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A Study on how Electromagnetic Radiation Affects the Blood System

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Abstract:
The mobile phone has evolved into a device that almost everyone needs. It's not only for making phone calls, though. Today, individuals use their mobile devices for everything from banking and other administrative tasks to working remotely and even attending lectures. Concerns about the possible connection between mobile phone radiation and the biological consequences on animals' neurological, haematological, reproductive, and endocrine systems have grown in response to the widespread use of mobile devices. The effects of electromagnetic radiation on the circulatory system are the subject of this article.

1. Introduction

Energy in the form of electromagnetic radiation (EMR) may be found both in nature and in man-made sources like wireless networks and mobile phones. Concerns have been expressed concerning the possible negative consequences of EMR exposure on human health, which has risen dramatically in recent years. While the impacts of EMR on many organ systems have been well-studied, the blood system's reaction to EMR has received less attention.[1]

The blood system is an intricate network of cells, tissues, and organs responsible for transporting oxygen and nutrients throughout the body and maintaining homeostasis. Anaemia, thrombosis, and bleeding disorders are only some of the major consequences of blood system malfunction. Exposure to electromagnetic radiation (EMR) may have harmful consequences on the circulatory system, according to mounting data that has accumulated in recent years.[2]

Magnetic resonance (MR) is a wave-like energy that propagates across the universe. It covers a wide range of frequencies, from extremely low-frequency (ELF) radiation to radio-frequency (RF) and microwave (MW) radiation. Power lines generate extremely low-frequency (ELF) radiation, whereas wireless devices such as mobile phones and Wi-Fi access points emit radio frequency (RF) and microwave (MW) radiation. The World Health Organisation (WHO) and the International Agency for Research on Cancer (IARC) have both called for further study into the potential health consequences of EMR exposure. The IARC has classed RF radiation as a probable human carcinogen.[3-4]

Blood cells, such as RBCs, WBCs, and platelets, are all produced in the bone marrow. While WBCs are essential to the immune response, RBCs are in charge of transporting oxygen to the body's numerous tissues and organs. Platelets assist stop bleeding by forming clots in the blood. Haemoglobin is a protein within red blood cells that transports oxygen from the lungs to the rest of the body. The proportion of RBCs in the blood is measured by the haemoglobin (Hct) level.[5]

Multiple researches have looked at the possible impacts of EMR on the circulatory system. For instance, when rabbits were exposed to RF radiation,

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their haematological parameters changed. RBC and Hb levels were found to be reduced, but WBC and platelet counts were found to be elevated, as stated by the authors. Rat brains exposed to MW radiation experienced oxidative damage, inflammation, and cognitive impairment.[6]

2. Material and Methods

Adaptation of Animals

Sixty male Swiss Albino mice averaging 20 + 10 g in weight were used in the study. A 25° C to 27° C temperature range and a 12 hour day/night cycle were used to house the animals. All procedures involving animals were carried out in accordance with the recommendations of the Presidency University IAEC and CPCSEA, Ministry of Environment, Forest, and Climate Change, Government of India.

Preparing a Diet

The mice were divided into four groups and given two different sets of isocaloric, house-made food formulations ad libitum, as described in the section on experimental design. Protein accounted for 21.36 percent of the total calories in a typical diet, which consisted of 100 grammes of casein (5 grammes), 46.50 grammes of chickpeas, 38.50 grammes of wheat meal, and 5 grammes of maize oil. The protein composition of the HPD was 33.37% of the total calories, and each 100 g serving comprised 20 g of casein, 31 g of chickpea, 5 g of maize oil, and 39 g of wheat flour.

Table1: Dietary Characteristics of Two Groups

% mass			**Proteins**		**Carbohydrates**	**Lipids**	**Vitamins and minerals**	**Energy**
Composition	Wheat Meal	Chick Peas	Casein	**TOTAL**				
Normal diet	4.6585	10.4625	5	20.1211	53.7355	8.0725	7.22	367.37 kcal
High Protein Diet	4.719	6.975	20	31.694	45.077	7.275	7.2	370.38 kcal

Conception of Experiments

The animals were divided into four groups at random. owning a dozen animals. Group A were fed a regular diet whereas Group B were provided a regular diet and exposed to mobile phone radiation at the same time. Group C was subjected to the same quantity of mobile phone radiation as Group B, but they were also given a high-protein meal supplement. Group D was not exposed to any radiation and received just the high-protein diet. After 3 months, 6 animals from each group were killed as a test.

After three months, the animals in Group B were split into two groups, B1 and B2, each with six animals, while the animals in Group C were split into C1 and C2, also each with six animals. Group B1 and C1 animals had a break in their radiation exposure and the same meals, whereas Group B2 and C2 animals were exposed to radiation continuously and received the same foods. All the animals in all the tribes were slaughtered at the conclusion of the month.

2.1 Studydesign

Exposure to radiation from cell phones:

Cell phones emitting frequencies similar to GSM at 1.8 GHz were used to expose animals to radiation using a power metre with a specific absorption rate of 1.5W/kg. The experimental groups' animals were subjected to constant radiation exposure for three months at the rate of three hours each day. Placed at a

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distance of 14 cm at an angle of 90 degrees from each other on the top of the plexiglass cage, the mobile phones were maintained in calling mode. During the time of exposure, the animals in the cage had free reign.

Serumcollection

The animals' hearts were punctured to extract around 2 ml of blood, and the serum was then separated using centrifugation for biochemical testing.

Quantifying haemoglobin and counting white and red blood cells:

Hayem's fluid was made of 0.5% (w/v) Sodium Chloride, 0.25% (w/v) Sodium Sulphate, and 0.25% (w/v) Mercuric Chloride, and a Sahli haemoglobinometer was used to assess haemoglobin levels.

Difficulty in counting:

Smear was made from a drop of blood on a clean glass slide. DC was performed using the compound microscope after being stained with Leishman solution.

Scanning electron microscopy sample prep:

A drop of blood was taken from the animals' middle caudal vein and put onto the cover slip, then left to air-dry. An agar sputter coater was used to provide a coating of 5 ng gold on the blood-smeared cover slips. The blood smears with the gold coating were microscopically analysed and photographed using a scanning electron microscope.

Assay for the Osmotic Fragility of Erythrocytes:

Osmotic fragility of erythrocytes was measured using the technique published by Faulkner and King with an Oyewale twist. Each animal's 1 mL of freshly drawn heparinized blood was pipetted into a series of test tubes containing 0, 0.1, 0.3, 0.5, 0.7, and 0.9g/L of NaCl (pH 7.4), where it was well mixed and kept at room temperature for 30 minutes. For 10 minutes, we centrifuged the tubes at 800 g. The absorbance was measured spectrophotometrically at 540 nm after the supernatant was carefully put into the glass cuvette. Each sample's haemolysis % was determined using Faulkner and King's method.

Malondialdehyde (MDA) production analysis:

Each animal had around 1 mL of blood drawn and centrifuged at 3000 g to remove the plasma. Erythrocyte packets were produced and MDA concentration was determined using the twofold heating technique of Draper and Hadley after R.B.Cs were washed three times with cold isotonic saline (0.9% w/v).The revised version of 58 by Yavuz et al.59 The concentration of haemoglobin in the cleansed RBCs was determined using the technique developed by Dacie and Lewis60.

2.3 Analytical Statistics

The data were presented as a mean + standard error of the mean (n=6). To find the significance level, a one-way analysis of variance was carried out. Significant differences at p 0.05 were reported.

3. Results

3.1 Shorttermeffect ofelectromagnetic radiation:

The impact of electromagnetic radiation on many measures of blood health was investigated:

Table 2: Albino mice exposed to mobile phone radiation had their RBC, WBC count, and haemoglobin percentage all affected by a high-casein diet

Parameters	TRBC million/cu- mm	W.B.C. thousands/mm^3	Hb% g/dl
GR A (Control)	5.7$\pm$0.141	5.05$\pm$0.029	11.05$\pm$0.017
GR B (Normal diet + radiation)	3.437$\pm$0.071*	6.323$\pm$0.092*	10.07$\pm$0.032*

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GR C (High casein+radiation)	4.95+0.13*	5.815+0.80*	10.11+0.022*
GR D (Only High casein diet)	5.8+0.089	5.467+0.103	11.08+0.027

The total number of R.B.Cs was considerably smaller in the mobile phone radiation exposed animals Gr B compared to the Gr A (p 0.05), as shown in Table.

"Animals in Group C had a dramatic rise in their RBC count, which almost reached the control figure. However, the High Protein diet group did not show any improvements in R.B.C. count compared to the control group.

As can be seen in Table, there was a statistically significant increase in the total number of W.B.Cs among the animals in the mobile phone radiation group as compared to the animals in the control group (Gr A).

In Group C, W.B.C. count decreased almost to pre-treatment levels, which is statistically significant (p0.05). High-protein diet (Gr D) and control group (Gr A) white blood cell (WBC) counts did not differ (p>0.05)."

Table 3: Differential WBC count in mice exposed to mobile phone radiation and fed a high-casein diet

Group of animals	**Eosinophil%**	**Lymphocyte%**	**Neutrophil%**	**Monocyte%**	**Basophil%**
GrA	25.8+0.02	22.5+0.03	29.03+0.1	19.4+0.02	3.2+0.01
GrB	33.3+0.06*	8.3+0.03*	35.4+0.02*	22.9+0.02*	0+0
GrC	22.42+0.07*	25.23+0.05*	33.64+0.09*	18.7+0.07*	0+0
GrD	29.03+0.01	22.58+0.09	22.58+0.02	22.58+0.1	0+0

Table 3 shows that there was no discernible variation in the ratio of monocytes to basophils. Eosinophil and neutrophil percentages are both significantly greater in Gr B mice compared to Gr A animals; however, the neutrophil percentage in Gr B is much higher at 35.4%. The proportion of eosinophils in Gr. C animals is quite close to that of Gr. A animals. Gr B animals had a much lower percentage of lymphocytes (8.3%) than Gr A animals. Group C animals have a lymphocyte percentage that is practically normal.

3.2 Mobile phone radiation's effect on the surface structure of red blood cells on a high-casein diet.

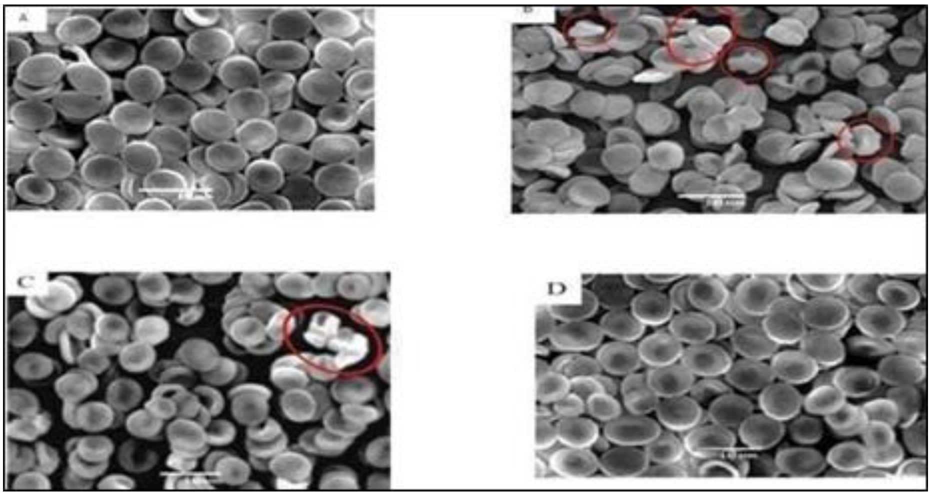

Figure 1: The RBC of a regular diet-treated mouse is shown by scanning electron microscopy

RBC from a mouse exposed to mobile phone radiation but fed a regular diet is shown in electron microscopic form in Fig. 1B. The cells on the film are irregular in form and adhere together, and there are fewer of them than in group A.

In Fig. 1C, we see the electron microscopic structure of R.B.C.s from mice fed a High Protein diet after being exposed to mobile phone radiation. There is noticeably less cellular deformation compared to the exposed group.

The renal basal cells of mice fed a high-protein diet are shown electron microscopically in Fig. 1D. Both the size and form of the cells are typical. The structure seems to be normal. SEM pictures of RBCs from the exposed group revealed that they were deformed in shape and adhered to one another in a rouleaux formation. RBCs had a typical biconcave form in the HPD treatment group.

3.2 Short-term radiation from mobile phones and the susceptibility of the R.B.C.:

Table 4: The osmotic fragility of RBC and its relationship to a high-protein diet after exposure to mobile phone radiation:

Concentration of saline(g/L)	GroupA	GroupB	GroupC	GroupD
Percentage of Hemolysis				
0.0	100±0.02	100±0.07	100±0.05	100±0.04
0.1	98±0.07	100±0.04	100±0.1	98±0.07
0.3	65±0.05	100±0.4*	100±0.2*	62±0.02
0.5	40±0.02	85±0.03*	60±0.4*	45±0.04

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0.7	10+0.01	64+0.2*	40+0.03*	8+0.04
0.9	0.4+0.04	4.5+0.02*	2.5+0.02*	0.5+0.02

Table 4 shows that in the presence of the control solvent (0 g/L NaCl in distilled water), all of the groups had complete haemolysis. At 0.1 g/L of NaCl, there was no significant difference in the percentage of haemolysis between the mice in the four groups (p>0.05). However, at concentrations of 0.3-0.9 g/L of NaCl, significant differences in haemolytic activity were seen across the groups (p0.05). Mice in Group C recovered the most quickly from haemolysis when treated with 0.05g/L of NaCl compared to the other radiation-exposed groups and the controls (p0.05), but animals in Group B displayed complete haemolysis. Group C animals, on the other hand, had the fewest haemolytic changes of the radiation-exposed groups (p0.05).

Radiation from cell phones' impact on RBC oxidative stress:

The level of oxidative damage in R.B.C. was studied by measuring the quantity of MDA it generated roups exposed to mobile phone radiation while eating a regular diet (Group B) showed a significant increase (p0.05) in erythrocyte MDA levels. The levels of MDA caused by mobile phone radiation in R.B.C. were reduced with the use of HPD, although they were still considerably greater than in controls (p0.05).

TABEL 5: Protein intake and the concentration of malondialdehyde (MDA) in RBC exposed to mobile phone radiation

Group of animals	**ErythrocyteMDAconcentration (mole/gHaemoglobin)**
A	30.7+0.38
B	81.5+0.32
C	49.5+0.8
D	31.2+0.5

3.3 The long-term impact of electromagnetic fields on blood counts

Radiation from cell phones' electromagnetic fields has an impact on RBC, WBC, and haemoglobin counts.

Group B2 (animals exposed to continuous mobile phone radiation) saw a decrease in overall R.B.C. count and haemoglobin content (p0.05). When Group B1 was compared to the controls, they showed no significant improvement in R.B.C. count or haemoglobin content after stopping radiation for one month. When given HPD at the same time as radiation, both total RBC and haemoglobin content were almost returned to normal (p0.05) in Groups C1 and C2.

Groups B1 and B2 (exposed to mobile phone radiation) had significantly higher total WBC counts than Group A (control) . Although HPD did not decrease WBC surge to the same extent as the control groups, it was significantly better than the continuous radiation group (Group C2, p0.05) and the control group (Group C1, p0.05).

Table 6. In mice exposed to mobile phone radiation, a high-protein diet decreases the quantity of red blood cells and

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white blood cells while increasing the percentage of haemoglobin:

Parameters	GRA (Control)	GRB(NormalDiet+Radiation)		GRC(HighCaseinDiet+Radiation)		GR D
		GRB1 (3monthsradiation+ 1monthstopgap)	GRB2 (4 monthscontinuousradiation)	GRC1 (3monthsradiation + 1month stopgap)	GRC2 (4 monthscontinuousradiation)	
TRBC million/cu-mm	5.4± 0.24	3.48±0.17*	3.05 ±0.17*	4.35 ±0.20*	5.37±0.21*	9.25±0.18
W.B.C. thousands/mm³	19.30± 0.18	23.36±0.16*	25.32 ±0.37*	19.25±0.35*	21.90±0.29*	23.36±0.16
Hb%g/dl	10.82±0.3	8.2±0.18*	6.6 ±0.22*	10.48 ±0.11*	7.45±0.21*	12.58±0.54

Table 7: The Impact of a High-Protein Diet on the WBC Differential in Radiation-Exposed Mice

Group ofAnimals	Eosinophil(%)	Lymphocyte(%)	Monocyte(%)	Basophil(%)
GroupA	35.8±0.29	26.12±0.26	2.94±0.04	0.4±0.25
GroupB1	41.18±0.39*	10.38±0.23*	1.94±0.04*	0±0
GroupB2	44.26±0.19*	7.88±0.97*	3.88±0.09*	0±0
GroupC1	34.32±0.4*	21.66±0.34*	3.74±0.13*	0.94±0.03
GroupC2	35.6±0.05	30.1±0.12*	3.3±0.02*	
GroupD	30.56±0.29*	29.12±0.1	2.2±0.02	

Differences in white blood cell counts between rats fed a regular diet and those fed a high-protein diet (HPD) after being exposed to mobile phone radiation are shown in Table. The number of basophils and

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monocytes did not vary much. However, in rats exposed to mobile phone radiation while on a regular diet (Gr B), the proportion of eosinophils and neutrophils increased while the percentage of lymphocytes decreased. In the group of animals subjected to constant electromagnetic radiation for 4 months, the impact was more severe. In animals exposed to HPD and electromagnetic radiation, the cell count returned to near-normal after being removed from the radiation for one month (Gr C1).

Radiation from cellphones' adversely affects the R.B.C.

Table 7 shows that in the presence of the control solvent (0 g/L NaCl in distilled water), complete haemolysis (100%) was seen in all groups. At 0.1 g/L of NaCl, the difference in haemolysis rates between the mouse groups was not statistically significant (p>0.05). At concentrations of 0.3-0.9 g/L of NaCl, however, significant haemolytic differences between groups were seen (p0.05). Animals in Group B2 exhibited complete haemolysis at 0.05g/L of NaCl, but mice in Group C1 recovered the most from haemolysis compared to the other radiation-exposed groups and controls (p0.05). Haemolytic changes were found to be lowest in Group C1 animals compared to the other radiation exposure groups (p0.05).

Table 8: The osmotic fragility of RBC and its relationship to a high-protein diet after exposure to mobile phone radiation

Concentratioaline(g/L)	**GroupA**	**GroupB1**	**GroupB2**	**GroupC1**	**GroupC2**	**GroupD**
PercentageofHemolysis						
0.0	100±0.02	100±0.04	100±0.07	100±0.78	100±0.05	100±0.21
0.1	98±0.03	100±0.08	100±0.85	100±0.04	100±0.08	96±0.08
0.3	70±0.07	100±0.21*	100±0.04*	100±0.06*	100±0.15*	65±0.25
0.5	50±0.05	100±0.04*	65±0.74*	70±0.07*	60±0.54*	50±0.07
0.7	10±0.08	80±0.78*	82±0.01*	55±0.21*	40±0.04*	8.2±0.23
0.9	0.6±0.01	10±0.07*	11.2±0.45*	2.5±0.36*	4.5±0.1*	0.4±0.02

Radiation from cellphones and oxidative stress in RBCs:

The amount of oxidative damage to R.B.C. was evaluated by measuring the level of MDA it generated. Specifically after being exposed to mobile phone radiation for four months (Group B2), there was a significant increase (p0.05) in MDA levels in erythrocytes. Levels of MDA, which had been raised owing to mobile phone radiation in R.B.C., were reduced to some degree thanks to HPD, although they were still substantially higher than in controls (p0.05). Erythrocyte MDA levels were significantly lower in Groups B1 and C1 after radiation treatment ended compared to Groups B2 and C2, respectively (p0.05).

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TABLE 9: Manoldialdehyde levels in RBC subjected to mobile phone radiation and the effects of a high-protein diet

GroupofAnimals	ErythrocyteMDAconcentration (mole/gHaemoglobin)
A	29.4+0.63
B1	58+2.24
B2	81+1.82
C1	33.8+1.46
C2	44.8+1.62
D	29.6+0.79

4. Discussion

According to the findings, when comparing the control group with the animals exposed to EMR while still eating a regular diet (Gr B animals), the overall number of R.B.C. is reduced and malformed structure is visible. Possible causes for the decline in RBC count include activation of an apoptotic pathway. Although the exact mechanism by which EMR triggers R.B.C. apoptosis is unknown, research suggests that pro-oxidant chemicals generated by the erythrocytes may be to blame. It hastens erythrocyte death, which coincides with less antioxidant protection inside RBCs and a faster pace at which haemoglobin is converted to methemoglobin. When methemoglobin is created in RBCs, it leads to oxidative stress and a breakdown in membrane structure. Since casein is an antioxidant, it blocks the production of oxidative stress and the breakdown of haemoglobin into methemoglobin. Animals on a high-casein diet that also received radiation had their erythrocyte counts and structures restored.

The results of the current research suggest that exposure to electromagnetic radiation might produce stress-induced tissue damage, as measured by an increase in eosinophil and neutrophil counts. Radiation-induced stress activates caspase 9 and promotes death of lymphocytes, resulting in a lower lymphocyte count. High-protein diets, especially those rich in casein, have been shown to reduce radiation-induced side effects and restore normal WBC levels by acting as antioxidants.[7]

Exposure to electromagnetic radiation increases erythrocyte apoptosis, which is responsible for the observed reduction in total R.B.C. in blood, as shown in the current research. Lipid peroxidation, a byproduct of oxidation, rises as a result of the elevated MDA content in erythrocytes. Apoptosis's precise mechanism is unknown; however lipid peroxidation and cell death are thought to be linked. Apoptosis is induced when lipid peroxidation rises, which speeds up the process by which haemoglobin is converted into methaemoglobin. Erythrocyte membranes become deformed and brittle as a result of electromagnetic radiation (EMR), as shown by osmotic fragility tests and distorted erythrocyte topography pictures. Furthermore, it is possible to state that RBC membrane fragility is a result of the rise in lipid peroxidation.[8]

Exposure to electromagnetic radiation causes a considerable drop in total haemoglobin content in blood, but unexpectedly, this decrease is not reversed upon cessation of radiation indicating that the damage is permanent. It has been hypothesised that the heme part of haemoglobin undergoes certain structural modifications as a result of its interactions with electromagnetic fields.[9]

Elevated degrees of lipid peroxidation and haemolysis

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of R.B.C. suggest that stress-induced tissue damage in the body produced by electromagnetic radiation may be the source of the observed increases in eosinophil and neutrophil counts. Radiation-induced stress activates caspase 9 and promotes death of lymphocytes, resulting in a lower lymphocyte count. The high-protein diet, of which casein is a key part, has antioxidant characteristics that reduce radiation's negative effects and help restore a normal WBC count.[10]

The R.B.C. count was brought back to normal in the High Protein diet Group because casein is involved in cell signalling pathways that promote cell growth and division.

5. Conclusion

There are two related pathways via which male Swiss Albino mice suffer damage from electromagnetic radiation released by mobile phones. The first is via the production of reactive oxygen species (ROS), which raises oxidative stress, and the second is through activation of the apoptotic pathway. Diets strong in protein can mitigate the consequences.

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