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Effects of Intermediate Frequency Magnetic Field Exposure at 85 kHz on Oxidative Stress in Mice

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Abstract

To explore the possible non-thermal biological effects of intermediate frequency magnetic field (IF-MF) on mice, we developed exposure apparatus using 85 kHz time-varying magnetic field and examined the effects on oxidative stress by subacute and acute exposure conditions. Our data showed no effect on oxidative stress under the exposure condition, which approximately corresponds to the basic restriction level of ICNIRP guidelines.

1. Introduction

Recently, many research institutions and companies have been investigating the development of wireless power transfer (WPT) systems. The WPT systems using the 85 kHz time-varying magnetic field have gained special attention as the charging method for electric vehicles. Therefore, there is growing concern about health effects induced by magnetic fields of this frequency band. The purpose of this study is to elucidate the effects of the 85 kHz magnetic field exposure on oxidative stress in mice.

2. Materials and Methods

A. Exposure apparatus

For magnetic field exposure at the 85 kHz sinusoidal wave, newly developed exposure apparatus [1] was used. The apparatus consisted of a power source and a magnetic field generation coil. The power source was fabricated with an inverter circuit composed of silicon carbide (SiC)-MOSFET switching elements whose allowable voltage and current are up to 1200V and 120A, respectively. The coil is a 2-layer and 11-turn structure made of a hollow copper tube with a 4-mm diameter to circulate water for active thermal dissipation; the inner and outer diameters are 110 mm and 145 mm, respectively. Numerical dosimetry of mice under the exposure conditions was performed by a combination of incident magnetic field calculation and induced electric field analysis. The incident magnetic field distribution was calculated by the finite volume method with the CST studio suite® 2015. The induced electric field within the mice was estimated by the impedance method [2]. In this study, we generated a magnetic intensity of 6.5 mT at 85 kHz at the center of the coil, and the estimated whole body averaged value of the induced electric field was 23.7 V/m, which is above the basic restriction of occupational exposure (22.9V/m) [3].

B. Animal experiments

We examined the following two protocols: 1) detection of oxidative stress markers in urine samples of mice under the subacute exposure conditions and 2) detection of bioluminescence using the oxidative stress indicator in mice under the acute exposure conditions.

For detection of the oxidative stress markers, male C57BL/6 NCrSlc (Japan SLC Inc., Shizuoka, Japan) were used. The mice were exposed to intermediate frequency magnetic field (IF-MF) at 85 kHz in a custom-made acrylic holder (Toyoshima Seisakusho Inc., Tokyo, Japan). The mice (5-weeks old at the start of the exposure) were divided into the following two groups: sham and exposure groups (n = 5 for each). Exposure to IF-MF was limited to 1 hour/day for 5 days/week. Exposure was continued subchronically for 2 weeks giving a total exposure time of 10 hours. Mice were maintained individually in the urine collection cage (Natsume Seisakusyo Co. Ltd., Tokyo, Japan) during exposure periods and urine samples were collected on designated days. As oxidative stress markers, 8-hydroxy-2'-deoxyguanosine (8-OHdG) and N-Hexanoyl lysine (HEL) in the urine samples were quantified by liquid chromatograph-tandem mass spectrometry and enzyme-linked immunosorbent assay, respectively.

For detection of bioluminescence using the oxidative stress indicators, Keap1-dependent oxidative stress detector-luciferase (OKD-LUC) mice were used (Trans Genic Inc., Ltd., Kobe, Japan). They are known to induce luciferase activity if the activation of nuclear factor erythroid 2-related factor 2 has occurred under oxidative stress conditions. The animals were exposed to IF-MF at 85 kHz in a custom-made acrylic holder for 1 hour. Five hours after exposure, AkaLumine™ was administrated as a substrate for luciferase and the whole-body bioluminescence image of OKD-LUC mice was captured by MetaMorph-MIIS system (Molecular Devices Inc., Tokyo, Japan).

X-rays exposed mice were prepared as a positive control for both the experiments.

3. Results and Discussion

We determined the concentration of 8-OHdG and HEL in the urine sample at, before, and after the subacute magnetic field exposure. No significant change was observed in either of the oxidative stress markers, although an increase in the amount of 8-OHdG was observed in the urine of the X-rays exposed mice.

The whole-body bioluminescence image of OKD-LUC mice after the acute magnetic field exposure also did not show any change.

These results show that no oxidative stress is induced under our experimental conditions, although further research is needed.

4. References

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