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Electromagnetic Fields

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Definition

Magnetic fields are generated by the movement of any electrical charge. A continuous electric current passing through a conductor creates a static magnetic field, while an electric current changing in time creates a variable magnetic field, which radiates electromagnetic waves spreading around the surrounding space at light speed. These electromagnetic fields enter living tissue but are known as non- ionizing radiation since they are weak and unable to break molecular bonds. Metals such as iron, zinc, manganese and cobalt are sensitive to electromagnetic fields that may exert their effects on proteins and cellular components containing these metallic elements.

Characteristics

Few environmental issues are as contentious as the question of whether exposure to electromagnetic fields affects biological systems. Considering the widespread use of electromagnetic radiation generating applications such as radio, television, wireless communications etc., the continuing change in the frequencies used, the health hazard implications of any connection between electromagnetic fields and cancer risk have raised a growing interest in the potential biological effects of electromagnetic fields on the mammalian cell growth, viability and response to genotoxic injury. This topic is still a subject of repeated argument, and caution in the interpretation of the effects of static and variable magnetic fields on cellular behaviour needs to be claimed. A measurable magnetic field is created even by the residential electric current. It is noteworthy that we are pervaded by the Earth's static magnetic field that is hundreds of times greater than the low frequency electromagnetic fields created by current within homes.

Epidemiological and clinical evidence

The first connection between human disease and electromagnetic fields was suggested by the observation of a higher incidence of cancer in children [**→ Childhood cancer**] living near power distribution lines. Afterwards major power lines have been held responsible for the occurrence of different cancer varieties. Results of different studies of a possible link between exposure to electromagnetic fields and childhood cancer, namely leukemia, have been rather inconsistent. One large study found no association between electromagnetic field exposure and an increased risk of childhood leukemia, in contrast to previous reports showing that the exposure to electromagnetic fields resulted in nearly a 20 percent increase in the risk of leukemia. This case-control investigation [**→ Case control association study**] did not find a significant link between the risk of childhood leukemia and the actual measurement of magnetic fields in children's current and former homes, including homes their mothers lived in during pregnancy of the affected subjects. Electromagnetic field exposure has also been associated with the risk of breast cancer, mainly in men. Epidemiological studies have shown that in industrialized countries, where the electromagnetic field generating devices are in use on a large scale, breast cancer risk is higher. It has been suggested that electromagnetic field exposure might promote breast neoplasm through inhibition of **→ melatonin** release. Different occupational epidemiological studies have shown an increased incidence of breast neoplasm in women employed in occupations with high electromagnetic field exposure as well as in male electrical workers. However, other investigations, not producing any significant correlation, failed to confirm these suggestive data from occupational studies. In a large Swedish cohort study, an approximate 10% increase in the risk of cancer was documented in people in the medium and high exposure levels. Several types of cancer including skin, digestive, respiratory, reproductive and urinary organs, were linked with occupational magnetic field exposure, suggesting an involvement of the endocrine and immune systems. Discrepancies in epidemiological studies dealing with this matter have involved different estimates of electromagnetic field exposure, measurement and characteristics; the statistical analysis performed with data obtained in such epidemiological reports is another Achilles heel and considerable biases can create misleading

conclusions. Higher exposure has been associated with an increase in the cancer risk even though care needs to be taken in drawing any conclusion, because no dose-response relation has been documented so far. New technologies have been introduced on a large scale only in more recent years and the possible short lag period between exposure and disease manifestation needs to be considered when examining the available data. Children are increasingly heavy users of communication sources (mobile phones) and they are likely to accumulate many years of exposure during their lives. They should be thoroughly monitored in study population to detect possible effects involving long induction periods or effects from long-term exposure.

Experimental evidence

In case of high-frequency magnetic fields, biological effects and health risks are related to the thermal effect associated with sources emitting fields high enough to cause a significant temperature rise in living tissue. Carcinogenesis is a multistep process of accumulating mutations and promoting events. It has been proposed that electromagnetic field exposure might enhance the effects of other carcinogens, provided that both exposures are chronic. The potential for genotoxicity of electromagnetic fields has been investigated and several negative studies in several exposure categories have presented sound and independent, reproducible data. Using in vivo animal models of carcinogenesis the assessment of the potential carcinogenic activity of electromagnetic fields have yielded negative results in different studies, while using the rat mammary carcinoma model results seem to be conflicting. According to available data it is unlikely that long-term exposure to electromagnetic fields is carcinogenic per se in animal models. However, a promoting effect in the development of cancer under certain exposure conditions cannot be ruled out. Since exposure conditions vary widely in the different models thus far proposed, independent replication of experimental results is absolutely crucial. Exposure to electromagnetic field, alone or in combination with ionizing radiation, appears to induce an insult at the cellular level; to inhibit DNA synthesis and the growth of human tumor cell lines in vitro. However, controversies still exist about the possibility that electromagnetic fields may influence tumor promotion. Different in vitro studies have failed to demonstrate any detectable effect of electromagnetic fields on the rate of DNA synthesis and cultured cell growth. Moreover, exposure of cultured mammalian cells to electromagnetic fields has not resulted in the production of detectable DNA lesions and has not affected intracellular **ATP** levels, suggesting that electromagnetic fields are not genotoxic and cytotoxic. On the other hand, investigating the genotoxic potential of electromagnetic fields using in vitro experiments, statistically significant and suggestive positive results have been reported. Following electromagnetic field exposure, enzymatic activity induction, DNA mutation in human and non-human cells, and DNA strand breaks in rat brain cells have been demonstrated. The static magnetic field has been shown to induce a remodelling and differentiation of human neuronal cells in the absence of any alteration of DNA, thus ruling out a direct effect of the magnetic field on DNA stability. Investigating the effects of a static magnetic field on the ability to proliferate of human breast cancer cells in vitro, it has been observed that magnetic field exposure only temporarily slows down cellular growth, which then eventually fully recovers. The reduced cell growth caused by the magnetic field could be explained by a temporary effect on some cellular metabolic events leading to the reduced DNA synthesis. Alternatively, it could be ascribed to a transient cellular differentiation, since induction of differentiated phenotype often correlates with decreased cell proliferation. These results are consistent with the observation that magnetic field induces time-dependent developmental effects on the process of differentiation of the chick cerebellar cortex. Human skin fibroblasts exposed to electromagnetic fields, generated by mobile phones, show alterations in cell morphology and increased expression of mitogenic signal transduction genes (MAP kinase kinase 3 [**→ MAP kinase**], G2/mitotic-specific cyclin G1 [**→ Cyclin G-associated kinase**]), cell growth inhibitors (transforming growth factor-beta [**→ Transforming growth factor**]) and genes controlling apoptosis (bax) [**→ Apoptosis signaling**]; a significant increase in DNA synthesis and intracellular mitogenic second messenger formation [**→ Signal transduction**] matches the high expression of MAP kinase family genes.

Clinical relevance

In conclusion, different studies have given no consistent or convincing evidence of a causal relation between electromagnetic fields and cancer. Available data from other reports suggest that the exposure to electromagnetic fields brings about a weak increase in the risk estimates of neoplasm. However, these studies generally lack statistical power and they have too many deficiencies to rule out an association. Considering that a weak association is not synonymous with a negligible or negative effect, additional more methodologically rigorous studies are warranted.

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