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Biological effects of low frequency electromagnetic fields

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Biological effects of low frequency electromagnetic fields

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Abstract

Recent studies have suggested a possible health effect of low-frequency electromagnetic fields. This report reviews the mechanisms of interactions, the main biological effects and the possibility of cancer induction.

Key Words: electromagnetic fields*; biological effects; non-ionizing radiation; cancer*

The main characteristic that defines an electromagnetic field (EMF) is its frequency or its corresponding wavelength. EMF of different frequencies interact with biological tissues in different ways. Electromagnetic waves are carried by particles called quanta (photons). Quanta of higher frequency (shorter wavelength) waves carry more energy than lower frequency (longer wavelength) fields. Some electromagnetic waves carry so much energy per quantum that they have the ability to break bonds between molecules. Cosmic, gamma and X rays are able to produce breakage in covalent bonds, and are called ionizing radiation. Fields whose quanta are insufficient to break molecular bonds are called non-ionizing radiation. Man-made sources of EMF that form a major part of industrialized life (electricity, microwaves and radiofrequency fields) are found at the relatively long wavelength and low frequency end of the electromagnetic spectrum and their quanta are unable to break chemical bonds.

Although magnetic energies are low, cell studies show that low frequency EMF interact with biological systems and may have health effects. In vitro studies have revealed a variety of sensitive cell-physiologic end-points. Effects have been reported on DNA, RNA, and protein synthesis; cell proliferation; cation fluxes and binding; immune responses; and membrane signal transduction (i.e., hormones, enzymes, and neuro-transmitters). It has been shown that such effects occurred as a result of short-term exposure of cells to EMF at frequencies of 100 Hz or less and at low field intensities. Although it is well established that low-frequency EMF affect biological systems in vitro, the use of these data to affirm that EMF produce human health effects is not clear (Cleary, 1993).

Interaction mechanisms of low-frequency electromagnetic fields with living tissues

Considering EMF interactions from a physical point of view, several mechanisms have been proposed to account for the initial interactions with cells, but these models have been limited by their inability to account for the wide range of experimental observations. The Mobile Charge Interaction model shows that magnetic fields interact with moving charges (i.e. charge flow) in cells and change their velocities, as in the classic interaction of a magnetic field with any moving charge (Goodman and Blank, 2002). Cell membranes have been identified as a primary site of interaction with the low frequency fields (Adey, 1988), being the alterations in these charges and molecules the first step in the production of biological effects.

Since magnetic fields interact with moving charges, as it has been shown in enzymes, it is possible that magnetic fields stimulate the stress response by interacting directly with moving electrons in DNA. Moreover, low-frequency magnetic fields penetrate the cell (unlike electric fields) and they could theoretically interact directly with the DNA in the nucleus (Goodman and Blank, 1999). The reported velocities of electron movement in DNA are comparable to those assumed in the calculation of the Lorentz force. The forces induced by magnetic fields may be large enough to affect processes that can change the rate of movement of electrons significantly, and thereby initiate changes in the DNA. Therefore, DNA sequences rich in C and T (high velocity of electrons in this bases) could generate large repulsive forces that could cause DNA chain separation (Goodman and Blank, 2002).

Mutations and combined effects with ionizing radiation

Exposure to extremely low frequency magnetic field (ELFMF) at 400 mT has been shown to induce mutations whereas at low flux densities (less than 1 mT) the induction of mutations is not clear. Long-term exposure to 5 mT ELFMF does not increase mutations, suggesting a threshold for mutation induction greater than 115 mA/m^2 or a magnetic density of 5 mT. However, an increment in the mutation rate induced by X rays has been observed after long-term exposure to 5 mT ELFMF (Miyakoshi et al., 1999).

Different studies suggest a possible amplification of the genotoxic effects of ionizing radiations (X-ray, gamma ray...) in cells exposed to ELFMF. It appears that exposure to the high density ELFMF at more than 50 mT may potentiate X-ray-induced DNA strand breaks (Miyakoshi et al., 2000) and increase the mutation rate in cells during the S phase of the cell cycle (Miyakoshi et al., 1999). Other studies on X-ray irradiated mice shows that the exposure to pulsing electromagnetic fields (PEMF) after total body x-ray irradiation implies a rapid decline in white blood cells in the peripheral blood of mice exposed to PEMF at all the x-ray dosages assayed (Cadossi et al., 1989). A study on rat tracheal epithelial cell lines shows an increased frequency of binucleated cells with micronuclei in cells exposed to 6 Gy of 60Co gamma rays and ELFMF (homogeneous sinusoidal 50 Hz- 100 mT), compared with gamma irradiation alone. This could enhance radiation-induced genomic alterations and increase the probability of neoplastic transformation (Lagroye and Poncy, 1997).

Electromagnetic fields and cancer

Only electromagnetic radiations at frequencies above the visible region have sufficient energy to directly initiate cancer. Different articles published suggest that if low-frequency electromagnetic fields are part of the carcinogenic pathway, they may act as a promoter or in the progression of established cancer accelerating cell growth (Salvatore et al., 1994), although other authors have observed no effects of EMF (Yoshizawa et al., 2002). Moreover, melatonin, a hormone produced by pineal gland has been shown to slow the growth of breast cancer cells. Recent lab studies show that EMF may decrease melatonin levels and thus promote cancer indirectly. Nevertheless, other studies have found no effects of EMF.

The relationship between EMF exposure and cancer is not clear. It will be very important in the future to continue investigating the EMF effects in biological systems from different points of view to give an answer to the established problems about the risk of EMF exposure.

Resumen

Estudios recientes han sugerido un posible efecto de los campos electromagnéticos de baja frecuencia sobre la salud. El presente trabajo realiza una revisión sobre los mecanismos de interacción, los principales efectos biológicos y la posibilidad de inducción de cáncer.

Palabras clave: *campos electromagnéticos; efectos biológicos; radiación no ionizante; cáncer*

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