The biological effects of non-native electromagnetic frequencies (nnEMFs) in health and disease patterns. *A review of research and findings, and recommendations for educating patients and practitioners for the purpose of improving overall health outcomes*

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The proliferation of man-made electromagnetic frequencies has generated numerous studies which explore and research the effects of microwave radiofrequency radiation and electromagnetic radiation, and the impact on the health of humans and animals. This paper will review the currently available studies, research, and recommendations which will unfold new solutions for ameliorating negative health impacts caused by over-exposure to non-native EMFs. The majority of peer-reviewed studies on nnEMF exposure indicate a long list of health problems that may result from chronic overexposure. Safe practices, as well as nutritional therapies and acupuncture, can be helpful in the overall protection from overexposure and recovery from acute or chronic overexposure.

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1. Introduction

Daily exposures to nnEMFs have grown exponentially in the last several decades with the introduction of wireless technologies such as cell phones, Wi-Fi, Bluetooth, Smart appliances, Smart meters and other wireless technologies which use radiofrequency (RF) radiation as the primary method for transmitting data. Other forms of nnEMFs include high voltage power lines and electrical wiring in the home, work, and automobile. Humans are increasingly exposed at home, work and in most public areas with the expanding number of cell towers, public Wi-Fi connections, and other public or private base stations or routers. Developing and implementing safe exposure limits and educating the public on potential hazards of overexposure may be necessary to avoid unintended overexposures and health consequences. Health care practitioners play a very important role in the ability to recognize, diagnose and treat unintended overexposures. For example, health practitioners have a duty to inform patients of the possible negative impacts of habits, behaviors and environmental exposures which may affect health outcomes. Practitioners educate patients on the appropriate food and water intakes, reducing or eliminating toxic exposures to environmental toxins and chemicals, smoking, drug and alcohol use, stress and poor lifestyle habits in order help their patients heal or to prevent illness. One of the newest environmental pollutants, and most under-recognized, is the increased chronic exposure to nnEMFs in the form of cell towers (2G, 3G, 4G, 5G +), cell phones, wireless tablets, laptops, baby monitors and other wireless appliances and devices which emit a very strong signal at close range contact with humans and other living beings. Research has raised questions about the safety of chronic exposure to high levels of nnEMF's.

2. Studies

Numerous studies show that negative health impacts stem from mitochondrial and DNA damage due to the strong oxidative effect of nnEMFs and could lead to the increased prevalence of chronic fatigue, depression, anxiety, autism / ADHD, immune system stress, memory impairment, diabetes, inflammatory neurological diseases, sleep pattern dysfunction, lowered fertility rates among both men and women, increases in antibiotic-resistant bacteria, cardiovascular disorders and stroke, cancers and possibly many other wide-ranging, chronic health issues [1-21, 24-42, 45, 48-52, 56-62, 65, 78, 80, 81, 85, 86, 90-99, 102].

2.1 Memory Impairment and Behavioral Disorders

Neurological diseases, including Alzheimer's disease-like symptoms, may be the result of long-term nnEMF exposure due to increased reactive oxygen species, oxidative stress and decreased antioxidant enzyme capacity. Animal studies showed that exposure to high-frequency EMFs resulted in significant pyramidal cell loss in the hippocampus of juvenile rats in the postnatal period after exposure to EMF in the prenatal period [4]. These studies also reported that continuous exposure to ELF-EMF led to a reduction in cell tolerance against oxidative stress. Another study consisted of rats exposed to 900 MHz for 3 hours per day for either 14 or 28 days and reported that the 28-day exposure group showed significant damage of the blood-brain barrier (BBB) and impairment of spatial memory by means of activation of the mkp-1/ERK pathway resulting in dephosphorylation [16],

which leads to increased stress response, neuroinflammation, neuronal cell death and decreased neuronal development [100]. The 28-day exposure group also showed cellular edema and neuronal cell organelle degeneration. An additional study of rats exposed to 2.45 GHz RF-EMF, 4 hours per day for 45 days, reported detrimental changes to the brain through the expression of apoptotic caspase 3, leading to memory decline, anxiety behavior and a reduction of brain antioxidants [21].

Human studies have also reported memory impairment after exposure to nnEMF's. Strong associations with figural memory impairment were reported after exposure to RF-EMF from cell phones in a study of 439 students in Switzerland, aged 12 to 17 years old [6]. In another study, five cohorts from Denmark, Korea, Netherlands, Norway, and Spain, consisting of 83,884 mother-child pairs which analyzed the effects of maternal use of cell phones and child behavioral changes, indicated that cell phone use during pregnancy showed a strong association with an increased risk for behavioral problems, especially hyperactivity and inattention issues, in the offspring [10].

A study of 7102 Chinese adolescents reported a significant correlation between mobile phone use and inattention. Mobile phone positioning was also significant in the outcomes. Children who carried the phone in their pockets or in front of the chest had significant levels of inattention, compared to those who did not carry a mobile phone; children who turned the power off at night had much less inattention compared to those who did not power off the phone while sleeping

[26]. It is also noted that adolescents with inattention are at a higher risk of mood and conduct disorders, and substance abuse [26].

2.2 Neuropsychiatric and Neurological

Decades of research provide numerous studies that show the effects of non-thermal microwave exposure to animals and humans. The Naval Research Institute Research Report (1971) listed 40 neuropsychiatric changes produced by non-thermal exposures including 5 central/peripheral nervous system (NS) changes, 9 CNS effects, 4 autonomic system effects, 17 psychological disorders and 4 behavioral changes [7]. This NMRI report also documented over 2300 citations of these and other effects of microwave exposures (RF-EMF) in humans and animals [7]. Studies show that mammalian nervous systems are more sensitive to any other organ in the body to the exposure of non-thermal microwave radiation (RF-EMF) and other low-frequency types of EMFs. Symptoms included headache, fatigue, irritability, dizziness, loss of appetite, depression, sleepiness, memory loss, emotional instability, hallucinations, tremor, and insomnia.

Studies show significant morphological lesions in the myelin sheath of rats, a greater risk of multiple sclerosis and demyelination symptoms in individuals with electrohypersensitivity [27, 28].

Sixty inhabitants of Rimbach, Germany were studied following the implementation of a mobile base station in 2004. Results indicated that, after 18 months, even those with the lowest exposure to RF-EMF had decreased dopamine and beta-phenylethylamine (PEA) levels. PEA is an excitatory neurotransmitter and increases

the actions of dopamine, increasing feelings of well-being and pleasure and is often low in patients with ADHD and depression [30]. Many of the 60 study participants had developed new symptoms including sleep disturbances, allergies, difficulty concentrating, headaches and dizziness.

Epidemiological studies on populations living near mobile phone base stations indicated that 80% of the studies where participants lived less than 500 meters (less than a third of a mile) from the base stations had an increased prevalence of neurobehavioral symptoms and cancer [30].

2.3 Sleep and Pain

A study consisting of 123 patients was conducted at a private hospital and indicated that Smartphone use was observed to increase headache duration and frequency in migraine patients as well as decrease overall sleep quality and increase daytime sleepiness [11]. Various methods of evaluation were used including the Visual Analog Scale (VAS), 24-hour Migraine Quality of Life Questionnaire (24-h MQoLQ), Pittsburgh Sleep Quality Index (PSQI) and Epworth Sleepiness Scale (ESS).

Four studies in Asia and three studies in Europe assessed the correlation between mobile phone use and headaches which reported a significant association, possibly due to a breakdown in the blood-brain barrier (BBB) and also changes in the dopamine-opiate system which both are affected by low-intensity electromagnetic energy [12].

A study showed that in a group of persons between the ages of 18-30 years of age, serum Beta-trace proteins were found to be downregulated and decreased further with the number of years of using a wireless phone while no effect was seen among older persons [30]. Beta-trace protein is the key enzyme in the production of prostaglandin D2, an endogenous sleep-promoting neurohormone [101, 103].

In China, a study of 854 participants were studied for the effects of EMF exposure at work. Results indicated the EMF exposure may damage human sleep quality rather than sleep duration [32].

2.4 Cardiovascular Disorders

Chronic exposure to RF-EMF has been shown to cause increases in cardiovascular disorders including increased blood pressure and irregular heart rhythms. Military studies, including the Moscow US Embassy as well as the Korean War radar study, showed significantly elevated cardiac disease rates in military occupational groups exposed to radar [24]. Exposure to base stations and other antenna arrays induced changes in calcium movement in the heart [30]. EMF exposure has been shown to cause rouleau formation of the erythrocytes. This stacking of the red blood cells reduces the surface area and can lead to a reduction of the removal of waste products from the cell as well as the release of nutrients [37]. Symptoms of rouleau formation include tingling sensation of the hands and feet, headaches, concentration problems, nausea, dizziness and heart, and blood pressure problems [37]. The presence of strong WiFi in schools can also prove to be detrimental to the health of children. Several students in an Ontario, CA school district complained

of heart palpitations, tachycardia and headaches only when at school, while 4 students had sudden cardiac arrests [37]. A cardiologist determined that when students with Wolff-Parkinson-White (WPW) syndrome, which is often undiagnosed, are exposed to microwave radiation while exercising, the increased stress on the heart can lead to supraventricular tachycardia [37]. Additional studies [48] conducted in the Eurasian Communist countries of the 20th century indicated that engineers and administrative officials exposed to long term radiofrequency radiation had significantly higher rates of coronary disease, hypertension, and disturbances of lipid metabolism.

2.5 Fertility

Chronic RF-EMF exposure has shown to impact both structural and functional aspects of the male reproductive system including a decrease in the diameter and weight of the seminiferous tubules, the mean height of the germinal epithelium, and pathological changes in biochemical components of testicular tissues [9]. In a systematic review, 23 eligible articles out of 526 were reviewed and findings indicated various degrees of degenerative changes to the testes, sperm count and motility after exposure to Wi-Fi radiation. The testes showed the highest amount of DNA damage compared to other organs following RF-EMF exposure through increased ROS levels, decreased antioxidant levels and increased lipid and nucleic peroxidation products. Three studies showed a significant decrease in testosterone, decreased sperm count, motility, viability, and changes to normal morphology following RF-EMF exposure. Increases in DNA fragmentation of the sperm was also

observed. Testicular temperature was elevated after RF-EMF exposure even though body temperature remained the same [25]. Five of the 23 studies involved human subjects.

2.6 Endocrine System

A study of 77 healthy university students between the ages of 19 and 29 years old indicated a statistically significant increase in TSH levels among the study participants when exposed to high mobile phone use. Similar results were also found in studies of dairy cattle and rats exposed to high EMF levels [14]. Exposure to non-thermal RF-EMF has shown to cause histological changes in the hypothalamus and pituitary glands where exposure initially causes an increase in activity, but over time, leads to an exhaustion of neuroendocrine activity [7]. These effects have shown to be irreversible with long term exposures.

2.7 Cancer

Radiofrequency radiation has been classified as a possible carcinogen to humans (group 2B) by the International Agency for Research on Cancer [34] and is the subject of the largest, and most well-designed, study conducted by the National Toxicology Program which determined clear evidence that cell phone radiation is linked to certain rare cancers of the heart and kidney [1]. Research also points to the probability that long term exposure to mobile phone use increases the risk of intracranial tumors [33]. Another study [102] suggests that pediatric brain tumors are on the rise in the United States at the rate of 1.37% annually between 1973 and

2008, indicating that environmental factors, including electromagnetic fields, may be contributing to this trend.

2.8 Diabetes and Insulin Resistance

A study of rats exposed to 2.45 GHz (Wi-Fi) reported increases in pancreas lesions in both the endocrine and exocrine cells caused by oxidative damage and inflammatory processes. The study showed that the harmful effect of RF-EMF exposure on the exocrine pancreas may be more severe in the developmental stage [15]. The exocrine pancreas is part of the digestive system in which it creates and secretes digestive enzymes into the intestine. RF-EMF exposure causes damage to Langerhans islets and can increase the risk of diabetes at a young age. High glucose levels, degenerated exocrine cells and increased oxidative stress markers were present in the RF-EMF group [15].

2.9 Oxidative Stress and DNA Damage

Studies performed on male and female infant rabbits showed increased lipid damage after exposure to RF radiation for 15 minutes per day for 7 to 14 days [13]. Additional studies indicated increasing free radical and oxidative damage to cell structures and DNA fragmentation after exposure to RF radiation due to increased reactive oxygen species and C 8-hydroxyguanosine (8-OHdG) [13, 20, 21, 25, 34, 35, 40]. Decreased DNA repair rates have also been reported with EMF exposure which is especially critical to the brain structures, as brain tissue is very sensitive to oxidative stress and may not have adequate protection against increased levels of oxidation [18].

3. Bio-mechanisms

There are several considerations for how nnEMFs may cause damage to living beings and induce various illnesses or diseases including oxidative stress, cellular signaling, and underlying genetic predispositions or single nucleotide polymorphisms (SNPs).

3.1 Voltage-Gated Channels

Voltage-gated ion channels include Calcium (Ca^{2+}), Sodium (Na^{+}), Potassium (K^{+}), and Chloride (Cl^{-}), and consist of proteins that allow these ions to selectively pass through or permeate cell membranes. These channels simulate important physiological events at the cellular level and their proper functioning is essential for robust health. Studies have indicated that nnEMF exposure can alter the Voltage-Gated Calcium Channels (VGCC's) [23] and produce undesirable results affecting neurotransmitters such as glutamate, GABA (gamma-aminobutyric acid) and acetylcholine which can produce neuropsychiatric effects and lead to anxiety, depression and other mood and behavioral disorders [7, 57]. VGCC's also play important regulatory roles in endocrine hormone production, cardiovascular function [7, 45, 46], oxidative stress, nerve impulses, gene expression, muscle contraction, adrenal function, and enzyme activity [23, 49, 50]. An abnormal influx of calcium into mast cells can prompt or exacerbate allergic reactions [5, 58]. It is important to note that short term activation of VGCC's can produce positive healing effects, while long term or chronic activation has been shown to lead to cell damage and DNA breaks [45, 50].

3.2 Peroxynitrite and Oxidation

Peroxynitrite (ONOO-) is a powerful oxidant and can transverse through cell membranes by anion channels [47]. nnEMFs create a substantial increase in peroxynitrite activity with long term exposure [5, 6, 45] and the effects of increased levels of Reactive Oxygen Species (ROS) and oxidation can include the depletion of antioxidants including glutathione which can lead to numerous inflammatory conditions, blood-brain barrier and cell damage and also DNA breaks [4,5, 7, 8, 13, 15,16, 18, 20, 21, 25, 29, 33, 34, 35, 40, 41, 49]. Chronic or long term increases of peroxynitrites can lead to diseases such as myocardial injury and chronic heart failure, atherosclerosis, hypertension, stroke, systemic inflammation, leukocyte sequestration, gut mucosal barrier failure and inflammatory bowel disease, chronic arthritis, kidney and lung damage, neurodegenerative disorders such as Multiple Sclerosis (MS), Parkinson's Disease (PD), Alzheimer's Disease (AD), Amyotrophic Lateral Sclerosis (ALS), Huntington's Disease (HD), and Traumatic Brain Injury (TBI), as well as early aging, diabetes, and cancer[47].

Increased serum nitrotyrosine is a marker of peroxynitrite activity and breakdown of the blood-brain barrier [86] and can be used as a predictor of over or chronic exposure to nnEMFs.

3.3 Autophagy

Autophagy is a homeostatic process that helps to control inflammation and support healthy immune response [52]. When autophagy is regulated properly, cellular debris is eliminated, cells are protected and inflammatory and immune responses are normal. Environmental toxic exposures, inflammation, along with genetic mutations, can lead to poor autophagy function and an increased risk of disease. nnEMFs can have a negative effect on autophagy function and may exacerbate autoimmune or inflammatory conditions with prolonged exposure. The mammalian target of rapamycin (mTOR) plays a pivotal role in response to oxidative stress and the autophagy process [53] and can be affected by a deficiency of glutathione. Regulating autophagy, especially in those who have genetic allele abnormalities such as homozygous and heterozygous expressions at ATG5 [82], ATG16L1 [83] and similar genetic expressions, can help protect against excessive or inappropriate apoptosis, cell and DNA damage [20].

3.4 Genetic Considerations

In addition to autophagy genetic considerations, other heterozygous or homozygous allele mutations including MTHFR, COMT, MAO, SOD2, HLA DR/DQ, GSTM1, and GSTT1 should also be considered [86, 87, 88]. MTHFR allele mutations cause a decrease in the level of folate available for all cellular functions. Increased inflammation, decreased production of serotonin and dopamine, decreased immune function and cellular ATP may ensue for those individuals exposed to

nnEMFs who have any variation of MTHFR allele mutation. COMT allele mutations affect detoxification pathways, oxidative damage, neurotransmitter production, and hormone metabolism. Individuals with COMT mutations may be more prone to oxidative stress, estrogen dominance, cancers and neuropsychological disorders with increased nnEMF exposures. MAO allele mutations affect neurotransmitter catabolism and individuals with these mutations may experience an increased incidence of aggressive behavior, major depression or autistic traits. SOD2 allele mutations can alter the ability to detoxify reactive oxygen species (ROS) and can lead to increased cell damage. Individuals with SOD2 allele mutations can be more prone to cardiomyopathy, cancers, and motor neuron diseases such as ALS. FUT2 allele mutations affect the intestinal microbiome and individuals with this mutation can be more prone to inflammatory bowel diseases. HLA DR/DQ genetic allele mutations can affect immune response and inflammation. Individuals with these mutations can have an increased probability of cancers and autoimmune conditions. GSTM1 and GSTT1 allele mutations can lead to decreased glutathione activity and reduction of cellular detoxification of environmental pollutants, carcinogens, and ROS. Individuals with these allele mutations may have a higher risk of DNA damage and cancers.

More studies are needed to determine how these and other genetic mutations may increase the likelihood of more severe health impacts with increased exposure to nnEMFs.

4. Need for Education

Although there has been a movement toward increased awareness of the possible detrimental effects of long-term, chronic or overexposure to nnEMFs, more education is necessary so that people can make informed decisions on their own health, the health of their children and the overall impact that increased levels of nnEMFs can have on our environment and our future. In fact, a recent report from Blue Cross Blue Shield [84] indicates that major declines in the health of millennials begin at age 27. An alarming double-digit increase in the prevalence rates of major depression (31%), psychotic conditions (15%), hyperactivity (29%), type II diabetes (22%), high cholesterol (12%), and hypertension (16%) occurred between 2014 and 2017. More research and education are necessary to examine the possible role of the rapid increase of technology use and the biological, social and environmental impacts that may result in increased disease rates and an unsustainable economic impact on our healthcare systems.

4.1 Healthcare Practitioners

Proper diagnosis of disease begins with well-informed healthcare practitioners who can effectively and accurately determine the root causes of disease patterns. To date, few healthcare practitioners are well informed of the negative health effects that over, or chronic, exposure to nnEMFs can create. Studies have reported the non-thermal effects of non-ionizing radiation as well as other types of nnEMFs for many decades, however, these results are not widely taught in medical schools or as ongoing continuing education for healthcare practitioners. Although there has

been a recent movement [85] to offer continuing education courses on this subject to licensed medical professionals, increased education and awareness are needed in all healthcare practices.

4.2 Public

Increased public awareness will allow people to make informed decisions on how they use technology as well as what policies they will support which will offer protection from over or chronic exposures to nnEMFs for themselves, their children and the environment [90-99]. The results of well-designed studies have been underpublicized for decades [90-99], which keeps the public from fully understanding the consequences of nnEMF exposures. Increased awareness is needed and policy changes are necessary to maintain the freedom of the public to make well-informed decisions that will impact their overall health.

4.3 Questionnaire for Diagnosis of Overexposure

In 2012, the Austrian Medical Association created guidelines [60] for the diagnosis and treatment of nnEMF related illnesses which were updated in 2016 with the EUROPAEM Guidelines for EHS [61]. The research and recommendations included in the guidelines are valuable tools for any healthcare practitioner to utilize for the proper diagnosis and treatment of disease in a modern world with the ever-increasing use of wireless technologies. A patient questionnaire [62] can be found in *Table 1*.

4.4 Laboratory Testing

Traditional laboratory testing and diagnostics [60, 86], including urine, saliva, and blood, can be useful in determining nnEMF exposure in patients. Twenty four hour blood pressure, heart rate, ECG and HRV can show variability based on environmental exposures. Early morning urine laboratory testing can include adrenaline, noradrenaline, dopamine, serotonin, and 6-OH melatonin sulfate levels. Other urine samples can include histamine, glycine, GABA, and glutamate. Saliva testing can include morning, mid-day and evening levels of cortisol as well as alpha-amylase and DHEA. Blood testing can include homocysteine, intracellular ATP and glutathione, malondialdehyde, 8-hydroxydeoxyguanosine, TNF-a, and vitamin and mineral levels such as B2, B6, D, CoQ10, selenium, copper, zinc, and magnesium. Increased nitrotyrosine levels can indicate excessive peroxynitrites and BBB disruption.

5. Recommending Safe Exposure Limits

Educating patients on safe exposure limits to wireless technology and other forms of nnEMFs is necessary to improve overall health outcomes. Interventions and treatments will not be as effective if the source of overexposure is not properly addressed and mitigated. Just as treating a patient for a lung disorder when the patient continues to smoke may not yield the successful health outcomes compared to the patient who understands the toxic effects of the exposure and then ceases to smoke, people who are

continually exposed to environmental toxins will not achieve excellent health outcomes if they are not educated on the necessity to lower or eliminate the toxic exposures.

5.1 Remediation of Home and Work

Lowering exposure to nnEMFs can be achieved through various methods and guidelines [59-61]. Some of these include:

1. ***Use Wired Technology Instead of Wireless***. Hardwire computers, laptops and other devices using ethernet connections which are more secure and often provide a faster connection speed. Use corded landlines instead of cell phones. Cell phones can be forwarded to a landline to safely receive calls and avoid overexposure to cell phone radiation. Use corded headsets, keyboard and mouse devices instead of wireless/Bluetooth. Do not sit next to a WiFi router or other wireless devices. Distance lowers exposure levels.
2. ***Remove Wireless and Electrical Equipment from the Bedroom***. Keep cell phones on 'airplane mode' and turn off all antennas (WiFi and Bluetooth) to reduce overall exposure to RF-EMFs. Check the interior and exterior walls for the presence of Smart Meters, electrical boxes, power drops, pool equipment, AC equipment or other motors. Do not sleep with your head next to a wall with these RF, electrical and magnetic nnEMF exposures. A minimum distance of 2 to 5 feet is necessary to avoid the high field levels that lead to biological damage and oxidative effects.

More distance may be necessary for individuals who are more reactive to these fields. Use battery-operated alarm clocks or keep plugged alarm clocks several feet from the head. Many plugged devices emit a strong electrical or magnetic EMF field.

3. ***Avoid Living or Working Under or Near Power Lines and Cell Towers***. Power lines and cell towers emit constant and often very high levels of nnEMFs. Shielding fabrics and paints may be used to mitigate exposure.
4. ***Do Not Carry Cell Phones and Other Wireless Devices on Your Body***. Read the manufacturer's legal warnings on how to reduce RF-EMF exposure. Be aware that many devices currently exceed FCC exposure limits and that testing is based on heat levels and not non-ionizing RF-EMF safety limits which are often far lower than current FCC standards.
5. ***Professional Testing and Analysis Tools***. Accurate determination of inappropriate nnEMF levels can only be obtained from using measuring devices such as RF, EMF or Tri-Field meters. Hiring a certified environmental health consultant to measure home and work exposure levels can effectively decrease exposure and increase positive health outcomes.

6. Health Interventions

In addition to mitigation and avoidance of nnEMFs, numerous health interventions and therapies can be useful for both the prevention and treatment of health issues caused

by over or chronic exposure to nnEMFs. Treatments should always accompany the reduction of toxic exposures to nnEMFs for the best outcomes.

6.1 Acupuncture

Acupuncture has been studied for the therapeutic benefits that result from its ability to regulate signaling pathways that lead to oxidative stress, excitotoxicity, inflammation, neuron survival and death, and also to promote angiogenesis, neurogenesis, and neuroplasticity [55]. These results may prove to be beneficial in the prevention or treatment of chronic or overexposure to nnEMFs. In a review article [55] that studied the effects of acupuncture on apoptosis and autophagy, several key acupuncture points consistently proved to reduce oxidative stress and inflammation and reduce excitotoxicity and neuron death. The most common points studied were: Du20, SP6, ST36, Ren6, Du14, and GB34. Another study [63] explored the benefits of how acupuncture point SP6 can correct cellular imbalances caused by Ca^{2+} leakage that leads to oxidative stress and depression. The results indicated the stimulation of SP6 reduced depression behavior via the alleviation of endoplasmic reticulum (ER) stress and oxidative stress in the amygdala. A study [64] of rats exposed to cadmium toxicity and exhibited high levels of ROS and lowered glutathione levels received acupuncture at LV3 and BL23 for two weeks. The treatment group showed a significant reduction in oxidation via reduced ROS compared to the control group. A review article [66] studied the overall effects of acupuncture on oxidative stress initiated diseases affecting the neurological system. Acupuncture point ST36 proved to reduce ROS production and oxidative/nitrative

stress and inflammation in patients with Vascular Dementia (VD). Acupuncture stimulation at LV3 and GB34 for 15 days provided neuroprotection and anti-inflammatory effects in Parkinson's Disease (PD) patients [66]. A review of conclusions indicated that acupuncture was effective in increasing antioxidant enzymes such as glutathione and SOD [66]. In another study [67] the use of Extra 1 (Yin Tang) can reduce the EEG spectral entropy in both males and females, therefore showing the ability for sedation and improving sympathetic-parasympathetic nerve balance in patients presenting with insomnia, high stress or anxiety symptoms. This may also prove to be helpful when treating patients with similar symptoms who have experienced chronic or over-exposure to nnEMFs. A study [68] of rats exhibiting high levels of oxidative stress and cognitive deficits showed improvement with the stimulation of acupuncture points Ren17, Ren12, Ren6, SP10, and ST36 once daily for 21 days. The treatment group showed a significant increase in hippocampal SOD and glutathione activity compared to the control group [68]. A study [69] confirmed that electroacupuncture at PC6 can offer cardioprotective effects which could possibly be related to its ability to correct Na^{+}, Ca^{2+} overload and mitochondrial damage, but more studies are needed to confirm this hypothesis. Two studies [70, 71] of the stimulation of ST36 and Du20 showed the reduction of ROS activity, oxidative stress, and inflammation that leads to the neurodegenerative process associated with stroke and Vascular Dementia (VD). In a rat study [72] stimulation of acupuncture points LV3, ST36 and Du20 daily for two weeks showed a reduction in the NADPH oxidative pathway and subsequent

reduction in ROS production. Oxidative stress and inflammation are consistently shown to be present in mammals who are chronically or over-exposed to nnEMFs. More specific studies on how acupuncture can help to modulate oxidative stress activity in nnEMF exposure are needed.

Leon Hammer, MD has written several articles about the emergence of the once very rare pulse quality termed 'leather pulse' due to increased exposure to environmental toxins. Leather pulse is described as 'extreme hardness' due to the chronic heat that has depleted fluids causing the vessel walls to lose flexibility and elasticity. According to Chinese medicine, the consequence is extreme essence, yin and blood deficiency [65]. This extreme condition leads to patients experiencing fluctuating symptoms with a high vulnerability to illness, which has previously been termed as 'neurasthenia' by the medical profession [65]. This article specifically correlates the 'leather pulse' with the increase of EMF radiation from the proliferation of wireless technology. His treatment protocol to manage symptoms includes five main principles: 1. eliminate radiation toxicity 2. nourish yin 3. nourish blood 4. nourish jing-essence 5. remove heat from blood and tissues [65]. The protocol includes many acupuncture points and herbal formulas to be tailored to the patients' specific needs. According to Chinese medical theory, radiation creates excess heat and dries the balancing fluid (yin), reduces the formation of blood by depleting the essence that sustains the bone marrow which produces blood. This can ultimately lead to cell mutations, tumors and cancers [65]. This is an interesting correlation to western biomedical studies that show how nnEMFs

affect bone marrow, reducing white blood cell production and altering red blood cell formation and function [48, 51].

6.2 Glutathione

Glutathione (GSH) is the most abundant low molecular weight thiol compound synthesized in the cells and plays a crucial role in protecting cells from oxidative damage and toxicity by maintaining redox homeostasis and regulating the cell cycle [73]. It is synthesized by adding cysteine to glutamate with the addition of glycine and is instrumental in removing many reactive oxygen species (ROS) and protecting against pathological consequences. Excessive ROS production can produce lipid peroxidation and a large influx of calcium into the mitochondria, as may occur with chronic or over-exposure to nnEMFs, causing acidification of the cytoplasm which can result in cell swelling or death [74]. GSH acts as an antioxidant by preventing damage to cellular components caused by ROS and may be a preventive treatment in cases of chronic or over-exposure to nnEMFs. Liposomal GSH supplementation has been shown to increase the plasma GSH levels in autism spectrum disorder (ASD) [75], and provide neuroprotection in mesencephalic neuronal cells in certain disorders such as Parkinson's Disease (PD) and other neurodegenerative and neuropsychiatric conditions that are associated with disturbances in GSH [76]. Liposomal GSH has been shown to directly remove ROS [76] and may thereby decrease inflammatory responses as are often recognized with chronic or over-exposure to nnEMFs. A study [77] investigated the occurrence of decreased glutathione levels in persons with type 2 diabetes and found that the increased

levels of free radicals attributed to the production of pro-inflammatory cytokines such as IL-6 and IL-7 and increased ROS production. One of the known effects of chronic or overexposure to nnEMF is increased blood glucose similar to type 2 diabetes [15] caused by inflammatory responses, therefore supplemental liposomal glutathione may attenuate this process and provide protection from damage caused by nnEMF exposure [89].

6.3 Antioxidants and Food Therapy

Increased oxidation caused by exposure to nnEMFs creates the need for increased levels of antioxidants either by supplementation or food therapy. Therapy can include additional intake of Vitamin A, C, E, Selenium, Iodine, Zinc, CoQ10, chlorophyll, B vitamins, vitamin D, essential fatty acids, flavonoids found in green or black tea, indoles from cruciferous vegetables, and sulfur compounds from garlic. A healthy lifestyle, including consuming nutrient-dense foods and avoiding processed and low nutrient foods, is necessary to preserve and promote health in any environment, however, it is even more important when living in a toxic environment. Consuming a diet consisting of whole foods high in nutrients that protect and promote immune system health, cellular metabolism and detoxification is necessary to strengthen the immune system and possibly delay the effects of chronic or overexposure to nnEMFs. More studies are needed to determine the specific therapeutic levels necessary to assist in mitigating the oxidative damage caused by exposure to nnEMFs.

6.4 Melatonin and Omega 3

A study [18] examined the effects of 900 MHz EMF exposure to rats and determined that the EMF exposed group exhibited damage to brain structures (cortex, hippocampus, and basal ganglia) by a decrease in the number of granular and pyramidal cells in those areas. The same report also indicated a decrease in Purkinje cells in rats exposed to the 900 MHz frequency, which could lead to several degenerative diseases including Autism, Alzheimer's and neurological or immune-based diseases [43,44]. Rats were divided into 4 groups: a control group with no EMF exposure, EMF exposure group, EMF exposure group supplemented with melatonin, and an EMF exposure group supplemented with EPA/DHA. The rats not supplemented with melatonin and EPA/DHA that were exposed to EMFs showed fewer Purkinje cells in the cerebellum as well as decreased numbers of granular cells and decreased pyramidal cells in the hippocampus. The administration of melatonin and EPA/DHA showed neuroprotective effects on repeated EMF exposure.

Melatonin acts as a powerful antioxidant and levels are decreased [61,78, 83] with exposure to nnEMFs. Supplementation is often recommended to assist in restoring healthy sleep patterns and reducing inflammation and cortisol response to stress. If nnEMF exposure is chronic/daily or excessive, long-term supplementation may be required to maintain healthy levels.

6.5 Magnesium

Magnesium is a crucial element for the proper cellular function of ATP, DNA, and RNA [78] and may also alleviate the elevation of calcium [79] caused by exposure to nnEMFs by increasing powerful antioxidant substances such as superoxide dismutase (SOD). A rat study [78] indicated that nnEMF exposure altered the mineral content of their teeth, specifically lowering the concentrations of serum Mg, Ca and Fe as well as decreasing Se levels in the kidneys, muscles, and brain, and decreasing glutathione activity in the kidneys and muscles. Supplementation with magnesium and other minerals may improve health outcomes, however, more studies are needed to determine the specific amounts necessary to alleviate the damage done by chronic or increased exposure to nnEMFs.

Magnesium is known to help calm anxiety and improve sleep as well as assist with detoxification processes by stimulating cell activity.

7. Further Studies are Needed

Studies are needed to determine the effects of how they may apply specifically to persons with chronic overexposure to nnEMFs. For example, further acupuncture studies may include specific points administered to subjects exposed to high levels of nnEMFs compared to a group who simply avoids exposure to nnEMFs and a group who does not receive acupuncture but also is exposed to high levels of nnEMFs. This type of study may help determine the overall effectiveness of acupuncture treatments, the

duration of symptom relief and also determine real biological changes incurred from treatments by utilizing laboratory testing of blood, serum, urine and other diagnostic testing and imaging. This reasoning can be applied to all potential therapies including herbal, nutritional, homeopathic, food therapies, lifestyle modifications as well as simple avoidance practices or physical mitigation of nnEMF exposures.

Table 1

Patient Questionnaire for Overexposure to nnEMF's

(adapted from the Austrian Medical Association's "Guidelines for the diagnosis and treatment of EMF related health problems and illnesses / EMF syndrome")

1. List of Symptoms: How often have you experienced the following health problems in the last 30 days?

Symptoms	*Never*	*Rarely*	*Sometimes*	*Often*	*Very Often*	*Since When? Month / Year*
Anxiety						
Chest Tightness						
Depression						
Difficulty Concentrating						
Restlessness						
Hyperactivity						
Irritability						
Exhaustion						
Fatigue						
Difficulty Finding Words						
Forgetfulness						
Headaches						
Dizziness						
Sleep Problems						

Noise Sensitivity						
Ear Pressure						
Ear Ringing						
Burning Eyes						
Nervous Bladder						

Heart Palpitations						
Blood Pressure Changes						
Blood Sugar Changes						
Muscle Tension						
Joint / Bone Pain						
Skin Rashes						
Burning / Numbness in Extremities						
Other_____						

2. Variation of Health Problems Depending on Time and Location

Which health problems do you perceive to be the most severe?	
Since when have you been experiencing these health problems?	
At what times of the day/week/month do the health problems appear?	
Is there a place where health problems increase?	
Is there a place where health problems increase or are very severe? (eg. home, work, driving, hotels, etc.)	
Is there a place where health problems decrease or disappear completely? (eg. home, work, vacation, parks/nature, friends house, etc.)	
Do you have an explanation for these health problems?	
Are you experiencing stress?	
Please list any environmental assessments made, measurements made or any measures taken up to now.	
Please list any environmental medicine diagnoses and treatments given up to now.	

3. Assessment of nnEMF Exposure at Home and Work

A. Do you use a cell phone at home or work? _____

How long have you been using it? _____

How much do you use it to make calls per day?
(hours/minutes)_____

Do you watch movies on your phone or pad device?_____

How many minutes/hours per day?_____

Have you noticed any relation to your health problems?_____

B. Do you have a cordless phone at home or work?_____

How long have you had it? (months/years)_____

How much do you use it to make calls per day?_____

Have you noticed any relation to your health problems?_____

C. Do you use wireless internet at home/work/car?_____

How long have you been using it? (months/years)_____

How much do you use it per day? (hours/minutes)_____

Have you noticed any relation to your health problems?_____

D. Is there a cell tower near your home or workplace?_____

How long has it been there? (months/years)_____

At what distance is it from your home/work?_____

Have you noticed any relation to your health problems?_____

E. Do you use wireless headsets?_____

How long have you been using them? (months/years)_____

How much do you use them per day? (minutes/hours)_____

Have you noticed any relation to your health problems?_____

F. Do you have a SmartMeter at your home or work?_____

How long have you had it? (months/years)_____

Where is it located? (near bedroom, etc)_____

Have you noticed any relation to your health problems?_____

G. Do you have Smart appliances/devices at home or work?_____

Specify what devices_____

How long have you had them?_____

Have you noticed any relation to your health problems?_____

H. Do you have energy efficient light bulbs in your immediate vicinity? (desk lamp, bedside lamp, etc)_____

How long have you had them? (months/years)_____

How much do you use them per day?_____

Have you noticed any relation to your health problems?_____

I. Do you Bluetooth / wireless / WiFi in your car?_____

How long have you been using it? (months/years)_____

How much time do you spend in your car per day?_____

Do you often drive on toll roads? (daily/weekly)_____

Have you noticed any relation to your health problems?_____

J. Are there power lines, transformer stations near your home or your workplace?_____

   How long are you exposed per day?_____

   Have you noticed any relation to your health problems?_____

K. Where are the power drop boxes, fuse box panels, etc. located in your home or work? _____

   How much time per day do you spend near them?_____

   Have you noticed any relation to your health problems?_____

Definitions of Terms and Abbreviations

nnEMF: non-native EMF: any man-made frequency or electrical impulse

RF-EMF: radio frequency EMF: wireless devices, WiFi, cell phones, towers

E/LF-EMF: low frequency EMF: electrical motors/boxes/panels, electrical wires

ONOO-: peroxynitrite: a destructive free radical oxidant

BBB: blood brain barrier

8-OHdG: C 8-hydroxyguanosine: biomarker of oxidative stress, carcinogenesis, DNA damage

ROS: reactive oxygen species: natural by-product of the metabolization of oxygen

VGCC's: voltage gated calcium channels:

TNF-a: tumor necrosis factor alpha: cytokine involved in systemic inflammation / immune cells

mpk-1: mitogen activated protein kinase: regulate immune responses / inflammation

ERK: extracellular signal regulated kinase: regulates cell proliferation / T cells

mkp-1/ERK pathway: signalling or 'on' 'off' switch often involved in development of cancers

SNPs: single nucleotide polymorphisms: genetic variations in DNA affect normal gene function

mTOR: mammalian target of rapamycin: regulates cell metabolism, growth and death

EHS: electrohypersensitivity: functional impairment caused by exposure to EMFs.

6-OH melatonin sulfate: urinary metabolite of melatonin

malondialdehyde: maker for lipid peroxidation

NADPH: Nicotinamide adenine dinucleotide phosphate: donates electrons to reduce oxidized compounds

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