BRAIN RESEARCH ▮ (▮▮▮▮) ▮▮▮–▮▮▮

Available online at www.sciencedirect.com

ScienceDirect

www.elsevier.com/locate/brainres

Research Report

2100-MHz electromagnetic fields have different effects on visual evoked potentials and oxidant/antioxidant status depending on exposure duration

Enis Hidisoglu[a], Deniz Kantar Gok[a], Hakan Er[a], Deniz Akpinar[b], Fatma Uysal[c], Gokhan Akkoyunlu[c], Sukru Ozen[d], Aysel Agar[e], Piraye Yargicoglu[a,*]

[a]Akdeniz University, Faculty of Medicine, Department of Biophysics, Turkey
[b]Mugla Sıtkı Kocman University, Faculty of Medicine, Department of Biophysics, Turkey
[c]Akdeniz University, Faculty of Medicine, Department of Histology and Embryology, Turkey
[d]Akdeniz University, Engineering Faculty, Department of Electrical and Electronics Engineering, Turkey
[e]Akdeniz University, Faculty of Medicine, Department of Physiology, Turkey

ARTICLE INFO

Article history:
Accepted 9 January 2016

Keywords:
Electromagnetic fields
Visual evoked potentials
Oxidative stress
Antioxidant
Nitric oxide

ABSTRACT

The purpose of the present study was to investigate the duration effects of 2100-MHz electromagnetic field (EMF) on visual evoked potentials (VEPs) and to assess lipid peroxidation (LPO), nitric oxide (NO) production and antioxidant status of EMF exposed rats. Rats were randomized to following groups: Sham rats (S1 and S10) and rats exposed to 2100-MHz EMF (E1 and E10) for 2 h/day for 1 or 10 weeks, respectively. At the end of experimental periods, VEPs were recorded under anesthesia. Brain thiobarbituric acid reactive substances (TBARS) and 4-hydroxy-2-nonenal (4-HNE) levels were significantly decreased in the E1 whereas increased in the E10 compared with their control groups. While brain catalase (CAT), glutathione peroxidase (GSH-Px) activities and NO and glutathione (GSH) levels were significantly increased in the E1, reduction of superoxide dismutase (SOD) activity was detected in the same group compared with the S1. Conversely, decreased CAT, GSH-Px activities and NO levels were observed in the E10 compared with the S10. Latencies of all VEP components were shortened in the E1 compared with the S1, whereas latencies of all VEP components, except P1, were prolonged in the E10 compared with the S10. There was a positive correlation between all VEP latencies and brain TBARS and 4-HNE values. Consequently, it could be concluded that different effects of EMFs on VEPs depend on exposure duration. In addition, our results indicated that short-term EMF could provide protective effects, while long-term EMF could have an adverse effect on VEPs and oxidant/antioxidant status.

*Corresponding author. Fax: +90 242 2274495.
E-mail address: pakkiraz@akdeniz.edu.tr (P. Yargicoglu).

http://dx.doi.org/10.1016/j.brainres.2016.01.018
0006-8993/

1. Introduction

The extensive use of mobile phones (MPs) over the last decade raises the questions of the possible health effects of electromagnetic field (EMF). More specifically, there is great concern for the effects of EMF on functions of the brain, since MPs have been used in close proximity to the head. The effects of EMF on the brain functions have been extensively investigated over the last 20 years (Vecchio et al., 2010). In the literature, there is a large body of studies with contrasting results on brain functioning during or following the exposure to EMF (Carpenter, 2013; Consales et al., 2012; Pall, 2013; Valentini et al., 2007). For example, in a study, exposed to 900 MHz signal for GSM (Global System for Mobile communications) at SAR 2 W/kg in the rat brain induced oxidative damage (Ilhan et al., 2004). In a different model, effects of GSM signal (890–915 MHz EMF, SAR 0.95 W/kg, for 12 h/day for 30 days) on the oxidative stress pathway were investigated and detrimental effects of EMF on the brain were found (Meral et al., 2007). In contrast to these findings, oxidant/antioxidant status were evaluated in the brain of radio frequency (RF)-exposed rabbits (900 MHz GSM signal, 2 W peak power, average power density 0.02 mW/cm^2, for 30 min/day) and no change in brain parameters of rabbits was observed (Irmak et al., 2002). On the other hand, Arendash et al. (2012) reported that long-term (7–9 months) RF-EMFs exposure, directly associated with cell phone use (918 MHz, SAR 0.25 W/kg), provide cognitive benefits. These discordant findings may have resulted from different study designs, exposure settings and the applied frequency and exposure duration.

Exposure to EMF may leads to increase free radicals which have been implicated in many pathophysiological processes and alterations in the activity of antioxidant enzymes which act as free radical scavengers to prevent or protect against lipid peroxidation (LPO) in tissues. Since the retina and brain tissues include high content of polyunsaturated fatty acids, free radical reactions produce marked damage to the structure and function of cell membranes in these tissues (Jain et al., 1991). Thus, it could be expected that EMF induced-LPO may cause alterations in brain functions. The electroencephalogram (EEG) has been frequently used to investigate the effect of microwave exposure on brain bioelectrical activity because of its advantage of providing a direct measure of neural activity. Earlier studies reported that microwave exposure caused the alterations in human brain electrical activity (Croft et al., 2008; Vecchio et al., 2010) and the increase in human EEG alpha band power (Curcio et al., 2005). In another human study, the exposure to GSM signals of 902 MHz at an SAR of 0.65 W/kg also caused changes in EEG signals during a visual working memory task (Krause et al., 2000). However, the authors were unable to replicate their previous findings in later study (Krause et al., 2004). Additionally, EMF did not produce measurable immediate changes of auditory evoked potentials in humans (Arai et al., 2003; Stefanics et al., 2007). Prior study indicated that EMF exposure can cause changes of cognition and long-term impairments on the learning and memory in rats. The results of this study showed that exposure to different doses of EMF can result in Alzheimer's disease like behavior and pathological manifestations (Jiang et al., 2013). However, other studies provided no evidence that EMF affected spatial working memory in the rats. For instance, normal rats exposed for 45 min per day at a SAR 1.5 W/kg or 15 minutes per day at a 6.0 W/kg during 8 or 24 weeks exhibited normal performance in radial arm maze. In another study, the rats exposed to GSM-950 MHz EMF for 45 min with lower (0.835 mW/cm^2) or higher-power (1.166 mW/cm^2) densities showed normal acquisition or consolidation of spatial navigation of rats in a water maze (Ammari et al., 2008; Jadidi et al., 2009). So far, only a few studies have investigated a third-generation (3G) mobile phone concerning human brain potentials. No evidence of any potential adverse effects of Universal Mobile Telecommunications System (UMTS) exposure was found on human resting EEG (Croft et al., 2010; Kleinlogel et al., 2008). Stefanics et al. (2008) found no effects of a 20 min UMTS-exposure on the early evoked gamma activity and the auditory N100 and P300 components. Eltiti et al. (2009) reported no significant effects of GSM or UMTS base station signals on human attention or memory functions whereas early behavioral studies reported significant effects of mobile phone exposure on attention and memory functions (improved cognitive performance). However, recent studies on cognitive functions found no significant effects.

Visual evoked potentials (VEPs) have been widely used to investigate the physiology and pathophysiology of the visual system, including the visual pathway and the visual cortex. Electrophysiologic recording of these potentials provide a powerful objective tool for identifying the earliest alterations in the visual system (Celesia, 1984; Chiappa and Ropper, 1982). VEPs are shown to be a sensitive method detecting the involvement of optic pathways in optic neuritis, ischemic optic neuropathy and demyelinating diseases (Halliday, 1976), and sensitive indicators of the neurotoxic effects caused by a broad range of compounds (Otto et al., 1988). Early components of the VEPs reflect the integrity of the optic nerve (Holder, 2004), whereas latter components reflect processing by higher cortical centers (Aminoff and Goodin, 1994). In the present paper, we recorded the flash-evoked potentials (FEPs) which is a complex electrical response of neural pathways that are activated during the photic stimulation (Fox and Rosenfeld, 1972).

Since there have been widespread use of EMF in various applications with potential leakage of such radiation into the environment, exposure to EMF is a potential health hazard to humans. So, several studies also suggest that occupational exposure to EMF may be associated with increased risk of neurodegenerative diseases (Hug et al., 2006; Jiang et al., 2013). Therefore, it is of great importance to investigate the biological effects of EMFs on the CNS and to develop potential preventive strategies. There is no consensus regarding whether EMF exposure could cause potential detrimental effects in whole animals or isolated cells. In present times, the use of the new generation MPs is fast spreading worldwide. However, the majority of MP studies have only employed 2nd generation (2G) MPs, with less research conducted on the effect of the newer 3rd generation MPs on cognitive/sensory processing. Additionally, there is no comprehensive study to date about the possible effects of UMTS-

Please cite this article as: Hidisoglu, E., et al., 2100-MHz electromagnetic fields have different effects on visual evoked potentials and oxidant/antioxidant status depending on exposure duration. Brain Research (2016), http://dx.doi.org/10.1016/j.brainres.2016.01.018