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Human Health Effects of EMFs: The Cost of Doing Nothing

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Abstract. Everyone is exposed to electromagnetic fields (EMFs) from electricity (extremely low frequency, ELF), communication frequencies and wireless devices (radiofrequency, RF), as well as naturally occurring EMFs. Concern of health hazards from EMFs has increased as the use of mobile phones and other wireless devices has grown in all segments of the population, especially children. While there has been strong evidence for an association between leukemia and residential or occupational exposure to ELF EMFs for many years, the standards in existence are not sufficiently stringent to protect from an increased risk of cancer. ELF EMFs also increase risk of at least two types of neurodegenerative diseases. For RF EMFs, standards are set at levels designed to avoid tissue heating, in spite of many reports of biological effects at intensities too low to cause significant heating. Recent evidence demonstrates elevations in risk of brain cancer and acoustic neuroma only on the side of the head where individuals used their mobile phone. Individuals who begin exposure at younger ages are more vulnerable. These data indicate that the existing standards for radiofrequency exposure are not adequate. While there are many unanswered questions, the cost of doing nothing may result in an increasing number of people, many of them young, developing these diseases.

1. Introduction

It has been known for many years that high energy EMFs (X-rays, gamma rays, cosmic rays) have sufficient energy to directly break chemical bonds, causing damage to molecules ranging from water to DNA that results in cancer and birth defects [1]. Thus these forms of EMF are “ionizing”. There is less consensus as to whether lower energy forms of EMFs, such as radiofrequency and ELF EMFs, can cause disease. In spite of strong evidence for such relationships from the biomedical community, most national and international bodies have discounted this evidence, based on the belief that lower energy EMFs cannot possibly cause serious disease [2]. This particular point of view is held by many in the physics and engineering communities, individuals not known for their detailed knowledge of medicine. There are legitimate concerns as to what mechanisms might explain these relationships. The purpose of this review is to provide an overview of the issues, explore both the associations between exposure and disease and the mechanisms that might explain them, and to propose biologically-based standards of exposure which, although difficult to achieve, would be more protective of human health.

While there are a variety of diseases of possible concern, this review will focus on only two major classes, cancer and neurodegenerative disease. This is for two reasons. The evidence for an association with EMF is strongest for these diseases, and these are very serious diseases that cause significant morbidity and mortality in humans.

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2. Health Effects of ELF EMFs

There has been evidence that residential exposure to elevated residential magnetic fields results in an increased risk for leukemia since the pioneering studies of Wertheimer and Leeper [3]. Most subsequent studies have confirmed elevated risks of leukemia [4-6], and several meta-analyses have shown significantly elevated odds ratios (ORs) whether exposure was determined through use of wire codes or measured magnetic fields [7-9]. In addition there is evidence that leukemia is elevated in adults employed in occupations that involve elevated exposure to EMFs from electricity [10]. Meta-analyses of occupational exposure have also reported elevated risks for leukemia, with less strong evidence for relations to other kinds of cancer [11]. There has also been a meta-analysis reporting a significant elevation in rates of brain cancer among adults working in "electrical" occupations [12].

There is also strong evidence for a relationship between occupational exposure to EMFs and neurodegenerative diseases, Alzheimer's and amyotrophic lateral sclerosis (ALS). In a meta-analysis of EMFs and Alzheimer's disease, Garcia et al. [13] report an OR ratio of 2.03 (95% CL = 1.38-3.00) for case-control studies, and 1.62 (95% CL = 1.16-2.80) for cohort studies. Ahlbom [14] reviewed seven studies of EMF exposure and ALS, and found an overall significant OR of 1.5 (95% CL = 1.2-1.7). More recent studies of Hakansson et al. [15] found an OR of 2.2 (95% CL = 1.0-4.7) among welders and other workers exposed to elevated magnetic fields.

3. Human Disease from Exposure to RF EMFs

Until recently there has been relatively little attention to RF exposures and human health. Older studies have reported elevations in both leukemia and brain tumors among individuals with occupational exposures to RF (see [16] for references), but results were not very consistent across studies. Recent reports have found elevated rates of leukemia among children who live near AM radio transmitter sites [17-19]. This is the same cancer elevated with exposure to powerline frequency EMFs, suggesting that leukemia is the cancer most likely to show elevated risk with whole body exposure to a variety of EMFs frequencies.

With the advent of enormous increases in the use of mobile phones, we now have a situation in which a very large segment of society is regularly exposed to high levels of RF. In addition, the whole population has increased exposure through the placement of mobile phone towers, wireless buildings and even wireless cities. The strongest evidence for hazards has come from Europe, especially Scandinavia, where mobile phones were initially manufactured, and have been in wide use for a longer period of time as compared to other parts of the world.

Recent studies have found an elevated risk of brain tumors and acoustic neurons in individuals who have used mobile phones regularly for ten years or longer. A meta-analysis by Hardell et al. [20] based on four studies finds an OR of 2.0 (95% CL = 1.2-3.4) for glioma among individuals who have used a mobile phone for ten years or more, but only on the side of the head where the phone was used. There was also an OR of 2.4 (95%CL = 1.1-5.3) for acoustic neuroma among long-term users. Risks for meningioma were elevated, but not statistically significant. Kundi [21] has reported on 33 epidemiological studies, and finds that the combined ORs from these studies show an OR of 1.5 (95% CL = 1.2-1.8) for glioma. There was also a nonsignificant elevation in ORs for acoustic neuroma but no relationship with meningioma. Hopefully, additional information will come from the pooled results of the INTERPHONE study, a 13-nation investigation coordinated by the World Health Organization, which should be available in the near future. Interestingly, the Israeli component of this study has found an elevated risk of parotid gland cancer with long-term mobile phone use [22], but results from the full INTERPHONE study of parotid gland cancers are also not yet available.

There is a particular concern about risks to children exposed to RF. Hardell et al. [23] studied relative risk based on the age when a person began to use a mobile phone, and found that individuals whose use began while they were in their 20's displayed ORs that were higher than those of older

persons for both analog and cordless phones when assessed at either >1 or >5 year latency. Later Hardell reported at a meeting (personal communication) that children who began use of a mobile phone prior to the age of 20 had an OR of developing glioma of 5.2 (95% CL = 2.2-12) after only one plus year of mobile phone use, while for all ages the OR was 1.4 (95% CL = 1.1-1.7). The same relative relationship was seen with use of a cordless phone, where use before the age of 20 years gave an OR of 4.4 (95% CL = 1.9-10), whereas for all ages the OR was 1.4 (95% CL = 1.1-1.8). These studies support the conclusion that cordless phones increase both exposure levels and disease by about the same magnitude as do mobile phones, and that use of either results in an increased risk of gliomas.

4. Why Have These Results not been Reflected in New Standards of Exposure?

In spite of this consistency in observations relating to ELF EMFs and leukemia, and the developing evidence for a relationship between mobile phone use and elevated risk of brain cancer and acoustic neuroma, there has been a general failure of governments and international advisory bodies to accept the reported relationships as being cause and effect, and to follow through with standards designed to reduce exposure. This is a consequence of two major scientific problems, as well as the public excitement and support of wireless technologies and the political power of the industry. Animal studies have not consistently demonstrated cancer as a result of exposure to ELF EMFs. In addition, no single mechanism has been identified to be the basis for the development of cancer following exposure to EMFs.

In spite of the widespread belief that most cancer is genetic, recent studies of identical twins have convincingly shown that most cancers result from some environmental exposure and are not primarily genetic [24]. This is not to say that genetics is unimportant, since genetic susceptibility will determine whether or not environmentally-induced cancers develop and become life-threatening. There is also the widespread and mistaken belief that all carcinogens act by causing direct DNA damage, as is the case with ionizing radiation. However, many proven human carcinogens do not cause direct DNA damage. These are identified as “non-mutagenic carcinogens” by the USEPA, and include such well-documented carcinogens as arsenic [25-26] and dioxins [27]. Exact mechanisms are not known to explain the carcinogenicity of either, although a number of possible factors are known. Thus the fact that ELF and RF EMFs are “non-ionizing” does not mean they are not carcinogens. Both ELF and RF EMFs are known to cause gene induction, generate reactive oxygen species, trigger formation of heat shock proteins and cause other alterations in cellular function, any one of which might lead to cancer (see [16] for references and detailed discussion).

The causes of Alzheimer’s disease and ALS are also not known. In the case of Alzheimer’s disease there is the accumulation in the brain of two different deposits that come from normal proteins, called amyloid plaques and neurofibulary tangles [28]. There is uncertainty whether these deposits cause the disease or are only associated with the disease. Recent evidence suggests that reactive oxygen species formation may be a major factor in causing cell death in Alzheimer’s disease [29]. ALS is even less well understood, but the disease is the result of death of upper and lower motoneurons [30]. Both reactive oxygen species [31] and heat-shock proteins [32] have been implicated in the resulting cell death. As with cancer, genetics plays a minor role in etiology of these diseases. There is no reason to discount an association with exposure to EMFs on the basis of lack of firm knowledge of a mechanism, as the mechanisms causing both diseases are uncertain. It is worth noting that reactive oxygen species and heat-shock proteins are implicated in both non-mutagenic carcinogen actions and these neurodegenerative diseases, and that both are altered by EMFs.

5. Proposed EMF Standards that are Based on Studies of Human Health after Exposure

The Bioinitiative Report [33] presents recommendations for standards of EMF exposure that are based on the epidemiological evidence in human populations. For ELF EMFs the proposed standard is 1 mG (0.1 μT), to be compared with the current International Commission on Non-ionizing Radiation Protection (ICNIRP) standard of 1,000 mG (100 μT). For RF radiation the proposed standard is 0.1

μW/cm^2, to be compared with the US Federal Communications Commission standard of 583 μW/cm^2 for 875 MHz cell phone frequency, and 1,000 μW/cm^2 in the frequency range of 1,800 - 1,950 MHz. The difference between these numbers show the magnitude of the problem. There is no question that a sudden imposition of standards so drastically different from those existing would impose severe hardship. However, there is also no question that the human studies clearly indicate that the existing standards are not protective of human health.

The benefits to society derived from electricity and wireless communications are significant, and certainly none of us is willing to return to the pre-electric age. However it is imperative that society at least acknowledge the disparities between current standards and current evidence of adverse health effects. Rigid and sudden imposition of the standards we propose is certainly unrealistic at the present time, but these levels are appropriate goals that could at least be approached by a combination of development of new technology and voluntary changes in behaviors.

6. The Costs of Being Wrong

At present we do not know precisely to what degree risk of cancer and neurodegenerative diseases is increased by excessive exposure to EMFs. Human studies are difficult under any circumstances, but those difficulties are even greater when studying the effects of EMFs. Levels of exposure for each of us vary over the course of every day as we move through our environment and use appliances and mobile phones. This makes exposure assessment extremely difficult. Under the circumstances of poor exposure assessment there is a great likelihood that the total risk is underappreciated.

There is considerable evidence that the developing organism is more vulnerable to several environmental insults than are adults [34-35]. The reality is that children throughout the world are using mobile phones at increasing rates and for long durations. Therefore, if there are real risks, and especially if children are more susceptible, we may be facing an epidemic of brain and other cancers. The concern is increased because, to date, there are few warnings to parents and physicians advising restrictions on use of mobile phones by children. While the evidence at present is certainly less than total proof of a relationship between exposure and elevated risk of cancer, it is sufficiently strong so as to demand precaution. The alternative may be significant increases in certain cancers, especially leukemia and brain cancer. It is not clear whether other kinds of cancer are also at increased risk following exposure, since there has not been much study of, for example, the possible health hazards of wearing a cell phone on your belt and pelvic cancers.

Fortunately, the rates of leukemia and brain cancer are not high. There have recently been significant improvements in treatment of leukemia, especially among children. Kundi [21] has hypothesized that use of mobile phones may increase rates of some forms of brain cancer, such as gliomas, by as much as 50%. Even if this is true, this certainly does not mean that every exposed person will develop brain cancer. Such an increase in brain cancer would still have a significant impact, not only on the individuals affected but also on society, especially given that much of this increase is likely to occur among young people.

Application of the Precautionary Principle is appropriate under the circumstances where there is a demonstrated elevation in rates of serious diseases in humans following elevated EMF exposure, but has many unanswered questions as to mechanisms responsible. We need additional research, of course, and much better exposure assessment. The evidence that we have at present is too convincing to be ignored. Our national and international standards are obsolete, and ignore evidence reported by many different investigators. The lack of certainty with regard to mechanisms and animal models is no reason to ignore studies of human health. Similar lack of certainty regarding mechanisms also exists for some chemicals, yet precautionary measures are commonly taken to reduce exposure. We need the electric and communications industries to be proactive in developing products that can be used with reduced exposures. We need governments and international organizations to set standards that are based on the evidence of whether there are hazards to humans, not on a hypothesis that is not

credible based on the evidence from animal and cellular studies. Most importantly, we need individuals to understand that personal decisions will significantly impact the level to which they are exposed to both ELF and RF EMFs.

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