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Radiation from wireless technology affects the blood, the heart, and the autonomic nervous system[1)]

Abstract: Exposure to electrosmog generated by electric, electronic, and wireless technology is accelerating to the point that a portion of the population is experiencing adverse reactions when they are exposed. The symptoms of electrohypersensitivity (EHS), best described as rapid aging syndrome, experienced by adults and children resemble symptoms experienced by radar operators in the 1940s to the 1960s and are well described in the literature. An increasingly common response includes clumping (rouleau formation) of the red blood cells, heart palpitations, pain or pressure in the chest accompanied by anxiety, and an upregulation of the sympathetic nervous system coincident with a downregulation of the parasympathetic nervous system typical of the "fight-or-flight" response. Provocation studies presented in this article demonstrate that the response to electrosmog is physiologic and not psychosomatic. Those who experience prolonged and severe EHS may develop psychologic problems as a consequence of their inability to work, their limited ability to travel in our highly technologic environment, and the social stigma that their symptoms are imagined rather than real.

Keywords: electrosmog; radio-frequency radiation; rouleau; tachycardia; WiFi; Wolff-Parkinson-White Syndrome.

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Introduction

Our exposure to devices using electricity and emitting extremely low-frequency and radio-frequency electromagnetic fields has been increasing ever since Edison invented the incandescent light bulb and Tesla and Marconi discovered that radio-frequency (RF) radiation can be transmitted without wires. Radio, television, computers, cell phones, and their accompanying cell phone antennas, cordless phones, wireless routers (WiFi), wireless baby monitors, wireless games, and smart meters are increasing our exposure to RF radiation and especially to microwave radiation (300 MHz–300 GHz).

As an example of the proliferation of this technology, access to WiFi was limited in 2002 but by 2012 access was virtually ubiquitous in the USA (Figure 1). We have city-wide WiFi in some communities, WiFi at work, at home, in school, universities, and hospitals, in restaurants and coffee shops, on public transit, at airports, and on an increasing number of airplanes. As a society, we seem to be insatiable for wireless technology and the connectivity it affords.

Although the downside to this technology, namely, the potentially harmful effects of nonionizing radiation, has received relatively little attention in North America and remains controversial, it is an area that deserves proper research funding based on the sheer number of users and people exposed worldwide to RF electromagnetic fields.

In this article, the relationship between electrosmog exposure and electrohypersensitivity (EHS), with a focus on the cardiovascular system, is presented, based on provocation studies and on reports of ill health among those living near cell phone base stations or exposed to WiFi in schools.

Electrohypersensitivity

Just as some people have multiple chemical sensitivity or react to pollen, mold, and certain types of food, a growing population is becoming "sensitive" to electromagnetic radiation.

Khurana et al. (1) reviewed ten epidemiologic studies, three dealing with cancer and seven with neurobehavioral effects, that examined the putative effects of mobile phone base stations. All of the neurobehavioral studies reported more symptoms with proximity to base stations, and only

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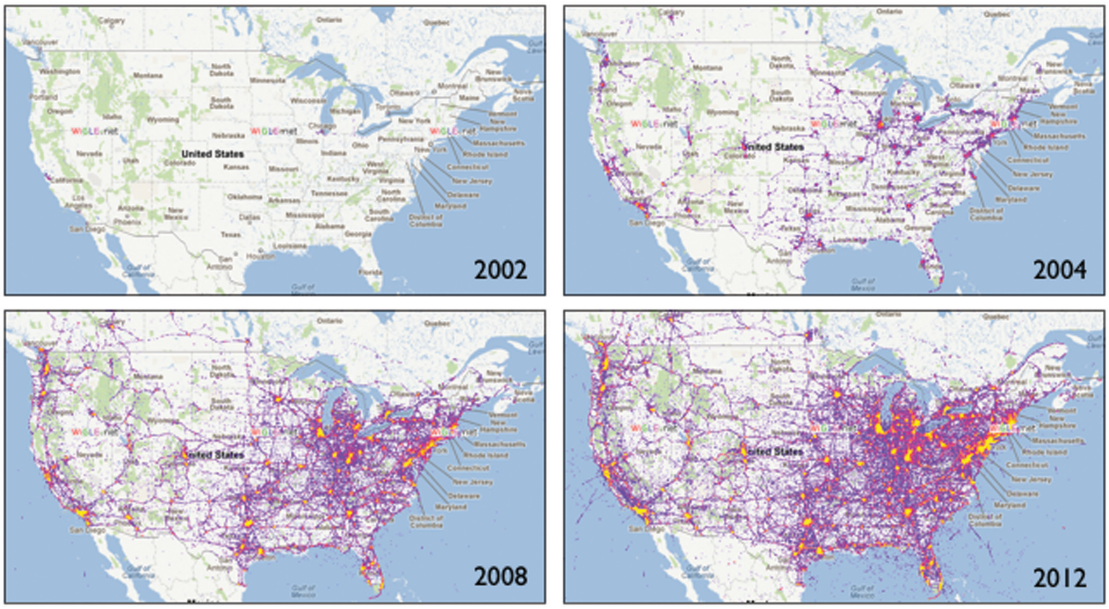

Figure 1 WiFi networks in the USA from 2002 to 2012 (source: wigle.net).

one attributed these health effects to stress rather than RF exposure.

The results from one of these studies are presented in Figure 2 (2). People who lived closest to the antennas experienced the following symptoms more often than those who lived further away: fatigue, sleep disturbance, headaches, feeling of discomfort, difficulty concentrating, depression, memory loss, visual disruptions, irritability, hearing disruptions, skin problems, cardiovascular problems, dizziness, loss of appetite, movement difficulties, and nausea. Many of these symptoms are more common as we age, thus I prefer to call this rapid aging syndrome (RAS). The difference between real aging and RAS experienced by those who are electrically hypersensitive is that when these people go into an electromagnetically clean environment, many of their symptoms diminish

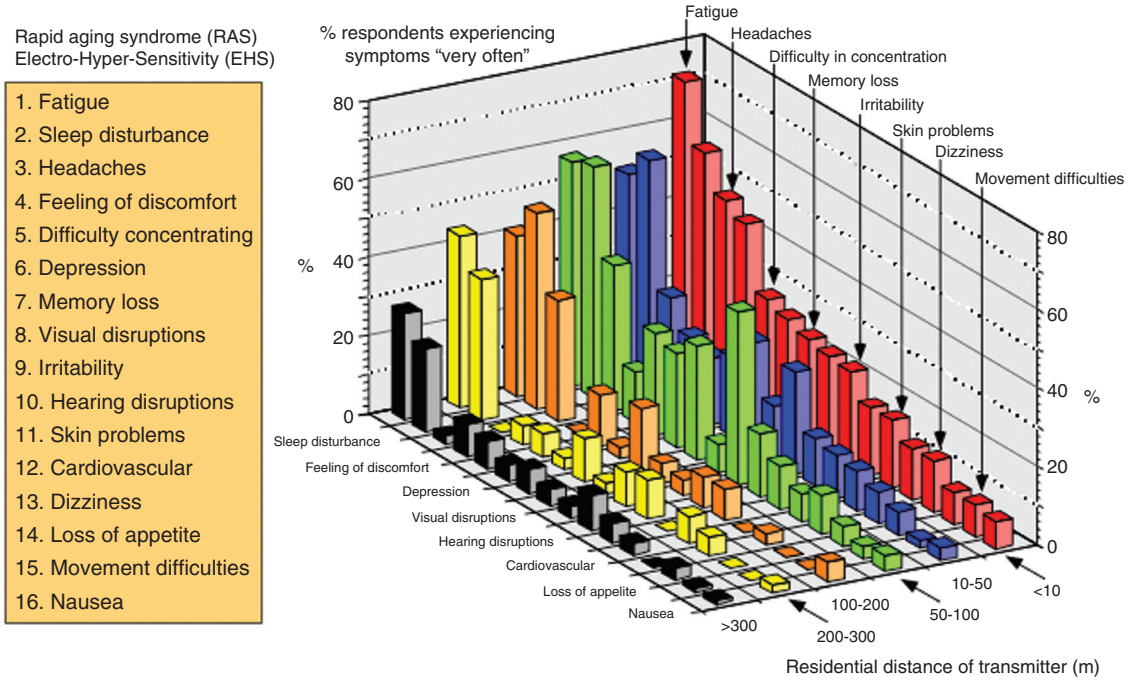

Figure 2 Symptoms experienced by people near cellular phone base stations [based on the work of Santini et al. (2)].

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or disappear. Obviously, this does not happen with real aging.

Because cell towers are proliferating and difficult to avoid in both urban and rural communities and if the results of Santini et al. (2) represent what is happening to those who live near cell towers, then it is quite likely that we are going to experience (or are in the midst of experiencing) an emerging health crisis that is contributing to chronic ill health and is promoting the sale of pain medication, sleep medication, antidepressants and antianxiety medication, pills to moderate energy level and mood, and drugs for those with attention deficit hyperactivity disorder such as Ritalin® (metylfenidat).

In 2006, Hallberg and Oberfeld (3) documented the increasing prevalence of EHS. Figure 3 clearly shows that self-perceived EHS is on the rise. According to the authors, by 2017, 50% of the population is going to be complaining of this illness. Admittedly, this is a rough calculation but it demonstrates that symptoms of EHS are increasing.

It is difficult to estimate the percentage of the population that has EHS. I use a conservative estimate of 3% of the population for those who have severe symptoms, and this is based on the population in Sweden who have registered as being electrohypersensitive (4). Another 35% population may have mild to moderate symptoms of EHS when exposed to electrosmog (5). Based on these percentages, the cumulative number of people who may be adversely affected in Canada, the USA, and Europe is 25 million, for severe sensitivity (EHS), and another 300 million, for mild to moderate sensitivity (electrosensitivity). People in this latter group can function in an electrosmog environment but may develop headaches or have difficulty sleeping and are living a life compromised by increasingly poor health as a consequence of their exposure (Figure 2).

Historically, environmental contaminants have been presented as contentious issues due, in part, to the media's need for "balanced reporting" and, in part, to the economic consequences of altering our behavior as consumers. This was certainly the case with asbestos, dichloro-diphenyl-trichloroethane (DDT), lead, mercury, acid rain, and tobacco smoke and is currently the case with climate change and EHS.

EHS may be viewed as a contentious issue, yet a growing number of international experts, scientists, and medical doctors have been asking governments and international agencies for decades to lower existing guidelines for RF radiation because the current guidelines do not protect public health. Table 1 provides a list of some of these resolutions and appeals.

Some governments have heeded the warnings and have exposure guidelines that are a fraction of those recommended by the World Health Organization (WHO) and accepted by the USA, UK, and Canada.

The WHO held an international workshop on electrosensitivity in Prague in 2004 (6), and they defined EHS as follows:

> "... 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.... Their exposures are generally several orders of magnitude under the limits in internationally accepted standards."

What role should the WHO and other leading health authorities play in helping these sensitive individual? Some would advocate, at the very least, lower exposure

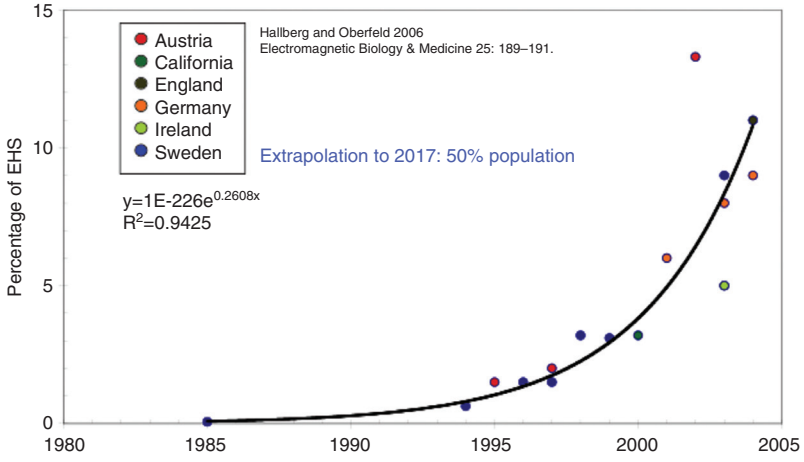

Figure 3 Estimated prevalence of self-proclaimed EHS in various countries [based on the work of Hallberg and Oberfeld (3)].

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Table 1 Appeals and resolutions from international groups of scientists and medical doctors.

Resolution/group	Country	Year	Link
Salzburg Resolution	Austria	2000	http://www.magdahavas.com/international-experts-perspective-on-the-health-effects-of-electromagnetic-fields-emf-and-electromagnetic-radiation-emr/
Catania Resolution	Italy	2002	www.emrpolicy.org/faq/catania.pdf
Freiburger Appeal	Germany	2002	http://www.magdahavas.com/international-experts-perspective-on-the-health-effects-of-electromagnetic-fields-emf-and-electromagnetic-radiation-emr/
World Health Organization	Czech Republic	2004	http://www.who.int/peh-emf/meetings/hypersensitivity_prague2004/en/
Irish Doctors' Environmental Association	Ireland	2005	www.ideaireland.org
Helsinki Appeal	Finland	2005	www.emrpolicy.org/headlines/helsinki_appeal_05.pdf
Benevento Resolution	Italy	2006	http://www.icems.eu/docs/BeneventoResolution_REVISED_march2008.pdf
BioInitiative Report	USA	2007 and 2012	www.bioinitiative.org
Venice Appeal	Italy	2008	http://www.icems.eu/resolution.htm
Porto Alegre	Brazil	2009	http://www.icems.eu/docs/resolutions/Porto_Alegre_Resolution.pdf
Seletun	Norway	2011	http://www.magdahavas.com/international-experts-perspective-on-the-health-effects-of-electromagnetic-fields-emf-and-electromagnetic-radiation-emr/
International Doctors Appeal	Germany	2012	http://www.icems.eu/resolution.htm

limits and possibly places where the radiation is not allowed, similar to smoke-free environments. Instead, the WHO recommended that this illness be referred to as "idiopathic illness", which basically means the cause is unknown. By refusing to acknowledge the cause, the WHO undermines the need for governing agencies to act.

In contrast to the WHO, the Austrian Medical Association (7) came out with guidelines to help doctors diagnose and treat those who experience EHS. In that document, they recognize that there is a rise in stress-related illness and that electrosmog may play a role. They even provide a temporary code (Z58.4, exposure to radiation) under the *International Classification of Diseases, 10th Edition* to be used for EMF syndrome, which is their term for EHS.

A group of psychologists considers EHS to be entirely a psychologic illness rather than a physiologic response to electrosmog (8, 9). A number of the articles reviewed by Rubin et al. are based on flawed assumptions about (1) who is truly experiencing EHS, (2) how people with EHS respond to exposure, (3) what frequencies and intensities they respond to, (3) how quickly they respond and recover following exposure, and (3) how the data should be analyzed. These flawed assumptions lead to flawed conclusions.

For example, not everyone who believes they have EHS actually have EHS. Thus, combing the results for the self-proclaimed "EHS group" is likely to dilute the results, producing no significant effect when analyzed statistically. The question that is being tested by this type of analysis is, "Do those who believe to be electrically sensitive all respond the same way to provocation testing?" and the answer is likely to be "no".

In the study by Rea et al. (10) of 100 people who believed they were electrically hypersensitive, only 16 responded consistently to real exposure and not to sham exposure. Had the results been statistically analyzed for the entire 100 subjects tested, they would have shown no effect of EMF exposure. Objective testing is required, and people should be assessed as individuals rather than members of a group for analysis. An analogous situation is if there were 16 people with diabetes among a group of 100 people who all thought they were diabetic. Statistical analysis of blood sugar measurements before and after consuming a standard meal for the entire group would likely miss the 16 people with diabetes.

The proper way to test for EHS is to monitor and assess individual responses to electrosmog exposure in a double-blind study, as was done by Rea et al. (10).

However, it is clear that those who experience EHS and are no longer able to live a "normal" life and who are not supported by their family, friends, and physicians also experience stress leading to psychologic problems including depression and anxiety disorders. Where I disagree with Rea et al. (10) about EHS is that I believe the physiologic response precedes the psychologic problem.

In this article, examples of the effects of electrosmog on the blood, heart, and autonomic nervous system (ANS) are provided, indicating that EHS is a physiologic response to electromagnetic pollution. The only legitimate use of the term "idiopathic" (i.e., disease or disorder that has no known cause) is in reference to the trigger that initiated the electromagnetic sensitivity. In some cases, with good medical investigation, this also can be surmised.

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Electrosmog affects the blood

Healthy blood consists of erythrocytes (red blood cells), which are round and which float freely in the plasma. A live blood sample, consisting of a drop of blood from a finger prick, can be viewed under the microscope, as shown in Figure 4. Changes in the size, shape, and clumping of these erythrocytes can indicate impaired health.

Figure 4 shows live blood (blood without any chemicals added to it) in an electromagnetically clean environment (A) and the blood from the same person spoke on a cordless phone for 10 min (B) and after using a wired computer for 70 min (C). The erythrocytes are sticking together and resemble a stack of coins. This is known as rouleau formation and indicates unhealthy blood.

Usually rouleau is caused by an increased fibrinogen concentration or other changes in plasma proteins as in multiple myeloma or macroglobulinemia. An alternative explanation is that the rouleau may be due to a reduction in the electrical potential at the cell membrane, which would weaken the repellent forces between cells. A third possibility is that it is a microscopic artifact, which, in this case, is unlikely because the results are repeatable. Research on the mechanisms involved in the rouleau formation is needed.

With rouleau formation, the surface area of the red blood cells is significantly reduced, and the release of nutrients and the removal of waste products are compromised. Symptoms may include headaches, difficulty concentrating, dizziness, nausea, heart and blood pressure problems as well as cold, numbness, or tingling sensation in the extremities (hands and feet).

The good news is that live blood analysis may be a useful diagnostic for EHS. How quickly the blood clumps and how quickly it recovers following exposure may be a good indicator of the degree of sensitivity.

Electrosmog affects the heart and the autonomic nervous system

Some people who are electrically hypersensitive complain of pain or pressure in the chest area, heart palpitations,

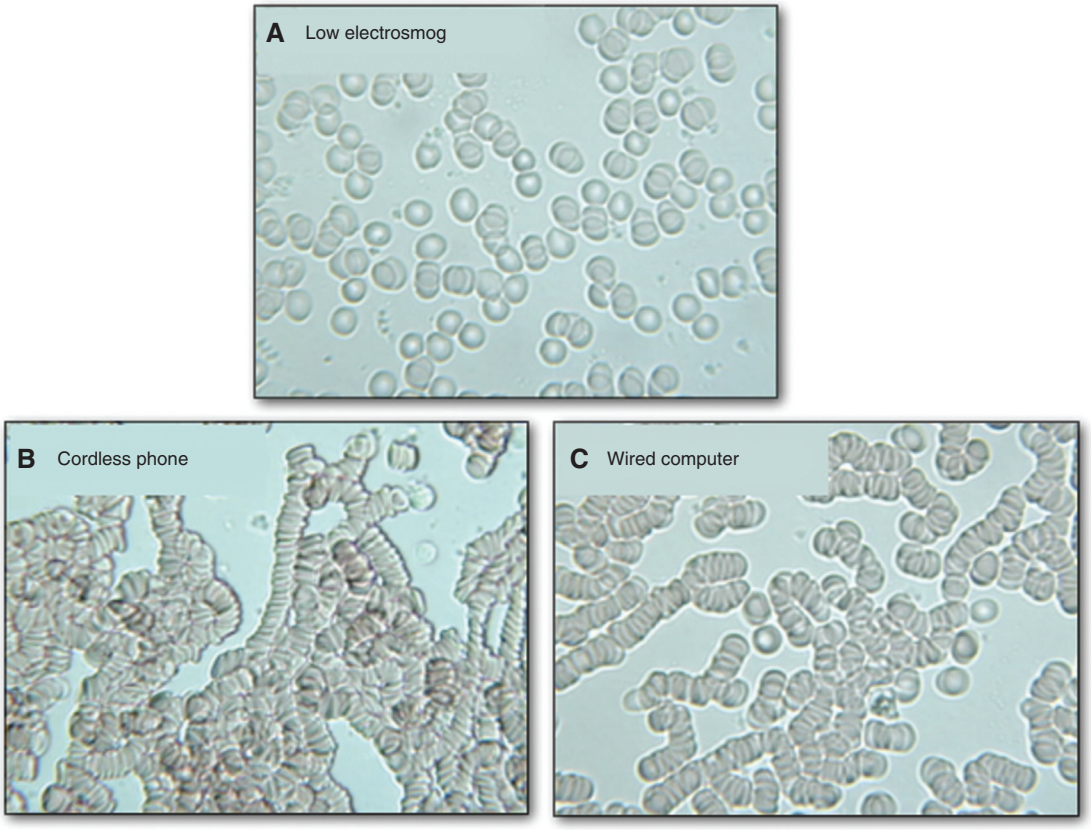

Figure 4 Live blood cells in a low-electrosmog environment (A), after using a cordless phone for 10 min (B), and after using a wired computer for 70 min (C).

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and/or an irregular heartbeat, accompanied by feelings of anxiety that develop rapidly. The symptoms resemble a heart attack and thus contribute to even more anxiety.

To test the effect of electrosmog on the heart, Havas et al. (11) designed a simple experiment where subjects were exposed to electromagnetic radiation generated by the base of a cordless phone. This was a double-blind study with randomized real and sham exposure. A cordless phone base station was selected as the source of exposure because the base emits a constant beacon signal when it is plugged into an electrical outlet. The beacon signal in this case was a pulsed frequency of 2.4 GHz, the same frequency used in WiFi.

In the original study (11), 25 subjects from Colorado were tested, and although most subjects did not react adversely to the radiation from the cordless phone base station (see Figure 5, subject A), a few did react with either tachycardia (rapid heart rate) or arrhythmia (irregular heart rate) (Figure 5, subject B). The reaction was often immediate and coincided with exposure to the radiation. When the radiation ceased, the heart returned to normal.

Two examples of responsive subjects are provided. The heart rate of subject B increased from a resting heart rate of 68 beats per minute (bpm) to a rapid 122 bpm during exposure, decreased to 66 bpm as soon as the radiation was stopped, and increased to 129 bpm when it was resumed. This reaction occurred while the subject was resting in a supine position and was unaware of when he or she was or was not exposed.

During the exposure to radiation from the cordless phone base station, subject C (Figure 6) experienced a slight increase in heart rate (from 65 to 86 bpm), an irregular heartbeat, and changes in the response of the sympathetic and parasympathetic nervous system (SNS and PNS, respectively). This upregulation of the SNS and downregulation of the PNS is an example of the "fight-or-flight" response, indicating physiologic stress. During periods of this type of stress, the body redirects most of the blood and energy from the internal organs to the arms and legs to prepare the organism for fighting or fleeing a stressful situation. Intermittent exposure may not cause a problem but if the exposure is continuous and long-term, the immune system of the body will be compromised and the body will not be able to repair itself, resulting in symptoms that are commonly experienced by those who are electrically hypersensitive. This inability to heal is what then accelerates the symptoms of aging (i.e., RAS).

The level of radiation in this experiment was well below international guidelines. Subjects were exposed to 3 $\mu W/cm^2$, or 0.3% of the guidelines recommended by International Centre for Non-Ionizing Radiation Protection (ICNIRP), the Federal Communication Commission (in US) (FCC), and Health Canada for 2.4-GHz frequencies. According to these organizations, harmful biologic effects do not occur below these thermal guidelines. Both blood and heart results from these provocation experiments indicate otherwise, i.e., that biologic effects that can have serious health implications do occur at levels well below current thermal guidelines.

The cordless phone provocation study has since been repeated for a larger group of subjects and shows similar results (12).

Some suggested that the radiation from the cordless phone was interfering with the technology rather than the heart. If this were the case, then 100% of the subjects would have had similar results because the

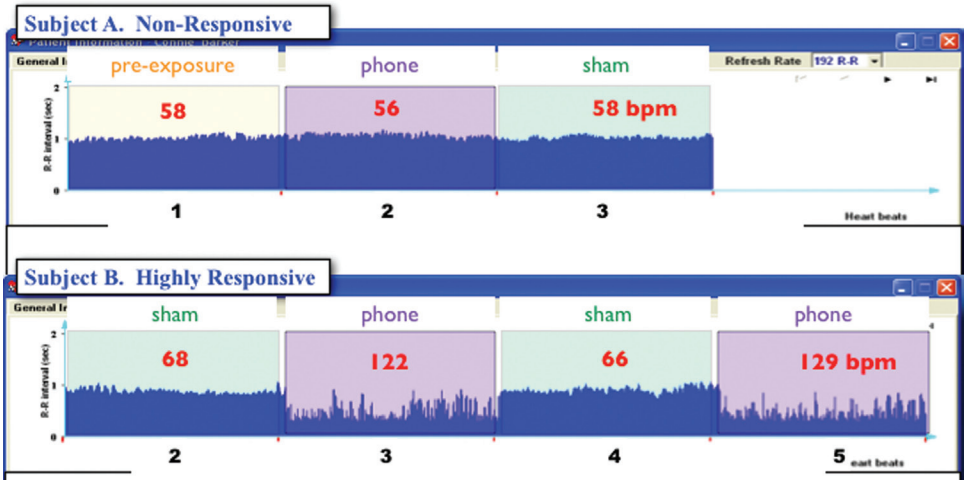

Figure 5 Rhythmograph of HRV during provocation with a digital 2.4-GHz cordless phone and sham exposure. The x-axis unit is time, with each stage lasting approximately 3 min. The y-axis is the R-R interval (in seconds).

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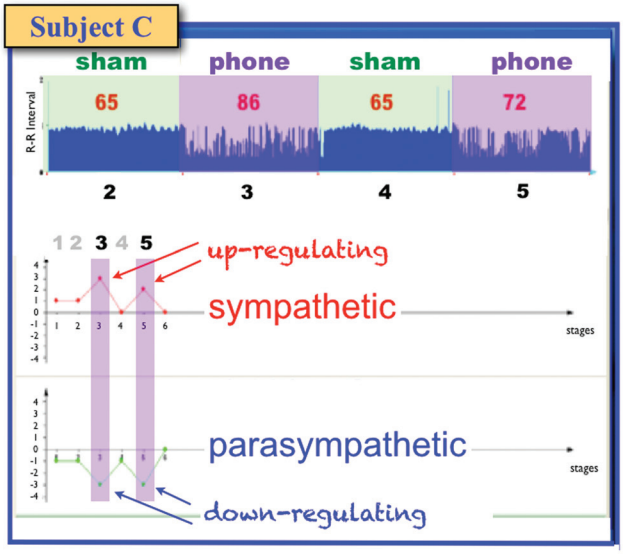

Figure 6 Rhythmograph of HRV and functioning of the SNS and PNS during provocation with digital 2.4-GHz cordless phone and sham exposure.

electromagnetic interference (EMI) would have been consistent rather than highly variable and individualistic. Additional testing of higher levels of radiation at the sensor did not affect the heart rate variability (HRV) of a subject who was nonresponsive to the original levels. Had it been EMI, then higher levels of exposure should have had a greater response, but this was not the case (12).

One subject (52-year-old man) told us that he normally experiences a delayed reaction to electrosmog exposure, and thus we monitored him for 30 min postexposure and observed the delayed response during a period of no exposure. The response included periods of short-term and intermittent irregularity in the R-R interval (HRV) as well as episodic downregulation of both the SNS and the PNS, which were both low to begin with (12). The normally low heart rate, 53–55 bpm, began to increase slightly (61 bpm) 25 min postexposure.

WiFi in schools affects student health

Students in schools with WiFi are complaining of headaches, difficulty concentrating, weakness, and heart palpitations, prompting their parents to take them to their family doctor and to their pediatric cardiologist to determine the nature of their problem.

In one Ontario school district, several students complained of heart problems. A 6-year-old girl had a "musical heart", and she experienced headaches and dizziness only at school. A 12-year-old boy had tachycardia (rapid heart rate). A 12-year-old girl experienced nausea, vomiting, no fever, insomnia, blurred vision, and tachycardia only at school. A 13-year-old boy had a pounding heart, insomnia, and headaches. His family moved to a different school district, and his symptoms disappeared.

In the same area, 4 students had sudden cardiac arrests (SCA) during exercise class within a 2-year period. Two of these students were resuscitated. The annual rate for SCA among young people in Canada is approximately 7 per year; hence, 4 in a small community is unusual.

According to Sinatra (13), a cardiologist, Wolff-Parkinson-White (WPW) syndrome, which is a disorder of the conduction system of the heart, is present in 1 out of 700 students. In a school district with 50,000 students, as many as 70 may have this generally undiagnosed condition. According to Sinatra (13), when students with WPW syndrome are exercising and are exposed to microwave radiation, the combined stress on the heart can lead to supraventricular tachycardia, thus creating the "perfect storm".

Fortunately, due to the Defibrillator Access Act, schools and other public buildings are installing defibrillators. What they should also be doing is trying to determine what is causing SCA and why students are complaining of headaches and heart palpitations at school. A key question that needs to be asked is, "What role does RF radiation from a school's WiFi system and from nearby cell phone base stations play in these symptoms?"

The effects of microwave radiation on the heart have been known for decades (14). In a 1969 symposium on the biological effects and health implications of microwave radiation, the authors clearly state that, "In the interest of occupational hygiene…researchers have recommended that cardiovascular abnormalities be used as screening criteria to exclude people from occupations involving radio-frequency exposures". Perhaps students need to be screened at school to ensure that they do not have an underlying heart condition that may be exacerbated with WiFi microwave exposure.

According to Drezner et al. (15), out-of-hospital SCA among young people is on the rise in the USA, although doctors do not know the reason. The increasing exposure to electrosmog may be to blame for at least part of this increase. More research is urgently needed in this area.

Children are much more sensitive to environmental toxins than are adults, and as such, there should be stricter guidelines for exposure. To date, at least nine countries have issued warnings that children should limit their use of cell phones. These countries include the UK (2000), Germany

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(2007), France (2008), Russia (2008), India (2008), Belgium (2008), Finland (2009), the USA (2009), and Canada (2012). The same warning should be issued for children exposed to wireless games and WiFi routers, depending on the amount of time students are exposed to these emitters.

WiFi routers emit a beacon signal that is continuous as long as the device is activated. In other words, you do not have to be connected to the Internet to be exposed to the radiation generated by the wireless router. When information is either uploaded or download, the radiation levels increase both at the router and at the computer. The same is true for cordless phones and wireless baby monitors. Voice-activated baby monitors and cordless phones that radiate only when in use are available in Europe but are not currently available in North America.

Historic research on microwave illness resembles current research on electrohypersensitivity

The information provided in this article is not new. Reviews as far back as 1969 summarized the effects of microwave radiation and identified many of the same symptoms. Dodge (16) reviewed the Soviet and Eastern European literature and reported that microwave radiation affects the central nervous system, ANS (as shown here), neurohumoral systems, endocrine glands and functions, eye and ocular function, blood and hematopoietic system (as shown here), and miscellaneous organs.

Dodge (16) identified general subjective complaints resulting from exposure to electromagnetic radiation (Table 2) that are similar to the symptoms experienced by those who live near cell phone base stations (Figure 2). The major difference is that Dodge was reviewing symptoms for men who were occupationally exposed, whereas Santini et al. (2) was documenting symptoms for those who lived near cell phone antennas and were exposed to radiation in their own homes and as such were unable to avoid exposure.

Glaser (17) reviewed the literature on the biologic effects of microwave radiation and provided more than 2000 references in 1972. Although many of these studies were conducted at levels above existing guidelines, we are getting similar results at levels of microwave radiation that are well below these guidelines.

Most revealing are the "psychophysiologic disorders" based on human behavioral studies. These disorders include the following and are similar to those reported by Santini et al. (2): neurasthenia (general "bad" feeling), depression, impotence, anxiety, lack of concentration, hypochondria, dizziness, hallucinations, sleepiness, insomnia, increased irritability, decreased appetite, loss of memory, scalp sensations, increased fatigability, chest pain, and tremor of the hands.

Both Glaser and Dodge worked for the US Navy and had access to information that was later declassified. In one limited-edition (only 15 copies were produced) document, Pollack and Healer (18) recommended that the power density guideline in the USA be reduced from 10,000 $\mu W/cm^2$ to the same level used in the Soviet Union (10 $\mu W/cm^2$), but little attention was paid to this recommendation.

Table 2 Subjective symptoms associated with RF and microwave radiation.

General subjective complaints resulting from exposure to electromagnetic radiation (16)	Symptoms experienced "very often" by those who live within 300 m of a cell phone base station (2)
Similar symptoms	
Pain in head and eyes	Headaches and visual disruptions
Weakness, weariness, and dizziness	Dizziness and fatigue
Depression, antisocial tendencies, and general irritability	Depression and irritability
Impairment of memory and general mental function	Memory loss
Adenoma and inability to make decisions	Difficulty concentrating
Chest pain and heart palpitation	Cardiovascular
Dyspepsia, epigastric pain, and loss of appetite	Loss of appetite
Sensitivity of mechanical stimulation and dermagraphism	Skin problems
Different symptoms	
Lacrimation	Irritability
Hypochondria, sense of fear, and general tension	Nausea
Inhibition of sex life (male)	Movement difficulties
Scalp sensations and hair loss	Hearing disruption
Trembling of eyelids, tongue, and fingers	Sleep disturbance
Asthma	Feeling of discomfort
Brittle fingernails	

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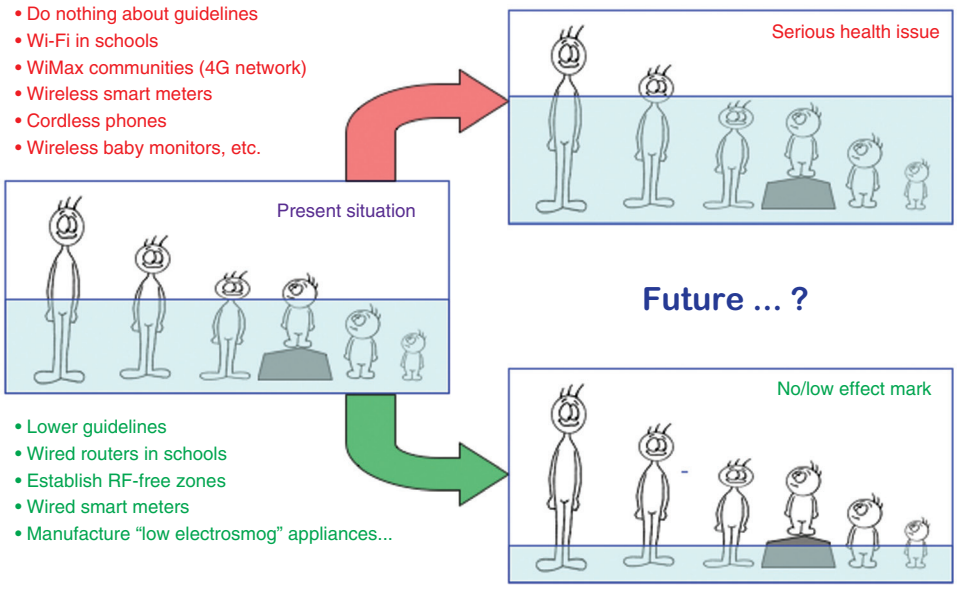

Figure 7 Two future health scenarios based on the steps we take or fail to take to reduce electrosmog exposure.

Years later, the power density guideline in the USA was reduced from 10,000 to 1000 μW/cm^2, although this was still based on thermal effects.

Where do we go from here?

If we do nothing about guidelines and allow WiFi to be installed in schools, if we allow WiMax to come into neighborhoods as part of the 4G network, if we allow wireless smart meters to be installed on homes, and if we fail to regulate the technology in a way that minimizes microwave exposure, then many more people are likely to become ill and some will die (Figure 7).

If we choose to minimize exposure by establishing biologically based guidelines rather than the current thermal guidelines, by encouraging wired Internet access in schools, universities, hospitals, workplaces, and homes, by installing wired smart meters, and by establishing RF-free zones for those who are highly sensitive, then we can reverse much of the damage that has been inflicted (Figure 7).

The choice is ours, and the real question is, "Do we have the foresight and courage to make the right decision or will we require a health tsunami before we act?"

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