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Evidences of the static magnetic field influence on cellular systems

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ABSTRACT

Efforts to elucidate the doubtful character of the static magnetic field (SMF) influence on living cells have been made, although the topic still faces controversies because confusing reports in the scientific literature. This study intended to collect the most relevant issues separated by different topics (relating the SMF to its action on cellular systems) and analyze how the many field intensities, cell types and exposure time would affect the cell or intracellular structures. The analysis was based in the search in online databases aiming to give a general view of how the data can show conformity. It is proposed that scientists have been searching for linearity in what is actually a well characterized nonlinear system and two outputs are considered: the high sensitivity of parameters in which specific cell responses are generated and also the complexity and particularity of each cellular system. It is possible to trigger effects from a SMF, however in a stochastic way and depending on the cell system.

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1. Introduction

Static Magnetic Fields (SMF) are supposed to interact with the living matter and cause changes in its properties. The effects of the magnetism on biological systems have long been of interest of the scientific and non-scientific community for its applicability in diverse fields, which can cover since the cancer treatment

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(Ghodbane et al., 2013; Li et al., 2013; Raylman et al., 1996), cardiological studies (Bekhite et al., 2013) and even the alcohol industry (Da Motta et al., 2004).

The harmful character of the SMF and the need to protect human health, mostly cause the increasing use of electronic devices and NMR equipments (Dini and Abbro, 2005; Ghodbane et al., 2013; Schenck, 2000), have been focus of discussion. Budinger (1985) mentions the SMF as agent of health risk on the DNA damage and the hormonal alterations. Ghodbane et al. (2013) report increases by the SMF in the reactive oxygen species (ROS) and also in the activity of paramagnetic free radicals with consequent effects in the DNA breakage, apoptosis and oxidative stress, reflecting in the cancer-generating process. Free radicals, created by the SMF (through the pair recombination mechanism), have also been discussed in the literature (Formica and Silvestri, 2004) as injurious. Schenck (2000) reports that although many studies have cited the harmful aspect of the magnetic fields (on cells, issues and organisms), no one has been yet established as a scientific fact.

Since the early twentieth century (Kimball, 1938), reports have tried to identify the action of SMFs on many kinds of cellular components. The literature relates experiments with widely diverse: field intensities (10^{-6} to 10^{1} T); exposure time (lasting real-time observation, minutes, hours and even days); organisms as microbial systems, plant cells, mammalian, human cells (McCann et al., 1993) and also intracellular constituents as microtubules (Chionna et al., 2005), proteins (Torbet and Ronzière, 1984) enzymatic activity (Maling et al., 1965) and nucleic acids (Potenza et al., 2004a). For this reason the results are confused and dispersed in an unclear constellation of effects.

Recently, Anton-leberre et al. (2010) reported that the SMF does not affect many cellular processes. Zhang et al. (2003) commented that the reported effects have just not been evaluated sufficiently. This criticism is based on inefficient consensus about experimental design, absence of guideline to exposure range (Higashi et al., 1993b) and even cases of fraud (De Certaines, 1992).

The cell can be considered as a complex system formed by a grouping of susceptible components to the SMF, such as electrical charges (ions, free electrons) and molecules with magnetic moments (Teng, 2005). All those elements could combine to produce cellular responses and, since the cellular environment comprises a non-linear system, magnetism-dependent phenomena could arise from combination of many ideal conditions.

This review aims to contribute with new evidences of the SMF influence on cellular systems as well as giving a discussion about early and recent reports so that it is possible to clarify remaining confusion and encourage new investigations.

2. Methods

The selection criterion for the articles was based in the relevance of the themes relating the SMF and particular cell systems. It was necessary to classify the papers per issue and to make the data survey separately, for each theme, by: SMF intensities, exposure time, type of the object (cell, intracellular structure or biomolecule) and the main observable effects.

Two different databases were consulted: Pubmed and Google Scholar (to overcome deficiencies of each one individually). The search was performed in english, without limit of year of publication (but prioritizing the most recent publications) and repetitive studies were excluded. It was used the term “static magnetic field” related to 10 specific and pre defined themes: DNA and gene expression, biomolecules orientation, cell growth, cell viability, cell morphology, calcium metabolism, enzymatic activity, radical pair recombination, biomolecules synthesis and cellular membranes.

The study focused mainly in the cellular system, ignoring however influence in multicellular living being (for example large number of studies involving physiology of pigeons and rats), but without caution in distinguishing prokaryotic from eukaryotic organisms, for example. It is also clear that variable magnetic fields and electromagnetic waves are excluded from the scope of this review. Our aim is specially to show a general and new prospect of publications involving the SMF and cell systems as well as giving a critical discussion about the theme.

3. SMF effects on nucleic acids and gene expression

Differential gene expression plays an essential role in regulation of metabolism, biosynthesis and in the cellular stress response. The SMF is cited as agent of changes in those processes once it acts on DNA integrity (Amara et al., 2007), mutation (Zhang et al., 2003) and also in the processes of the DNA transcription (Paul et al., 2006) and translation (Goto et al., 2006).

We tried to find some relationship between the SMF arrangement and the expressed genes or the DNA damage. Experiments ranging from low (15 mT) intensity (Jouni et al., 2011) to strong (37 T) fields (Anton-leberre et al., 2010) intensities, lasting minutes, hours and days of exposure were evaluated and they do not present linear correlation with the effects. The dose and exposure time were considered by Laramee et al. (2014) as an important factor to arise effects once it was possible to observe different expression levels of hsp70 gene with variable SMF intensities (peak of expression between 10 and 100 mT) and longer time of exposure (higher expression with 48 h).

Escherichia coli was often cited in these studies (Ji et al., 2009; Potenza et al., 2004a; Zhang et al., 2003) for being a model and pioneer organism with a sequenced genome (Blattner, 1997), but observations have been made on many other organisms as diverse as *Salmonella enteric* (May and Snoussi, 2009), *Drosophila melanogaster* (Kale and Baum, 1980), plant cells (Paul et al., 2006) and human cells (Amara et al., 2007).

The events and elements that form the machinery of DNA and RNA metabolism: multienzyme complex, transcription factors, transposition activity and mutagenicity are listed in the literature as subject to the SMF action. Ikehata et al. (1999) studying four tester strains of *S. typhimurium*, mentioned that the double strand DNA has probably an anisotropic character, but, once the genomic DNA is generally located compacted with nucleoid proteins, it would lose its susceptibility to the field and thus the magneto-mechanic effect could not explain observed responses. The authors also suggest that electronic interactions, alterations in the mutation pathway of chemical mutagens, changes in membrane permeability and alkylation process are possible ways to affect the DNA.

The effects reported are varied in these studies. Authors such as Anton-leberre et al. (2010) and Kale and Baum (1980) verified low or no one DNA susceptibility to a SMF. Mahdi et al. (1994) found no evidences of DNA damage when exposing *E. coli* to a 0.5–3 T SMF. Amara et al. (2007) failed to find significant DNA strand breaks in exposed human THP1 cells. No effects were also identified in the gene expression when Schwenzer et al. (2007) applied a 3 T SMF to human embryonic lung fibroblasts.

On the other hand, Goto et al. (2006) reported the gene Ntan1 of rat hippocampal neurons as being affected for a 100 mT SMF and Jouni et al. (2011) observed a significant enhancement of chromosomal aberrations (bridge, fragments and lagging chromosomes) and in the chromosome number when they exposed cells of *Vicia faba*, pre-cultivated in natural radiation background, to a 15 mT SMF. Zhang et al. (2003) showed that a high SMF (up to 9 T) can significantly increase the mutation frequency of soxR and sodAsodB mutants.