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Effects of the acute exposure to the electromagnetic field of mobile phones on human auditory brainstem responses

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Abstract The purpose of this study was to evaluate the short-term effects of the electromagnetic fields (EMF) of mobile phones on human auditory brainstem responses. This prospective study of healthy adults evaluated the influence of EMF. Eighteen healthy adult volunteers participated in this study. Mobile telephones emitting signals in the region of 900 MHz and with the highest SAR value of 0.82 W/kg were positioned in direct contact to the right ear, which was exposed to the phone signal for 15 min before and after ABR testing with click stimuli of 60 and 80 dB nHL intensities. The latencies of the waves and interwave latencies were measured on screen by an experienced audiologist. The differences of the mean latencies of waves I, III and IV were not significant in initial and post-exposure ABR measurements at both 60 and 80 dB nHL stimulus levels ($P > 0.05$). Similarly, differences of the mean interwave intervals I-III, I-V and III-V remained insignificant at the initial and postexposure ABR measurements at stimulus levels of both 60 and 80 dB nHL ($P > 0.05$). Acute exposure to the EMF of mobile phones does not cause perturbations in ABR latencies. However, these negative results should not encourage excessive mobile communication, because minor biological and neurophysiological influences may not be detectable by the current technology.

Keywords Cellular phone radiation · Auditory brainstem responses · Electromagnetic field · Biological effects

Introduction

The introduction of mobile phones into daily life has caused public concerns regarding the possible adverse effects of electromagnetic radiation on human health. Heating of biological tissues is a consequence of the thermal effects of electromagnetic fields (EMF), but studies have shown that this is not a major health issue for most handsets that do not violate safety guidelines [1]. Still, the non-thermal effects of EMF on living organisms are a subject of research. Because of the proximity of mobile phone handsets to the head, the central nervous system (CNS) is exposed to higher specific absorption rates (SAR) of ~900 or 1,800 MHz of microwave radiation transmitted by the device [2]. This fact has led several researchers to investigate the non-thermal biological effects of microwave radiation on CNS.

Although opposing studies exist [3, 4], several studies have reported the effects of EMF on EEG [5, 6, 7]. Reiser et al. [6] reported that 15 min of exposure to 900 MHz pulsed microwave radiation results in an increase in beta-1 and delta-power on EEG. Von Klitzing [7] found changes in the alpha activity pattern on EEG immediately after exposure. In two recent studies, Krause et al. [5, 8] reported that exposure to EMF modulates EEG responses specifically during cognitive processes and auditory memory tasks.

Our knowledge regarding the influences of EMF on the auditory system is based mainly on animal studies [9, 10, 11, 12]. Chou et al. [3] reported that exposure to 918-MHz pulsed microwave is accompanied by a mechanical disturbance of the hair cells in the guinea pig cochlea. Later on, the same authors reported that EMF influences evoked auditory potentials in guinea-pigs and rats [10, 14]. But the effects of EMF exposure to the human

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auditory system remained uninvestigated until very recently [15]. Ozturan et al. [15] reported no measurable changes in otoacoustic emissions following 10 min of exposure. Although this study shows clearly that the EMF of mobile phones has no effect at the cochlear level, the influence on the rest of the auditory system is obscure. The aim of the current study is to investigate the acute effects of EMF in the short term on healthy human auditory brainstem responses (ABR).

Material and methods

Subjects

Eighteen healthy right-handed adult volunteers (11 males and 7 female; mean age, 23 years; range, 20 to 28) participated in this study. All subjects had bilateral pure-tone thresholds of 15 dB or better in frequencies from 250 to 8,000 Hz and had normal type A tympanograms. Volunteers with tinnitus, middle ear pathology or a history of noise exposure were not enrolled in the study. All subjects gave their written informed consent prior the experiment. The Medical Ethical Review Committee of Taksim State Hospital approved the study.

EMF procedure

A Nokia 6310i mobile telephone was positioned in direct contact to the right ear as in normal communication. This mobile telephone emits and receives radio signals in the region of 900 MHz, and the highest SAR value for this model when tested for compliance against the standard was 0.82 W/kg. After the measurement of initial ABR, without removing the electrodes, the subject's ear was exposed to the activated mobile phone signal for 15 min. Then the mobile device was turned off, and ABR testing was repeated.

ABR measurements

The auditory brainstem response was recorded with the Interacoustics EP15 computerized ABR system (Assens, Denmark) running Windows 98. Active electrodes were attached to the ipsilateral mastoid region and were referenced to a vertex electrode. Click acoustic stimuli, alternating in polarity, were presented by an earphone on the ear at a rate of 21/s with 60 and 80 dB nHL intensities. With a filter setting of 100 to 3,000 Hz, 1,500 sweeps were averaged. The latencies of the waves measured with a cursor from a screen by an experienced audiologist.

Statistical method

Statistical analysis was performed using GraphPad Prisma V.3 statistical software. Continuous variables expressed as mean and standard deviations were compared using the paired t -test. A probability value less than 0.05 was regarded as significant.

Results

At the initial ABR measurement at 60 dB nHL, the stimulus level mean latencies of waves I, III and V were 2.12 ms (SD: 0.14), 4.11 ms (SD: 0.27) and 5.94 ms (SD: 0.35), respectively. Following acute exposure to the EMF of the mobile phone, the mean latencies were 2.17 ms (SD: 0.16) for wave I, 4.10 ms (SD: 0.23) for wave III and 5.97 ms (SD: 0.33) for wave V, and the differences of the initial and postexposure latencies were not significant ($P > 0.05$; Fig. 1).

At 80 dB nHL, the click stimulus level initial latency means for waves I, III and V were 1.41 ms (SD: 0.14), 3.62 ms (SD: 0.34) and 5.48 ms (SD: 0.30), respectively. Post-exposure latency means were 1.41 ms (SD: 0.12) for wave I, 3.60 ms (SD: 0.19) for wave III and 5.48 ms (SD: 0.29) for wave V, and the differences of the initial and succeeding latencies were not significant ($P > 0.05$; Fig. 2).

Mean interwave intervals (I-III, I-V and III-V) were 2.02 ms (SD: 0.24) for the first, 3.88 ms (SD: 0.34) for the second and 1.79 ms (SD: 0.27) for the last interval at baseline ABR study with 60 dB nHL stimulus. Following EMF exposure, the mean intervals for waves I-III, I-V and III-V were 2.00 ms (SD: 0.18), 3.93 ms (SD: 0.28) and 1.82 ms (SD: 0.25), respectively, and the differences between initial and postexposure intervals were not significant ($P > 0.05$).

Similar baseline measurements were done at 80 dB nHL stimulus level mean intervals for I-III, I-V and III-V 2.21 ms (SD: 0.16); 3.98 ms (SD: 0.27) and 1.80 ms (SD: 0.19) were calculated, respectively. Following EMF exposure the mean intervals for waves I-III, I-V and III-V were 2.20 ms (SD: 0.15), 4.06 ms (SD: 0.29) and 1.83 ms (SD: 0.24), respectively, and the differences of

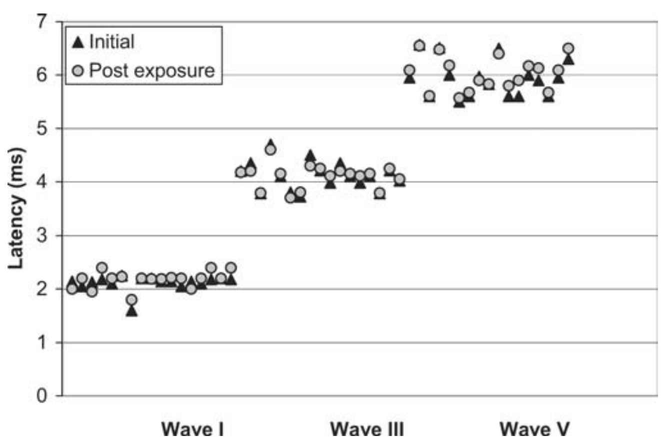

Fig. 1 *Scatter plot* displaying the initial and post exposure latencies of three waves at 60-dB stimulus level in 18 subjects

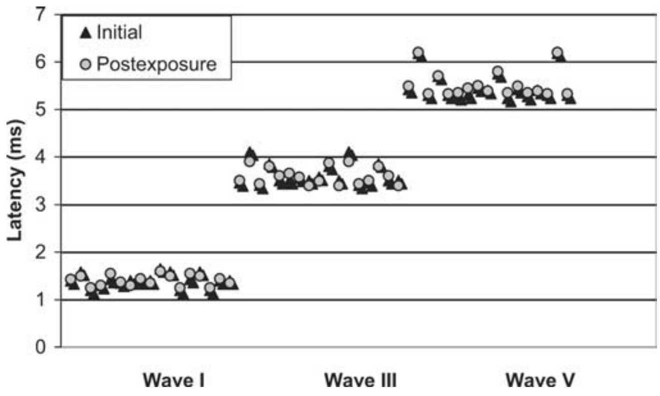

Fig. 2 *Scatter plot* displaying the initial and post exposure latencies of three waves at 80-dB stimulus level in 18 subjects

the initial and post-exposure interval means were not significant (P >0.05).

Discussion

The use of cellular mobile phones has increased dramatically in recent years. In Turkey, approximately one in every three people owns a mobile phone, and the average monthly communication time for users is 40 min per month. There is a constant rise in these numbers, which is even more accentuated in western communities [16].

The dependence on mobile communication and its possible adverse effects raises public anxiety. The biological effects of the EMF emitted by mobile phones are generally grouped as thermal and non-thermal. Modern mobile phones may raise the temperature of deep tissues by maximally 0.1°C [17]. Nevertheless, the upper limit of temperature increase assumed to be non-detrimental for human health is 1°C [17, 18]. However, several thermal effects of EMF on living organisms are shown in experimental studies, such as an alteration of the permeability of the blood-brain barrier [19]. Modification of sleep patterns [20], increase in blood pressure [21], potential genotoxicity and DNA strand breaks [22] are among the non-thermal effects of EMF. Regarding these biological changes, probably there is no clear cut between the thermal and non-thermal effects of EMF; a combination of both may be responsible.

Widespread use of handsets instead of hand-free devices makes the brain vulnerable to the effects mentioned above. Acute exposure of rats to amplitude-modulated microwaves resulted in changes of energy metabolism in the brain as a consequence of direct disturbance of the mitochondrial electron transport [23]. Moreover, an alteration of the neurotransmitter activities, such as a fluctuation in acetylcholinesterase activity or fall in sodium-dependent high-affinity choline uptake, is reported in mammals [24, 25, 26]. Probably, these metabolic, electrochemical and other unknown effects of EMF lead to alterations in biological electrical activities. In animal studies, an increase in total EEG spectral power or delta power is shown following EMF exposure [27]. As an electrochemical instrument, the human brain must also be influenced by EMF. Although universally no conclusions could be reached so far, several alterations of human EEG by EMF have been reported [5, 28, 29, 30]. The main finding in these human EEG studies is the decrease in sleep onset latency and the enhancement in superficial sleep stages [20]. Modulation in the response of EEG oscillatory activity during the cognitive process is another observed influence of EMF on brain activity. Recently, Krause et al. [8] reported that exposure to EMF causes some desynchronization on EEG during auditory memory tasks.

As a part of CNS, one could not assume an auditory apparatus immune from these effects of EMF. An exponential increase in SAR is shown as the distance from the mobile phone decreases, or vice versa [30]. Therefore, auditory pathways must be as prone to the effects of EMF as other regions of the brain. In fact, animal studies done with evoked-response audiometry (ERA) showed that evoked responses might be elicited by microwaves [11, 14]. Furthermore, Seaman and Lebovitz [9] showed that response characteristics of the cochlear nucleus to microwave pulses were similar to the acoustic stimuli in cats. These and some other animal studies have demonstrated that EMF may severely influence auditory functions or test results. It is reasonable to expect that the EMF of mobile phones modulates the electrical activity of the auditory system like the brain. On the other hand, our current knowledge regarding the effects of mobile phones on the human auditory system is mainly limited to the recent work of Ozturan et al. [15]. In this study, the authors concluded that 10 min of exposure to the EMF emitted from mobile phones had no effect at the cochlear level. But the effects of EMF emitted from mobile phones to the rest of the auditory system or, in other words, auditory tests such as ABR, have not been investigated so far.

In this study, we investigated in healthy adults the effects of EMF transmitted by mobile cellular phones to ABR, which represents the electrical activity of the distal portion of the auditory pathway with five waveforms. We compared intrasubject changes in absolute latencies and intervals of waves I, III and V, representing the electrical activity of the cochlear nerve, cochlear nucleus and lateral lemniscus, respectively, following 15 min of EMF exposure [31]. Our study revealed that EMF causes no significant alteration in the latencies of these three major waves obtained at both 60 and 80 dB nHL stimulus levels. Similarly, the changes in I-III, I-V and III-V interweave intervals remain insignificant following EMF exposures at both stimulus levels. All these data show that acute short-term exposure to EMF does not alter auditory nerve electrical conduction.

Although focused on a different level of the human auditory system, our study concurs with the results of Ozturan et al. [15]. The current study demonstrated that 15-min exposure to EMF emitted by mobile phones has no influence on ABR. Three major possible explanations may be made for this negative result. First, longer exposures such as 60 min may have altered these results, but such communication time is not preferred because it is beyond the monthly average in most countries. Second, modern mobile phones have no actual effect on the human auditory system. Because SAR decreases exponentially as the distance from the EMF source increases, the brainstem may be under less influence than the temporal lobe [30]. Also, the brainstem may be assumed to be protected by the thicker petrous part of the temporal bone. Third, EMF may have minor influences that cannot be detected by current ABR technology. Our ABR recordings were made after the termination of mobile phone communication because EMF influences both the stimulus source and the recording system negatively. Although some experimental methods measuring otoacoustic emissions simultaneously exist, currently, there is no worldwide available procedure to record ABR simultaneously with mobile phone communication. Moreover, ABR recordings made at 60 and 80 dB stimulus levels may not reflect the spontaneous electrical activity of the auditory pathway. It can be speculated that these click stimuli may mask the effect of EMF on the brainstem electrical activity.

This study shows merely that the acute EMF of mobile phones do not cause perturbations in ABR latencies in the short term. Together with previous otoacoustic emission studies, it can be concluded that EMF do not influence human hearing functions in the short term [15]. However, the observed negative results should not encourage unnecessary and excessive mobile communication, because minor biological and neurophysiological influences may be beyond the capabilities of our current recording technology. Neither the current study nor the body of literature provides sufficient information regarding the long-term biological effects of EMF. Concerns regarding the adverse effects of EMF on human health are lasting; therefore, guidelines for limiting exposure to electromagnetic fields should be followed [32].

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