Auditory Brainstem Responses and EMFs Generated by Mobile Phones

Shilpa Khullar · Archana Sood · Sanjay Sood

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Abstract There has been a manifold increase in the number of mobile phone users throughout the world with the current number of users exceeding 2 billion. However this advancement in technology like many others is accompanied by a progressive increase in the frequency and intensity of electromagnetic waves without consideration of the health consequences. The aim of our study was to advance our understanding of the potential adverse effects of GSM mobile phones on auditory brainstem responses (ABRs). 60 subjects were selected for the study and divided into three groups of 20 each based on their usage of mobile phones. Their ABRs were recorded and analysed for latency of waves I–V as well as interpeak latencies I–III, I–V and III–V (in ms). Results revealed no significant difference in the ABR parameters between group A (control group) and group B (subjects using mobile phones for maximum 30 min/day for 5 years). However the latency of waves was significantly prolonged in group C (subjects using mobile phones for 10 years for a maximum of 30 min/day) as compared to the control group. Based on our findings we concluded that long term

exposure to mobile phones may affect conduction in the peripheral portion of the auditory pathway. However more research needs to be done to study the long term effects of mobile phones particularly of newer technologies like smart phones and 3G.

Keywords Auditory brainstem responses · Cellular phones · Electromagnetic waves · GSM phones

Introduction

Over a period of few years mobile phones have produced a revolution, involving not only communication systems and technological sphere, but also the whole social and environmental domain. Their widespread use has produced a huge and irreversible modification in everyday life, quickly becoming irreplaceable communication tools [1]. There are more than 2 billion mobile cellular phones in use throughout the world [2].

Discarding the wire means that communication is through electromagnetic waves (EMWs) which could have potential hazards. Many recent studies have raised questions regarding the safety of such RF–EMWs (Radiofrequency–Electromagnetic waves) exposure to humans [3]. Adverse effects studied by several clinical trials include the possible link to increased risk of vehicular accidents, leukemias, sleep disturbances and more serious brain tumours [4]. There is significant public interest and concern regarding exposure to electromagnetic fields (EMFs) and increased incidence of tumours particularly acoustic neuromas because of the close association of the acoustic nerve to the handset of the mobile phone [4]. Cell phones transmit and receive microwave radiation at frequencies which excite rotation of water molecules and some organic

S. Khullar (✉)
Department of Physiology, ESIC Dental College and Hospital,
Sector-15, Rohini, Delhi 110089, India
e-mail: drshilpakhullar@gmail.com

A. Sood
Department of Biochemistry, ESIC Dental College and Hospital,
Sector-15, Rohini, Delhi 110089, India

S. Sood
Holy Family Hospital, New Delhi, India

S. Khullar
E-605, First Floor, Greater Kailash Part-2, New Delhi 110048,
India

molecules, associated with thermal effects and non-thermal effects. The thermal effects include: headache, sensation of warmth or burning around the ear, burning sensation on the facial skin and alteration of the blood–brain barrier [5].

The vast majority of the sustained cell phone EMWs related biological consequences can be explained by the ‘non-thermal effects’. These effects include all the interactions of EMWs with biological tissues without production of heat or a measurable rise in temperature. Specifically the magnetic field rather than the electrical field of EMWs has the most harmful potential on living organisms because of its ability to penetrate human bodies while electrical field has poor human skin penetration ability [5]. In fact, the induced alternating currents in our bodies resulting from cell phone EMW exposure can explain the biological non thermal effects at tissue, cellular and sub-cellular levels. The non-thermal effects include: disturbance of sleep patterns, increase in blood pressure, effect on cognitive functions and potential carcinogenic effects of mobile phones particularly acoustic neuromas [5].

Due to the close proximity of the antenna of the mobile handsets to the user’s ear and head, the brain is inevitably exposed to the EMFs with a specifically high specific absorption rate (SAR). Experimental research indicates that approximately 40–45 % of the mobile phone’s RF output power energy is absorbed in the user’s head [2].

Hence use of mobile phones and the consequent biological effects and/or risks, cannot be restricted to the domains of personal lifestyle but involves the whole population and should be considered as a high priority environmentally related health issue [1].

The aim of our study was to see the effect of EMFs emitted by GSM (Global system for mobile communications) phones (operating within the band of 900–2,000 MHz) [6] on the auditory brainstem responses (ABRs).

Materials and Methods

This study was conducted in the Neurophysiology lab, Dept. of Physiology, Maulana Azad Medical College (MAMC), New Delhi. The study protocol was approved by the ethical committee of the institute and extended over a period of 1 year between 2009 and 2010.

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

Group A: Subjects who have never used a mobile phone

Group B: Subjects using mobile phones for the past 5 years

Group C: Subjects using mobile phones for the past 10 years

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

Subject Selection

The subjects were selected from amongst the students and staff of Maulana Azad Medical College, Lok Nayak Hospital, GB Pant Hospital and Guru Nanak Eye Center, New Delhi as well as from the general population. A written informed consent was obtained from them and each one was explained the test procedures they were subjected to

Inclusion Criteria

1. Subjects between the ages of 18–40 years of either sex
2. Subjects using GSM phones only, made by “Nokia” for the past 5 years (for group B) and for 10 years (for group C)
3. 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

1. Subjects with metabolic disorders known to effect hearing
2. Subjects taking ototoxic drugs (Aminoglycosides, Diuretics, Analgesics)
3. Subjects with history of chronic smoking and/or alcohol abuse
4. Noise induced hearing loss

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 (EBNeuro, Italy). The subject was asked to lie down at the time of testing in a sound proof room at ambient room temperature.

Ag/AgCl disc electrodes were affixed according to '10–20 International System' of electrode placement. Active electrode was placed at ipsilateral ear lobule (A_i), reference electrode was placed at C_z and ground electrode was kept at the forehead (F_z). Electrical impedance was kept below 5 k Ω . Acoustic transients (alternating clicks) were now delivered through earphones. Each brief click stimulus is a square wave pulse of 0.1 ms. A click rate of 11 kHz was used. A total of 1,500 individual sweeps were recorded using filter band pass of 300–3,000 Hz with artefact rejection level up to 25 μ 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, interpeak latencies (IPLs) were determined.

Statistical Analysis

The collected data was tabulated and inter group variation was assessed using one-way ANOVA and Tukey–Kramer multiple comparison test, p value < 0.05 was considered to be statistically significant.

Results

The absolute latency of waves I–V can be seen in Table 1.

The absolute values of IPLs of the three groups can be seen in Table 2.

No significant difference in the latencies was observed between groups A and B as well as between groups B and C. On comparison between groups A and C, latency of waves I and II was more significantly higher ($p < 0.01$) in group C compared to waves III, IV and V ($p < 0.05$) (Table 3). On comparing the IPLs between the three groups, no significant differences could be seen ($p > 0.05$).

Discussion

The rapid worldwide increase in the use of mobile phones raises questions about the possible adverse effects of emitted EMFs on health. Although there is no clear evidence to show harmful effects of EMFs at the levels emitted by mobile phones, there is widespread public

concern that there may be potential for harm [1]. Health consequences of long term use of mobile phones are not known in particular but available data indicates the development of non-specific annoying symptoms on acute exposure to mobile phone radiation [7, 8].

Several studies have investigated the interaction between mobile phones and brain functions in humans including their effect on hearing [9–17]. Some of the similar recent studies have been highlighted below:

In a study conducted to see the effect of EMF emitted by cell phones on hearing Oktay MF [18], investigated three categories of subjects:

1. 20 men who have used a mobile phone frequently and spoke for approximately 2 h per day for 4 years
2. 20 men who have used a mobile phone for 10–20 min per day for 4 years
3. 20 men who have never used a mobile phone

Similar to our findings, no differences were observed between moderate mobile phone users (10–20 min/day) and the control group. However this study shows that a higher degree of hearing loss is associated with long term exposure to EMWs generated by mobile phones.

A study done to see the effect of GSM phones on hearing carried out video-nystagmographic recordings of 13 subjects, brainstem electric response audiometry of 24 ears, and recordings of distortion products of otoacoustic emissions of 20 ears. The result showed that the electromagnetic generated by mobile phones do not have any effect on the inner ear, vestibular apparatus and brainstem [19].

An Indian study similar to ours attempted to see the audiological disturbances in long-term mobile phone users (GSM phones). 112 subjects who were long term mobile phone users (>1 year) and 50 controls underwent a battery of audiological tests: PTA, tympanometry, distortion product otoacoustic emissions, ABRs and MLRs. No significant difference between users and controls for any of the audiological parameters could be seen. However they concluded that long-term and intensive mobile phone use may cause inner ear damage but a larger sample size would be required to reach definitive conclusion [20].

A recent study concluded that short-term exposure to mobile phone EMFs did not affect the transmission of sensory stimuli from the cochlea up to the midbrain along the auditory nerve and the brainstem auditory pathways [21].

Table 1 Absolute peak latencies of waves I to V in groups A, B and C (mean $\pm$ SD)

Groups	I	II	III	IV	V
A	1.66 $\pm$ 0.22	2.59 $\pm$ 0.24	3.58 $\pm$ 0.28	4.95 $\pm$ 0.12	5.46 $\pm$ 0.27
B	1.70 $\pm$ 0.14	2.72 $\pm$ 0.25	3.72 $\pm$ 0.16	5.04 $\pm$ 0.15	5.61 $\pm$ 0.15
C	1.81 $\pm$ 0.12	2.88 $\pm$ 0.19	3.79 $\pm$ 0.11	5.11 $\pm$ 0.30	5.72 $\pm$ 0.20

Table 2 Interpeak latencies (in ms) of groups A, B and C (mean $\pm$ SD)

Groups	I–III	I–V	III–V
A	1.93 $\pm$ 0.24	3.81 $\pm$ 0.33	1.89 $\pm$ 0.35
B	2.01 $\pm$ 0.18	3.90 $\pm$ 0.23	1.89 $\pm$ 0.21
C	1.99 $\pm$ 0.16	3.91 $\pm$ 0.21	1.92 $\pm$ 0.22

Table 3 Intergroup comparison of absolute latencies and interpeak latencies

Parameter (ms)	Group A vs B	Group B vs C	Group A vs C
Wave I lat.	NS	NS	* *
Wave II lat.	NS	NS	* *
Wave III lat.	NS	NS	*
Wave IV lat.	NS	NS	*
Wave V lat.	NS	NS	*
Interpeak lat. I–III	NS	NS	NS
Interpeak lat. I–V	NS	NS	NS
Interpeak lat. III–V	NS	NS	NS

NS not significant i.e. p value > 0.05 ; * p value < 0.05 ; * * p value < 0.01

A study in Poland evaluated the ABRs in 45 young healthy volunteers before, during and after exposure to EMFs generated by antenna of a mobile phone. The ABR waveforms showed no significant difference due to exposure, suggesting that short-term exposure to mobile phones did not affect the transmission of sensory stimuli from the cochlea up to the midbrain along the auditory nerve and the brainstem auditory pathway [22].

A study was done on the student population in UK on the adverse effects of mobile phones on the auditory pathway. Duration of ownership and daily usage ranged between 0–7 years and 0–45 min respectively. The results of the study confirmed that the prevalence of mobile phone ownership among the student population is extremely high. However there appears to be no harmful effects of mobile phone usage on their audiovestibular systems within the range of exposure of the study, in so far as can be detected by the self-reporting method employed [23].

All these negative findings in most of the studies should not encourage mobile phone usage because minor biological and neurophysiological influences may not be detected with the current technology [24].

A recent study in rabbits in the year 2011 investigated the ABRs during exposure to electromagnetic radiation emitted by cellular phones. The prolongation of interval latencies I–V and III–V indicates that exposure to EMFs emitted by mobile phone can affect the normal electrophysiological activity of the auditory system, and these findings fit the pattern of general responses to a stressor [25].

A study conducted in Saudi Arabia concluded that 60 min of exposure to EMFs emitted by mobile phones had an immediate effect on the hearing threshold assessed by pure-tone audiometry and inner ear (assessed by DPOAE) in young human subjects. It may also lead to other otologic symptoms [26]. Another study in the same country reported a case of sensorineural hearing loss due to usage of GSM phone in a 42 year old male subject [27].

A recent meta-analysis aimed to clarify whether RF–EMF have an influence on the well-being in self reported sensitive persons as well as in non-sensitive people. A literature search revealed 17 studies including 1,174 participants. The single effects for various subjective and objective outcomes were meta-analytically combined to yield a single population parameter. The results showed no significant impact of short-term RF–EMF exposure on any parameter including the auditory ones. However the authors suggested that future research should focus on the possible side effects of long-term exposure [28].

A study was done to see the effect of UMTS (3G) exposure at a SAR on the human auditory system. Results from 73 participants did not show any consistent pattern of effects on the auditory system after a 20 min UMTS at exposure 1,947 MHz at a maximum SAR over 1 g of 1.75 W/kg at a position equivalent to the cochlea [29].

Conclusion

Our study demonstrated that short term exposure (up to 30 min/day) to EMFs emitted from GSM mobile phones does not induce any measurable change in ABRs over a period of 5 years. However continued exposure over a period of 10 years may increase the latency of waves I and II representing the peripheral portion of the auditory pathway. However additional studies are needed to study the long-term effects of mobile phone usage. In addition as new generation of mobile sources of EMFs (such as 3G and smart phones) are being rapidly introduced, it is of utmost importance to establish whether or not these new generation of mobile phones have potential adverse effects on brain functions in humans

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