RESEARCH ARTICLE

Does the duration of mobile phone usage affect the human auditory system? A middle latency auditory-evoked potential study in young adults

Anu Priya J[1], Arun Kumar M[2], Roopakala M S[2]

[1]Department of Physiology, Dr. Somervell Memorial CSI Medical College, Trivandrum, Kerala, India, [2]Department of Physiology, M. S. Ramaiah Medical College, Bangalore, Karnataka, India

Correspondence to: Anu Priya J, E-mail: dr.priya07@gmail.com

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ABSTRACT

Background: Mobile phones emit microwave range of electromagnetic radiations. The human auditory cortex has a greater chance of being affected by these radiations due to the close proximity during usage. Middle latency auditory-evoked potential (MLAEP) recording helps in testing the integrity of the thalamo-cortical pathway of the human auditory system. **Aims and Objectives:** The aims and objectives are (1) to compare the latencies of MLAEPs in short- and long-term mobile phone users based on years of usage and (2) to compare the latencies of MLAEPs in mobile phone users grouped based on the duration of usage per day. **Materials and Methods:** MLAEP recording was done in 20 short- and long-term mobile users described as the history of usage of mobile phone less than and more than 1 year, respectively. Further, the group was categorized based on the duration of usage per day. Mean latencies of the MLAEP waves Na, Pa, and Nb were measured and compared statistically using Student's *t*-test (two tailed, independent) and Mann–Whitney U test. **Results:** The mean latencies of MLAEP waveforms in both the ears were found to be significantly increased in long-term mobile phone users and in individuals who use mobile phones for more than 1 h per day. **Conclusion:** The study shows that long-term usage, as well as longer duration of usage of mobile phones, significantly affects the nerve conduction velocity in the thalamo-cortical region of the human auditory pathway.

KEY WORDS: Auditory-Evoked Potential; Middle Latency; Brainstem; Mobile Phone; Long-Term Mobile Users; Short-Term Mobile Users; Auditory Pathway

INTRODUCTION

Mobile technology has undergone a lot of advancements since 1973, the year when Motorola's Martin Cooper made the first call from a handheld mobile phone.[1] For the past few decades, mobile technologies and services have been benefiting the world by helping in economic growth.[2] and also improving social bonding in a busy world.

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The number of cell phone users is expected to reach around 8.9 billion in the year 2020.[3] The increase in mobile phone usage in the modern era has led to various concerns related to its effects on human health. The benefits of a mobile phone are numerous. But at the same time, one should note that these devices basically function as radiotransmitters that emit electromagnetic radiations that might cause health problems. When a radiotransmitter is used close to the body, some of the radiofrequency (RF) power is absorbed. The amount of radiation absorbed during usage of a phone varies based on the device used and is measured as the specific absorption rate (SAR). In general, people keep the mobile phone device near the ear to communicate. The human auditory system lies in close proximity to the source of radiation. Hence, the tissues are at greater risk to absorb relatively greater amount of radiation. Though the SAR levels are being monitored and controlled in an optimum range, there is a concern as to whether or not chronic exposure to these radiations in a day-to-day basis affects the auditory system in the long run. Longer the mobile usage in terms of days and hours per day, higher the risk of hazards of radiation emitted from the mobile phones.

Middle latency auditory-evoked potentials (MLAEPs) constitute the middle (10–80 ms) component of the electrical potentials generated by the nervous system in response to brief sound stimulation. It tests the integrity of the auditory pathway from the thalamic medial geniculate body up to the primary auditory cortex. The source of these activities is the summation of the action potentials generated by the afferent tracts and the electrical fields or activities of the synaptic discharges or post-synaptic potentials on those tracts. The recording of MLAEP is a noninvasive technique. The resulting waveforms show voltage (amplitude) as a function of time (latency). The components are labeled according to their sequence by polarity. The latency studies the conduction velocity of nerve impulses, and the amplitude studies the number of nerve cells which are stimulated.

Some researches have been done to study the effects of mobile phone radiation exposure on the auditory system. Variable results have been obtained regarding the subjective and objective effects of exposure to these radiations. Most of these studies have been done following a short-term exposure. Very few studies have been done to assess the effects of long-term exposure.

In this study, the effect of duration of mobile phone usage on the latencies of MLAEP waves Na, Pa, and Nb was studied.

MATERIALS AND METHODS

Forty individuals were recruited for the study. All the individuals were staffs or students of M. S. Ramaiah Medical College and teaching hospitals. The study was conducted between January 2014 and April 2015. Ethical clearance to conduct the study was obtained from the M. S. Ramaiah Medical College ethical committee for human research. Informed written consent was obtained from all the individuals.

The individuals included in the study belonged to the age group of 18–30 years. The individuals chosen were apparently healthy with normal hearing. They had no history of ear diseases or deafness. Individuals who use global system for mobile communication (GSM) mobile phones with SAR <2 W/kg were chosen for the study in order to obtain information relevant to the most common mobile communication system, i.e., GSM and the currently accepted SAR range.

A detailed history was taken before the recordings, and individuals with a history of head/ear trauma, significant occupational noise exposure, family history of deafness, history of any systemic illness that might affect the nervous system, tobacco chewing, chronic alcoholism or cigarette smoking, intake of ototoxic drugs or any other medication that might affect normal functioning of the nervous system, and history of any ear surgery, radiotherapy, or chemotherapy were excluded from the study.

History of mobile phone usage was obtained, regarding the years of usage, duration of attending calls each day, the preferred ear while attending a mobile phone call, mobile phone model, years since purchase of the current mobile, and the frequency of changing mobile phones. Individuals with a history of usage of hand-free devices were excluded from the study as the radiation exposure has been proved to be comparatively minimal in these individuals.[4,5]

Ear examination was done by an ear, nose, and throat specialist using otoscopy and tuning fork tests. Audiometry was done to rule out conductive hearing loss. Anthropometrical details such as weight in kilograms and height in centimeters were recorded from all the individuals.

The individuals were divided into two groups: Twenty individuals who had a history of mobile phone usage for duration of more than 1 year (long-term users) and twenty individuals who had a history of mobile phone usage for <1 year (short-term users). Further, the forty individuals were divided into two other groups based on the duration of mobile phone usage per day: Group A: <60 min usage/day, (29 individuals) and Group B: >60 min usage/day (11 individuals).

The peak latencies of Na, Pa, and Nb components of MLAEP were recorded using Galileo NT machine using silver disc surface electrodes which were placed according to the 10–20 International System of Electrode Placement. The positive electrode was placed at C_z. The negative electrodes were placed at A_1 and A_2, respectively, for the left and right ear recordings. The active electrodes were placed on the skin overlying the mastoid process. Grounding was done by placing an electrode on the forehead (F_z). All electrodes were plugged to a junction box, and skin to electrode impedance was kept below 5 K Ohm.

The hearing threshold was obtained using the Galileo NT machine. Monaural brief click acoustic stimuli with an intensity of 60 dB above the hearing threshold were given via headphone to the ear to be tested. For MLAEP acquisition, 1500 acoustic click stimuli were presented to both the ears separately. The low filter was set at 10 Hz and high filter at 200 Hz. Alternating condensation and rarefaction click stimuli were given at a frequency of 10 clicks per second. The contralateral ear was suitably masked by white noise at 40 dB, thus preventing the false response. Responses to the click stimuli were averaged, amplified, and displayed as a graph plotted with amplitude (in microvolts) and time (in milliseconds from the onset of stimulation) on the screen of Galileo NT Evoked Potential Recorder. The individual waveforms were manually selected based on their polarity and order of appearance with relation to time. The latencies of MLAEP waves Na, Pa, and Nb were noted down from the recording displayed on the screen [Figure 1].

Statistical Analysis

Kolmogorov–Smirnov Z-test was used to check for the normality of distribution of the data. Descriptive statistical analysis has been carried out in the present study. The age parameter was not normally distributed and so, it was compared using Mann–Whitney U test and is expressed as median (interquartile range). All other parameters were normally distributed and were compared using Student's unpaired *t*-test and are shown as mean ± SD. *P* value ($P \leq 0.05$) is considered statistically significant.
+Suggestive significance (*P* value: $0.05 < P < 0.10$)
*Moderately significant (*P* value: $0.01 < P \leq 0.05$)
**Strongly significant (*P* value: $P \leq 0.01$).

The tests were used to assess whether there is significant difference in the values of the MLAEP parameters in between the two groups. The Statistical Software SPSS 18.0 was used for the analysis of the data.

RESULTS

This comparative study was done between twenty short-term mobile users and twenty long-term mobile users. Parameters such as age, weight, and height of the groups were compared. The latencies of MLAEP waves (Na, Pa, and Nb) of the auditory-evoked potentials of the two groups were compared.

There was no significant difference in the parameters such as age, weight, and height between the two groups as shown in Table 1. Based on the years of usage, the mean values of absolute latencies of MLAEP waveforms Na, Pa, and Nb, recorded from the right and left sides, showed strongly significant difference between the two groups, with the long-term users having an increased latency period compared to the short-term users, as shown in Table 2.

The individuals were also divided into two other groups as follows: Individuals who use mobile phone for <60 min per day (29 users) and individuals who use mobile phone for more than 60 min per day (11 users). Based on the duration of usage per day, the mean values of absolute latencies of MLAEP waveforms Na, Pa, and Nb, recorded from the right and left sides, showed strongly significant differences between the two groups, with Group B having an increased latency period compared to Group A [Table 3].

Table 1: Comparison of age, weight, and height

Parameters	Short-term users	Long-term users	*P* value
Age	19 (18–21)^	19 (18–30)^	0.338
Weight	59.85±8.19^^	61.35±10.97^^	0.627
Height	161.90±6.68^^	162.8±8.31^^	0.708

^Median (interquartile range) ^^Mean±SD.

DISCUSSION

In this study, an increase in MLAEP latencies (Na, Pa, and Nb) is noted in long-term mobile phone users, suggesting a delay in the conduction of auditory impulses from the level of the medial geniculate body to the auditory cortex. This indicates that long-term exposure to mobile phone radiations can significantly affect the thalamo-cortical nervous pathways present in the auditory system of the brain.

Furthermore, when the individuals were grouped and compared based on the hours of mobile phone usage per day, the individuals who use mobile phones for more than an hour per day were found to have an increased latency of these waves compared to those who use it for less than an hour per day. These findings again suggest a delay in the conduction of auditory impulses from the level of the medial geniculate body to the auditory cortex. This indicates that the auditory pathway is affected greatly with increased duration of mobile phone usage.

As mobile phones are placed closer to the auditory system when used for calls, the radiations have a greater propensity to affect the auditory system. Most of the mobile phones have low SAR power (<2 W/kg). This may be protective against acute, short-term effects of the mobile phone radiations on human health. However, chronic, long-term exposure to these low-power RF waves can lead to some biological effects. The effects of such exposure have to be studied[6,7] to obtain unequivocal results.

The neural generators of MLAEP waveforms are as follows: Na – subcortical generators such as the medial geniculate body and polysensory thalamic nuclei located in the brainstem, Pa and Nb - cortical generators such as the primary auditory cortex and adjacent areas.[8] The more specific generators of Pa and Nb waveforms are as follows: Pa - medial portion of the Heschl's gyrus and Nb - lateral face of the supratemporal gyrus.[9] The latencies of MLAEP provide information about the conduction speed of auditory impulses in the higher levels of the auditory pathway, i.e., the area of the auditory cortex.

A study conducted by Panda *et al.* on individuals who have been using mobile phone for more than 1 year duration showed a bilateral lower MLAEP amplitude response.[10] In terms of latency response, this is the first study done to assess the effect of long-term exposure to mobile phone radiations

Table 2: Comparison of MLAEP waveform latencies in short- and long-term mobile users

MLAEP wave latencies	Short-term mobile users (ms)	Long-term mobile users (ms)	*P* value
Right ear			
Na	25.95±2.10	28.85±2.62	0.000**
Pa	32.33±2.28	38.15±2.35	0.000**
Nb	38.60±2.14	46.60±3.27	0.000**
Left ear			
Na	25.47±1.90	27.80±3.49	0.01**
Pa	31.43±2.19	35.70±3.01	0.000**
Nb	37.65±2.50	42.55±3.90	0.000**

**Strongly significant (*P* value: *P*≤0.01). MLAEP: Middle latency auditory-evoked potential

Table 3: Comparison of MLAEP wave latencies based on duration of mobile usage per day

MLAEP wave latencies (in ms)	<60 min usage	>60 min usage	*P* value
Right ear			
Na	26.82±2.34	28.94±3.29	0.028*
Pa	34.51±3.39	37.18±4.02	0.041*
Nb	41.31±4.17	46.00±5.18	0.005**
Left ear			
Na	25.94±2.20	28.46±4.10	0.016*
Pa	32.63±2.93	36.04±3.37	0.003**
Nb	39.28±3.79	42.27±4.17	0.036*

**Strongly significant (*P* value: *P*≤0.01) *moderately significant (*P* value: 0.01<*P* ≤ 0.05). MLAEP: Middle latency auditory-evoked potential

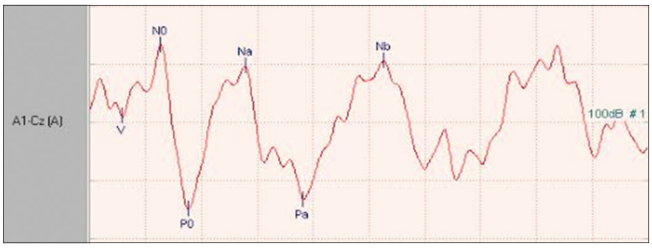

Figure 1: Middle latency auditory-evoked potential recording of left-sided stimulus (A1-CZ)

on the latencies of MLAEP.

The BioInitiative Report 2012,[11] based on an international research and public policy initiative, has enlisted various biological effects that can occur due to exposure to electromagnetic radiations. Studies by Lai and Singh,[12] Paulraj and Behari,[13] and Nikolova *et al.*[14] have demonstrated that deoxyribonucleic acid (DNA) damage such as DNA double-strand breaks occur as a result of exposure to RF-electromagnetic wave. Most cells can repair single-strand DNA breaks. However, DNA double-strand breaks, if not properly repaired, are known to lead to cell death or apoptosis.[15]

Most animal studies have reported evidence for neuronal damage in the cortex, hippocampus, basal ganglia, reduced memory functions, increased permeability of the blood–brain barrier, and signs of neuronal damage in the brains of rats exposed to microwaves from GSM mobile phones.[16-18] Whereas, a study by Grafström *et al.* showed no significant alteration in the histopathological parameters, when comparing the GSM-exposed animals to the sham-exposed controls.[19]

The International Agency for Research on Cancer which is a part of the World Health Organization has grouped these radiations as Group 2B carcinogens implying that they are possibly carcinogenic.[20] In a study done on molluscan neuron, the high SARs produced by cell phone-like RF field simulations led to a delay in the cellular mechanism for processing and storage of information.[21]

In terms of latency response, this is the first study done to analyze the effect of long-term exposure to mobile phone radiations on the latencies of MLAEP. Further MLAEP studies and brain neuroimaging techniques in a larger study group might provide substantial scientific evidence regarding the effects of the mobile phone radiations on the human auditory system.

Considering all the possible biological effects of these radiations, it is important to follow certain precautionary measures that can prevent or at least minimize the damage caused by these radiations to such an extent that it does not affect health adversely. Based on the current study, it is advised to limit the usage of mobile phones so as to reduce the close exposure to the radiations emitted by them and thus prevent any harmful effects. Based on other similar studies, it is also advised to consume a balanced, nutritious diet that provides adequate antioxidants, as antioxidants have been proved to be protective against damage by electromagnetic radiation-induced oxidative stress.[22,23]

CONCLUSION

The study shows that long-term usage, as well as longer duration of usage of mobile phones, significantly affects the nerve conduction velocity in the thalamo-cortical region of the human auditory pathway.

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