Impaired Public Health in the Wireless Age — a Challenge for Environmental and Dietary Medicine in the 21st Century.

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Life on Earth has evolved over millennia, establishing and fine-tuning extremely complex and dynamic equilibria with nature – with countless natural chemical entities as well as with natural energy forms such as visible light and UV electromagnetic radiation (EMR). Planet earth in the 21st century is an incredibly complex concoction of man-made chemicals and energies, on top of those naturally occurring ones, be they in their original form or modified by human action. Non-ionising EMR from man-made sources due to the ever increasing electrification of human life, particularly with the rapid expansion of mobile/wireless/satellite communication and surveillance technologies over the last couple of decades, poses a new form of EMR energy living organisms have to cope with today, without an evolutionary adaptation. A complex array of EMR from artificial sources blankets each and every one of us in modern human society. This environmental phenomenon is called the 'electro-smog' – virtual smog that engulfs cities and towns as these wireless networks rapidly expand.

Exposure to man-made non-ionising EMR can take different forms (Figure 1). This could be in the form of extremely low frequency electromagnetic fields (ELF-EMF) emitted by 50-60 Hz power lines (particularly high voltage power lines) and electrical appliances in our living environments. Though domestic electrification started in 1879 or 135 years ago, much of the world remained without until after the mid-20th century making global human exposure to man-made electricity only very recent in our evolutionary history. These ELF-EMFs are localized and intensities drop rapidly with distance from the source. With increased use of electric appliances over the past few decades, human exposure has certainly increased to these ELF-EMFs. However the most rapidly increased exposures come with the higher frequency radiowaves and microwaves (the high frequency end of the radiowave spectrum) emanating from TV/radio broadcasting towers, mobile base stations and countless wireless communication systems and devices. These higher energy radiofrequency radiation (RFR) waves propagate differently in the air and have much far-reaching fields.

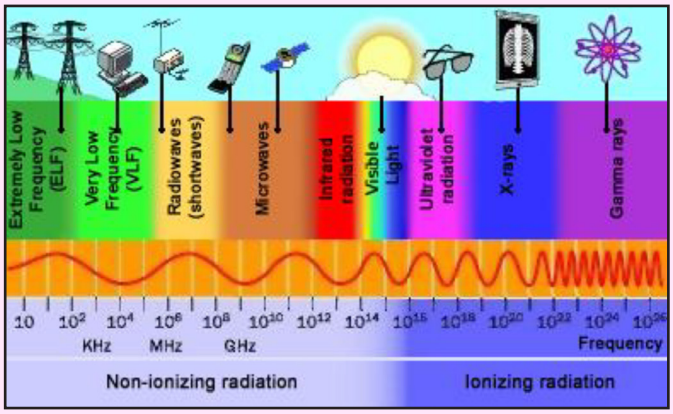

Figure 1. The electromagnetic spectrum arranges different types of electromagnetic waves according to their frequency. As the frequency increases the photon energy carried in the waves also increases whilst the wavelength decreases. Source: http://www.boredofstudies.org

The impact of EMR on human health, particularly on cancer risk, has been investigated in many studies over the last few decades and some have shown highly significant associations, although establishing causal relationships has been difficult[1-18]. The BioInitiative Report[19] by an international panel of scientists and clinicians is the most up-to-date scientific information source with collated peer-reviewed publications (www.bioinitiative.org) in the area of EMR research. It lists a few thousand scientific papers that have demonstrated in vitro and in vivo biological effects induced by ELF-EMR and RFR and examines biological effects in light of their impact on human health. In this review, we focus on RFR and omit negative studies (those that failed to show biological effects of RFR) as the purpose of this communique is to bring some of the positive studies to the attention of the clinical readership.

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The WHO's International Agency for Research on Cancer (IARC) classified RFR as a possible human carcinogen (2B) in 2011, in the same category as lead and DDT – agents that authorities actively try to minimize public exposure of. Yet, there is clearly a large gulf between the available scientific data on biological effects of RFR and public policy as the recommended 'Precautionary Principle' appears to be rather limited to paper in many parts of the world[20] including here in Australia, where wireless networks are rapidly rolled out even in primary schools. Here, we briefly look at public exposure levels, regulation, biological effects and their potential impact on public health and also what we can do about it.

Public Exposure of RFR and its regulation

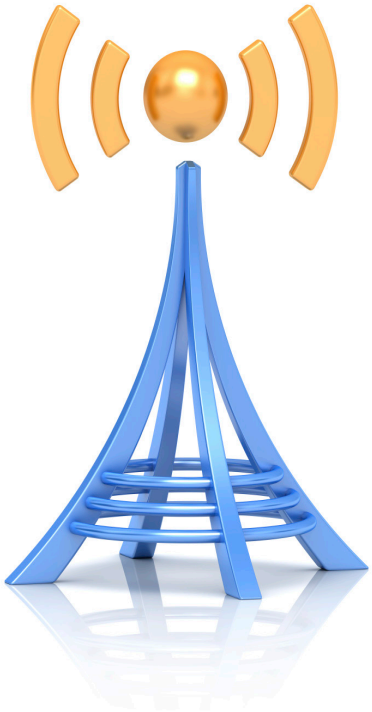
Up until a couple of decades ago, considerable RFR exposures were limited to individuals in certain occupations such as those working with defence radar and telecommunication systems and populations living near radio/TV/mobile/radar transmission towers. In stark contrast, today, almost everyone has RFR emitters in their immediate living environment in the forms of mobile/cordless phones, countless wireless devices – WiFi-enabled laptop/tablet computers to a variety of games consoles –Wii, X-Box etc., baby monitors, security systems, satellite navigation systems and so on. Operating microwave ovens also leak a considerable amount of RFR – raising ambient levels even 5m away.

Our RFR exposure levels depends on many factors including the power output of the sources around us, the distance, shielding or augmenting materials around and of course the length of exposure. A single wireless device can potentially increase RFR levels in one's immediate environment by several folds of magnitude. For example, we found a common cordless phone used in Australian homes to increase the RFR field in its immediate environment from the ambient power density level of 0.00013 $\mu W/cm^2$ to 43.2 $\mu W/cm^2$ simply being switched on to standby mode – 3.3 x 10^5-fold increase instantly. This appears to be typical for many models of cordless phones. It should be noted that fields as low as 0.000001 $\mu W/cm^2$ can sustain a functional mobile phone signal. With multiple emitting devices, the fields get stronger and more complex due to different physical properties of EMR waves such as different carrier frequencies, modulation frequencies and the information embedded in the signal.

It is noteworthy that exposure standards vary between countries by several folds of magnitude. For example Switzerland, Italy, China and Russia all have exposure standards with power densities 100 times lower (more stringent) than Australia[21]. The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) sets the public exposure standards and the Australian Communications and Media Authrority (ACMA) regulates the adherence to the standards in Australia. In 2002, ARPANSA relaxed the public exposure standard for RFR in the 3 kHz to 300 GHz frequency range, adopting the 1998 guidelines of the professional advisory body International Commission on Non-Ionizing Radiation Protection (ICNIRP). The details of the standard are found at: www.arpansa.gov.au/Publications/Codes/rps3.cfm.

RFR standard setting for public exposure has been a controversial process and there is much criticism of the influence of the industry (being regulated by the standard) in setting it and lack of consideration of scores of scientific papers that have reported significant biological effects at low levels of exposure. Dr. Don Maisch's PhD dissertation[22] addressed the complex issues in standard setting in detail (available at: www.emfacts.com). The most critical issue is that the ICNIRP guidelines were based on acute thermal effects and therefore cannot confer protection against long-term effects nor non-thermal effects (biological effects that occur in the absence of tissue heating). Further, more vulnerable populations such as children, the elderly and some chronically ill people may not be protected[23].

Exposure standards depend on different frequency bands. For example, the current Australian standard allows for public exposure 450 $\mu W/cm^2$ for 900 MHz and 1000 $\mu W/cm^2$ for≥2 GHz frequencies commonly used for mobile/cordless telephones and wireless (WiFi) data transmission. So, should we be concerned about devices such as the above mentioned cordless phone creating an EMR field with power density 43.2 $\mu W/cm^2$ at homes, possibly near children when it is clearly well below the standard?



Evaluation of the scientific literature clearly provides a rationale for concern as a wide range of biological effects are now known to occur at much lower levels of RFR. For example, some healthy volunteers had increased heart rate and heart rate variability with just 3-8 $\mu W/cm^2$ from a cordless phone in a US-Canadian study[2]. Whilst exactly how the documented biological effects translate into health issues is far from being elucidated, an increasing number of independent experts are concerned about the current levels of public exposure. The BioInitiative report concluded that the ICNIRP exposure standard is not adequate to protect public health and needs to be made more stringent by 10,000 fold – to be biologically protective enough based on the current knowledge.

Biological effects of RFR and their implications in human disease

As we are complex electro-chemical beings, it should come as no surprise that the fields of EMR around us can impact on our basic biological functions. It has been known for several decades that RFR readily penetrates biological tissue and is capable of inducing electrical fields that result in flow of ions and rotation of asymmetric charged molecules (dipoles) changing the electrochemical status of cells[5, 24-26]. A few of the reported effects of RFR at permitted non-thermal levels include nuisance auditory sensations (microwave hearing) and headache[27, 28], increased eye damage including cataract formation related to occupational exposure in Australian telecommunication workers[29, 30] and increasing blood pressure[31].

It has been known for a while that RFR is capable of changing binding affinity of cell membrane-embedded molecules and thereby interfere with signal transduction pathways influencing physiological responses to the environment – most notably with the involvement of Ca^{2+}. RFR exposure has been found to cause an increased intracellular influx of Ca^{2+} in a number of studies[32-35], which would influence a wide range of cellular pathways changing expression of molecular products. The ability of weak RFR fields to enhance the up-regulation of ornithine decarboxylase (essential for cell growth and DNA synthesis) by cancer-promoting phorbol esters was well document more than 25 years ago[36]. Recently, Professor Martin Pall of Washington State University published a comprehensive review of EMR-induced Ca^{2+}-mediated cellular effects in which he proposed biological effects of EMR to be primarily via voltage-gated calcium channels (VGCC)[37].

Genotoxic effects

Over the last two decades, concerning evidence of genotoxic effects of RFR such as single and double strand breaks and micronuclei formation has been accumulating. Dr. Hugo Ruediger of the Medical University of Vienna in 2009 published a review of 101 studies that had investigated genotoxic effects of RFR. Of those, 49 found genotoxic effects at low non-thermal levels of exposure while 43 did not. Further nine studies found RFR to enhance the action of other genotoxic agents[38] making the case of RFR as a genotoxic environmental agent very strong. When researchers at Washington University found acute exposure (2 hr) of 2.45 GHz RFR (same as WiFi) at 2000μW/cm^2 could induce in vivo DNA strand breaks in exposed rat brains, they also found that pre- and post- exposure injection of either melatonin or spin-trapping compound N-tert-butyl-μ-phenylnitrone (PBN) could block this effect. As melatonin and PBN are powerful free-radical scavenging antioxidants, it appeared that RFR-induced DNA breaks were mediated by oxidative stress[39, 40].

Oxidative stress

An increasing number of cell in vitro studies and in vivo studies have shown increased levels of endogenous markers of oxidative stress and depleted antioxidant levels in various tissue and cell types upon exposure to RFR[41-48]. Some studies have further demonstrated ameliorative effects upon supplementation with antioxidant preparations including vitamin C and E, melatonin, caffeic acid, gingseng and garlic extract[43, 49-52]. These findings are complemented by limited human data where exposure to RF-EMR has shown increased oxidative stress and reduced antioxidant status. For example, 15 minutes of mobile phone usage in healthy volunteers has shown to up-regulate salivary superoxide dismutase (SOD) enzyme which then started dropping off as the RFR exposure further progressed, indicating an underlying increase in superoxide radical production (oxidative stress) triggered and continued by RFR exposure[53].

Cytotoxic effects of RFR on reproductive tissue, particularly spermatozoa have been well documented and also appear to occur via oxidative stress mechanisms[46, 54, 55]. Declining sperm quality in reproductive age men, increased demand for assisted reproductive technologies (ART) and increasing incidence of testicular and prostate cancer could well be largely caused by RFR-transmitting devices such as mobile phones and laptop computers being held very closely to gonads for extended periods of time.

Immune effects

Immune effects of RFR is another area deserving attention of the clinical communities. There is compelling evidence for RFR to elicit chronic immune responses as outlined in the BioInitiative Report. For example, a large and stringently controlled in vivo study conducted at the Washington University (funded by the US Air Force) found low-level chronic exposure (21.5 hr/d for 13 months) of 2.4GHz RFR - same as WiFi, to double the splenic B- and T-cells indicating stimulation of the lymphoid system in irradiated rodents. Mitogen-stimulation studies found significant differences between irradiated animals and the sham-exposed controls in their responses to various B- and T-cell specific mitogens. After 25 months, there was a near four-fold increase of primary malignancies in the exposed animals compared to the sham-exposed animals. However, in the absence of a statistically significant increase in any particular type of malignancy, the authors trivialized this result claiming that an agent is not usually considered carcinogenic unless it induces a significant response in any one tissue type[56]. Similarly, an Australian study using a transgenic strain of mice found a 2.4-fold increase in lymphomas in RFR-exposed animals with 900MHz RFR (commonly used with mobile phones), with two 30 min exposures per day up to 18 months. The exposed animals also developed lymphomas earlier[24].

In a human study investigating the immune effects of residential exposure levels of RFR in a case controlled group of healthy young women, a range of immune markers were found to be significantly different in women with the higher RFR exposures[57]. Higher RFR exposure group showed a statistically significant reduction in the cytotoxic activity in peripheral blood. This effect in healthy young women could compromise their immune functions. A recent review reported that in general, short-term exposure to low level RFR may temporarily stimulate certain humoral or cellular immune functions, whilst prolonged exposure appear to inhibit the same functions[58]. These and other experimental data indicate that prolonged low-level RFR exposure can cause immune derangement and could contribute to chronic immune disorders and cancer.

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Effects on the central nervous system

Another key area of study is the impact of RFR on the CNS and in neurodevelopment[32, 34, 56, 59-63]. At a time when the prevalence of a spectrum of neurodevelopmental disorders in children is rapidly rising, implication of rapidly increased RFR exposure over the last couple of decades should be investigated as a priority. Dr. Martha Herbert, a paediatric neurologist at Harvard Medical School and Cindy Sage MSc, a highly experienced EMR researcher and BioInitiative Report co-editor, have published two excellent reviews exploring plausible molecular mechanisms by which EMR could play a role in the pathobiology of neurodevelopmental disorders[64, 65]. Moreover, Dr. Hugh Taylors research team at the Department of Obstetrics, Gynaecology and Reproductive Sciences at Yale University found that in utero exposure to RFR from mobile phones could affect the neurobehavioral development of mice. The offspring of irradiated mothers showed impaired memory and hyperactivity reflective of children with attention deficit hyperactivity disorder (ADHD). The affected mice had impaired glutamatergic synaptic transmission onto layer V pyramidal neurons of the prefrontal cortex in a dose-responsive manner[66]. Children with ADHD also have neuropathology of the prefrontal cortex. Considering the highly aqueous environment of foetuses in utero that can readily absorb RFR, protection of unborn children from risky maternal RFR use such as mobile phones and WiFi-enabled computers near the pregnant belly is warranted.

Effects on the CNS in the older population also demands attention as neurodegeneration underlies increasing prevalence of dementia, mainly due to Alzheimer's disease. Oxidative stress is implicated in the pathobiology of neurodegenerative disorders and RFR should be further investigated as a contributor to this process as pointed out in the BioInitiative Report. Further, RFR at non-thermal levels has been found to make the blood brain barrier (BBB) more permeable in experimental rodent models[67, 68]. Similar effects in humans could render the brain more susceptible to circulating environmental toxins that are usually kept away by a tight BBB. Moreover, biochemical and physiological changes in the brain induced by RFR via oxidative stress and affected melatonin production[69] could directly contribute to psychological disturbance manifested as stress, anxiety, insomnia, depression, cognitive deficits and conditions such as schizophrenia[70, 71]. These are common symptoms reported by people living near RFR transmitters such as mobile base stations[72-78]. In fact, RFR has been shown to induce stress and elevate salivary cortisol levels in healthy human volunteers under experimental conditions resembling living near mobile base stations[79].

Academic studies in New Zealand have recently shown that use of mobile and wireless device in adolescents are associated with headaches, sleep disruption and feeling tired at school[80, 81]. In light of their findings and also data from brain cancer studies, authors suggested limiting usage of mobile/cordless phones to 15 min/day for young people.

Brain tumours

Much of the research on RFR from mobile phones has focused on brain tumours. The Interphone Study, coordinated by the WHO between 2000-2004 and partly funded by the industry included 5,117 brain tumor cases in a set of case-controlled studies where participants were retrospectively questioned on their past mobile phone usage going back to 1990s and even late 1980s[82]. The study reported contradicting and inconclusive findings attributed to biases and errors. Although authors concluded with a general no effect, scrutiny of Appendix 2 Table in the supplementary data (separately presented online at: http://ije.oxfordjournals.org/content/suppl/2010/05/06/dyq079.DC1/Interphone_Appendix2.pdf) showed doubling of gliomas (OR 2.18, 95% CI 1.43-3.31) in those who had at least 10 years of mobile phone usage and those with the highest cumulative call times in excess of 1640 hours (OR 1.82, 95% CI 1.15-2.89). Intriguingly, those 'heaviest users' who had twice the risk of gliomas averaged their mobile phone usage to just 27 min per day – what we would call 'low usage' these days.

Much of the criticism of the Interphone study is on the blatant flaws of the design including classification of subjects who had made at least one call per week on a mobile phone for a period of at least 6 months as 'regular users'. They also did not question participants on their cordless phone usage which is likely to expose them to even more RFR as people tend to spend more time on cordless phones than on mobile phones and also because cordless phones emit much higher baseline RFR levels when in stand-by mode, often on bedside tables and work areas where people spend most of their day. Both these errors in experimental design would introduce biases in favour of a no-effect outcome and this study further contributed to the continued controversy of this issue[83, 84].

Research studies into health effects of RFR have been found to be influenced by the funding source by a team of Swiss and British researchers[85]. They found that industry-funded studies reported the largest number of outcomes, but were least likely to report a statistically significant result. There is a clear need for making research and regulation of RFR independent from the industry that produces RFR.

We see clearly that Interphone data cannot be used to give assurances to the public on currently allowed RFR exposure levels, as done by various parties including health authorities. In contrast, brain tumour studies by an independent Swedish group led by neurosurgeon Dr. Lennart Hardell in which both mobile and cordless phone usage have been taken into account, show consistent associations between astrocytomas, gliomas and acoustic neuromas and phone usage[11, 17, 86-90]. Their results show worse outcomes (5 times increased risk) for younger patients who started usage before the age of 20 years. The WHO's Interphone study however did not include participants under 30 years of age. Using the well-established Bradford Hill criteria for cancer causality, the Hardell group has recently shown that RFR should now be upgraded as group 1 carcinogen by the IARC[18]. Their results were further affirmed by a French study recently that showed increased risk of gliomas and meningiomas in their 'heaviest' mobile phone users who had ≥896 hour of cumulative usage[91].

Around three TV/radio broadcasting towers in northern Sydney where ambient RFR levels were higher than in neighbouring areas, a statistically significant association between increased childhood leukaemia incidence and mortality and proximity to TV towers was found[8]. Similarly, other studies have shown increased cancer around TV/radio transmitters[92], mobile base stations[93, 94] and also associated with occupational exposure to RFR[16, 95-98].

The scientific evidence from several lines indicate that cytotoxic effects of EMR contribute to a general pro-inflammatory scenario with chronic exposures, the extent of which would differ based on other environmental/dietary factors as well as one's genetic and biochemical differences.

Electro-hypersensitivity in chronically ill people

Electro-hypersensitivity (EHS) at present is largely a self-diagnosed condition affecting people who claim to have various symptoms, from headaches, anxiety, chronic fatigue, fibromyalgia to skin rashes associated with exposure to certain EMR sources. Interestingly it has been described as an accelerated aging syndrome[2, 99-101]. Many of these diagnosed with idiopathic environmental sensitivities could be sufferers of EHS. Whilst it is an officially recognized functional impairment in Sweden now, in most of the Western world recognition and care of EHS appears to be limited to integrative medical practices. EHS sufferers often report receiving disappointing treatment from the mainstream medical system that usually attribute a psychosomatic basis to their symptoms rather than physiological.

Perhaps the well reported increase in the use of complementary and alternative medications (CAM) in the last couple of decades in Australia and many other parts of the Western world[102] is reflective of increasing prevalence of chronic conditions affecting people's health and wellbeing and insufficient support from the mainstream health system in alleviating those conditions. In this regard, EHS emerges as a new environmental disease[1, 103-105] requiring urgent attention of the medical system. Instead of assuming that the current public exposure standards that are based on acute thermal effects can effectively protect public health against chronic non-thermal effects, the medical community must objectively investigate the role of EMR in the pathophysiology of human disease.

Public Health in the wireless age

There is enough scientific evidence to postulate the rapidly increased exposure of human populations around the globe to RFR as a cause for increased incidence of chronic inflammatory diseases and cancer. Considering the well-established contribution of oxidative stress in many pathogenic pathways and the evidence that RFR can increase oxidative stress, it is important that clinicians assess patients' exposure to RF-EMR through mobile/cordless phones and various wireless devices as well as their residential and occupational exposure through proximity to radio/TV transmission towers/mobile base stations and WiFi routers. This may be particularly relevant for people affected by neurodegenerative, neurobehavioural, atopic, autoimmune, metabolic and endocrine disorders.

Clinicians need to carefully monitor subjective and objective symptoms following intervention in the form of reduction of exposure. Existing data suggest that effects on more vulnerable paediatric populations and foetuses in utero need to be investigated as a priority, and in the meantime, prudent avoidance ought to be exercised in order to reduce long-term impact of RFR on public health. Current public exposure standards exclude radiation absorption patterns of children and Prof. Om Gandhi, a pioneering former chairman of the IEEE standard setting committee, has shown that currently used models severely underestimate EMR absorption by children[106].

A range of genetic and epigenetic factors may modify one's susceptibility to EMR. Those who are affected by conditions such as iron overload in haemochromatosis for example may be more susceptible to exacerbated oxidative stress through the Fenton reactions. Similarly, those with impaired antioxidant defences, for example those who cannot readily synthesize powerful antioxidant glutathione (GSH) due to defective methylation pathways could also be at an increased risk. Further, individuals on diets low in antioxidants or with digestive problems as well as those exposed to chemical environmental pollutants such as tobacco smoke and vehicle exhaust, could also be at increased risk due to synergistic action of RFR adding to the total allostatic load. Concurrent dietary supplementation with antioxidants while actively reducing exposure levels may be required in the clinical management of patients.

Understanding how EMR exerts its biological effects, its interactions with other dietary and environmental factors as well as how to modulate those effects pose a clear challenge for clinical medicine in the 21st century when RFR is an inescapable reality.

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References

1. Genuis, S.J., Fielding a current idea: exploring the public health impact of electromagnetic radiation. Public Health, 2008. 122(2): p. 113-24.

2. Havas, M. and J. Marrongelle, Replication of heart rate variability provocation study with 2.4-GHz cordless phone confirms original findings. Electromagn Biol Med, 2013. 32(2): p. 253-66.

3. Khurana, V.G., et al., Cell phones and brain tumors: a review including the long-term epidemiologic data. Surg Neurol, 2009. 72(3): p. 205-14; discussion 214-5.

4. Adey, W.R., Introduction: Effects of electromagnetic radiation on the nervous system. Ann N Y Acad Sci, 1975. 247: p. 15-20.

5. Adey, W.R., Tissue interactions with nonionizing electromagnetic fields. Physiol Rev, 1981. 61(2): p. 435-514.

6. Li, C.Y., et al., A population-based case-control study of radiofrequency exposure in relation to childhood neoplasm. Sci Total Environ, 2012. 435-436: p. 472-8.

7. Henshaw, D.L. and R.J. Reiter, Do magnetic fields cause increased risk of childhood leukemia via melatonin disruption? Bioelectromagnetics, 2005. Suppl 7: p. S86-97.

8. Hocking, B., et al., Cancer incidence and mortality and proximity to TV towers. Med J Aust, 1996. 165(11-12): p. 601-5.

9. Dolk, H., et al., Cancer incidence near radio and television transmitters in Great Britain. I. Sutton Coldfield transmitter. Am J Epidemiol, 1997. 145(1): p. 1-9.

10. Draper, G., et al., Childhood cancer in relation to distance from high voltage power lines in England and Wales: a case-control study. BMJ, 2005. 330(7503): p. 1290.

11. Carlberg, M. and L. Hardell, On the association between glioma, wireless phones, heredity and ionising radiation. Pathophysiology, 2012. 19(4): p. 243-52.

12. Carpenter, D.O., Human disease resulting from exposure to electromagnetic fields. Rev Environ Health, 2013. 28(4): p. 159-72.

13. Davis, R.L. and F.K. Mostofi, Cluster of testicular cancer in police officers exposed to hand-held radar. Am J Ind Med, 1993. 24(2): p. 231-3.

14. Degrave, E., et al., Causes of death among Belgian professional military radar operators: a 37-year retrospective cohort study. Int J Cancer, 2009. 124(4): p. 945-51.

15. Yakymenko, I. and E. Sidorik, Risks of carcinogenesis from electromagnetic radiation of mobile telephony devices. Exp Oncol, 2010. 32(2): p. 54-60.

16. Yakymenko, I., et al., Long-term exposure to microwave radiation provokes cancer growth: evidences from radars and mobile communication systems. Exp Oncol, 2011. 33(2): p. 62-70.

17. Hardell, L. and M. Carlberg, Mobile phones, cordless phones and the risk for brain tumours. Int J Oncol, 2009. 35(1): p. 5-17.

18. Hardell, L. and M. Carlberg, Using the Hill viewpoints from 1965 for evaluating strengths of evidence of the risk for brain tumors associated with use of mobile and cordless phones. Rev Environ Health, 2013. 28(2-3): p. 97-106.

19. The BioInitiative Group, BioInitiative Report: A Rationale for Biologically-based Public Exposure Standards for Electromagnetic Radiation, E. Cindy Sage and David O. Carpenter, Editor. 2012.

20. Damvik, M. and O. Johansson, Health risk assessment of electromagnetic fields: a conflict between the precautionary principle and environmental medicine methodology. Rev Environ Health, 2010. 25(4): p. 325-33.

21. Foster, K., Exposure Limits for Radiofrequency Energy: Three Models. http://www.who.int/peh-emf/meetings/day2Varna_Foster.pdf.

22. Maisch, D., The Procrustean Approach – Setting Exposure Standards for Telecommunications Frequency Electromagnetic Radiation. An examination of the manipulation of telecommunications standards by political, military, and industrial vested interests at the expense of public health protection. 2010, The University of Wollongong.

23. International Commission on Non-Ionizing Radiation, P., General approach to protection against non-ionizing radiation. Health Phys, 2002. 82(4): p. 540-8.

24. Repacholi, M.H., et al., Lymphomas in E mu-Pim1 transgenic mice exposed to pulsed 900 MHZ electromagnetic fields. Radiat Res, 1997. 147(5): p. 631-40.

25. Lawrence, A.F. and W.R. Adey, Nonlinear wave mechanisms in interactions between excitable tissue and electromagnetic fields. Neurol Res, 1982. 4(1-2): p. 115-53.

26. Adey, W.R., Biological effects of electromagnetic fields. J Cell Biochem, 1993. 51(4): p. 410-6.

27. Frey, A.H., Headaches from cellular telephones: are they real and what are the implications? Environ Health Perspect, 1998. 106(3): p. 101-3.

28. Frey, A.H. and E. Coren, Holographic assessment of microwave hearing. Science, 1980. 209(4461): p. 1144-5.

29. Frey, A.H., Data analysis reveals significant microwave-induced eye damage in humans. J Microw Power Electromagn Energy, 1985. 20(1): p. 53-5.

30. Hollows, F.C. and J.B. Douglas, Microwave cataract in radiolinemen and controls. Lancet, 1984. 2(8399): p. 406-7.

31. Braune, S., et al., Resting blood pressure increase during exposure to a radio-frequency electromagnetic field. Lancet, 1998. 351(9119): p. 1857-8.

32. Rao, V.S., et al., Nonthermal effects of radiofrequency-field exposure on calcium dynamics in stem cell-derived neuronal cells: elucidation of calcium pathways. Radiat Res, 2008. 169(3): p. 319-29.

33. Maskey, D., et al., Calcium-binding proteins and GFAP immunoreactivity alterations in murine hippocampus after 1 month of exposure to 835 MHz radiofrequency at SAR values of 1.6 and 4.0 W/kg. Neurosci Lett, 2012. 506(2): p. 292-6.

34. Maskey, D., et al., Effect of 835 MHz radiofrequency radiation exposure on calcium binding proteins in the hippocampus of the mouse brain. Brain Res, 2010. 1313: p. 232-41.

35. Adey, W.R., Neurophysiologic effects of radiofrequency and microwave radiation. Bull N Y Acad Med, 1979. 55(11): p. 1079-93.

36. Adey, W.R., Cell membranes: the electromagnetic environment and cancer promotion. Neurochem Res, 1988. 13(7): p. 671-7.

37. Pall, M.L., Electromagnetic fields act via activation of voltage-gated calcium channels to produce beneficial or adverse effects. J Cell Mol Med, 2013. 17(8): p. 958-65.

38. Ruediger, H.W., Genotoxic effects of radiofrequency electromagnetic fields. Pathophysiology, 2009. 16(2-3): p. 89-102.

39. Lai, H. and N.P. Singh, Melatonin and a spin-trap compound block radiofrequency electromagnetic radiation-induced DNA strand breaks in rat brain cells. Bioelectromagnetics, 1997. 18(6): p. 446-54.

40. Lai, H. and N.P. Singh, Acute low-intensity microwave exposure increases DNA single-strand breaks in rat brain cells. Bioelectromagnetics, 1995. 16(3): p. 207-10.

41. Ragy, M.M., Effect of exposure and withdrawal of 900-MHz-electromagnetic waves on brain, kidney and liver oxidative stress and some biochemical parameters in male rats. Electromagn Biol Med, 2014.

42. Yurekli, A.I., et al., GSM base station electromagnetic radiation and oxidative stress in rats. Electromagn Biol Med, 2006. 25(3): p. 177-88.

43. Bilgici, B., et al., Effect of 900 MHz radiofrequency radiation on oxidative stress in rat brain and serum. Electromagn Biol Med, 2013. 32(1): p. 20-9.

44. Burlaka, A., et al., Overproduction of free radical species in embryonal cells exposed to low intensity radiofrequency radiation. Exp Oncol, 2013. 35(3): p. 219-25.

45. Liu, C., et al., Exposure to 1800 MHz radiofrequency electromagnetic radiation induces oxidative DNA base damage in a mouse spermatocyte-derived cell line. Toxicol Lett, 2013. 218(1): p. 2-9.

46. Aitken, R.J. and G.N. De Iuliis, Origins and consequences of DNA damage in male germ cells. Reprod Biomed Online, 2007. 14(6): p. 727-33.

47. Esmekaya, M.A., C. Ozer, and N. Seyhan, 900 MHz pulse-modulated radiofrequency radiation induces oxidative stress on heart, lung, testis and liver tissues. Gen Physiol Biophys, 2011. 30(1): p. 84-9.

48. Cetin, H., et al., Liver antioxidant stores protect the brain from electromagnetic radiation (900 and 1800 MHz)-induced oxidative stress in rats during pregnancy and the development of offspring. J Matern Fetal Neonatal Med, 2014.

49. Avci, B., et al., Oxidative stress induced by 1.8 GHz radio frequency electromagnetic radiation and effects of garlic extract in rats. Int J Radiat Biol, 2012. 88(11): p. 799-805.

50. Ozguner, F., et al., Mobile phone-induced myocardial oxidative stress: protection by a novel antioxidant agent caffeic acid phenethyl ester. Toxicol Ind Health, 2005. 21(9): p. 223-30.

51. Akbari, A., G. Jelodar, and S. Nazifi, Vitamin C protects rat cerebellum and encephalon from oxidative stress following exposure to radiofrequency wave generated by a BTS antenna model. Toxicol Mech Methods, 2014. 24(5): p. 347-52.

52. Maskey, D., et al., Neuroprotective effect of against alteration of calcium binding proteins immunoreactivity in the mice hippocampus after radiofrequency exposure. Biomed Res Int, 2013. 2013: p. 812641.

53. Abu Khadra, K.M., et al., Evaluation of selected biochemical parameters in the saliva of young males using mobile phones. Electromagn Biol Med, 2014.

54. Desai, N.R., K.K. Kesari, and A. Agarwal, Pathophysiology of cell phone radiation: oxidative stress and carcinogenesis with focus on male reproductive system. Reprod Biol Endocrinol, 2009. 7: p. 114.

55. Agarwal, A., et al., Effect of cell phone usage on semen analysis in men attending infertility clinic: an observational study. Fertil Steril, 2008. 89(1): p. 124-8.

56. Chou, C.K., et al., Long-term, low-level microwave irradiation of rats. Bioelectromagnetics, 1992. 13(6): p. 469-96.

57. Boscolo, P., et al., The immune response of women with prolonged exposure to electromagnetic fields produced by radiotelevision broadcasting stations. Int J Immunopathol Pharmacol, 2006. 19(4 Suppl): p. 43-8.

58. Szmigielski, S., Reaction of the immune system to low-level RF/MW exposures. Sci Total Environ, 2013. 454-455: p. 393-400.

59. Chen, C., et al., Exposure to 1800 MHz radiofrequency radiation impairs neurite outgrowth of embryonic neural stem cells. Sci Rep, 2014. 4: p. 5103.

60. Xu, S., et al., Exposure to 1800 MHz radiofrequency radiation induces oxidative damage to mitochondrial DNA in primary cultured neurons. Brain Res, 2010. 1311: p. 189-96.

61. Maskey, D., et al., Chronic 835-MHz radiofrequency exposure to mice hippocampus alters the distribution of calbindin and GFAP immunoreactivity. Brain Res, 2010. 1346: p. 237-46.

62. Marino, A.A. and S. Carrubba, The effects of mobile-phone electromagnetic fields on brain electrical activity: a critical analysis of the literature. Electromagn Biol Med, 2009. 28(3): p. 250-74.

63. Saikhedkar, N., et al., Effects of mobile phone radiation (900 MHz radiofrequency) on structure and functions of rat brain. Neurol Res, 2014: p. 1743132814Y0000000392.

64. Herbert, M.R. and C. Sage, Autism and EMF? Plausibility of a pathophysiological link part II. Pathophysiology, 2013. 20(3): p. 211-34.

65. Herbert, M.R. and C. Sage, Autism and EMF? Plausibility of a pathophysiological link - Part I. Pathophysiology, 2013. 20(3): p. 191-209.

66. Aldad, T.S., et al., Fetal radiofrequency radiation exposure from 800-1900 mhz-rated cellular telephones affects neurodevelopment and behavior in mice. Sci Rep, 2012. 2: p. 312.

67. Sirav, B. and N. Seyhan, Effects of radiofrequency radiation exposure on blood-brain barrier permeability in male and female rats. Electromagn Biol Med, 2011. 30(4): p. 253-60.

68. Nittby, H., et al., Radiofrequency and extremely low-frequency electromagnetic field effects on the blood-brain barrier. Electromagn Biol Med, 2008. 27(2): p. 103-26.

69. Clark, M.L., et al., Biomonitoring of estrogen and melatonin metabolites among women residing near radio and television broadcasting transmitters. J Occup Environ Med, 2007. 49(10): p. 1149-56.

70. Fournier, M., et al., Impaired metabolic reactivity to oxidative stress in early psychosis patients. Schizophr Bull, 2014. 40(5): p. 973-83.

71. Landgraf, D., M.J. McCarthy, and D.K. Welsh, Circadian clock and stress interactions in the molecular biology of psychiatric disorders. Curr again. Int J Neurosci, 2013. 123(8): p. 593-4.

72. Bortkiewicz, A., et al., Subjective complaints of people living near mobile phone base stations in Poland. Int J Occup Med Environ Health, 2012. 25(1): p. 31-40.

73. Santini, R., et al., [Symptoms experienced by people in vicinity of base stations: II/ Incidences of age, duration of exposure, location of subjects in relation to the antennas and other electromagnetic factors]. Pathol Biol (Paris), 2003. 51(7): p. 412-5.

74. Hutter, H.P., et al., Subjective symptoms, sleeping problems, and cognitive performance in subjects living near mobile phone base stations. Occup Environ Med, 2006. 63(5): p. 307-13.

75. Berg-Beckhoff, G., et al., Mobile phone base stations and adverse health effects: phase 2 of a cross-sectional study with measured radio frequency electromagnetic fields. Occup Environ Med, 2009. 66(2): p. 124-30.

76. Blettner, M., et al., Mobile phone base stations and adverse health effects: phase 1 of a population-based, cross-sectional study in Germany. Occup Environ Med, 2009. 66(2): p. 118-23.

77. Shahbazi-Gahrouei, D., et al., Health effects of living near mobile phone base transceiver station (BTS) antennae: a report from Isfahan, Iran. Electromagn Biol Med, 2014. 33(3): p. 206-10.

78. Abdel-Rassoul, G., et al., Neurobehavioral effects among inhabitants around mobile phone base stations. Neurotoxicology, 2007. 28(2): p. 434-40.

79. Augner, C. and G.W. Hacker, Are people living next to mobile phone base stations more strained? Relationship of health concerns, self-estimated distance to base station, and psychological parameters. Indian J Occup Environ Med, 2009. 13(3): p. 141-5.

80. Redmayne, M., New Zealand adolescents' cellphone and cordless phone user-habits: are they at increased risk of brain tumours already? A cross-sectional study. Environ Health, 2013. 12: p. 5.

81. Redmayne, M., E. Smith, and M.J. Abramson, The relationship between adolescents' well-being and their wireless phone use: a cross-sectional study. Environ Health, 2013. 12: p. 90.

82. Interphone Group, Brain tumour risk in relation to mobile telephone use: results of the INTERPHONE international case-control study. Int J Epidemiol, 2010. 39(3): p. 675-94.

83. Peres, J., One conclusion emerges from Interphone study: controversy will continue. J Natl Cancer Inst, 2010. 102(13): p. 928-31.

84. Davis, D.L., et al., Swedish review strengthens grounds for concluding that radiation from cellular and cordless phones is a probable human carcinogen. Pathophysiology, 2013. 20(2): p. 123-9.

85. Huss, A., et al., Source of funding and results of studies of health effects of mobile phone use: systematic review of experimental studies. Environ Health Perspect, 2007. 115(1): p. 1-4.

86. Hardell, L., M. Carlberg, and K. Hansson Mild, Use of cellular telephones and brain tumour risk in urban and rural areas. Occup Environ Med, 2005. 62(6): p. 390-4.

87. Hardell, L., M. Carlberg, and K. Hansson Mild, Case-control study on cellular and cordless telephones and the risk for acoustic neuroma or meningioma in patients diagnosed 2000-2003. Neuroepidemiology, 2005. 25(3): p. 120-8.

88. Hardell, L., M. Carlberg, and K. Hansson Mild, Pooled analysis of two case-control studies on use of cellular and cordless telephones and the risk for malignant brain tumours diagnosed in 1997-2003. Int Arch Occup Environ Health, 2006. 79(8): p. 630-9.

89. Hardell, L., M. Carlberg, and K. Hansson Mild, Mobile phone use and the risk for malignant brain tumors: a case-control study on deceased cases and controls. Neuroepidemiology, 2010. 35(2): p. 109-14.

90. Hardell, L., M. Carlberg, and K. Hansson Mild, Use of mobile phones and cordless phones is associated with increased risk for glioma and acoustic neuroma. Pathophysiology, 2013. 20(2): p. 85-110.

91. Coureau, G., et al., Mobile phone use and brain tumours in the CERENAT case-control study. Occup Environ Med, 2014. 71(7): p. 514-22.

92. Dolk, H., et al., Cancer incidence near radio and television transmitters in Great Britain. II. All high power transmitters. Am J Epidemiol, 1997. 145(1): p. 10-7.

93. Khurana, V.G., et al., Epidemiological evidence for a health risk from mobile phone base stations. Int J Occup Environ Health, 2010. 16(3): p. 263-7.

94. Dode, A.C., et al., Mortality by neoplasia and cellular telephone base stations in the Belo Horizonte municipality, Minas Gerais state, Brazil. Sci Total Environ, 2011. 409(19): p. 3649-65.

95. Richter, E., et al., Cancer in radar technicians exposed to radiofrequency/microwave radiation: sentinel episodes. Int J Occup Environ Health, 2000. 6(3): p. 187-93.

96. Szmigielski, S., Cancer morbidity in subjects occupationally exposed to high frequency (radiofrequency and microwave) electromagnetic radiation. Sci Total Environ, 1996. 180(1): p. 9-17.

97. Szmigielski, S., Cancer risks related to low-level RF/MW exposures, including cell phones. Electromagn Biol Med, 2013. 32(3): p. 273-80.

98. Milham, S., Most cancer in firefighters is due to radio-frequency radiation exposure not inhaled carcinogens. Med Hypotheses, 2009. 73(5): p. 788-9.

99. Havas, M., Radiation from wireless technology affects the blood, the heart, and the autonomic nervous system. Rev Environ Health, 2013. 28(2-3): p. 75-84.

100. Hagstrom, M., et al., Reducing electromagnetic irradiation and fields alleviates experienced health hazards of VDU work. Pathophysiology, 2012. 19(2): p. 81-7.

101. Johansson, O., Electrohypersensitivity: state-of-the-art of a functional impairment. Electromagn Biol Med, 2006. 25(4): p. 245-58.

102. Coulter, I.D. and E.M. Willis, The rise and rise of complementary and alternative medicine: a sociological perspective. Med J Aust, 2004. 180(11): p. 587-9.

103. Genuis, S.J. and C.T. Lipp, Electromagnetic hypersensitivity: fact or fiction? Sci Total Environ, 2012. 414: p. 103-12.

104. Marino, A.A., Electromagnetic hypersensitivity syndrome revisited again. Int J Neurosci, 2013. 123(8): p. 593-4.

105. McCarty, D.E., et al., Electromagnetic hypersensitivity: evidence for a novel neurological syndrome. Int J Neurosci, 2011. 121(12): p. 670-6.

106. Gandhi, O.P., et al., Exposure limits: the underestimation of absorbed cell phone radiation, especially in children. Electromagn Biol Med, 2012. 31(1): p. 34-51.