Nerve Cell Damage in Mammalian Brain after Exposure to Microwaves from GSM Mobile Phones

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The possible risks of radio-frequency electromagnetic fields for the human body is a growing concern for our society. We have previously shown that weak pulsed microwaves give rise to a significant leakage of albumin through the blood–brain barrier. In this study we investigated whether a pathologic leakage across the blood–brain barrier might be combined with damage to the neurons. Three groups each of eight rats were exposed for 2 hr to Global System for Mobile Communications (GSM) mobile phone electromagnetic fields of different strengths. We found highly significant ($p < 0.002$) evidence for neuronal damage in the cortex, hippocampus, and basal ganglia in the brains of exposed rats. ***Key words:*** **blood–brain barrier, central nervous system, microwaves, mobile phones, neuronal damage, rats.** ***Environ Health Perspect*** **111:881–883 (2003). doi:10.1289/ehp.6039 available via** ***http://dx.doi.org/*** [Online 29 January 2003]

The voluntary exposure of the brain to microwaves from hand-held mobile phones by one-fourth of the world's population has been called the largest human biologic experiment ever (Salford et al. 2001). In the near future, microwaves will also be emitted by an abundance of other appliances in the cordless office and also in the home. The possible risks of radio-frequency electromagnetic fields (RF EMFs) for the human body is a growing concern for our society (for a review, see Hyland 2000). Most researchers in the field have dwelled on the question of whether RF EMFs may induce or promote cancer growth. Although some have indicated increased risk (Hardell et al. 2002; Repacholi et al. 1997), most studies, including our own, have shown no effects (Salford et al. 1997a) or even a decreased risk (Adey et al. 1999).

The possible risks of microwaves for the human body has attracted interest since the 1960s (i.e., before the advent of mobile phones), when radar and microwave ovens posed a possible health problem. Oscar and Hawkins (1977) performed early studies on effects of RF EMFs on the blood–brain barrier. They demonstrated that at very low energy levels (< 10 W/m^2), the fields in a restricted exposure window caused a significant leakage of ^{14}C-mannitol, inulin, and also dextran (same molecular weight as albumin) from the capillaries into the surrounding cerebellar brain tissue. These findings, however, were not repeated in a study using ^{14}C-sucrose (Gruenau et al. 1982). A recent *in vitro* study has shown that EMF at 1.8 GHz increase the permeability of the blood–brain barrier to sucrose (Schirmacher et al. 2000). Shivers and colleagues (Shivers et al. 1987; Prato et al. 1990) examined the effect of magnetic resonance imaging upon the rat brain. They showed that the combined exposure to RF EMFs and pulsed and static magnetic fields gave rise to a significant pinocytotic transport of albumin from the capillaries into the brain.

Inspired by this work, since 1988 our group has studied the effects of different intensities and modulations of 915 MHz RF EMFs in a rat model where the exposure takes place in a transverse electromagnetic transmission line chamber (TEM-cell) during various time periods. In series of more than 1,600 animals, we have proven that subthermal power densities from both pulse-modulated and continuous RF EMFs—including those from GSM (Global System for Mobile Communications) mobile phones—have the potency to significantly open the blood–brain barrier such that the animals' own albumin (but not fibrinogen) passes out of the bloodstream into the brain tissue and accumulates in the neurons and glial cells surrounding the capillaries (Malmgren 1998; Persson et al. 1997; Persson and Salford 1996; Salford et al. 1992, 1993, 1994, 1997b, 2001) (Figure 1). These results have been duplicated recently in another laboratory (Töre et al. 2001). Similar results have been reported by others (Fritze et al. 1997).

We and others (Oscar and Hawkins 1977; Persson et al. 1997) have pointed out that when such a relatively large molecule as albumin can pass the blood–brain barrier, so too can many other smaller molecules, including toxic ones, which may escape into the brain because of exposure to RF EMFs. We have hitherto not concluded that such leakage is harmful for the brain. However, Hassel et al. (1994) have shown that autologous albumin injected into the brain tissue of rats leads to damage to neurons at the injection site when the concentration of albumin in the injected solution is at least 25% of that in blood. In the present study, we investigated whether leakage across the blood–brain barrier might cause damage to the neurons.

Materials and Methods

TEM-cells used for the RF EMF exposure of rats were designed by dimensional scaling from previously constructed cells at the National Bureau of Standards (Crawford 1974). TEM-cells are known to generate uniform electromagnetic fields for standard measurements. A genuine GSM mobile phone with a programmable power output was connected via a coaxial cable to the TEM-cell; no voice modulation was applied.

The TEM-cell is enclosed in a wooden box (15 × 15 × 15 cm) that supports the outer conductor and central plate. The outer conductor is made of brass net and is attached to the inner walls of the box. The center plate, or septum, is constructed of aluminum.

The TEM-cells were placed in a temperature-controlled room, and the temperature in the TEM-cells was kept constant by circulating room air through holes in the wooden box.

The specific absorption rate (SAR) distribution in the rat brain has been simulated with the finite-difference time-domain method (Martens et al. 1993) and found to vary < 6 dB in the rat brain.

The rats were placed in plastic trays (12 × 12 × 7 cm) to avoid contact with the central plate and outer conductor. The bottom of the tray was covered with absorbing paper to collect urine and feces.

Thirty-two male and female Fischer 344 rats 12–26 weeks of age and weighing 282 ± 91 g were divided into four groups of eight rats each. The peak output power of 10 mW, 100 mW, and 1,000 mW per cell from the GSM mobile telephone was fed into two TEM-cells simultaneously for 2 hr. This exposed the rats to peak power densities of 0.24. 2.4, and 24 W/m^2, respectively. This exposure resulted in average whole-body SARs of 2 mW/kg, 20 mW/kg, and 200 mW/kg, respectively. For further details about exposure conditions and SAR calculations, see Martens et al. (1993) and Malmgren (1998). The fourth group of rats was simultaneously

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