Effect of electromagnetic fields on some biomechanical and biochemical properties of rat’s blood

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Abstract: In order to study the effect of electromagnetic fields (0.3 mT, 50 Hz) on some biomechanical and biochemical properties of rats’ blood, healthy thirty male albino rats of 150 ± 10 g were divided into three equal groups namely A, B1, B2. Group A used as a control group, group B1 was continuously exposed to a magnetic field of (0.3 mT, 50 Hz) for a period of 21 days for direct effect studies. Group B2 was continuously exposed to the same magnetic field for the same period of time, then was housed away from the magnetic field for a period of 45 days for delayed effects studies. After examination, the results indicated that the apparent viscosity and the consistency index increased significantly and very high significantly for groupe B1 and B2 compared to control at P<0.05. Red blood cell counts (RBCs) membrane elasticity had significantly and very high significantly decreased for groups B1 and B2. Moreover, delayed effects studies indicated that there is deterioration in the bone marrow functions. These results are supported by the blood film image, where irregularities and deformations in the RBCs membranes had been occurred. We conclude that the cell membrane properties are highly affected by the extremely low frequency (ELF) magnetic fields, which proved to be biologically toxic.

1. Introduction

There are numerous sources of environmental extremely low frequency (ELF) magnetic fields, both naturally occurring and man–made, to which humans are exposed [1]. Large intermittent, time varying magnetic fields are produced in the atmosphere as a result of intense solar activity and thunderstorms, and can reach levels up to 0.5 μT (T=Tesla =10^4 gauss) during magnetic storm [1].

Numerous man made sources of ELF magnetic fields are present in at home, work place and public places such as urban transit systems. These sources include electric power transmission and distribution lines, long-range ELF military communication systems and a wide variety of appliances, tools, and machines used in offices and various industries [1-3]. Recently, there has been a considerable research effort on biological effects and potential hazards of low-frequency electric and magnetic fields.

The aim of the present work is to study the effect of electromagnetic fields (0.3 mT, 50 Hz) on some biophysical and biochemical properties of rat’s blood.
2. Materials and Methods

2.1. Experimental animals
Thirty male albino rats, each of average weight of 150±10 g were divided into three groups as follows: group A as control group, group B1 is directly exposed continuously to magnetic field of 0.3 mT (50Hz) for 21 days, group B2 was used for late effect studies after 45 days.

2.2. Determination of the rheological properties of blood
Viscosity is an expression of the degree of slipperiness between two layers of fluid. Shear stress is expressed as force per unit area (F/A). The shear stress, required to produce a shear rate, is defined as the viscosity [4]. Rheological properties of blood are determined by the Brookfield DV-III programmable rheometer. Brookfield DV-III programmable rheometer measures fluid’s parameters of shear stress and viscosity at given shear rates according this relation, shear stress = (shear rate)$^n$, where $n$ is the zero shear Newtonian viscosity [5]. The exponent $n$, often called flow index.

2.3. Osmotic fragility
A stock solution of buffered sodium chloride, osmotically equivalent to 100 g/L (10%). The percent of hemolysis (H%) can be plotted as a function of the percentage of sodium chloride concentration [6].

2.4. Histology
The blood film was made by a manual method for making wedge blood smears. The RBCs were examined by using image analyzer system called SAMICA (Scanning and Measuring with Automatic Image Contour Analysis) with magnification of 1000 times.

2.5. Statistical analysis
Analysis of data was performed using student ANOVA test and comparing between means using Least Significant Difference (LSD) at P < 0.05 as outlined in [7].

3. Results

3.1. Rheological Properties of Blood
Figure 1(a) illustrates the variation of the blood viscosity (cP) as a function of the shear rate (s$^{-1}$) from all groups. As shown, the viscosity of the blood from groups B1 and B2 has higher values at all shear rates as compared with control group A. Moreover, this increase in the value of the blood’s viscosity is maximum at shear rate (7.50 s$^{-1}$) for samples from group B2 as compared with control group A. The variation of the shear stress (dyne/cm$^2$) as a function of the shear rate (s$^{-1}$) for the blood samples from groups A, B1 and B2 are shown in figure 1(b).

![Figure 1](image-url)

Figure 1: Variation of the blood viscosity (left) and shear stress (right) versus shear rate for groups A, B1, and B2.
3.2. Osmotic Fragility Test
Figure 2(a,b) shows the results of osmotic fragility measurements for the RBCs collected from animals of different groups of A, B1 and B2, where the percentage of the hemolysed cells are plotted as a function of the percentage of NaCl concentration. The differentiations of these results were plotted against the NaCl% and shown in figure for the three groups. The differential curves results indicate the behavior of the curves pass through a maximum (C %) at which maximum hemolysis rate occurs.

![Figure 2: Osmotic fragility (left) and differentiation curves(right) for group A, B1, B2.](image)

3.3. Histology
Figure 3 shows an image for a blood film from all groups as scanned and magnified 1200 times by the image analyzer. The photo 3-a (left) indicates regular traditional forms of the RBCs. Alos, we note that the compression occurred on some adjacent cell membrane (marked by arrows) due to the repulsive coulomb forces originated from the positive surface charges on the RBCs, membrane. It is clear from the figure 3-b (middle), that changes had occurred in the morphology of RBCs membrane of the exposed group. These changes, in the cell membrane, can be easily noticed from the formed aggregates of several adjacent blood cells and some cells diffused in each other forming common membrane (marked by arrows). Figure 3-c (right) illustrates the scanned blood film image from the exposed group 45 days post exposure to magnetic field. The image shows that the newly generated RBCs’ membrane had many disorders as compared with control group. It can be also noticed that some cells diffused in others, all cell membranes are irregular and the back ground of the slide is unclear because of hemolysis.

![Figure 3. Blood film for groups A,B1, and B2 (x1200).](image)

4. Discussion
The studies focused on the mechanical properties of the RBC’s membrane, which plays an important role on the RBCs metabolic activity and it was used as an example to the possible injury that may occur in
other cells from different organs. This was achieved through viscosity, osmofragility studies and blood film images.

From the present data, one may easily find that the apparent viscosity of the blood increases significantly and the half maximum width of the osmo fragility curves suffered highly significantly decrease for blood collected from group B1. Moreover, from the blood film for group B1 one may find the formation of aggregates and diffusion of adjacent cells. Therefore, one may presume that the direct effect of the 0.3 mT, 50Hz magnetic field on the cellular membrane is the disturbance of the molecular free motion of the bilayer macromolecules forming the cellular membrane. These magnetic forces will cause some changes in the packing properties of these macromolecules that may lead to changes of the cell membrane mechanical properties such as the elastic range and permeability.

One may easily notice, from the blood film for normal samples from group A, that there are coulomb forces between adjacent RBCs that prevent formation of aggregates or diffusion. These electric forces are strong enough to cause bending to the cell membranes when a cell is in close proximity between two cells (marked by arrows in figure 3(a)(left)). Alos, the highly significantly decrease of $W_{\text{hmax}}$ for the RBCs from group B2. The decrease of $W_{\text{hmax}}$ means the decrease of the elastic range of the cell membrane and hence folding of the cells to pass through the blood capillaries (which have much smaller diameter than the RBCs diameter) will be reduced and hence the RBCs will fail to reach the target cells to carry on their metabolism. One may state here that the direct effect of exposures to the 50 Hz, 0.3 mT magnetic field is the change of the cell membrane properties. Delayed effect studies did not show any sort of repair to different organs especially to the RBCS. The newly generated RBCs have irregular membrane form as the blood was full of aggregates of RBCS, in additional to the pronounced hemolysis occurred. This finding indicates that the bone marrow (the blood generating system), was heavily injured, either directly by the influence of the magnetic field or indirectly as a feedback to the defects of the RBCs, which failed to do their metabolic activities with the bone.

5. Conclusions
Exposure to the 50 Hz, 0.3 mT magnetic fields is biologically toxic. When investigating the hazards of non ionizing radiation, it is necessary to study the physical properties of the RBCs and to have blood film magnified to 1200 times. Also, It is necessary to encourage and to support research work in the radiation hazards for non ionizing radiation; since it is distributed everywhere and there is no dosimetry system that exists till now.

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