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Hematologic and Cortisol Alterations Observed in Young Mice Placed in Front of a Color Television Screen[#]

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ABSTRACT

Four-week-old Swiss male mice were placed 20 cm from a color television screen switched on for 5 continuous days/week, 9 ± 2 h/Day for 106 days. The control group was nonexposed. The average magnetic field was 0.8 μT at the front of the exposed mice cage, and 0.23 μT at the back. Hematologic and cortisol values were measured on Days 0, 22, 57, and 106. Statistical analysis on weight and hematological values were performed using analysis of variance for repeated measures involving baseline values, group, time, and interaction between group

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and time as fixed factors. Polymorphonuclear neutrophils were significantly lower in the exposed group than control, but no interaction between time and exposure was found. On Day 22, erythrocytes, hemoglobin, hematocrit, and mean corpuscular hemoglobin were significantly higher in the exposed group. An interaction between time and group was found. Day 57 cortisol values of the exposed group were significantly higher than control, and on Day 106, values of the exposed group were significantly lower than control (Student *t* test). Such an observation could be explained by a feedback control following long-term irradiation exposure. In conclusion, exposure of very young mice to the electromagnetic emissions from a television screen appears to modify hematological parameters, reaching values characteristic of adult mice.

Key Words: Neutrophils; Mouse; Cortisol; Television; Electromagnetic fields.

INTRODUCTION

Experimental and clinical data suggests that hematologic parameters and immune function may be altered by exposure to electric and magnetic fields (Bonhomme-Faivre et al., 1998; Boscolo et al., 2001; Dasdag et al., 2002; Seto et al., 1996; Tremblay et al., 1996; Vallejo et al., 1996). Electromagnetic fields (EMF) emitted by video display units may increase embryo mortality, alter humoral immunity and its hormonal control, and reduce body weight (Youbicier-Simo et al., 1997). When switched on, a television screen (TV) emits electromagnetic fields ranging from x-rays to extremely low frequencies (ELF) with ELF and very low frequency fields (VLF) quantitatively the most important (Kavet and Tel, 1991; LuKetina, 1975). Biological effects have been studied mainly through exposure to VDT. Epidemiological studies have reported increased risk of childhood leukemia associated with the length of time children watch TV or play video games on TV sets, indicating a possible health effect of electric and magnetic fields generated by the television (Kaune et al., 2000). We exposed mice to the EMF from a television to determine if exposure can induce biological changes, and present data from hematological and cortisol measurements in exposed and nonexposed groups.

MATERIALS AND METHODS

Four-week-old male Swiss mice (Breeding Center, Olivet, France) ($n = 9$) were placed in transparent plastic 21×14 cm cages (two cages), washed daily, and stacked horizontally in the same place side by side at a distance of 20 cm from a TV screen switched on for 5 continuous days/week, 9 ± 2 h per Day for 106 days. The day/night hours in the experiment room were 12 h/12 h. The volume was turned down for the two groups during the experiment. Temperature ($22 \pm 2^{\circ}$C) and relative humidity ($60 \pm 10\%$) were identical in the two rooms. The exposure system was a TV set (Waltham 230 V, 50 Hz, 35 cm diagonal screen), and the television in the control room was neither turned on nor plugged in. In each group, the two cages contained 4 to 5 mice free to roam in their cages. Measurement of the magnetic flux density

(mfd) was performed with a bandwith of 40 to 280 Hz (Mag check 50+, USA). We measured mfd in three dimensions and calculated the sum of the squares. The square root of the sum was the result of the three partial measurements.

The magnetic field was $0.8\,\mu T \pm 0.05\,\mu T$ in front of the cage, $0.5\,\mu T \pm 0.03\,\mu T$ inside at the center of the cage, and $0.23\,\mu T \pm 0.04\,\mu T$ at the back with a frequency content of 50 Hz and 150 Hz. The TV was left on standby at night after exposure (0.03 μT). The VLF value is 0.07 μT measured with an Hi 603 (Holaday, USA) with a band of 12 to 200 KHz.

The control group ($n = 9$) was placed in another room under identical light, noise, and temperature conditions, but with the magnetic field at 0.01 μT. The geomagnetic field in the exposure room was 57.2 μT (Geo-magnetometer BPM 2001 Bio-physic Mersmann D5471 Wassenach) and was identical to the field in the control room. The light value was 400 lux (lux-meter LX 101, Bioblock, France). The electric field at 50 Hz was 30 volts/M in the center of the cage for the exposed groups and 3 volts/M for the control groups (EFM 130 Electric field measurement, Stockbridge MA, USA). Blood was drawn at the same time on MonDay morning after 2 days of nonexposure by retroorbital puncture. Blood was taken on the same Day for hematology and cortisol assays.

Hematological parameters (total leukocyte and differential leukocyte counts) and body weight were measured at Days 0, 22, 57, and 106. The experiment was carried out in a blind fashion for the analysis of the blood parameters. Blood samples were analyzed with a Sysmex NE 1500-10A (Medical Electronics, Japan) and included erythrocyte counts (RBC), absolute leukocytes (WBC), hemoglobin (HGB), hematocrit (HCT), mean corpuscular hemoglobin concentration (MCHC), mean corpuscular hemoglobin (MCH), and platelets.

Differential leukocyte counts were carried out after May–Grunwald–Giemsa staining of the slides (200 cells/mouse). All data are presented as means ± standard error (SE) for each group for control values**.** Statistical analyses on weight and hematological values were performed using analysis of variance for repeated measures involving baseline values, group, time, and interaction (group × time) as fixed factors. We tested two covariance patterns: compound symmetry and first-order auto-regressive. Akaike's information criterion was used to compare the two models. All analyses were performed with SAS software (SAS Institute, Cary, NC, USA).

Serum cortisol levels were measured on the 0800 samples by the fluorescence immunopolarization technique (TDX, Abbott Rungis, France) on Days 22, 57, and 106. The reagents of the TDX assay provided allow for the measurement of cortisol concentration over the range 0–600 ng/mL. The lowest measurable level (sensitivity) is determined to be 4.5 ng/mL. All serum samples were assayed together with calibration and quality control. Student's t test was used to analyze differences between exposed and control animals on a given day. A p value <0.05 was considered significant for all statistical analysis.

RESULTS

For almost all the parameters (except for hematocrit value), a difference due to the time of measurement of the parameters was found ($p_{\text{time}} < 0.0001$). This is usual

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for hematological values that vary in time, so these results were expected for animals in their growth phase (Green, 1966).

There was no significant difference in body weight due to exposure ($p_{group} = 0.3995$) between the two groups.

Hematological Data of Swiss Mice (Tables 1 and 2)

- Erythrocytes: For this parameter, there was a difference between control vs. exposed groups ($p_{time \times group} < 0.0001$). The effect of exposure can be seen on Day 22 ($p < 0.0001$) with the exposed group showing higher values of erythrocytes (mean difference between exposed and control group of 1.62×10^{12}/L [SE $= 0.33 \times 10^{12}$/L]).
- Hemoglobin, hematocrit, MCH: For this group of measurements, an interaction between time and exposure was shown. On Day 22, hemoglobin and hematocrit were significantly higher (respectively, $p = 0.0003$ and $p = 0.0009$) in the exposed group [mean difference between exposed and control group for hemoglobin of 2.42 g/dL (SE = 0.58 g/dL)].
- MCHC, mean corpuscular volume (MCV): There was no significant difference between exposed and control groups.
- Leukocytes, lymphocytes, monocytes, eosinophils, and platelets: There was no statistical difference between exposed and control groups.
- Polymorphonuclear neutrophils (PMN): PMNs were significantly higher in the control group ($p_{group} = 0.0266$). The mean difference between exposed and control group was -605.4 10^6/L [SE $= 246.2 \times 10^6$/L].

Cortisol (Table 3)

We observed an increase in cortisol values at Day 57 in the exposed group and a decrease at Day 106.

DISCUSSION

We have observed changes in cortisol and hematological values in 4 week-old male Swiss mice exposed to the electromagnetic field emitted by a TV screen.

Several studies have shown a decrease in cortisol values after exposure to ELF including 50 or 60 Hz electric and magnetic field exposure (Wilson et al., 1989), and we have previously observed a decline in cortisol levels in mice from a magnetic field generated by a transformer station and high current bus bars after 190 days of exposure (Bonhomme-Faivre et al., 1998).

In this study, exposed mice showed an increase in cortisol levels first, followed by a decline in cortisol values, which could be due to feedback control after a lengthy exposure.

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Table 1. Hematological data of 4 week-old Swiss mice exposed to a TV screen.

Parameter/time (days)	Control	Exposed	p_{time}	p_{group}	$p_{time \times group}$
Erythrocytes (10^{12}/L)			<0.0001	0.1001	<0.0001
0	6.455 ± 0.873	6.087 ± 0.887			
22	6.537 ± 0.980	8.134 ± 0.460			<0.0001
57	8.112 ± 0.698	8.093 ± 0.653			0.9809
106	8.790 ± 0.400	8.458 ± 0.769			0.3678
Hemoglobin (g/dL)			<0.0001	0.2025	<0.0001
0	13.200 ± 1.173	12.688 ± 1.186			
22	11.322 ± 1.828	13.655 ± 0.858			0.0003
57	14.855 ± 1.329	15.077 ± 0.767			0.5995
106	14.288 ± 0.625	13.411 ± 1.297			0.1847
Hematocrit (%)			0.1330	0.6609	0.0001
0	40.600 ± 6.263	36.366 ± 5.366			
22	38.188 ± 5.411	44.544 ± 3.354			0.0009
57	43.422 ± 4.473	40.498 ± 3.721			0.3658
106	45.677 ± 2.118	41.788 ± 4.035			0.1040
Mean corpuscular hemoglobin (pg)			<0.0001	0.3056	0.0163
0	20.577 ± 1.463	21.000 ± 1.393			
22	17.311 ± 0.762	16.788 ± 0.503			0.0705
57	18.322 ± 0.712	18.677 ± 0.898			0.2949
106	16.255 ± 0.350	15.844 ± 0.450			0.1435
Mean corpuscular volume (μm^3)			<0.0001	0.3363	0.7803
0	62.811 ± 3.295	59.755 ± 1.978			
22	58.700 ± 6.273	54.744 ± 2.145			
57	53.500 ± 2.253	50.611 ± 1.447			
106	52.666 ± 3.289	49.388 ± 1.530			
Mean corpuscular hemoglobin concentrations (g/dL)			<0.0001	0.1489	0.0608
0	32.877 ± 3.123	35.177 ± 2.326			
22	29.677 ± 2.606	30.722 ± 1.014			
57	34.311 ± 1.690	36.900 ± 2.0285			
106	31.322 ± 0.949	32.077 ± 0.370			
Platelets (L)			<0.0001	0.5424	0.1247
0	1066.44 ± 301.083	1155.89 ± 339.470			
22	613.777 ± 256.580	648.888 ± 153.908			
57	1098.67 ± 324.924	1320.44 ± 169.619			
106	669.777 ± 282.545	543.888 ± 295.743			
Body weight (g)			<0.0001	0.3995	0.9665
0	21.755 ± 4.395	23.688 ± 2.842			
22	30.266 ± 1.897	31.711 ± 3.246			
57	37.311 ± 3.788	39.111 ± 4.621			
106	37.311 ± 3.788	39.111 ± 4.261			

Note: Values given are mean ± standard error.

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Table 2. Hematological data of 4 week-old Swiss mice exposed to a TV screen.

Parameter/time (days)	Control	Exposed	p_{time}	p_{group}	$p_{time \times group}$
Leukocytes (10^6/L)			<0.0001	0.3539	0.5890
0	3.023 ± 0.658	2.771 ± 0.937			
22	3.142 ± 1.239	2.764 ± 1.160			
57	6.084 ± 1.714	5.762 ± 1.999			
106	3.584 ± 1.731	2.527 ± 1.109			
Polymorphonuclear neutrophils (10^6/L)			<0.0001	0.0266	0.0818
0	909.0 ± 327.2	768.0 ± 321.4			
22	938.4 ± 759.6	639.6 ± 272.0			
57	2267.1 ± 1301.5	1094.7 ± 502.3			
106	1022.4 ± 536.4	468.1 ± 256.7			
Lymphocytes (10^6/L)			<0.0001	0.7459	0.0515
0	2110.4 ± 473.2	1962.2 ± 616.6			
22	2166.6 ± 771.5	2083.0 ± 925.6			
57	3707.4 ± 758.3	4645.3 ± 1577.4			
106	2492.6 ± 1227.2	2029.4 ± 920.9			
Monocytes (10^6/L)			0.0003	0.1216	0.2906
0	46.11 ± 28.12	41.00 ± 22.24			
22	37.55 ± 15.79	41.77 ± 20.50			
57	103.4 ± 75.86	85.33 ± 36.64			
106	69.33 ± 40.71	30.22 ± 23.36			
Eosinophils (10^6/L)					
0	0 ± 0	0 ± 0			
22	0 ± 0	0 ± 0			
57	0 ± 0	0 ± 0			
106	0 ± 0	0 ± 0			

Note: Values given are mean ± standard error.

Table 3. Serum cortisol values (ng/mL) of mice exposed to TV screen (mean ± sd).

	Day 22	Day 57	Day 106
Control	5.9 ± 3.5	16.9 ± 8.9	35.5 ± 14.8
Exposed	10.7 ± 5.4	29.0 ± 8.9[a]	15.4 ± 10.5[a]

[a]Student's t test: compared to control $p < 0.05$.

We speculate that interruption of, or intermittent, ELF exposure might block a rise in cortisol levels leading to adverse effects such as those observed when steroid therapy is abruptly discontinued (asthenia, tendency toward depression, muscle weakness, mental changes, muscle and joint pain, anorexia, nausea). This could explain the subjective symptoms described in humans after chronic exposure to ELF.

An additional explanation may be an increase in ACTH and cortisol values at high-level prolonged exposure, followed by development of a feedback

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control with development of acute adrenal insufficiency from inhibition of hypothalamic–pituitary–adrenocortical function.

The few studies published addressing cortisol level after electromagnetic field exposure report either an increase or a decrease in the values (Gorczynska and Wegrzynowicz, 1991; Portet and Cabanes, 1988; Woldanska-Okonska and Czernicki, 2003). This variability in results may correspond to biological variations related to the length or the values of electric and magnetic fields at exposure, or to the experimental conditions and the timing of cortisol determinations. We cannot exclude sensitivity of the exposed mice to the flicker rate of the screen, which is a nonfield effect.

For the hematological parameters erythrocytes, hemoglobin, and hematocrit, the exposed group showed higher values than the control group after 22 Days of exposure. The Day 22 values of increased erythrocytes, hemoglobin, and hematocrit in the exposed group are similar to values of the control group at Day 57, and neutrophil and monocyte counts in the exposed group at Day 57 approach those of the control group at Day 106. The apparent acceleration of some parameters over time when mice were in their growth phase may be linked to a change in erythrocytic and granulocytic hematopoietic growth factors.

We observed a decrease in neutrophil counts in the exposed group, and this could affect the immune function of the animal. We have previously observed comparable changes in mice exposed to 5.0 μT EMF (Bonhomme-Faivre et al., 1995). We have also shown that when B16 melanoma-bearing mice were placed in front of a TV screen for 37 days, tumor volume was increased compared to nonexposed, possibly due to ELF magnetic field effects on the immune system, similar to that observed in this study (Santini et al., 1998). This may also relate to reports indicating that the life span of chronically exposed mice is shorter than that of control after microwave exposure (Liddle et al., 1994).

The observations on hematological parameters may be interpreted as an alteration of the hematological development, and after chronic exposure, when hematological parameters are stabilized, EMF could lead to a decrease in immune defenses both in the mouse and in man (Tremblay et al., 1996).

The data in this study confirm our previous data (particulary for erythrocytes, hematocrit, and monocytes) on mice exposed to EMF from transformers and high voltage lines (Bonhomme-Faivre et al., 1998).

It is important to monitor animals individually during prolonged exposure, and they should be placed in experimental conditions similar to those used for humans as in pharmacotoxicology. Swiss mice, routinely used in pharmacology and toxicology studies, appeared to be an excellent model for such studies.

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