opioids may be the underlying factors of the headaches reported by mobile phone users. Other non-cancer health effects of EMF reported are - fatigue, nausea, impaired thermoregulation and general discomfort (5).Due to close proximity of the antennae of the mobile phone to the user's ear and head, the inner ear, 8th cranial nerve and brain are inevitably exposed to the EMF with a specifically high specific absorption rate (SAR). Some authors have reported that approximately

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40-50% of mobile phones radiofrequency output power energy is absorbed in the user's head (6).

The auditory brainstem-evoked response (ABR) may allow quantifying the activity and functions of auditory organ, including the auditory nerve and subcortical centers. These are potential recorded from ear and vertex in response to brief auditory (click) stimuliand assess conduction through the auditory pathway upto the level of midbrain.Various studies have investigated the electrophysiological effects of EMF to human body (7,8), but the results of these studies have been ambiguous and contradictory. Therefore,the present study was conceived to investigate the effects of mobile phones on human auditory brainstem responses in long-term GSM (global system for mobile communication) mobile phone users to provide more clarity into this public health problem.

Material and Methods

After approval from the Institutional Ethical Committee, Government Medical College, Jammu, the present study was conducted over a period of six months i.e., January to June, 2015.

The study comprised of 60 subjects of either sex divided into three groups of 20 each:

- *Group A:* Subjects who never used a mobile phone
- *Group B:* Subjects using mobile phones for the past 4 years
- *Group C:* Subjects using mobile phones for the past 8 years

The daily usage by subjects in groups B and C was limited to a maximum of 30 minutes.

Subject Selection

The subjects were selected from amongst the volunteers and patients attending ENT OPD. A written informed consent was obtained from them and each one was explained the test procedures they were subjected to.

Inclusion Criteria

- Subjects between the ages of 15-30 years of either sex.
- Subjects using GSM phones only,for the past 4 years (for group B) and for 8 years (for group C).
- Subjects with normal hearing (i.e. with no apparent impairment of hearing between 0 and 25 dB taking the average of the threshold of hearing for frequencies 500, 1,000 and 2,000 Hz).

Exclusion Criteria

- Subjects with history of ear discharge, hearing loss, ear surgery.
- Subjects with metabolic disorders known to affect hearing.
- Subjects taking ototoxic drugs (aminoglycosides, diuretics, analgesics).
- Subjects with history of chronic smoking and/or alcohol abuse.
- Noise induced hearing loss.
- Any hormonal imbalance e.g., thyroid, acromegaly.

Special emphasis was laid on history of headache, dizziness, fatigue, loss of concentration, memory loss, warmth behind ear/on ear, burning skin, tingling/tightness.

Complete medical history was taken in each of the subjects along with general and complete systemic examination before recording the ABRs.

Clinical ENT examination was performed including examination of the external ear to rule out any hearing loss due to wax, debris, discharge, polyp and perforation of the tympanic membrane. Auditory threshold was determined using pure tone audiometry (PTA).

Along with this a complete history of mobile phone usage was taken from the subjects: the number of years he has been using a mobile phone and the average duration of use per day (for groups B and C).

Recording of ABRs

ABRs were recorded using computerized evoked potential recording system (EB Neuro, Italy). The subject was asked to lie down at the time of testing in a sound proof room at ambient room temperature. Three disc electrodes were affixed according to '10-20 International System' of electrode placement. Active electrode was placed at ipsilateral mastoid process.Reference electrode was placed at vertex of the skull and Ground electrode was kept at the forehead in the midline.Electrical impedance was kept below 5 k?. Acoustic transients (alternating clicks) were delivered through earphones. Each brief click stimulus was a square wave pulse of 0.1 ms. A click rate of 21 kHz was used. A total of 2,000 individual sweeps were recorded using filter band pass of 300-3,000 Hz with artefact rejection level up to 25 =V

Two to three repetitions of the recording were done to ensure reproducibility i.e. latency measured on separate recordings agreed with each other within 0.1 ms or less and absolute peak latency (I, II, III, IV and V) andinterpeak latencies (IPLs - I-III, III-V and I-V) were determined. Both the ears of all the subjects were tested (one ear at a time), while masking the contralateral ear with white noise 40dB below the ipsilateral click stimuli.

Statistical Analysis

The collected data was tabulated and comparison of all three groups and intergroup variations were assessed using one-way analysis of variance(ANOVA) and

unpaired Student's 't' test respectively. A p value of less than 0.05 was considered as statistically significant.

Results

Comparison of absolute peak latencies and interpeak latencies of ABR waves I to V in Group A, Group B and Group C in left ear, right ear and both ears are depicted in Table 1. Though there was steady increase in peak and interpeak latencies in Group B as compared to Group A, and Group C as compared to Groups B and A, the overall difference was statistically not significant [p>0.05]. Intergroup comparison of absolute peak latencies and interpeak latencies of ABR waves are given in Table 2. The present study did not observe any statistically significant association duringintergroup comparison[Group A and Group B, Group B and Group C and Group A and Group C] in bothabsolute peak latencies [waves I to V], as well as in interpeak latencies of ABR waves[I-III, III-V and I-V], in either left or right ear.When absolute wave latencies and interpeak latencies in ABR were analyzed in both the ears taken together, again no statistically significant association could be established [p>0.05]. The results indicate that conduction of electrical impulse generated to acoustic stimuli from cochlear nerve to auditory brainstem is not affected by mobile phones. In the mobile phone users groups B and C (n=40), 35 subjects said that they used both the ears, right more than left, while 5 mostly used left ear while calling. Thus, comparison of lateralization of mobile phone use for each group was not possible statistically. 9 patients among the chronic mobile phone users (Group C) reported headache, 7 complained of loss of concentration and another 7 complained of warmth behind the ear. Two patients reported insomnia and fatigue. None of the mobile phone users complained of tingling sensation, dizziness or memory loss.

Discussion

Mobile phone operates on wireless technology, with communication typically occurring via a 900-1800 MHz signal that is pulsed at 217 Hz. This signal carries essentially no power when the user is not talking or receiving but when the user communicates the power of this pulsed EMF reaches a maximum of 250 mW (9). The effects of EMF on biological system have been extensively investigated over the last few years with particular attention has been given to the effect of microwave exposure on the central nervous system (10). A study carried out in USA, UK, New Zealand and Australia showed that the major complaints of mobile phone users included headache, fatigue, general ill-being, muscular pains and nausea (11). The degree of adverse biological effects of the mobile phone microwave radiation depends on various factors, likethe duration of the irradiation, individual characteristics of the central nervous system and immune systems, genetic susceptibility and other factors like the rate of absorption and the distribution of EMF energy by different tissues of the body (4,12).

Short term exposure [10-30mins] to EMF from commercial mobile phones have shown contradictory results by various authors (5,7,8,13,14). Still less data is available regarding chronic effects created by EMF. Cochlear nerves and temporal lobes are the neural structures most exposed to the pulsed EMF and mobile phones are ideally positioned to affect the auditory system. Such fields have been shown to have some adverse effects on the brain (15).

Panda *et al.* (16) conducted a study of 112 subjects who were long-term mobile users (>1 year) and 50 controls. Authors reported that no significant difference between users and controls for pure-tone audiometry (PTA), ABR, middle latency responses (MLRs) and distortion otoacoustic emissions. However, they concluded that long-term and intensive mobile phone use may cause inner ear damage. A study conducted by Kapranaet *et al.* (17) on rabbits reported prolongation of interval latencies I-V and III-V after exposure and EMF emitted by mobile phone, thereby reflecting the effect of EMF on normal electrophysiological activity of the auditory system. The results of the current study revealed that EMF causes no significant alteration in the latencies and interpeak latencies of the ABR waves, suggesting that the neural pathways mediating on auditory stimulus, from cochlear nerve to mid-brain, are not affected by exposure to EMF emitted by mobile phones. Similar to the current study, other authors have reported no significant effect of EMF generated by mobile phone on auditory parameters including otoacoustic emissions and ABR (4,17,18,19,20).

Some authors like Liburdy&Vanek (21) and Khullar *et al.* (22) have reported positive findings on microwave interactions with cell membranes. Khullar *et al.* in their study of 60 subjects found that there was no significantdifference in ABR parameters between non-users and moderate users (maximum 30 minutes/day for 5 years). However, the latency of waves I and II was significantly prolonged in chronic users (using mobile phones for 10 years for a maximum of 30 minutes/day) representing the involvement of peripheral portion of auditory nerve.While Patel and Qureshi (23) reported increased mean hearing loss on PTA in a study group of long-term mobile users (1 hour/day) as compared to control group of mobile phone users (<15 minutes/day).

The energy radiated by a mobile telephone is low. GSM

Table 1. Comparison of Absolute Peak latencies, Interpeak latencies of ABR Waves I to V in Groups A, B and C (mean±SD) in left Ear, Right Ear and Both Ears

Variables	Group A (Controls)	Group B (past 4 years)	Group C (past 8 years)	Statistical inference (p-value)
Left ear (n=20)				
Wave I lat.	1.65 ± 0.06	1.66 ± 0.01	1.66 ± 0.01	0.59*
Wave II lat.	2.57 ± 0.04	2.55 ± 0.03	2.63 ± 0.22	0.13*
Wave III lat.	3.57 ± 0.03	3.64 ± 0.40	3.58 ± 0.04	0.59*
Wave IV lat.	4.50 ± 0.26	4.58 ± 0.16	4.60 ± 0.18	0.27*
Wave V lat.	5.59 ± 0.26	5.64 ± 0.27	5.71 ± 0.31	0.40*
Interpeak lat. I-III	1.90 ± 0.03	1.89 ± 0.03	1.92 ± 0.08	0.19*
Interpeak lat. III-V	2.02 ± 0.27	2.09 ± 0.27	2.11 ± 0.30	0.57*
Interpeak lat. I-V	3.93 ± 0.26	4.05 ± 0.14	4.08 ± 0.29	0.11*
Right ear (n=20)				
Wave I lat.	1.66 ± 0.03	1.66 ± 0.02	1.65 ± 0.03	0.40*
Wave II lat.	2.62 ± 0.22	2.58 ± 0.03	2.57 ± 0.02	0.43*
Wave III lat.	3.62 ± 0.22	3.58 ± 0.03	3.57 ± 0.01	0.43*
Wave IV lat.	4.53 ± 0.31	4.61 ± 0.16	4.63 ± 0.21	0.36*
Wave V lat.	5.67 ± 0.24	5.73 ± 0.30	5.77 ± 0.32	0.54*
Interpeak lat. I-III	1.90 ± 0.03	1.89 ± 0.03	1.92 ± 0.08	0.19*
Interpeak lat. III-V	2.02 ± 0.27	2.09 ± 0.27	2.11 ± 0.30	0.57*
Interpeak lat. I-V	3.93 ± 0.26	4.05 ± 0.14	4.08 ± 0.29	0.11*
Both ears (n=40)				

*Not significant (p>0.05)

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. This safety feature of GSM mobile telephones may be one reasons for the statistically insignificant results obtained in the present study (24). Evidence generated so far has shown that heat generated by chronic mobile phone use may not be significant enough to affect the biological tissue, thus not disturbing the thermoregulation mechanism. Safety guidelines on mobile phones impose upper limits on the radiation intensity to ensure that this does not happen (24,25) so that the permeability of the blood brain barrier as well as the active transport of Na+, K+ and release of Ca++ ions by cell membranes does not get altered. The power of mobile

Table 2. Intergroup comparison of absolute peak latencies, interpeak latencies of ABR waves I to V in Groups A, B and C (mean±SD) in left ear, right ear and both ears

Variables	Statistical inference (p-value)		
	Group A vs Group B	Group B vs Group C	Group A vs Group C
Left ear (n=20)			
Wave I lat.	0.46*	1*	0.46*
Wave II lat.	0.08*	0.11*	0.23*
Wave III lat.	0.44*	0.50*	0.37*
Wave IV lat.	0.24*	0.71*	0.16*
Wave V lat.	0.55*	0.45*	0.82*
Interpeak lat. I-III	0.29*	0.12*	0.30*
Interpeak lat. III-V	0.41*	0.82*	0.32*
Interpeak lat. I-V	0.07*	0.67*	0.09*
Right ear (n=20)			
Wave I lat.	1*	0.22*	0.29*
Wave II lat.	0.42*	0.22*	0.31*
Wave III lat.	0.42*	0.16*	0.31*
Wave IV lat.	0.31*	0.73*	0.23*
Wave V lat.	0.48*	0.68*	0.27*
Interpeak lat. I-III	0.42*	1*	0.42*
Interpeak lat. III-V	0.58*	0.90*	0.46*
Interpeak lat. I-V	0.43*	0.87*	0.44*
Both ears			
Wave I lat.	0.24*	1*	0.24*
Wave II lat.	0.24*	0.10*	0.77*
Wave III lat.	0.84*	0.50*	0.43*
Wave IV lat.	0.12*	0.15*	0.06*

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 0.10C increase in temperature of deep tissues like brain. Such minor increase in temperature cannot cause any adverse on the body (24,26).

Conclusion

The long-term exposure up to 30 minutes/day of mobile phones is not the cause of adverse effects on the auditory system as far as brainstem auditory evoked responses are concerned. However, it is not reasonable to conclude that exposure to EMFs during mobile telephone use does not lead to any hazardous health effects. The health impact of mobile phone on each individual is variable as the population is genetically heterogeneous. At present we can guide young mobile phone users with potentially longer lifetime exposure to cut short the dialogue periods and use the hand-sets for essential purposes only. By

using speaker phones or hands-free system, the direct exposure to electromagnetic radiations emitted by mobile phones can be minimized.

References

1. Knave B. Electromagnetic fields and health outcomes. *Ann Acad Med Singapore* 2001; 26(5): 489-493.
2. Themir K, Sultan M. Association of mobile phone radiation with fatigue, headache, dizziness, tension and sleep disturbance in Saudi population. *Saudi Med J* 2004; 25(16): 732-36.
3. Michael M, Colin B, Mike K. The health hazards of mobile phones. *Br Med J* 2000; 320: 1288-1289.
4. Ozturan O, Erdern T, Miman MC, Kalcioglu MT, Oncel S. Effects of the electromagnetic field of mobile telephones on hearing. *Acta Otolaryngol* 2002; 122(3): 289-293.
5. Szyjkowska A, Gadzicka E, Szymczak W, Bortkiewicz A. The risk of subjective symptoms in mobile phone users in Poland - an epidemiological study. *Int J Occupt Med Environ Health* 2014; 27(2): 293-303.
6. Stefanics G, Kellenyi L, Molnar F, Kubinyi G, Thuroczy G, Hernadi I. Short GSM mobile phone exposure does not alter human auditory brainstem response. *BMC Pub Health* 2007; 7: 325.
7. Kellenyi L, Thuroczy G, Faludi B, Lenard L. Effects of mobile GSM radiotelephone exposure on the auditory brainstem response (ABR). *Neurobiology* 1999; 7: 79-81.
8. Arai N, Enomotor 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: 1390-1394.
9. Croft RJ, Chandler JS, Burgess AP, Barry RJ, Williams JD, Clarke AR. Acute mobile phone operation affects neural function in humans. *Clin Neurophysiol* 2002; 113(10): 1623-1632.
10. Balikci K, Ozcan IC, Balik DT, Balik HH. The effects of long-term use of mobile phones on human health. URSI EMTS 2004; 498-500.
11. Bortkiewicz A. A study on the biological effects of exposure mobile-phone frequency EMF. *Med Pr* 2001; 52(2): 101-106.
12. Galeev AL. The effects of microwave radiation from mobile telephones on humans and animals.*Neurosci Behav Physiol* 2000; 30: 187-194.
13. Al-Dousary SH. Mobile phone induced sensorineural memory loss. *Saud Med J* 2007; 28(8): 1283-1286.
14. Bak M, Sliwinska-Kowalska M, Zmyslony M, Dudarewicz A. No effects of acute exposure to the electromagnetic field emitted by mobile phones on brainstem auditory potentials in young volunteers. *Int J Occup Med Environ Health* 2003; 16(3): 201-08.
15. Lonn S, Ahlbom A, Hall P, Feychting M. Mobile phone use and the risk of acoustic neuroma. *Epidemiology* 2004; 15(6): 653-659.
16. 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.
17. Kaprana AE, Chimona TS, Papadakis CE, *et al*. Auditory brainstem response changes during exposure to GSM-900 radiation: an experimental study. *Audiol Neurootol* 2011; 16(4): 270-76.
18. Parazzini M, Lutman ME, Moulin A, *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, *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, Jaaskelainen SK, Toivo T, Hamalainen H. No effects of mobile phone electromagnetic field on auditory brainstem response. *Bioelectromagnetics* 2010; 31(1): 48-55.
21. Liburdy RP, Vanek PF Jr. Microwaves and the cell membrane. II. Temperature, plasm and oxygen mediate microwave-induced membrane permeability in the erythrocyte. *Radiat Res* 1985; 102(2): 190-205.
22. 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.
23. Patel H, Qureshi R. Effects of long-term use of mobile phones on hearing status of healthy individuals compared to infrequent mobile phone users in age group of 15-40 years. *IJSR* 2013; 2(11): 177-179.
24. Gupta N, Goyal D, Sharma R, Arora KS. Effect of prolonged use of mobile phone on brainstem auditory evoked potentials. *J Clin Diagn Res* 2015; 9(5): CC07-CC09.
25. Hyland GJ. Physics and biology of mobile telephony. *Lancet* 2000; 356(9244): 1833-36.
26. Van Leeuwen GM, Lagendijk JJ, Van Leersum BJ, *et al*. Calculation of change in brain temperatures due to exposure to a mobile phone. *Phys Med Biol* 1999; 44(10): 2367-79.