Short-term whole body exposure of intermediate frequency magnetic fields to rats does not affect blood properties and immune systems

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Abstract

Due to the lack of the science based evidences, we explored short term exposure effects of intermediate frequency of magnetic fields (IF-MF) to the experimental animals. Male Sprague-Dawley rats (6-7 week old) were divided into 4 groups; cage-control, sham, 2 mT and 3.8 mT exposure group, respectively. IF-MF at 21 kHz was exposed to the animals under fixed conditions in an acrylic holder. Exposure was done at 1hour/day for 3 consecutive days. On the 4th day following the exposure, biochemical and hematological parameters in the blood were analyzed. We also examined the effects to the immunological functions such as cytotoxic activity and phagocytotic activity. Results indicate that there is no effects to these parameters, even high magnetic flux density (3.8 mT; 141 times higher than the reference level to general public of ICNIRP guideline 2010) was exposed to the animals.

1. Introduction

The use of induction heating (IH) cooking hob makes our life more convenient. On the other hand, there exist public concerns on possible health effect about the intermediate frequency (IF) magnetic fields from IH cooking hob. Although there are many studies on the biological effects of electromagnetic fields exposure to extremely low frequency and radio frequency, there are very few studies on IF-MF. Therefore, WHO recommended to study the biological effects of IF-MF exposure in the environmental health criteria monograph No.238 [1]. In this study, we explored the effects of IF-MF to the experimental animals by using newly developed exposure apparatus which emit high intensity of IF-MF at 21 kHz [2]. Following the IF-MF exposure to rats, we analyzed the biochemical and the hematological parameters of the peripheral blood and several immune functions.

2. Materials and Methods

Animals and IF-MF exposure

Male Sprague-Dawley rats (6-7 week old, Japan SLC Inc., Shizuoka, Japan) were used. For IF-MF exposure,

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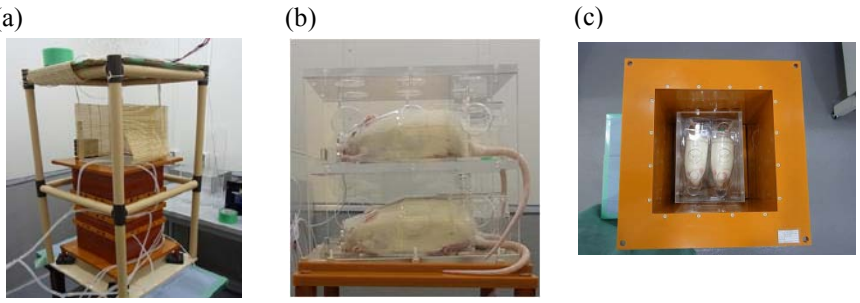

Figure1. Overall view of IF-MF exposure apparatus (a). Rats were located in the acrylic holders (b) and put them inside of the coil during the IF-MF exposure (c).

we used a coil as shown in Figure 1, whose inner space was 23 x 23 x 40 cm [2]. The apparatus was able to generate IF-MF at 21 kHz (frequency) and up to 3.8 mT (magnetic flux density). Uniform magnetic intensity was obtained in a space of 15 x 15 x 15 cm inside of the coil. To avoid thermal effect from the coil, we use water-loop cooling circuit during the IF-MF exposure. According to the dosimetry, mean induced electric density were 4.7 [V/m], which is corresponding to 1.7 fold compared to basic restriction to the general public of ICNIRP guideline revised in 2010.

Rats were divided into 4 groups; cage-control, sham, 2 mT and 3.8 mT exposure group (n=11-14). IF-MF at 21 kHz was exposed to the animals under fixed condition in an acrylic holder (Natsume Seisakusho Co. Ltd.). Exposure to IF-MF was done at 1hour/day for 3 consecutive days. On the 4th day following the exposure, the whole blood was collected and sent to the analysis. After scarification with deep anesthesia, spleen was excised to prepare the lymphocytes.

Analysis

Biochemical and the hematological parameters in the blood were analyzed. For the biochemical analysis, 14 parameters were analyzed using a biochemical analyzer (VetScan VS2, Avaxis Inc., USA). For hematological analysis, 22 parameters were measured by use of a fully-automated 5-part differential cell counter (VetScan HM5, Avaxis Inc., USA).

For the cytotoxic assay, natural killer cell fraction prepared from spleen was used as effector cell. Cultured YAC-1 cell (mice lymphoma) was used as target cell. The cytotoxic activity was assayed by using CytoTox 96 Non-Radioactive Cytotoxicity Assay kit (Promega Co., USA). Experimental procedure was basically followed by the standard protocol.

For the phagocytotic assay, granulocytes were fractionated from peripheral blood by density separation method using percoll (GE Healthcare Bioscience Co., USA). Granulocytes were co-incubated with FITC-conjugated polystyrene beads for 1 hour at 37 ^{o}C. After washing granulocytes, cells were analyzed by flowcytometer (Cytomics FC500, Beckman Coulter, Inc., USA).

One-way ANOVA was applied for statistical analysis by using SPSS software.

Ethical approval of animal study

This study was approved by the committee of animal experiment in National Institute of Public Health.

3. Results

Biochemical data of peripheral blood was shown in Table 1. Significant differences compared to that of cage control group were observed in total protein concentration and glucose level. However, these differences do not

attribute to the intensity of IF-MF exposure. The data did not show dose-dependent relationship. Hematological data did not show any significant differences (data not shown).

Immune function such as cytotoxic activity and phagocytotic activity also did not show any effects due to IF-MF exposure (data not shown).

Therefore, no effects were noticed under these experimental conditions.

Table 1 Comparison of biochemical data of peripheral blood

	(unit)	cage control (n=14)	sham (n=12)	2 mT (n=12)	3.8 mT (n=11)
Albumin	g/dL	4.54 ± 0.15	4.85 ± 0.27*	4.61 ± 0.19	4.78 ± 0.19
Total protein	g/dL	5.75 ± 0.23	6.04 ± 0.30	5.76 ± 0.23	6.03 ± 0.25 *
Total globulin	g/dL	1.24 ± 0.17	1.19 ± 0.15	1.14 ± 0.12	1.24 ± 0.12
ALP	U/L	554.9 ± 87.4	566.1 ± 108.5	612.9 ± 96.8	505.9 ± 103.1
ALT	U/L	56.5 ± 10.11	55.5 ± 8.82	61.2 ± 8.3	51.6 ± 6.2
Amylase	U/L	938.1 ± 85.7	940.3 ± 109.7	882.8 ± 61.2	906.2 ± 100.9
TBIL	mg/dL	0.19 ± 0.27	0.2 ± 0	0.2 ± 0	0.19 ± 0.03
BUN	mg/dL	18.7 ± 3.34	19.1 ± 2.8	19.3 ± 3.4	20 ± 3.8
Phosphate	mg/dL	10.08 ± 0.66	9.77 ± 0.93	10.15 ± 0.64	9.72 ± 0.79
Creatinine	mg/dL	0.3 ± 0.88	0.29 ± 0.10	0.28 ± 0.06	0.23 ± 0.05
Glucose	mg/dL	283.4 ± 47.2	232 ± 25.6*	254.3 ± 34.5	242.9 ± 50.2 *
Ca^{++}	mg/dL	11.2 ± 0.29	11.1 ± 1.66	10.7 ± 1.92	11.6 ± 0.35
Na^{+}	mmol/L	139.1 ± 1.83	141.3 ± 2.53	140.5 ± 4.50	140.2 ± 1.60
K^{+}	mmol/L	6.06 ± 0.55	6.13 ± 0.51	5.95 ± 0.46	5.9 ± 0.49

ALP: alkaline phosphatase, ALT: alanine aminotransferase, TBIL: bilirubin, BUN: blood urea nitrogen

* $p < 0.05$ (*vs* cage control group)

4. Discussion and Conclusion

In this study, we reported the biochemical and the hematological effects of 21 kHz IF-MF exposure at the high magnetic flux density to rat. Additionally, we also tested some of immune function. Our experimental condition was maximum 3.8 mT, which is 141 times higher than the reference level to general public of ICNIRP guideline (2010). Even under this extremely high intensity of magnetic fields, the parameters did not change by the exposure. From these results, we concluded that IF-MF did not show any toxicity under this experimental condition. However, the exposure protocol in this study was limited only 3 consecutive days and total 3 hours; therefore, further study will be needed.

5. References

[1] WHO Environmental Health Criteria 238 (2007): Extremely Low Frequency (ELF) Fields. WHO, Geneva, Switzerland

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6. Acknowledgement

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