Toward Magnetogenetics: Effects of Magnetic Fields on Living Cells

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Magnetogenetics is an elegant approach to precisely controlling the biological functions of a cell, group of cells, tissues, and even organisms using magnetic fields and genetic engineering technologies. We discuss new biological and therapeutic effects of magnetic fields (MFs). Spatially modulated gradient MFs can affect cellular functions of human THP-1 leukemia cells in the following ways: i) induce cell swelling, ii) increase ROS production, iii) inhibit cell proliferation, and iv) elicit apoptosis of THP-1 monocytic leukemia cells in the absence of chemical or biological agents [1]. A high static MF can control the diffusion of biologically active molecules including oxygen, hemoglobin, and drugs, thereby affecting many physiological processes in organisms, e.g., wound healing [2]. It is important for clinical applications to treat a number of myopathies associated with the defective calcium regulation in muscle cells that exposure of skeletal muscle cells to a spatiotemporally modulated 70 mT MF triggers a significant increase in cytosolic Ca2+ levels leading to actin polymerization [3]. The analysis performed in [4] showed that specific ion channels in cells can be turned off and on by remotely applying a high gradient magnetic field, thus modulating the cell membrane potentials. The suggested model and mechanisms provide a general framework for identifying possible hidden mechanisms of biomagnetic effects associated with modulation of ion channel activity by high gradient static magnetic fields. Effects of a high static MF on the DNA synthesis and lung cancer-bearing mice were examined in [5,6]. In mice treated 88 h with a 9.4 T static magnetic field, tumor growth and DNA synthesis were significantly inhibited, G2 cell cycle was arrested, while the ROS and P53 levels were increased. Using a static gradient MF, in probiotic bacteria E. coli Nissle 1917, we shortened the duration of the mitotic phase and thereby accelerated cell division [7]. We show how magnetic forces can influence gene expression and propose a mechanism of cell reprogramming: the MF application generates focused magneto-mechanical stress, enhancing actin filament tension, transmitted stress on the cell nucleus and DNA, leading to changes in gene expression, differentiation pathways, or cellular reprogramming [8]. The physiological sequences of the MF – cell interactions for organisms in health and disease are also discussed.

References:

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