Loss of Bone Calcium in Exposure to 50 Hz Magnetic Fields

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Loss of Bone Calcium in Exposure to 50 Hz Magnetic Fields

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This study investigates the effect of whole body exposure to magnetic fields on the calcium level of blood and bone in a trial to avoid the liability of osteoporosis, fractures, and delayed union of fractures after exposure to magnetic fields present everywhere in the environment. The procedures of the study included analysis for calcium level in both bone and blood. The procedures were performed on 50 Guinea pigs equally divided into 5 groups. Groups A, B, C, and D were exposed to 50 Hz, 0.2 mT magnetic field for 30 d. Group E animals were the control. Group A was sacrificed immediately after exposure; Group B was left away from the field for 15 d for spontaneous repair; Group C received the drug Centrum dissolved in drinking water for 15 d after exposure to the magnetic field; and Group D received centrum in drinking water during the period of exposure (30 d). After sacrificing all animals, the calcium level in both bone and blood was evaluated. Values of blood analysis revealed significant increase in the blood calcium level in exposed animals compared with the control group (P < 0.002) with excess in Group A. This indicated that the calcium left the bone to the blood. Values of the bone analysis revealed significant decrease in bone calcium concentration level in Group A compared with the control group and improvement in the bone condition in Groups C and D, indicating the role of trace element after the exposure period as a compensatory agent of magnetic field damage and its role during the exposure period as a radio-protecting agent.

Keywords EMFs; Blood analysis; Bone calcium.

Introduction

Electromagnetic radiation is present in a variety of forms that we encounter every day. The electromagnetic spectrum extends from extremely low-frequency (ELF) electromagnetic fields (EMFs), such as those associated with electrical power systems and including X-rays and high-energy gamma rays, to extremely high-frequency electromagnetic fields (EMFs). In between those extremes, radio waves, microwaves, infrared radiation, visible light, and ultraviolet radiation are found (Carpenter and Ayrapetyan, 1994).

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Recently, there has been considerable concern and controversy about the effects on health from increasing exposure of populations to ELF-EMFs, normally defined as less than 200–300 Hz, which are present in both residential and workplace environments (Fadel et al., 2003; World Health Organization, 2005; Efstathopoulos et al., 2006).

The mechanism of interaction between ELF-EMFs and biological structures is still obscure. Epidemiological studies have demonstrated the therapeutic effects of EMFs at different intensities and frequencies. However, several epidemiological studies have demonstrated increases in the appearance of pathology like childhood leukemia, chronic fatigue syndrome, cancer, impaired reproductively, and other diseases in populations exposed to ELF (50–60 Hz) EMFs (Hulbert et al., 1998; Saunders, 2003). On the other side, the EMFs have been used as a method of controlling tumor growth (Fadel et al., 2003). Also, EMFs have been found to be beneficial to a wide variety of biological phenomenal as in the promotion of healing of ununited fractures (Liesner et al., 2002; Frederick et al., 2000; Takahashi et al., 2000; Deibert et al., 1994).

A subject of considerable contemporary interest and debate is the possible relationship between human’s exposure to electromagnetic fields and adverse health effects. Therefore, the main objective of this work is to evaluate the risk of whole body exposure for the prolonged period to ELF magnetic fields on the bone characterization and structures of animals as a step forward to evaluate human risk. Moreover, to find out the possible repair period for the injuries thus occurred. Furthermore, to evaluate the role of magnetic field radio-protector on the repair mechanism as well as the level of damage.

Materials and Methods

Subjects

Fifty male Guinea pigs, aged 3–4 months and weight 400–500 g, were equally divided into five groups namely A, B, C, D, and E. Animals of Group E were used as the control group and did not receive any treatment during the course of the experiment. Animals of Groups A, B, C, and D were whole body exposed to 50 Hz, 0.2 mT magnetic field for a period of 30 d at a rate of 8 h/d. Group (A) animals were sacrificed immediately at the end of the exposure period and subjected to experimental studies. Group (B) were left for a period of 15 d after the end of the exposure period, away from any radiation, then sacrificed and subjected to the experimental studies. Animals of Group C were left away from the magnetic field for a period of 15 d and received a drug (Centrum) dissolved in the drinking water during this period then the animals were sacrificed and subjected to experimental investigations. The drug named Centrum in the form of tablets was purchased from Lederle Laboratories Division and manufactured by American Cyanamid Company, Pearl River NY. It is normally prescribed by physicians to compensate for the lack of trace elements and the recommended daily drug of mass (for human is one tablet/day). Therefore, the concentration of this drug in drinking water for the animals was considered based on the ratio of human weight to animal weight (80 Kg/0.5 Kg). One tablet dissolved in one liter of water for 20 animals (animals in Groups C and D).

Group D animals received Centrum during the exposure period and then were sacrificed and subjected to experimental investigations immediately at the end of the
exposure period. All animals in all groups were incubated in the same environmental conditions (good light, ventilation, 25°C temperature) and all of them received the same diet.

**Experimental Procedures**

1. **The Magnetic Exposure System:** The magnetic field exposure provides a homogenous magnetic field generated by 4 solenoids of 270 turns each of electrically insulated 2.2 mm Copper wire, wound around a copper cylindrical chamber of 55 cm external diameter as shown in Figure 1. Water was pumped in a copper jacket separating the wire winding and chamber in order to keep the temperature of the chamber constant during the exposure period (Fadel et al., 2003).

The temperature of the flowing cooling water at the outlet of the jacket and the temperature inside the irradiation chamber were periodically measured through the use of thermocouple thermometer, which can give readings for the temperature variations within ±0.1°C. The actual current passing in the solenoids was about 2 A. The animals were kept in special plastic cages that permit normal ventilation and daylight. The cages with the animals were fixed on supports inside the irradiation chamber.

The magnetic field was measured by means of a hand-held Gauss/Tesla meter (Model 4048 with probe T-4048.001 by Bell Technologies, Inc., USA), and the magnetic flux density in the area where the animals were housed, was 0.2 ± 0.01 mT. The coils were connected to a various fed from the mains (220 Vpp and 50 Hz).

2. **Preparation for Biochemical Testing:** After sacrificing all of the animals, the blood samples were collected in tubes for the estimation of the blood calcium level in the same day of sacrificing. The humerus of both sides were dissected free and cleaned of soft tissue. All humeral specimens were stored in physiological buffered saline solution at 4°C until biochemical testing was done (Yan et al., 2007).

3. **Blood Calcium Analysis:** The serum calcium content of each blood sample was measured by using Atomic Absorption Spectrophotometry. In this system, serum calcium forms a colored complex with O-Cresolphthalein which has an absorption characteristic band at 660 nm.

4. **Bone Calcium Concentration:** Humeral specimens of all animals were stored for one week in saline solution. All specimens were extracted for calcium assays. Each
specimen was weighted before analysis then prepared by dissolving in 10% Nitric Acid over a period of 24 h. Calcium assays were performed via Atomic Absorption Spectrometry. Raw assay data were normalized to the initial specimen weight.

Results
1. **Blood Calcium Level.** The average value of the blood calcium level for animals of Groups A, B, C, and D was high as compared with the control Group E (see Table 1 and Figure 2). This increase in blood calcium level was greatest in Group A.

   ANOVA of blood calcium level of all groups were performed showed that there was significant difference in the blood calcium level between Groups A, B, C, D, and E (control) with \( P = 0.002 \).

2. **Bone Calcium concentration.** The average value of calcium concentration in the bone of the different groups revealed that the concentration of \( \text{Ca}^{++} \) in bone had been dramatically decreased in Group A as compared with control Group E. Slight repair in the level of \( \text{Ca}^{++} \) in animals of Group B. However, the administration of trace elements post exposure to the magnetic field (Group C) caused slight increase

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean ± SD (mg/dl)</th>
<th>Minimum (mg/dl)</th>
<th>Maximum (mg/dl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>14.1 ± 0.23</td>
<td>13.500</td>
<td>14.60</td>
</tr>
<tr>
<td>B</td>
<td>10.0 ± 1.97</td>
<td>4.1</td>
<td>12.10</td>
</tr>
<tr>
<td>C</td>
<td>10.513 ± 0.799</td>
<td>6.60</td>
<td>13.20</td>
</tr>
<tr>
<td>D</td>
<td>11.714 ± 0.238</td>
<td>10.70</td>
<td>12.80</td>
</tr>
<tr>
<td>E</td>
<td>9.175 ± 0.542</td>
<td>6.60</td>
<td>11.200</td>
</tr>
</tbody>
</table>

**Table 1**

Blood calcium level for different groups

**Figure 2.** Blood calcium level in different groups.
in the Ca\(^{++}\) level in bone as compared with Group (A). The administration of trace elements during exposure to magnetic fields kept the concentration of the Ca\(^{++}\) in bone much closer to control group E as in Table 2 and Figure 3.

ANOVA of bone calcium concentration of all groups were performed showed that there was significant difference in the bone calcium concentration between Groups A, B, C, D, and E with \(P = 0.000\). Two-Sample Test (T-Test) and Confidence Interval Test (CI) Test were performed to compare between bone calcium concentration and blood calcium level. These tests proved that the increase in the blood calcium level was accompanied with decrease in the bone concentration level that means the blood calcium level is inversely proportional to bone calcium concentration.

**Discussion**

The object of the present article was to investigate the effect of whole body exposure of mammalian animals to 50 Hz, 0.2 mT magnetic fields on the bone structure and functions. The role of trace elements as a protective agent, on the induced damaging effects of the magnetic field, was studied through the administration of the animal’s drug during or after exposure. The drug administered was Centrum which contains trace elements such as Molybdenum (Mo) and Selenium (Se), in addition to some important anabolic elements such as Magnesium (Mg), Calcium (Ca), Copper (Cu), and some other vitamins.
The level of Mo in the body is normally balanced by the level of Cu; a decrease of Mo level is associated with a decrease of Cu level. Since Cu ions are responsible for the binding of Ca\(^{++}\) in bone and binding of iron (Fe) in goblin molecules to form hemoglobin, the concentration of Mo as well as Cu in the blood form an essential factor for bone to bind Ca\(^{++}\) as for bone marrow to generate red blood cells (Smith, 1999). All these were the objectives of the use of this drug.

As can be noticed from the results, the concentration of Ca\(^{++}\) in blood serum was dramatically increased in animals of Group A as compared with control Group E. This indicates that whole body exposure of the animal to 50 Hz, 0.2 mT magnetic field resulted in the release of Ca\(^{++}\) from the bone which will lead finally to the less of bone physical and structural properties.

This analysis is supported by the bone calcium concentration which indicated the less of Ca\(^{++}\) from the bone of animals of Group A. The results also indicated that delayed effect studies of the calcium concentration in both blood serum and bone was slightly improved for animals of Group B, where the Ca\(^{++}\) concentration in blood was decreased, as compared with Group A as its concentration in bone was increased. This result indicates that the instantaneous influence of 50 Hz, 0.2 mT magnetic fields on bone may be deteriorated after getting away from the field and the body starts to carry on natural repair to the damaged sites. As was indicated in published reports (see Carpenter and Ayrapetyan, 1994; Fadel et al., 2002; Sellmeyer et al., 2002), exposure to 50 Hz magnetic field at densities higher than 3 \(\mu\)T can expect the less in concentration of calcium in bone and other tissues which may cause the deterioration of cellular functions in the different organs.

As can be noticed from the results, the administration of Centrum drug during exposures to the magnetic field deteriorated the destructive effects of radiation on Ca\(^{++}\) ions in both blood serum and bone. This can be noticed from the data for Group D as compared with all other groups and with the control Group E. The level of Ca\(^{++}\) in bone for this group is much higher than any other group demonstrated as compared with control. This result indicates that the administration of this drug during exposures to 50 Hz magnetic field decreases the harmful effects of radiation and hence can be used as a magnetic field protective agent. Moreover, the administration of this drug following prolonged exposures to 50 Hz magnetic field improves the repair process and increases healing of damaged sites. However, the increase of Ca\(^{++}\) in blood for Group D as compared with Group B may be mainly due to the administration of the drug which contains Ca\(^{++}\).

Calcium is one of the important mineral contents of bone matrix. Mineral contents is inorganic component forming more than 45% of bone matrix and responsible for hardness of bone. Only 30% of bone matrix in the form of protein (organic component) and the remaining is water. The organic component is responsible for the elasticity of bone. In the adult subject, there is balance between inorganic and organic ratio maintaining mechanical properties of bone within normal values (Frankel and Nordine, 2001).

From the results of this work, it was found that the exposure to 50 Hz, 0.2 mT can have an effect on both chemical properties of bone as a result of stimulation of inactive bone cells responsible for bone remodeling. Imbalance of bone remodeling produces osteoporosis (George and Vashishth, 2005). On a study to investigate the cellular responses to mechanical forces, it was found that the generated magnetic field can cause biological effects on bone cells. But magnetic responses of biological systems have not been well characterized (Panagopoulos et al., 2000). Furthermore, it was found that the basic mechanism for action of the electromagnetic fields on
cells is the forced-vibration of all the free ions on the surface of a cell’s plasma membrane, caused by an external oscillating field and it have shown that this coherent vibration of electric charge is able to irregularly gate electrosensitive channels on the plasma membrane and thus cause disruption of the cell’s electro-chemical balance and function (Panagopoulos et al., 2002).

References


