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Mini Review

Carcinogenic effects of Non-Ionizing Radiation: A Paradigm Shift

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Abstract

We are in the midst of a paradigm shift when it comes to our understanding of the biological effects of non-ionizing electromagnetic frequencies generated by our use of electricity, electronics and wireless technology. Ionizing radiation (IR) has enough energy to break chemical bonds and is known to cause cancer. However, because non-ionizing radiation (NIR) lacks this energy, it was assumed that these lower frequencies cannot be carcinogenic. This concept is based on a flawed assumption. NIR can and does cause cancer not by increasing the production of free radicals but by interfering with the repair mechanisms that neutralize free-radicals. While the mechanisms differ, the consequences of both NIR and IR are the same–oxidative stress resulting in cellular damage including cancer.

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INTRODUCTION

Science advances in two ways … by smooth incremental additions to our understanding and by revolutionary shifts in our knowledge that Kuhn [1], classified as a "paradigm shift." *A paradigm shift is a change from one way of thinking to another and is driven by agents of change.*

We are currently experiencing a paradigm shift regarding the biological effects of non-ionizing radiation (NIR). Paradigm shifts are often met with opposition. Here is a quote attributed to Arthur Schopenhauer that I've modified:

All truth (A paradigm shift) passes through four stages.

First, it is ignored.

Second, it is ridiculed.

Third, it is violently opposed.

Forth, it is accepted as being self-evident.

Most physicists and many health authorities will tell you that NIR cannot cause cancer because it doesn't have enough energy to break chemical bonds. For example, according to the National Cancer Institute, U.S. [2], *Radiofrequency energy, unlike ionizing radiation, does not cause DNA damage that can lead to cancer. Its only consistently observed biological effect in humans is tissue heating*. And, according to the Swedish Radiation Protection Authority [3], *there is no biologically plausible mechanism to support a carcinogenic effect of non-ionizing RF waves.*

At the same time, empirical evidence–one of the cornerstones of science–documents a link between cancers and exposure to extremely low frequency electromagnetic fields (ELF EMF) produced by electricity (50 and 60 Hz) as well as radio frequency (RF) and microwave (MW) radiation generated by electronic and wireless technology (kHz to GHz) at levels currently found in the environment and at levels well below international guidelines [4].

EPIDEMIOLOGICAL STUDIES OF CANCER AND EXPOSURE TO EXTREMELY LOW FREQUENCY ELECTROMAGNETIC FIELDS (ELF EMF)

More specifically epidemiological studies document an increase leukemia risk for children who live in homes nears power lines or transformers [5]. This study was independently replicated [6], and the results confirmed an odds ratio of 2.8-increased risk of childhood leukemia at magnetic flux density of 2.2 mG. They later reported a much higher risk in homes with conductive plumbing that carried a ground current and generated an elevated magnetic field [7]. The matched odds ratio increased from 1.72 (1.03-2.88) to 3.00 (1.33-6.76)–with conductive plumbing–when analysis was limited to cases and controls who were residentially stable from the reference date to the study date.

The Bonneville Power Authority [8], reviewed much of the early research on the health effects of low frequency electromagnetic fields. In their chapter on human cancers associated with EMF exposure, of the 226 studies available at the time, 48% (108) reported an increased cancer risk and 4% (8) reported a decreased cancer risk with exposure to extremely low frequency electromagnetic fields (Table 1). The weight of evidence strongly supports an overall increased cancer risk

Table 1: Human studies of EMF and cancer, based on chapter 3 of the Bonneville Power Authority Review.

Population	Cancer Type	Total	Risk		Net Increased Risk (NIR)	
		# of studies	Increased	Decreased	# of studies	% of studies
children residential	leukemia	19	11	0	11	58%
adults residential	leukemia	11	4	0	4	36%
adults occupational	leukemia	61	29	4	25	41%
	brain	55	24	2	22	40%
	breast	20	9	2	7	35%
	cancer	34	16	0	16	47%
child, occupational parents	cancer	12	8	0	8	67%
appliances & heated beds	cancer	14	7	0	7	50%
	total	226	108	8	100	44%
	total (%)	100%	48%	4%	44%	

(mostly leukemia, brain and breast cancer) with magnetic fields in the order of 2 to 12 mG experienced in homes near power lines or in occupational settings [9].

EPIDEMIOLOGICAL STUDIES OF CANCER AND EXPOSURE TO RADIO FREQUENCY RADIATION (RFR)

For radio frequency and microwave radiation generated by wireless technology, the scientific literature documents an increased risk of ipsilateral gliomas [10,11], meningiomas [12,13], acoustic neuromas [14,15], and salivary gland tumors [16,17], associated with mobile phone use for 10 years or longer.

Similarly women who keep their cell phones in their bras for at least 10 years, have a greater risk of development multifocal breast cancer in the area in contact with the cell phone [18], and men who keep their cell phone in their pocket in standby mode have a greater risk of developing testicular cancer [19].

People who live within 500 m of cell phone antennas [20-22], and within 2 km of radio or TV broadcast antennas [23-25], have a greater risk of developing and dying from various types of cancers as do those occupationally exposed such as police officers using radar [26,27], telegraph operators [28], and radar exposed military personnel [29].

While health care authorities will say that the scientific evidence is *inconclusive*, *unconvincing* and/or *inconsistent*, the fact that so many studies in different countries using different methods are getting similar results cannot be dismissed so easily. Clearly there is a discrepancy between theory and observation.

BIOLOGICAL CONSEQUENCES OF NON-IONIZING RADIATION

Biological organisms are much more complex than simple chemical solutions. They have non-linear homeostatic mechanisms that come into play when their environment changes. If it becomes too hot, many mammals will initiate a cooling effect by perspiring and/or altering behavior. When it is too cold, these same organisms will reduce blood flow to their extremities to protect vital body organs.

Similarly, exposure to NIR in the environment initiates changes in the body that are highly complex and interrelated. These changes, all of which can contribute to cancer, include increased calcium flux between cells and altered cell signaling [30], increased permeability of the blood brain barrier allowing potentially toxic substances to enter the brain [31-33], reduced oncostatic effect of melatonin [34,35], production of heat shock proteins indicating cellular stress [36], induced ornithine decarboxylase activity [37,38], and both single and double strand DNA breaks [39,40].

However, the largest body of evidence–and what I believe to be the most convincing–comes from studies of free-radical production and oxidative stress leading to cellular damage, degeneration and cancer [41]. Yakymenko reviewed the scientific literature and provided evidence documenting RF activation of key pathways generating reactive oxygen species (ROS), activation of peroxidation, oxidative damage of DNA, increase in biomarkers of oxidative stress and carcinogenesis and changes in the activity of antioxidant enzymes (Table 2). Ninety-three of the 100 available peer-reviewed studies, dealing with oxidative effects with low-intensity RF exposure, confirmed that RF induces oxidative stress in biological systems.

ELF EMFs have effects similar to RFR. Lai [42], tabulated scientific abstracts dealing with the effects of ELF EMF on free radicals. He found that 84% of the publications (i.e. 97 of 110 studies) reported effects that include production of free radicals and reactive oxygen species (ROS); evidence of oxidative damage including DNA and neurological damage; apoptosis; altered antioxidant enzyme activity (both increase and decrease); and altered immune system response. Supplementation with anti-oxidants (Zn, Se, Vitamin C, and melatonin) ameliorated the harmful effects of NIR.

These two, relatively recent compilations of the scientific literature [41,42], that document oxidative damage generated by NIR from ELF to MW frequencies, in combination with other well documented mechanisms of action (stress protein production, altered calcium flux, increased permeability of the blood-brain-barrier, single and double strand DNA breaks) clearly point to the fact that NIR can and does cause cancer.

CONCLUSIONS

Since the 1950s, scientists have been debating whether NIR

Table 2: Number of studies documenting a statistically significant response to radio frequency radiation. Based on data provided by Yakymenko [41]. Note that the number of observations adds up to more than the total number of studies because some studies reported more than one observation.

	Observation	Increase +	Number of sides with stattistically significant results (p<0.05) following exposure to radio frequency radiation				
		Decrease -	in vitro	in vivo	in humans	total	Explanation/function of biochemicals
1	levels of reactive oxygen species (ROS)	+	10	7		17	
2	Different ROS produced compared to sharm exposure		2			2	
3	DNA fragmentation	+	1	3		4	Indicates damage to DNA
4	induced apoptosis through oxidative stress	+	1	4		5	Apoptosis is programmed cell death and occurs when the body is unable to repair the damage
5	maloedialdehyde (MDA) levels	+	1	26		27	Maloedialdehyde (MDA) is a reactive organic compound that occurs naturally and is a marker for oxidative stress
6	levels of 8-hydroxy-2'-deoxyguanosine (8-OH-dG)	+	1	3		4	8-hydroxy -2'-hdoexyguanosine (8-OH-dG) is a biomarker of oxidative stress and carcinogenesis
7	Nitric oxide (NO) levels	+	1	10		11	Nitric Oxide (NO) is a free radical that plays important role as a cellular signalling molecule involved in many physiological and pathological processes in mammals
		-		1		1	
8	Lipid peroxide (LPO) levels	+	1	14	1	16	Lipid peroxides (LPO) are fats that have been damaged by oxidative stress. Free radicals""steal'' electrons from the lipids in cell membranes, resulting in cell damage. This process proceeds by a free radical chain reaction mechanism
		-		1		1	
9	protein oxidation (PO) levels	+		6		6	protein oxidation is evidence of oxidative degradation of proteins
10	glutathion (GSH) levels	+	1			1	Gluthathione is an oxidant
		-		8		8	
11	glutathion peoxidase (GSH pro) activity	+	1	2		2	Gluthathion peroxidase (GSH px) refers to a family of enzymes whose main biological role is to protect the organism from oxidative damage
		-		13	1	14	
12	superoxidedismutase (SOD) activity	+	1	4	1	6	Speroxidase (SOD) is an enzyme that facilitates the conversion of the superoxide radical (O2)or hydrogen peroxide (H2O2) . Superoxide is produced as a by-product of oxygen metabolism and, if not regulated, causes cell damage. SOD is an important antioxidant defense in nearly all living cells exposed to oxygen.
		-		14	1	15	
13	catalase (CAT) activity	+	1	6		7	Catalase (CAT) is a common enzyme foud in nearly all living organisms exposed to oxygen. It catalyzes the decomposition of hydrogen peroxide to water and oxygen and is an important enzyme in protecting the cell from oxidative damage by reactive oxgen species (ROS)
		-		13		13	
14	anti-oxidant beneficial effects	+	1	28		29	Common anti-oxidants tested include vitamin C, selenium, zinc,melatonin
	Total Studies Reviewed		17	69	4	90	

in vivo studies based on cells/organells from human, rats and mice
animals studies include rats, mice, rabbits, guinea pigs, earth worms, quail and drosophila (fruit fly)
*note: three plants studie not included

can be carcinogenic. The scientific evidence is now sufficiently robust to end this debate. Oxidative damage can explain the increased cancer risk among those chronically exposed to NIR at current levels in the environment and at levels well below international guidelines. NIR can and does cause cancer through a series of complex interactions that include oxidative damage to cells that can lead to cellular degeneration including cancer. The mechanism involves altered activity of antioxidant enzymes, altered immune system response, increased free radical accumulation in cells, oxidative damage to DNA, and apoptosis. Additional support comes from the fact that supplementation with antioxidants can ameliorated the harmful effects of NIR. It is time for the debate on the carcinogenicity of NIR to end and for scientists to recognize that we are experiencing a paradigm shift in our understanding of the biological effects of NIR. Our concept of the biological effects of NIR is much more complex then previously assumed and our understanding now much richer because of the international research effort in this area. The time has come for the scientific community to accept the carcinogenic effects of NIR as a "self-evident" truth and for policy makers and regulators to ensure that the public and those occupationally exposed to NIR are protected against this type of pollution.

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