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Review

Electromagnetic hypersensitivity: Fact or fiction? ☆

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ABSTRACT

As the prevalence of wireless telecommunication escalates throughout the world, health professionals are faced with the challenge of patients who report symptoms they claim are connected with exposure to some frequencies of electromagnetic radiation (EMR). Some scientists and clinicians acknowledge the phenomenon of hypersensitivity to EMR resulting from common exposures such as wireless systems and electrical devices in the home or workplace; others suggest that electromagnetic hypersensitivity (EHS) is psychosomatic or fictitious. Various organizations including the World Health Organization as well as some nation states are carefully exploring this clinical phenomenon in order to better explain the rising prevalence of non-specific, multi-system, often debilitating symptoms associated with non-ionizing EMR exposure. As well as an assortment of physiological complaints, patients diagnosed with EHS also report profound social and personal challenges, impairing their ability to function normally in society. This paper offers a review of the sparse literature on this perplexing condition and a discussion of the controversy surrounding the legitimacy of the EHS diagnosis. Recommendations are provided to assist health professionals in caring for individuals complaining of EHS.

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Not everything that is faced can be changed. But nothing can be changed until it is faced.

James Baldwin

1. Introduction

In the early years of the 21st century, there are increasing reports throughout the world of individuals and clusters of people complaining of various clinical symptoms in response to minimal exposure to everyday levels of electromagnetic radiation (EMR). Some individuals experience difficulty around wireless systems, when using cordless or cell phones, when exposed to some types of artificial light, or in response to various other common electromagnetic exposures. Once exposed, such vulnerable individuals often develop a variety of symptoms involving various organ systems. Although originally thought to be psychogenic in origin, such symptoms are being reported by ever-increasing numbers of previously healthy individuals (Hallberg and Oberfeld, 2006) – a phenomenon which has generated a closer assessment of the origins of electromagnetic hypersensitivity (EHS) complaints.

In this paper, a review of the emerging literature related to the perplexing EHS condition will be presented along with a case history detailing the development of EHS and subsequent recovery in an otherwise healthy individual. Consideration of physical, psychological and social aspects of this disorder will be presented. As well as an exploration of the polarizing debate that surrounds the EHS issue, recommendations are provided as to how clinicians might empower patients with EHS to regain their health and improve their wellbeing.

2. Background

The surge of wireless telecommunication throughout the world is provoking many people to question whether various EMR frequencies can have adverse effects on human health. It is widely accepted that ionizing high-frequency radiation from X-rays or emissions from radioactive materials are hazardous, with high energy levels capable of harming humans; (Ramirez et al., 2005; Brenner et al., 2003) the detrimental impact of non-ionizing radiation on humans, however, is not widely accepted.

A variety of sources emit anthropogenic EMR including high voltage power lines, cell phones, wireless internet, hair dryers, CT scanners, and radioactive nuclei (Fig. 1). While the wavelengths and frequencies emitted by these sources vary, they all have the capacity

to emit energy in the form of electromagnetic radiation. The question for many scientists and patient advocacy groups, however, is twofold: 1) do some frequencies of non-ionizing radiation have the potential to cause adverse physiological effects?; and 2) do some individuals become hypersensitive to otherwise non-perceptible everyday exposure levels of electromagnetic radiation (EMR)?

These quandaries prompted the World Health Organization (WHO) to form an international coalition in 1996 to research the impact of EMR on human health (World Health Organization, 2011a). The coalition continues to the present time and conducts research studies that are underway around the globe. While there is ongoing debate about the potential adverse effect of non-ionizing EMR, there appears to be an intriguing divide. Thus far, most research carried out by independent non-government or non-industry affiliated researchers suggests potentially serious effects from many non-ionizing EMR exposures; (Sage, 2007) research funded by industry and some governments seems to cast doubt on the potential for harm (Genuis, 2008). Emerging research, however, continues to uncover an assortment of potential sequelae resulting from exposure to anthropogenic EMR (Genuis, 2008; Dode et al., 2011; Dode, 2011; Li et al., 2011; Marino et al., 1977; Kabuto et al., 2006) including the finding – recently reported in the *Journal of the American Medical Association* (JAMA) – of alterations in brain glucose metabolism in response to cell phone radio frequencies (Volkow et al., 2011).

The issue of EHS legitimacy remains equally contentious with strong voices advocating on both sides. As widespread exposure to anthropogenic EMR with reports of consequent hypersensitivity is a recent phenomenon unprecedented in human history, it is interesting to trace a few major milestones in the unfolding EHS story.

2.1. Historical milestones related to electromagnetic hypersensitivity

In the 1950s, various centers in Eastern Europe began to describe and treat thousands of workers presenting with recent onset of clusters of multi-system complaints. These individuals were generally employed in i) the manufacture, inspection, operation, or repair of equipment involved in microwave transmission, and/or ii) the operation of radio frequency devices. The constellation of health complaints was initially given the name 'Radio Wave Sickness' and afflicted individuals often presented with symptoms such as headaches, weakness, sleep disturbance, emotional instability, dizziness, memory impairment, fatigue, and heart palpitations (Sadchikova, 1960).

This emerging public health issue persisted through the 1960s and 70s and early reports from various parts of the world began to detail

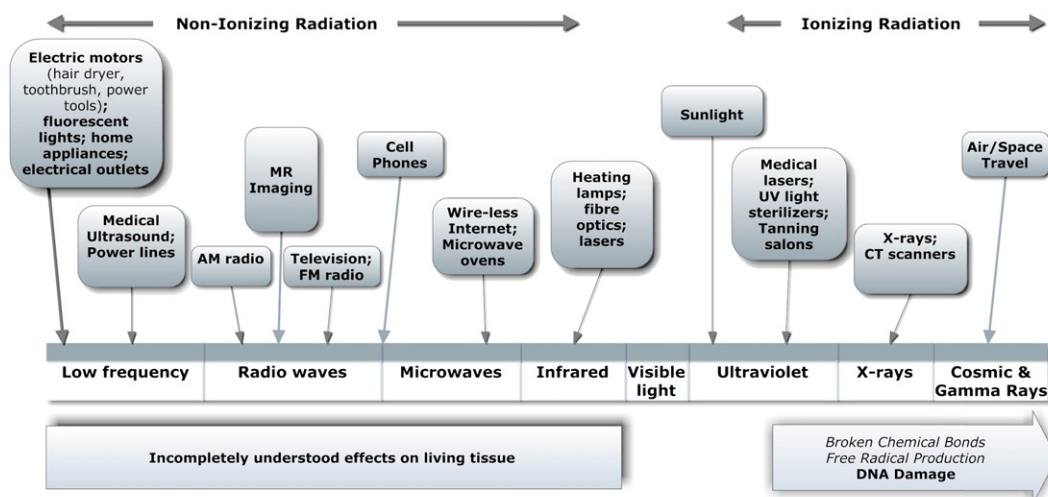


Fig. 1. The electromagnetic spectrum.

research findings on the health effects of exposure to microwave and radiofrequency radiation (Klimková-Deutschová, 1973; Glaser, 1971; Zaret, 1973; Frey and Seifert, 1968; Frey, 1970). Increasing attention also began to mount in the public arena with books such as 'The Zapping of America' in 1977 (Brodeur, 2000) and 'Terminal Shock' in 1985 (DeMatteo, 1985) fuelling escalating concern about adverse EMR exposure. Although scientific discussion of this health issue was sparse in the medical literature, a neuroscientist from Sweden, Dr. Olle Johansson began to document a constellation of symptoms, including CNS complaints, cardiac symptoms, and skin changes in individuals exposed to various sources of non-ionizing radiation. In response, a Swedish Association for the Electrosensitive ('FEB Föreningen för el-och bildskärmskadade') was formed and established a mandate to support those with this condition they called 'Electrical Hypersensitivity'. To engender further recognition and support, this group in 1994 disseminated a press release exhorting individuals throughout the globe "to join hands" in addressing this mounting health challenge (The Swedish Association for the Electrosensitive, 1994) – an affliction that has since been referred to as electrical hypersensitivity, electromagnetic hypersensitivity, electrical sensitivity or simply electro-sensitivity.

Clinical research to verify the physiological nature of this condition began in the 1990s. Rea et al. in 1991 reported abnormal responses to certain EMR frequencies (in comparison to blank challenges) by some hypersensitive individuals (Rea et al., 1991). As well as various clinical symptoms, a double blind assessment in this study of various physiological parameters confirmed pulmonary and cardiac changes in some EHS patients (Rea et al., 1991). Ongoing work by Johansson and colleagues confirmed evidence of physiological dermal changes in response to certain EMR exposures in sensitive individuals (Johansson et al., 2001; Johansson and Liu, 1995) With this latter observation, a hypothesis on the pathophysiological mechanism of EHS was introduced based on theorized degranulation of mast cells in various tissues – with release of a spectrum of mediators such as histamine – in response to EMR exposure (Gangi and Johansson, 2000).

In the early 2000s, estimates of the occurrence of EHS began to swell with studies estimating the prevalence of this condition to be about 1.5% of the population of Sweden, (Hillert et al., 2002) 3.2% in California, (Levallois et al., 2002) and 8% in Germany (infas Institut für angewandte Sozialwissenschaft GmbH, 2003). With the escalating prevalence of EHS and the increasing research interest in this health condition, the WHO convened a working group and an international meeting in 2004 in Prague to discuss this apparent disorder. Although not acknowledging a physiological causation for the EHS entity, the group defined EHS as "... a phenomenon where individuals experience adverse health effects while using or being in the vicinity of devices emanating electric, magnetic, or electromagnetic fields (EMFs) ... Whatever its cause, EHS is a real and sometimes a debilitating problem for the affected persons" (Mild et al., 2004). Ongoing debate about the veracity of the EHS affliction has erupted, however, as various researchers have found insufficient evidence to support claims about the physiological nature of this disorder. In this paper we endeavor to review the literature on EHS and to then explore apparent contradictions in evidence regarding the etiology and legitimacy of the EHS diagnosis.

2.2. Overview of electromagnetic hypersensitivity

In review, the reported phenomenon whereby vulnerable individuals experience health symptoms from being in close proximity to devices emitting some frequencies of EMR is referred to as EHS (Leitgeb and Schrottner, 2003). While the majority of the population do not perceive any health changes in response to EMR exposure, an increasing number of individuals report a variety of unpleasant symptoms (Table 1) that they attribute to the EMR exposure. The EMR appears to act as a trigger for perceived physiological disturbances in the body. The range of frequencies associated with EHS is usually within the non-ionizing range of the electromagnetic spectrum (Fig. 1).

Table 1

Common reported signs and symptoms associated with electromagnetic hypersensitivity (EHS).

Some common signs and symptoms of electromagnetic hypersensitivity (Havas, 2006; Johansson, 2006)

Headache
Thought processing difficulties
Memory impairment
Heart palpitations
Sleep disorder
General malaise
Blurred vision
Weakness
Dizziness
Chest discomfort
Muscle pain
Tinnitus
Fatigue
Nausea
Night sweats
Restless legs
Paresthesias

As a bioelectrical entity, the human organism in the 21st century is increasingly exposed to three general types of anthropogenic non-ionizing EMR:

- Extremely low frequency EMR from power lines, electrical appliances and electronic equipment.
- Electrical pollution: the operation of some electronic equipment (such as plasma televisions, some energy efficient appliances, variable speed motors, etc.) has the ability to manufacture frequency signals generally in the 3–150 kHz range (very low to low frequency portion of the electromagnetic spectrum) which then flows along and radiates from wiring in affected homes and other buildings. This has been referred to as electrical pollution or dirty electricity (Havas, 2006).
- Microwave and radiofrequency emissions from wireless telecommunication devices such as wireless telephones, cell towers, antennas as well as broadcast transmission towers (Sage, 2007).

Some individuals with EHS experience symptoms when exposed to EMR in the extremely low frequency ranges; others appear to be more sensitive to frequencies emitted in the radiofrequency or microwave range. Furthermore, some people will complain of distinct symptoms in response to different frequencies – such as mood changes when exposed to one frequency range and musculoskeletal discomfort at a different frequency range. Some appear to have sensitivity responses throughout the non-ionizing range of frequencies, and a subgroup manifests sensitivity with CNS symptoms and visual disturbance in response to natural frequencies in the visible light component of the spectrum (Coyle, 1995). There is also research exploring the link between some disorders of hearing such as tinnitus and sensitivity to certain frequencies of EMF (Landgrebe et al., 2009).

As a result, unpleasant symptoms may occur when the vulnerable individual has exposure to EMR produced by common objects such as cell phones, wireless headsets, fluorescent lighting, some computers, cordless phones, appliances, and telecommunications signals (Havas, 2006). Additional sources of EMR sometimes not considered are motors such as in furnaces, various types of electronic surveillance equipment (e.g. metal detectors at airports), as well as industrial machinery such as medical diathermy (cautery tools) (Floderus et al., 2002).

Until recently, the diagnosis of EHS has not received much support from the medical community due to the lack of objective evidence to support the EHS diagnosis. In an effort to determine the legitimacy of EHS as a neurological disorder, however, a collection of scientists and physicians recently conducted a double-blinded research study on the outcome of EMR provocation which was subsequently published in the *International Journal of Neuroscience* (McCarty et al., 2011). The researchers were able to objectively demonstrate somatic reactions

from an EHS patient in response to EMR provocation using levels typically found in the contemporary environment. They conclude that “EMF hypersensitivity can occur as a *bona fide* environmentally-inducible neurological syndrome” (McCarty et al., 2011).

Furthermore, a recent study by Havas et al. (2010) demonstrated physiological responses to low-dose EMR exposure in some individuals. Immediate and dramatic changes in both heart rate and heart rate variability were evident in affected participants with microwave exposure levels at only 0.5% of existing Canadian and American guideline limits (Havas et al., 2010). This study suggests that some individuals may experience cardiac symptoms and autonomic nervous system dysregulation as a pathophysiological response to electromagnetic stressors.

2.3. Pathogenesis of electromagnetic hypersensitivity

As with other multi-system illnesses such as multiple chemical sensitivity (MCS), fibromyalgia, and chronic fatigue syndrome (CFS), the exact pathogenesis of EHS is not completely understood. Emerging evidence suggests, however, that the aberrant biological process for developing EHS occurs through an intriguing pathophysiological mechanism (Fig. 2) referred to as sensitivity-related illness (SRI) (Genuis, 2010a; De Luca et al., 2010). In addition, recent evidence has demonstrated a potential for disruption of catecholamine production in response to EMR that may affect the human organism in many ways.

a) Sensitivity related illness

SRI describes a pathophysiological response to bioaccumulation of foreign materials originating from various potential sources such as toxic chemicals, surgical implants, infections, dental materials, and radioactive compounds. The mechanism by which the body becomes hyper-reactive or hyper-sensitized to electromagnetic energy may start with a totally unrelated toxicant insult or multiple insults in the form of foreign exposures. This pathway to illness has been referred to as TILT (Toxicant Induced Loss of Tolerance) (Miller, 2001; Miller, 1997).

After a threshold of bioaccumulation is achieved, an individual's immune system loses the normal adaptive responses with immune tolerance and becomes sensitized to exposures from seemingly

insignificant and unrelated environmental stimuli. For example, a study in Sweden found that people with EHS had significantly higher levels of accrued polybrominated diphenyl ethers (PBDEs) — very common and hormonally active persistent pollutants used as flame retardants and which bio-accumulate in adipose tissue (Hardell et al., 2008). (Until recently, these compounds have routinely been applied to mattresses, for example, to meet fire regulation standards and consequently off-gas nightly into the slumbering recipient.)

In patients with TILT, subsequent triggering of the hypersensitive immune system by chemical or electromagnetism precipitates a clinical reaction resulting from a dysregulated biochemical response from various components of the immune system (Genuis, 2010a; Duramad et al., 2007; Tracey, 2007). It is unclear why some people, after developing TILT, develop sensitivity to chemical triggers, to electromagnetic stimuli, or to both. The nature of the reaction is mediated by the unique makeup of the bioaccumulated toxicant load and/or the distinctive genetic and biochemical thumbprint of the individual (Genuis, 2010a). The ensuing antibody, cytokine, interleukin, and chemokine activation by environmental stimuli may affect various organ systems and physiological functions including the endocrine system, the autonomic nervous system, genetic expression, and so on — resulting in abnormal multi-system signs and symptoms (Genuis, 2010a; Ashford and Miller, 1998). (This activation phenomenon has been referred to as MATES: Minute Assorted Triggers Evoke Symptoms (Genuis, 2010a)).

Although the precise pathophysiological mechanisms of the hypersensitivity response to EMR have not been clearly delineated, emerging research confirms that some frequencies of EMR can exert immune dysregulation in vitro with increased production of selected cytokines — a common feature of SRI (Stankiewicz et al., 2010; Dabrowski et al., 2003). Furthermore, the development of the immune dysregulation associated with SRI and EHS after toxicant bioaccumulation appears to involve genomic considerations. De Luca et al. (2010) discovered that people who suffer from EHS may have various defects in genes involved in toxicant elimination within their body. These genes are responsible for producing antioxidant/detoxification enzymes such as glutathione-S-transferases, superoxide dismutase, catalase, N-acetyl transferases, cytochrome 450 enzymes and others (Wormhoudt et al., 1999). As a result these people may have impaired detoxification mechanisms resulting in a predisposition to toxicant bioaccumulation.

b) Catecholamine dysregulation

Another important mechanism that may be responsible for some of the manifestations of EHS involves disruption and dysregulation of catecholamine physiology in response to adverse EMR (Buchner and Eger, 2011). Although EMR frequencies were first reported to affect regulation of endocrine systems including adrenal gland function in 1977, (Marino et al., 1977) recent research highlights a dose-response relationship which occurs well below established limits for technical radiofrequency radiation exposure (Buchner and Eger, 2011). Furthermore, with ongoing exposure — such as living in close proximity to a cell phone base station — this pathophysiological reaction may involve a protracted alteration of norepinephrine, epinephrine, dopamine and phenylethylamine biology with yet unrecognized health implications (Buchner and Eger, 2011). As these endogenous compounds are well known to be instrumental in several fundamental biological actions including autonomic nervous system function, neurotransmission, state of alertness and response to stress, it is uncertain if dysregulation elicited by adverse EMR exposure may be involved in EHS and/or predispose vulnerable individuals to a variety of health issues associated with catecholamine and neurotransmitter dysregulation.

Other pathophysiological mechanisms for the EHS phenomenon have been proposed. Costa et al. (2010) have submitted that heavy metal poisoning has the potential to precipitate EHS — as EMR influences metals to become re-mobilized in the body possibly resulting in systemic symptoms. There has also been the suggestion that in the

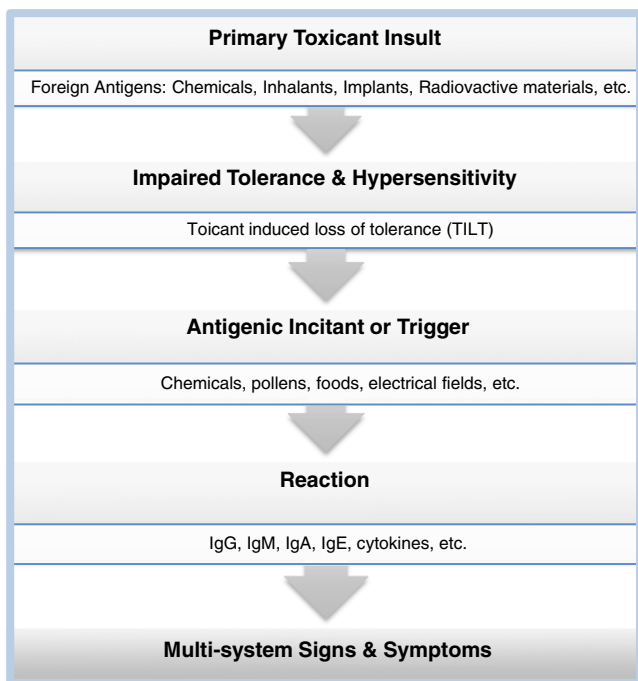


Fig. 2. Pathogenic mechanism for development of sensitivity related illness.

complex clinical environment of the 21st century, EHS may – in part – involve a multifaceted interplay between certain neurocognitive factors within the patient's psyche (Landgrebe et al., 2008).

In review, the exact pathophysiological mechanism of EHS has not been fully elucidated. The observation that 1) EHS patients are generally previously healthy individuals who have sustained a toxicant burden; and 2) EHS often subsides when elimination of toxicants is achieved, suggests that the TILT mechanism may feature prominently in the ethology of this complex clinical phenomenon. The precise role of prolonged catecholamine dysregulation in the manifestation of EHS remains to be elucidated.

2.4. Biochemical markers for electromagnetic hypersensitivity

It would be clinically advantageous if there was one pathognomonic marker reflecting a defined mechanism for the development of EHS. Such is not the case. Ongoing research continues to identify changes within the immune system that may be involved in the immune dysregulation associated with EHS. For example, while DNA bond breakage generally requires the high thermal energy found in ionizing radiation, Mashevich et al. (2003) found that very low frequency EMR and microwaves can lead to altered genotypes in human lymphocyte DNA via non-thermal protein stress. Furthermore, recent evidence suggests that DNA replication and mitosis can be disrupted and form altered proteins in the presence of EMR (Lin et al., 1997; Lin et al., 1998; Tsurita et al., 1999; de Pomerai et al., 2000). Accordingly, abnormalities within cellular machinery may lead to aberrant immune responses. No single biochemical marker unique to EHS that reflects such underlying changes, however, has yet been identified.

Furthermore, the immune system may become hyper-reactive in direct response to regulatory influences from other organ systems such as the CNS. A paper by D'Andrea et al. (2003) explains that microwaves and radio frequencies are capable of affecting central nervous system physiology. Through a review of numerous laboratory studies on humans and animals, microwaves were shown to affect the permeability of the blood brain barrier to drugs and to impact hormones, blood cortisol levels, memory functioning, electroencephalogram (EEG) readings, as well as neurochemistry markers (D'Andrea et al., 2003; Salford et al., 2008). Thus far, however, no consistent laboratory finding has been identified which objectively establishes a diagnosis of EHS.

3. Management of electromagnetic hypersensitivity

With appropriate care, it is possible for patients with EHS to improve considerably and be restored to normal functioning. By understanding the pathway to the development of SRI, by practicing avoidance of triggers and further toxicant exposure, and by instituting appropriate therapeutic measures when necessary, patients consistently improve. An overall environmental approach to managing exposure related illness, such as EHS, is depicted in Fig. 3 (Genuis, 2010a). Details of this

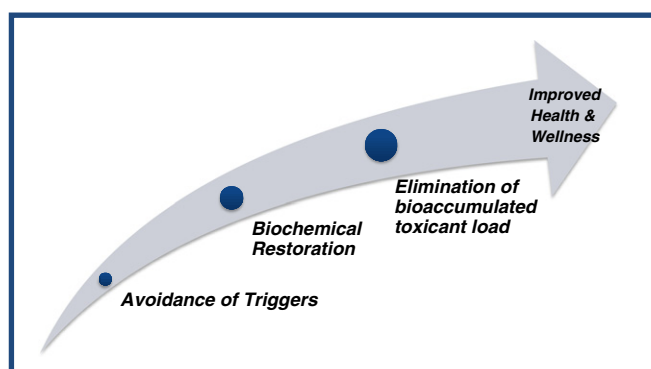


Fig. 3. Intervention approach to manage sensitivity related illness.

management approach can be found in other papers (Genuis, 2010a; Genuis, 2011) but the general approach is summarized in the three following phases.

(a) Avoid environmental triggers

In order for symptoms to diminish, it is necessary for SRI patients to avoid inciting triggers. For patients with EHS, they must be vigilant about avoiding frequencies of EMR that ignite their symptoms. Table 2 makes suggestions on how common sources of EMF exposure might be reduced for people with EHS. As a result of the underlying toxicant burden, however, many individuals with EHS also experience symptoms in response to chemical triggers. These must be addressed as well for success to be achieved. Various jurisdictions have begun to establish safe residences and places of respite for individuals suffering from EHS.

(b) Remediate nutritional and biochemical status

Once a concerted effort is underway to avoid inciting exposures, the next step involves remediating the nutritional biochemistry of the individual. During states of chronic stress and inflammation, the body quickly depletes its store of nutrients required for the cellular machinery and normal functioning of inherent physiology. Biochemical testing is available to assess the state of nutritional biochemistry, and interventions should be tailored to address specific abnormalities. Detoxification biochemistry must be optimal in order to proceed to the final step – diminution of the total toxicant load that initiated the health problem in the first place.

Table 2

Examples of strategies to reduce electromagnetic radiation.

Sources of adverse EMR	Considerations to reduce EMR exposure
Cell phones and cordless phones	<ul style="list-style-type: none"> Minimize use of cell and cordless phones and use speaker phones when possible Leave cell or cordless phone away from the body rather than in pocket or attached at the hip
Wireless internet	<ul style="list-style-type: none"> Use wired internet Turn off the internet router when not in use (e.g. night-time) Use power line network kits to achieve internet access by using existing wiring and avoiding wireless emissions.
Computers releasing high EMR	<ul style="list-style-type: none"> Limit the amount of time spent working on a computer Avoid setting a laptop computer on the lap Increase the distance from the transformer Stay a reasonable distance away from the computer
Handheld electronics (electric toothbrush, hair dryer, Smart phone, electronic tablets, etc.)	<ul style="list-style-type: none"> Limit the use of electronics and/or revert to using power-free devices Turn devices off before going to sleep Minimize electronics in bedrooms
Fluorescent lights	<ul style="list-style-type: none"> Consider using alternate lighting such as incandescent. (Uncertainty exists about the safety of LED lights) Rely on natural sunlight for reading
Household power	<ul style="list-style-type: none"> Measure levels of EMR and modify exposures as possible Avoid sleeping near sites of elevated EMR Filters can be used to mitigate dirty power
High voltage power lines and substations	<ul style="list-style-type: none"> Consider relocating to an area not in close proximity to high voltage power lines
Transmission towers and emitters (cell phone tower, radar, etc.)	<ul style="list-style-type: none"> Maintain considerable distance from emitters Consider forms of shielding (shielding paints; grounded metal sheets)
Utility neutral-to-ground bonded to water pipes	<ul style="list-style-type: none"> Increase size of neutral-wire to substation and install dielectric coupling in water pipe.

(c) Reduce the toxicant burden

The total burden of toxicants encumbering the immune system must be reduced to diminish the hyperactive immune response and to achieve optimal health. Some recent research is beginning to make the link between specific toxicants such as heavy metals and EHS, (Costa et al., 2010) but it is imperative to explore the total load that encompasses the range of potential toxicants including various adverse chemical agents, implants, some dental materials, mold exposures and other toxins (Genuis, 2012). For some toxicants, the avoidance of further exposure will allow the body to detoxify spontaneously and eliminate these compounds; for some persistent toxicants such as cadmium, lead, perfluorinated compounds, and others, active intervention may be required to reduce the accrued toxicant burden (Genuis, 2011; Genuis, 2010b). When detoxification is undertaken effectively and further exposure is avoided, patients consistently begin to recover from their hypersensitivity problems.

3.1. Explore associated health challenges

Management of all EHS patients should include a thorough health assessment as well as investigations and interventions to identify and address all determinants of illness. Both Dahmen and Hillert, for example, found that people with EHS had an elevated prevalence of thyroid dysfunction and liver disease (Hillert et al., 2002; Dahmen et al., 2009). The mental health symptoms that sometimes accompany or result from EHS may be responsive to cognitive behavioral therapy with amelioration of depression, anxiety, phobias, and other related symptoms (Hillert et al., 1998; Rubin and Das, 2006).

One of the major health challenges with EHS is sleep quality. As adverse EMR is frequently encountered inadvertently in the bedroom from sources such as electronics, wireless systems, and possibly metal bed materials (Hallberg and Johansson, 2010), restful sleep is often interrupted. Sleep interference and disturbed day/night rhythms often ensue resulting in delayed waking, daytime napping, impaired concentration, and other issues. Any EHS treatment program needs to check for and address factors that may incite sleep disturbance (Hobbs, 2011).

3.2. Neural re-training

There is ongoing discussion in the scientific literature about neuroplasticity and the innate ability of the brain to be retrained with resultant modification of established brain responses (Berlucchi, 2011; Cioni et al., 2011). As a result, there has been the emergence of training interventions endeavoring to modify hypersensitivity reactions in patients with various sensitivity related conditions including EHS (Hooper, 2011). Limited scientific study is available to date on the efficacy of such neural retraining approaches, but some patients anecdotally report that reducing the toxicant burden combined with intense retraining of pathological brain responses yields preferred outcomes.

3.3. EMF shielding

Recognizing that the initiating trigger of EHS is exposure to EMR, some EHS patients endeavor to block exposure to offending frequencies within their home or workplace via shielding modalities (Less EMF Inc., 2011). While some frequencies of EMR can be readily blocked by various materials, other anthropogenic sources of EMR such as low frequency magnetic waves are more difficult to block. No scientific study of the impact of such shielding techniques on EHS patients is available thus far, but anecdotally some individuals claim benefit. The issue of shielding, however, can be complex as exposure can also be affected by reflection within a shielded environment so that adverse EMR can backfire into the allegedly protected domain (Torrens, 2008).

3.4. Grounding technique

A simple technique with uncertain efficacy involves the discharge of accumulated electrical charge into the earth by intermittently 'grounding' the EHS patient (Chevalier et al., in press). This unassuming practice involves placing bare feet on the earth, or on another conductive surface (e.g. metal sheet) which is in direct contact with the earth. Although more science is required to determine the credibility of this approach, some patients with disabling EHS report clinical benefit and provisional relief from symptoms using this modality. Caution is required, however, as grounding in the area of buried power lines or in the vicinity of current from other electrical sources diverted into the earth may aggravate symptoms.

A case history is presented for consideration to illustrate the challenges and potential successful outcomes associated with clinical management of this condition.

4. Case history of electromagnetic hypersensitivity

A 35 year-old previously healthy, well-educated and highly functioning married mother of two children noticed an abrupt decline in her health and ability to function within three weeks of moving into a newly renovated house. She developed progressive fatigue, muscle pain, cognitive decline, anxiety, and uncharacteristic memory impairment – to the point where she forgot to pick up her children from elementary school on multiple occasions. Despite seeing multiple physicians and undergoing extensive testing (including MRIs and CTs) her symptoms worsened to the point where she experienced ongoing night sweats, nausea, severe headaches, muscle weakness, myalgias and weight loss of near 20 lb. No explanation was found and she was given assorted diagnoses including allergic disease, psychosomatic illness, early multiple sclerosis and chronic fatigue syndrome.

It was notable, however, that when she went on trips away from the newly renovated house, her symptoms conspicuously improved, only to return in full force when she came home. Concerned that she may be experiencing an adverse reaction within her home environment, she thoroughly cleaned the premises and instituted air and water purification as well as making every effort to eat a well-balanced diet. Despite her efforts, the symptoms continued to worsen. In desperation she sought help from additional health professionals and was introduced to the idea of possibly being sensitive to EMR within her home.

With vigilant observation, she made a clear connection between her symptoms and exposure to the numerous electrical items in her environment. Her symptoms were worse when near fluorescent lights, microwaves, and kitchen appliances. Despite limiting her exposure to these appliances, however, her night time symptoms of nausea, fevers, chills, tremors, and vomiting persisted; whenever she spent a night at a motel, these symptoms would abate.

In addition to her own health issues, she noted increasing illness in other family members. Her children developed unremitting respiratory ailments as well as several ear and throat infections requiring repeated medical interventions; her husband also developed respiratory difficulties including pneumonia. When looking for the initiating cause of the health problems, she noted a number of off-gassing chemical exposures related to the recent renovations and, in particular, discovered a floor stain that had been improperly finished and was off-gassing heavily. With concern about the potential impact of ongoing off-gassing from the renovation in addition to a 200 A power supply to their home and close proximity to a power generation station, they decided to move to an environment with less EMF and chemical exposure.

Upon moving to an older home near a nature reserve, her symptoms began to improve but did not completely resolve until she took measures to reduce the quantity of EMR in her new environment – measures such as converting to wired internet connections and

turning off power to non-essential appliances during the night. Her health subsequently improved markedly and she was able to return to normal activities including cycling with her family, rollerblading, and going for long walks. Thirteen years later, her health remains stable and she is able to live an active normal life, but takes ongoing measures to avoid chemical and pronounced EMF exposures.

It is hypothesized that this previously healthy individual experienced a toxicant burden and consequent TILT after moving into a newly renovated home with various chemical exposures. A hypersensitivity to EMR ensued resulting in myriad symptoms – that settled when she avoided EMR. After relocation and avoidance of further exposure, her body burden diminished as she spontaneously eliminated toxicants by endogenous mechanisms. As a result of the diminished total toxicant load, her SRI slowly diminished as her TILT abated, and her hypersensitivity to electromagnetic triggers settled.

5. Quality of life considerations

For individuals suffering from EHS, there are a number of issues that consistently arise. A major challenge of EHS is the imperceptible nature of EMR to otherwise healthy people. The absence of perceptible stimuli inclines physicians, family members, friends, employers, and insurance companies to classify the symptoms of EHS as psychogenic or psychiatric in origin (Rubin et al., 2010; Kanaan et al., 2007; Das-Munshi et al., 2006; Rubin et al., 2011). As a result, patients with EHS frequently experience ridicule and eventual rejection or dismissal by their usual systems of support. This common outcome has a profound impact on many aspects of life including employment, accommodation, health-care, finances as well as having a profound bearing on social, emotional and psychological dimensions of life (Parsons, 2011).

5.1. Social impact

EHS has been described by patients as a 'loner's disease'. Due to the prevalence of ubiquitous EMR in the contemporary urban environment, EHS causes patients to experience extreme social isolation. The serious symptoms confine them to their home. Venturing out to shopping malls, libraries, theaters, hospitals, and doctors' offices is often precarious because of the prevalence of wireless routers, cell phones, antennas, and other sources of EMR. Furthermore many patients are often no longer able to spend time in the homes of family members due to EMR issues. As a result, huge stresses are placed on marriages and families – especially if family members are not willing to reduce EMR in the home environment.

The pronounced physical and psychological symptoms often prompt EHS patients to take medical leaves from their employment and many eventually leave work all together. The inability to participate in previously enjoyed leisure activities and meaningful occupations is worsened by the lack of empathy and fractured relationships with family, colleagues and health care providers.

5.2. Physical and psychological impact

People with EHS frequently experience debilitating symptoms which can affect any body system including the central nervous system, musculoskeletal system, gastrointestinal tract, and endocrine system. Symptoms often lead to ongoing psychological stress and intense fear of being 'hit' by EMR wherever they go. Many patients become incapacitated by such fear – knowing that an invisible wireless signal may incite major symptoms in their body at any time and any place. This unremitting fear and preoccupation with health issues can have a major impact on well-being, to the point where EHS individuals develop a phobia and disdain of electricity, with some desiring to escape civilization.

Cross-sectional surveys conducted in Sweden found that people with EHS expressed increased tendencies to anxiety and states of

hyper-vigilance and stress (Johansson et al., 2010). These psychological factors may be further mediators of illness in people with EHS and place them at increased risk for other psychologically-related disorders (De Luca et al., 2010; Johansson et al., 2010). Furthermore, the lack of support and acceptance by loved ones often leads EHS individuals to question their own sanity and to states of diminished self-esteem. Finally, the underlying toxicant burden associated with EHS makes patients vulnerable to other sensitivity related conditions such as fibromyalgia, chronic fatigue syndrome, and multiple chemical sensitivity (Genuis, 2010a).

6. Debate about the legitimacy of electromagnetic hypersensitivity

Despite increasing reports in the world literature recognizing EHS as a legitimate clinical entity, (World Health Organization, 2011a; McCarty et al., 2011; Havas et al., 2010; Havas, 2000; World Health Organization, 2011b; Chemical Sensitivity Network, 2011) many people remain skeptical about the veracity of the idea that a subsection of the population experiences illness and disability as a result of intolerance of ordinary everyday levels of EMR (Levallois, 2002). Some consider the EHS condition to be purely psychosomatic (Rubin et al., 2010; Das-Munshi et al., 2006) – a "made-up term used by hypochondriacs and alternative-medicine practitioners to explain away unrelated medical problems" (National Post, 2011).

This stance is buttressed by the failure of numerous studies to prove a connection between people's reported EHS and their actual exposure to EMR (Nam et al., 2009; Mortazavi et al., 2007). In fact, many of the studies show that people with self-reported EHS were more sensitive to devices emitting no EMR than true EMR (Frick et al., 2005). In contrast to the more recent double-blind work confirming measurable physiological change in response to EMR exposure (McCarty et al., 2011), Rubin et al. (2011) found that participants with self-reported EHS did not have any abnormal physiological responses to acute EMR exposure. Looking at twenty-nine single or double-blind studies that exposed people to real and sham EMR, they report that most of the studies did not show any significant association between EMR and consistent symptoms in the self-reported EHS participant (Rubin et al., 2011).

Secondly, many EHS patients with EMR-induced brain dysfunction have CNS symptoms involving mood, cognitive ability, perception, and behavior. Because of the labile nature of this condition depending on incitant exposures, EHS patients are often perceived as inconsistent and unreliable, which makes it tempting for skeptics to label their condition as psychogenic. As a result of these various factors, many clinicians, politicians, and industry groups have chosen to label EHS as a fictitious malady.

After reviewing all available evidence, however, the WHO in 2004 released a factsheet identifying non-specific multi-system illness resulting from EMR exposure as 'electromagnetic hypersensitivity' (EHS) (World Health Organization, 2011b). In May of 2011 a coalition of physician scientists met with officials in the WHO responsible for developing the International Classification of Diseases (ICD). The WHO expressed a willingness to consider professional and public input on evidence supporting the inclusion of EHS into the 11th version of ICD to be released in 2015 (Chemical Sensitivity Network, 2011).

Various national governments have also recognized EHS as an emerging medical problem. Sweden (with about a quarter of a million people with EHS reported in 2004 (Johansson, 2006)) classifies EHS as a functional impairment (Johansson, 2006). Taking steps to diminish the risk of toxicant exposures – the source etiology of SRI and EHS – the Swedish Chemicals Agency has introduced recommendations in the form of a 'Substitution Principle'. This report recommends: "If risks to the environment and human health and safety can be reduced by replacing a chemical substance or product either by another substance or by some non-chemical technology, then this replacement should take place"

(Swedish Chemicals Agency, 2007). Other nations have also begun to introduce guidelines and legislation in relation to EHS. Spain, for example, recognizes EHS as a permanent disability (Grupo Medico Juridico, 2011) while the Canadian Human Rights Commission includes EHS among environmental sensitivities as a disability to be accommodated under Canadian federal legislation (Sears, 2007a). With conflicting outcomes in EHS research to date, however, legislative and public health action has been slow in many jurisdictions.

What considerations might potentially explain the apparent inconsistencies and contradictions in study outcomes and conclusions about the legitimacy of the EHS diagnosis?

6.1. Response to challenges relating to the EHS diagnosis

- ❖ **Lack of Clinical Response to EMR in some Research:** Individuals with EHS may be sensitive to different frequencies; not all electromagnetic frequencies are the same. Just as people with food intolerances are not sensitive to all foods and chemically sensitive patients are not sensitive to all chemical exposures, EHS patients are not necessarily sensitive to all frequencies in the electromagnetic spectrum. Testing EHS patients for identifiable physiological changes by exposing them to one frequency may miss frequencies that they are sensitive to – it is equivalent to testing people for food intolerances by exposing them to only one food or testing for all atopic illness in a patient by testing with only one antigen.
- ❖ **Fluctuating Clinical Response to EMR in some Research:** For those individuals with SRI, levels and intensity of intolerance can change over the short and long term (Genuis, 2010a; Ashford and Miller, 1998; Miller and Ashford, 2000). The intensity of response can fluctuate depending on changing levels of the total body burden, incitant dose, overall inflammatory status of the body, concomitant associated triggers, medication or natural health product use, general health, emotional state, and various other determinants.
- ❖ **Delayed Clinical Response to EMR in some Research:** Clinical change following incitant exposure is not necessarily immediate and can be delayed in onset. As some inflammatory responses can take time to manifest, immediate clinical testing for the purposes of research may not be reliable.
- ❖ **Differing Clinical Outcomes in Different Individuals:** Some of the studies claiming to disprove EHS utilize a reductionist approach to assessing patient suffering. Each person with EHS is a unique individual functioning in a complex environment, not a machine in a laboratory. Many of the studies attempt to create a controlled environment, and then draw conclusions – which are not generalizable to the complex environment where biochemically unique individuals with distinct genomes exist, and where a multiplicity of interconnected determinants may impact susceptible persons.
- ❖ **Psychogenic Etiology:** Many patients with EHS have been able to recover and have achieved sustained health using physiological interventions, without psychological therapies. In other words, correction of patho-physiology rather than patho-psychology has been successful in ameliorating this condition. This suggests that there may be a physiological basis for at least some portion of EHS.
- ❖ **Lack of Objective Evidence:** Unlike hypertension or diabetes, where isolated predetermined clinical markers determine diagnosis, EHS is not easily measured with quantifiable criteria. Without objective markers, some health professionals tend to dismiss the EHS diagnosis. EHS generally does not occur in isolation – it is often one component of complex multi-system health problems resulting from SRI (Genuis, 2010a; Dahmen et al., 2009; Sears, 2007b). EHS is a person-specific syndrome based on a person's total environmental burden, on their overall health, and how their unique bioelectric cellular chemistry responds to external EMR. Individuals with EHS may have associated biochemical deficiencies, toxicant bioaccumulation, and individual genetic polymorphisms that affect cellular detoxification processes,

neurocognitive biology, and other determinants of health and illness (Landgrebe et al., 2008).

- ❖ **EHS Defies Experience and Doesn't Make Sense:** As most healthy people do not perceive EMR in their environment, it may be counter-intuitive to accept that some individuals experience physically disabling symptoms as a result of seemingly incidental exposure. As a result, many scientists and clinicians are not willing to entertain the possibility that such sensitivity exists, and automatically default to the psychogenic attribution of disease. It is instructive to consider, however, that just as some vulnerable individuals with peanut allergy can experience life-threatening anaphylaxis from exposure to minuscule amounts of everyday peanuts, some EHS persons can develop debilitating responses to everyday levels of EMR.
- ❖ **Conflict of Interest Issues:** Sensitivity to environmental factors has huge implications for issues relating to insurance, employment, human rights, liability, policy initiatives, legislation, industrial policies, lifestyle and so on – issues with profound economic implications. In science and medicine as in other disciplines, there are those so closely allied to vested interests that they have seemingly been inoculated against truth, against credible research, and against observed fact (Michaels, 2008; Moynihan, 2003). Regardless of how compelling the evidence to the contrary, some unscrupulous or uninformed scientists continue to serve and represent the vested interests that fund them or the entrenched ideas and ideologies that propel them (Michaels, 2008; Angell, 2000). It has been suggested that perhaps some of the facts about EHS are being obfuscated and that 'evidence' has been manipulated to instill doubt and to impede public health regulation in exposure related matters (Genuis, 2008; Michaels, 2008).
- ❖ **Historical Precedent:** History repeatedly demonstrates that a disorder failing to fit the existing scientific paradigm of a specific era does not automatically translate into the condition being a psychosomatic or metaphysical nonentity. Many afflictions from Parkinson's to peptic ulcer disease were initially thought to be psychological rather than physiological in origin (Pall, 2007; Marshall, 2002).
- ❖ **Knowledge Translation:** Medical history consistently demonstrates that the adoption of new knowledge in clinical medicine is notoriously slow (Genuis, 2012; Genuis and Genuis, 2006; Doherty, 2005; Grol and Grimshaw, 2003). Currently, EHS is generally ignored, ridiculed or denied in much the same way that many other conditions such as ulcerative colitis, migraine headaches, multiple sclerosis and post-traumatic stress disorder were summarily dismissed in the past (Pall, 2007).

7. Conclusion

Over the last 50 years, there has been an anthropogenic electromagnetic revolution with the widespread release of electronic equipment, wireless systems, electrical machines as well as pervasive high voltage power lines and telecommunication emitters; in the next 50 years we will begin to witness the consequences of these developments. We have an ethical responsibility to define the impact of such technology on the human organism and to develop methodologies to investigate and manage adverse sequelae.

When exposed to certain frequencies of EMR, patients with EHS experience non-specific signs and symptoms affecting multiple body systems; many are rendered disabled and unable to function effectively in society. Evidence is accumulating, however, that many EHS patients can be successfully managed clinically and can experience substantial recovery. General recommendations for treating people with SRI, including EHS, involve reducing and avoiding environmental triggers, remediating biochemical and nutritional status, and diminishing bioaccumulated toxicant loads (Genuis, 2010a). In addition, some patients find cognitive behavior therapy and neural re-training to be

helpful adjuncts in addressing psychological stress and acquiring skills to overcome EHS.

Further research is required to fully understand the detailed pathophysiology of EHS and to enhance current therapies to ameliorate the suffering experienced by afflicted individuals. Public health measures including community education and appropriate governmental regulation relating to environmental chemical toxicant exposure and EMR are urgently required to preserve public health and to stem the increasing incidence of this preventable medical disorder. The 'Substitution Principle' invoked by Sweden, requiring adoption of least-risk and most sustainable strategies, is a logical approach to promote innovative technologies to protect individual and public health.

Recent evidence in the scientific literature suggests that various objective physiological alterations are apparent in some EHS persons claiming to suffer after exposure to certain frequencies of EMR (McCarty et al., 2011; Havas et al., 2010). As a result, many scientists now recognize that hypersensitivity to EMR can be a debilitating medical condition that is affecting increasing numbers of people throughout the world. While EHS patients can initiate steps to reduce exposure to EMR once they recognize the importance of doing so, more clinicians familiar with EHS and the SRI mechanism of ill-health (Genuis, 2010a) are needed to diagnose, assist and treat the burgeoning number of suffering individuals who are at a total loss to explain their various symptoms. In the end, regardless of whether one chooses to believe that EHS is fact or fiction, every ethical health provider has an obligation to sincerely listen to his/her patients, including those with EHS, and to do everything possible to ameliorate their suffering.

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References

- Angell M. Is academic medicine for sale? *N Engl J Med* 2000;342(20):1516–8.
- Ashford N, Miller C. Chemical exposures: low levels and high stakes. 2nd ed. New York: John Wiley and Sons; 1998.
- Berlucchi G. Brain plasticity and cognitive neurorehabilitation. *Neuropsychol Rehabil* 2011;1:1–19.
- Brenner DJ, et al. Cancer risks attributable to low doses of ionizing radiation: assessing what we really know. *Proc Natl Acad Sci USA* 2003;100(24):13761–6.
- Brodeur, P., *The Zapping of America: Microwaves, Their Deadly Risk, and the Coverup*. London: WW. Norton & Co.; 1977; p. 1–343.
- Buchner K, Eger H. Changes of clinically important neurotransmitters under the influence of modulated RF fields – a long-term study under real-life conditions. *Umwelt-Medizin-Gesellschaft* 2011;24(1):44–57.
- Chemical Sensitivity Network, Platform created by WHO in order to get an ICD code for MCS and EHS [accessed July 31, 2011 at <http://www.csn-deutschland.de/blog/en/platform-created-by-who-in-order-to-get-an-icd-code-for-mcs-and-ehs/>]. 2011.
- Chevalier, G., Sinatra, ST., Oschman, JL., Sokal, K., Sokal, P. Earthing: health implications of reconnecting the human body to the earth's surface electrons. *J Environ Public Health*. in press.
- Cioni G, D'Acunto G, Guzzetta A. Perinatal brain damage in children: neuroplasticity, early intervention, and molecular mechanisms of recovery. *Prog Brain Res* 2011;189:139–54.
- Costa A, et al. Heavy metals exposure and electromagnetic hypersensitivity. *Sci Total Environ* 2010;408(20):4919–20. author reply 4921.
- Coyle B. Use of filters to treat visual-perception problem creates adherents and sceptics. *CMAJ: Can Med Assoc J* 1995;152(5):749–50.
- Dabrowski MP, et al. Immunotropic effects in cultured human blood mononuclear cells pre-exposed to low-level 1300 MHz pulse-modulated microwave field. *Electromagn Biol Med* 2003;22(1):1–13.
- Dahmen N, Ghezel-Ahmadi D, Engel A. Blood laboratory findings in patients suffering from self-perceived electromagnetic hypersensitivity (EHS). *Bioelectromagnetics* 2009;30(4):299–306.
- Das-Munshi J, Rubin GJ, Wessely S. Multiple chemical sensitivities: a systematic review of provocation studies. *J Allergy Clin Immunol* 2006;118(6):1257–64.
- DeMatteo B. Terminal shock: the health hazards of video display terminals. Raleigh: NC Press; 1985. p. 1–239.
- De Luca C, et al. Biological definition of multiple chemical sensitivity from redox state and cytokine profiling and not from polymorphisms of xenobiotic-metabolizing enzymes. *Toxicol Appl Pharmacol* 2010;248:285–92.
- de Pomerai D, et al. Non-thermal heat-shock response to microwaves. *Nature* 2000;405(6785):417–8.
- Dode AC, 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):3649–65.
- Dode AC. Dirty electricity, cellular telephone base stations and neoplasia. *Sci Total Environ* 2011.
- Doherty S. History of evidence-based medicine. Oranges, chloride of lime and leeches: barriers to teaching old dogs new tricks. *Emerg Med Australas* 2005;17(4):314–21.
- Duramad P, Tager IB, Holland NT. Cytokines and other immunological biomarkers in children's environmental health studies. *Toxicol Lett* 2007;172(1–2):48–59.
- D'Andrea JA, et al. Microwave effects on the nervous system. *Bioelectromagnetics* 2003 (Suppl 6):S107–47.
- Floderus B, Stenlund C, Carlgren F. Occupational exposures to high frequency electromagnetic fields in the intermediate range (> 300 Hz–10 MHz). *Bioelectromagnetics* 2002;23(8):568–77.
- Frey A, Seifert E. Pulse modulated UHF energy illumination of the heart associated with change in heart rate. *Life Sci* 1968;7(Part II):505–12.
- Frey A. Cardiac and neural effects of modulated RF energy. *Proceedings of the 23rd Annual Conference on Engineering in Medicine and Biology*, 12.; 1970. p. 175.
- Frick U, et al. Comparison perception of singular transcranial magnetic stimuli by subjectively electrosensitive subjects and general population controls. *Bioelectromagnetics* 2005;26(4):287–98.
- Gangi S, Johansson O. A theoretical model based upon mast cells and histamine to explain the recently proclaimed sensitivity to electric and/or magnetic fields in humans. *Med Hypotheses* 2000;54:663–71.
- Genuis SJ. Fielding a current idea: exploring the public health impact of electromagnetic radiation. *Public Health* 2008;122:113–24.
- Genuis SJ. Sensitivity-related illness: the escalating pandemic of allergy, food intolerance and chemical sensitivity. *Sci Total Environ* 2010a;408(24):6047–61.
- Genuis S. What's out there making us sick? *J Environ Public Health* 2012. doi:10.1155/2012/605137.
- Genuis SJ. Human detoxification of perfluorinated compounds. *Public Health* 2010b;124(7):367–75.
- Genuis SJ. Elimination of persistent toxicants from the human body. *Hum Exp Toxicol* 2011;30(1):3–18.
- Genuis SK, Genuis SJ. Exploring the continuum: medical information to effective clinical practice: Paper 1. The translation of knowledge into clinical practice. *J Eval Clin Pract* 2006;12:49–62.
- Glaser, Z. Cumulated index to the Bibliography of reported biological phenomena ("effects") and clinical manifestations attributed to microwave and radio-frequency radiation: report, supplements (no. 1–9), BEMS newsletter (B-1 through B-464), 1971–1981 - Indexed by Julie Moore, Riverside, CA: Julie Moore & Associates, 1984.
- Grol R, Grimshaw J. From best evidence to best practice: effective implementation of change in patients' care. *Lancet* 2003;362(9391):1225–30.
- Grupo Medico Juridico, La hipersensibilidad a las ondas que producen los teléfonos móviles se convierte en una nueva causa de incapacidad permanente. Accessed on October 18th 2011 at [<http://www.noticiasmedicas.es/medicina/noticias/10451/1/La-hipersensibilidad-a-las-ondas-que-producen-los-telefonos-moviles-se-convierte-en-una-nueva-causa-de-incapacidad-permanente/Page1.html#>]. 2011.
- Hallberg O, Oberfeld G. Letter to the editor: will we all become electrosensitive? *Electromagn Biol Med* 2006;25(3):189–91.
- Hallberg O, Johansson O. Sleep on the right side-Get cancer on the left? *Pathophysiology: The official journal of the International Society for Pathophysiology/ISP*, 17(3).; 2010. p. 157–60.
- Hardell L, et al. Increased concentrations of certain persistent organic pollutants in subjects with self-reported electromagnetic hypersensitivity – a pilot study. *Electromagn Biol Med* 2008;27(2):197–203.
- Havas M. Biological effects of non-ionizing electromagnetic energy: a critical review of the reports by the US National Research Council and the US National Institute of Environmental Health Sciences as they relate to the broad realm of EMF bioeffects. *Environ Rev* 2000;8:173–253.
- Havas M. Electromagnetic hypersensitivity: biological effects of dirty electricity with emphasis on diabetes and multiple sclerosis. *Electromagn Biol Med* 2006;25(4):259–68.
- Havas M, et al. Provocation study using heart rate variability shows microwave radiation from DECT phone affects autonomic nervous system. In: Giuliani L, Soffritti M, editors. "Non-thermal Effects and Mechanisms of Interaction Between Electromagnetic Fields and Living Matter", *European J Oncology – Library*. National Institute for the Study and Control of Cancer and Environmental Disease/Bologna: Mattioli; 2010. p. 273–300. 2010. 2010.
- Hillert L, et al. Cognitive behavioural therapy for patients with electric sensitivity – a multidisciplinary approach in a controlled study. *Psychother Psychosom* 1998;67(6):302–10.
- Hillert L, et al. Prevalence of self-reported hypersensitivity to electric or magnetic fields in a population-based questionnaire survey. *Scand J Work Environ Health* 2002;28(1):33–41.
- Hobbs A. Sleep-powered wellness. Calgary: Bold World Books; 2011.
- Hooper, A., *Dynamic Neural Retraining System*. Accessed October 18, 2011, at [<http://www.dnrsystem.com/>]. 2011.
- Infas Institut für angewandte Sozialwissenschaft GmbH. In: trahlenschutz Bf, editor. Ermittlungen der Befürchtungen und Ängste der breiten Öffentlichkeit hinsichtlich möglicher Gefahren der hochfrequenten elektromagnetischen Felder des

- Mobilfunks – jährliche Umfragen. Bonn: Institut für angewandte Sozialwissenschaft GmbH; 2003. p. 1–34.
- Johansson O. Electrohypersensitivity: state-of-the-art of a functional impairment. *Electromagn Biol Med* 2006;25(4):245–58.
- Johansson O, et al. Cutaneous mast cells are altered in normal healthy volunteers sitting in front of ordinary TVs/PCs – results from open-field provocation experiments. *J Cutan Pathol* 2001;28:513–9.
- Johansson A, et al. Symptoms, personality traits, and stress in people with mobile phone-related symptoms and electromagnetic hypersensitivity. *J Psychosom Res* 2010;68(1):37–45.
- Johansson O, Liu P-Y. “Electrosensitivity”, “electrosupersensitivity” and “screen dermatitis”: preliminary observations from on-going studies in the human skin. In: Simunic D, editor. Proceedings of the COST 244 Biomedical Effects of Electromagnetic Fields – Workshop on Electromagnetic Hypersensitivity. Brussels/Graz: EU/EC (DG XIII); 1995. p. 52–7.
- Kabuto M, et al. Childhood leukemia and magnetic fields in Japan: a case-control study of childhood leukemia and residential power-frequency magnetic fields in Japan. *Int J Cancer* 2006;119(3):643–50.
- Kanaan RA, Lepine JP, Wessely SC. The association or otherwise of the functional somatic syndromes. *Psychosom Med* 2007;69(9):855–9.
- Klimková-Deutschová E. Neurologic findings in persons exposed to microwaves. In: Czernski P, et al, editor. Biologic Effects and Health Hazards of Microwave Radiation: Proceedings of an International Symposium, Warsaw, 15–18 Oct; 1973. p. 268–72.
- Landgrebe M, et al. Cognitive and neurobiological alterations in electromagnetic hypersensitive patients: results of a case-control study. *Psychol Med* 2008;38(12):1781–91.
- Landgrebe M, et al. Association of tinnitus and electromagnetic hypersensitivity: hints for a shared pathophysiology? *PLoS One* 2009;4(3):e5026.
- Leitgeb N, Schrottner J. Electrosensitivity and electromagnetic hypersensitivity. *Bioelectromagnetics* 2003;24(6):387–94.
- Less EMF Inc., The EMF Safety Superstore: EMF Shielding Device. Accessed on Oct 18th 2011 at [<http://lessemf.com/emf-shie.html>], 2011.
- Levallois P. Hypersensitivity of human subjects to environmental electric and magnetic field exposure: a review of the literature. *Environ Health Perspect* 2002;110(Suppl 4):613–8.
- Levallois P, et al. Study of self-reported hypersensitivity to electromagnetic fields in California. *Environ Health Perspect* 2002;110(Suppl 4):619–23.
- Li DK, Chen H, Odouli R. Maternal exposure to magnetic fields during pregnancy in relation to the risk of asthma in offspring. *Arch Pediatr Adolesc Med* 2011;165(10):945–50.
- Lin H, et al. Electromagnetic field exposure induces rapid, transitory heat shock factor activation in human cells. *J Cell Biochem* 1997;66(4):482–8.
- Lin H, et al. Myc-mediated transactivation of HSP70 expression following exposure to magnetic fields. *J Cell Biochem* 1998;69(2):181–8.
- Marino AA, et al. In vivo bioelectrochemical changes associated with exposure to extremely low frequency electric fields. *Physiol Chem Phys* 1977;9(4–5):433–41.
- Marshall B. Helicobacter pioneers: firsthand accounts from the scientists who discovered helicobacters. Victoria, Australia: Blackwell; 2002.
- Mashevich M, et al. Exposure of human peripheral blood lymphocytes to electromagnetic fields associated with cellular phones leads to chromosomal instability. *Bioelectromagnetics* 2003;24(2):82–90.
- McCarty DE, et al. Electromagnetic hypersensitivity: evidence for a novel neurological syndrome. *Int J Neurosci*. <<http://www.ncbi.nlm.nih.gov/pubmed/21793784>> 2011 Sep 5. [Epub ahead of print].
- Michaels D. Doubt is their product: how industry's assault on science threatens you health. New York: Oxford University Press; 2008.
- Miller CS. Toxicant-induced loss of tolerance – an emerging theory of disease? *Environ Health Perspect* 1997;105(Suppl 2):445–53.
- Miller CS. The compelling anomaly of chemical intolerance. *Ann N Y Acad Sci* 2001;933:1–23.
- Miller CS, Ashford NA. Multiple chemical intolerance and indoor air quality. In: Spengler JD, Samet JM, McCarthy JF, editors. Chapter 27 in 'Indoor air quality handbook'. New York: MacGraw-Hill; 2000.
- Mild K, Repacholi M, van Deventer Ee. Electromagnetic hypersensitivity. Proceedings International Workshop on EMF Hypersensitivity Prague, Czech Republic October 25–27; 2004. p. 196.
- Mortazavi SM, Ahmadi J, Shariati M. Prevalence of subjective poor health symptoms associated with exposure to electromagnetic fields among university students. *Bioelectromagnetics* 2007;28(4):326–30.
- Moynihn R. Who pays for the pizza? Redefining the relationships between doctors and drug companies. 1: entanglement. *BMJ* 2003;326(7400):1189–92.
- Nam KC, et al. Hypersensitivity to RF fields emitted from CDMA cellular phones: a provocation study. *Bioelectromagnetics* 2009;30(8):641–50.
- National Post Editorials. Saturday July 30, 2011 Spreading wireless panic. *National Post*; 2011. p. A13.
- Pall ML. Explaining ‘unexplained illness’: disease paradigm for chronic fatigue syndrome, multiple chemical sensitivity, fibromyalgia; post-traumatic stress disorder, gulf war syndrome and others. New York: Harrington Park Press; 2007.
- Parsons, S., Living with electrohypersensitivity: a survival guide. [Accessed on August 3rd, 2011 at <http://www.weepinitiative.org/livingwithEHS.html>]. 2011.
- Ramirez CC, Federman DG, Kirsner RS. Skin cancer as an occupational disease: the effect of ultraviolet and other forms of radiation. *Int J Dermatol* 2005;44(2):95–100.
- Rea WJ, et al. Electromagnetic field sensitivity. *J Bioelectricity* 1991;10:241–56.
- Rubin GJ, Das Munshi J, Wessely S. A systematic review of treatments for electromagnetic hypersensitivity. *Psychother Psychosom* 2006;75(1):12–8.
- Rubin GJ, Nieto-Hernandez R, Wessely S. Idiopathic environmental intolerance attributed to electromagnetic fields (formerly ‘electromagnetic hypersensitivity’): an updated systematic review of provocation studies. *Bioelectromagnetics* 2010;31(1):1–11.
- Rubin GJ, Hillert L, Nieto-Hernandez R, van Rongen E, Oftedal G. Do people with idiopathic environmental intolerance attributed to electromagnetic fields display physiological effects when exposed to electromagnetic fields? A systematic review of provocation studies. *Bioelectromagnetics* 2011;32(8):593–609.
- Sadchikova M. State of the nervous system under the influence of UHF. In: Letavet AA, Gordon ZV, editors. The Biological Action of Ultrahigh Frequencies. Moscow: Academy of Medical Sciences; 1960. p. 25–9.
- Sage, C., The bioinitiative report. Accessed Aug 2/2011 at [<http://www.bioinitiative.org/report/index.htm>]. 2007.
- Salford LG, et al. The mammalian brain in the electromagnetic fields designed by man with special reference to blood-brain barrier function, neuronal damage and possible physical mechanisms. *Progress of Theoretical Physics Supplement No. 173*; 2008. p. 283–309.
- Sears M. The medical perspective on environmental sensitivities. Government of Canada: Canadian Human Rights Commission; 2007a http://www.chrc-ccdp.gc.ca/legislation_policies/policy_enviro_n_politique-eng.aspx. Accessed Oct 22, 2011 at.
- Sears M. The medical perspective on environmental sensitivities. Government of Canada: Canadian Human Rights Commission; 2007b available at http://www.chrc-ccdp.ca/research_program_recherche/esensivities_hypersensibilitee/toc_tdm-en.asp. accessed Oct 11/2009.
- Stankiewicz W, et al. Immunotropic effects of low-level microwave exposures in vitro. In: Giuliani L, Soffritti M, editors. “Non-thermal Effects and Mechanisms of Interaction Between Electromagnetic Fields and Living Matter”, *European J Oncology – Library. National Institute for the Study and Control of Cancer and Environmental Disease Bologna: Mattioli*; 2010. 2010.
- Swedish Chemicals Agency, The Substitution Principle. Stockholm, Sweden. Accessed Oct 22, 2011 at [http://www.kemi.se/upload/Trycksaker/Pdf/Rapporter/Report8_07_The_Substitution_Principle.pdf]. 2007.
- The Swedish Association for the Electrosensitive, Electrically Hypersensitive Individuals Join Hands Across the World. Accessed Oct 22/2011 at [<http://www.feb.se/FEBletters/world.html>]. 1994.
- Torrens P. Wi-Fi geographies. *Annals of the Association of American Geographers*. 98(1); 2008. p. 59–84.
- Tracey KJ. Physiology and immunology of the cholinergic antiinflammatory pathway. *J Clin Invest* 2007;117(2):289–96.
- Tsurita G, et al. Effects of exposure to repetitive pulsed magnetic stimulation on cell proliferation and expression of heat shock protein 70 in normal and malignant cells. *Biochem Biophys Res Commun* 1999;261(3):689–94.
- Volkow ND, et al. Effects of cell phone radiofrequency signal exposure on brain glucose metabolism. *JAMA* 2011;305(8):808–13.
- Wormhoudt LW, Commandeur JN, Vermeulen NP. Genetic polymorphisms of human N-acetyltransferase, cytochrome P450, glutathione-S-transferase, and epoxide hydrolase enzymes: relevance to xenobiotic metabolism and toxicity. *Crit Rev Toxicol* 1999;29(1):59–124.
- World Health Organization, Electromagnetic Fields and Public Health: Electromagnetic Hypersensitivity. [accessed on July 31. 2011 at <http://www.who.int/mediacentre/factsheets/fs296/en/index.html>]. 2005.
- World Health Organization, Electromagnetic Fields. [accessed on July 7th 2011 at <http://www.who.int/peh-emf/en/>]. 2011.
- Zaret M. Microwave cataracts. *Medical Trial Technique Quarterly* 1973;19(3):246–52.