



Editorial



Over the past two decades the uses and users of electromagnetic fields (EMF) have grown exponentially as a result of advancing technologies and changes in basic operating systems and social lives throughout the world. Exposures to electromagnetic fields are estimated to be a billion times greater than those with which we evolved prior to the industrial era. They range from those devices used in direct proximity to the human body such as mobile phones and tablets, to those operated at some distance such as base stations, wireless routers and other wireless transmitting devices, television and radio transmission and routine household exposures to low levels of EMF. At the same time, increasing rates of autism, developmental disorders, infertility and neurodegenerative disease remain unexplained, with some experts such as Harvard Professor Martha Herbert MD PhD, suggesting that exposures to EMF could be etiologically important, along with a number of other factors.

The tremendous and fast-changing growth in EMF technology for communication and industry during the past century has made it especially difficult to evaluate technologies' impacts on human health and the environment. Effectively, we are challenged to try to study the bus in which we are riding, while also adapting to the latest and fastest means of transport. This special issue seeks to make a contribution to current literature about EMF by reviewing some of the basic underlying experimental science in the field relating to assessing impacts of electromagnetic fields on the structure and function of the developing nervous system.

In particular, in this Special Issue, we present five reviews, followed by five research papers on the effects of the EMF on the nervous system. Many of our Turkish colleagues are able to carry out cutting-edge research in this field because of the long and distinguished tradition of first-rate science that has been supported by grants from NATO, the European Union, and the Turkish government for more than three decades. We are especially pleased that this issue includes much work from our Turkish colleagues who are able to produce carefully designed and executed studies of EMF exposures carried out under appropriately controlled conditions.

The review by Dasdag and Akdag evaluates *in vitro* and *in vivo* studies of the effect of radiofrequency emitted from mobile phones on oxidative stress, which is a marker of aging and of inflammatory processes conducive to cancer and neurodegenerative diseases. They conclude that exposures to EMF from mobile phones, radar or similar equipment are causally related to increased oxidative stress and DNA damage.

The review paper by Pall explores the possible relation between microwave radiation and widespread neuropsychiatric effects. He notes that current literature indicates that short wave, radio station, occupational and digital TV antenna exposures may produce similar neuropsychiatric effects such as sleep disturbance/insomnia, headache, depression/depressive symptoms, fatigue/tiredness, dysesthesia, concentration/attention dysfunction, memory changes, dizziness, irritability, loss of appetite/body weight, restlessness/anxiety, nausea, skin burning/tingling/dermographism and EEG changes. Pall proposes that these diverse endpoints may be linked in that they share a common etiology arising from the capacity of EMF to interfere at the basic cellular level with voltage-gated calcium channels.

The review of Altunkaynak et al. discusses and evaluates experimental methods commonly used to examine the effects electromagnetic fields on the nervous system such as stereology, immunohistochemistry and electron microscopy. They note the exciting opportunities in the field for cross-disciplinary work that combines these techniques and refines the capacity to understand and identify mechanisms operating at the cellular level.

Say et al. discuss evolving evidence on subtle effects of EMF emitted by mobile phones on peripheral nerves. They summarize current knowledge on the possible positive or negative effects of electromagnetic fields. In their exploration of the current literature, experimental and clinical studies have demonstrated that EMF can have profound effects on peripheral nerves, including potentially positive effects on peripheral nerve regeneration. Finally, they state that further studies are required of effects of EMF on the peripheral nerve regeneration.

Kaplan et al. address the impact of EMF on brain development. Recent works have demonstrated that EMF not only inhibits the formation and differentiation of neural stem cells during embryonic development, but also affect adult brain function and structure. In both prenatally and postnatally exposed animals, effects can be seen on the hippocampus and on pyramidal cell formation – areas critical to learning, balance and memory.

In the review of Terzi et al., they report roles of oxidative stress on neurodegenerative disease pathophysiology. They also summarize epidemiologic studies of cell phone usage and prevalence of intracranial tumours. Finally, they emphasize that more research about the usage of long-term mobile phones is required.

Sahin et al. examined the effect of 2100 MHz radiofrequency radiation emitted by a generator simulating a 3G-mobile phone, on the brain of rats following 10 days and 40 days of exposure. They

found that compared with control groups, oxidative DNA damage increases in the brain during 10 days of exposure, and also that this damage has lessened following 40 days of exposure. They attribute this decrease to DNA adaptation and repair mechanisms.

Another research paper by Akdag et al. aim to detect the effects of prolonged radiofrequency radiation emitted from Wi-Fi devices on DNA damage in various tissues of rats. Using comet assays, DNA damage was found to be greater with exposure in the brain, kidney, liver, and skin tissues of the rats in the experimental group compared with the control group. They also determined that the testes are particularly sensitive to RF radiation.

The research paper of Celik et al. evaluates the impact of pre- and post-natal exposures to 2.45 GHz (Wi-Fi) on the brain and liver of newborn animals. The authors suggest that Wi-Fi induces oxidative stress in the brain and liver of developing rats as a result of lower glutathione peroxidase (GSH-Px), GSH and antioxidant vitamin concentrations. Their work suggests opportunities for nutritional intervention that may ameliorate some of these impacts.

The second research paper, by Guler et al., addresses the effects of radiofrequency radiation with characteristics similar to the widely used global system for mobile communications (GSM) mobile phone, on oxidative DNA damage, lipid peroxidation, and cellular apoptosis in neural tissue. The authors point out that neuronal necrobiosis and gliosis, but not apoptotic changes, are detected in radiofrequency radiation exposed rabbits, indicating that changes in neuronal structure may prove more sensitive than apoptosis to EMF.

The third original study by Ikinici et al. investigated changes in the spinal cords of male rat pups exposed to 900 MHz EMF during early and mid-adolescence. They report that biochemical alterations and pathological changes may occur in the spinal cords of male rats following exposure to 900 MHz EMF for 1 h a day between postnatal days 21 and 46.

In the fourth paper, Odaci et al. investigate the impact on the cerebella of 32-day-old female rat pups following exposure to 900 MHz EMF during the prenatal period, using stereological and histopathological techniques. They report that prenatal exposure to EMF affects the development of Purkinje cells in the female rat cerebellum and that the consequences of this pathological effect persist after the postnatal period.

The final paper in this issue, by Sirav and Seyhan, describes a study to investigate the possible effects of pulse modulated

radio-frequency radiation on the permeability of the blood-brain barrier of rats. Their study confirms previous reports that mobile phone radiation increases the permeability of blood-brain barrier under non-thermal exposure levels.

Despite the widespread and growing use of wireless and other technology throughout the world today, the effects of that technology on human health are not well studied and not fully understood. It is hoped that this special issue will prompt more concerted attention to this issue. The findings reported here are preliminary in some respects, but they are clear indications of a subject matter that should receive much higher priority from government and industry.

Children today are being conceived and growing up surrounded by technologies and exposures that did not exist even five years ago. Some of the several thousand wireless applications and technologies that have been promoted for infants and toddlers appear ill-advised, as the American Academy of Pediatrics, the Ministry of Health of India and Israel, Environmental Health Trust, Ondokuz Mayıs University Medical School, and other professional groups have warned. It is our hope that this issue, showing that EMF can have a broad range of neurological and neurodevelopmental impacts, will stimulate a major investment in additional research on this topic. We believe that a simple, modest monthly fee of one penny imposed on each user, manufacturer and internet provider for each wireless transmitting device for the next eight years would yield sufficient funds to create independent regionally coordinated programs of training, research and development, and monitoring to advance the field. Until such a program is established and yielding results, it is prudent for policy makers to develop strategies to reduce direct exposures, especially those that affect the rapidly developing nervous systems of the young. As a recent Canadian Parliamentary Report advised, until more experimental and human research is in hand, public educational programs about what is already known about the capacity of non-thermal levels of EMF to affect human health should be more rapidly advanced. We welcome opportunities to continue to work with governments and industry to further that aim.

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