ACUTE EFFECTS OF LOCAL EXPOSURE TO RADIO-FREQUENCY ELECTRO-MAGNETIC FIELDS WITH A LOOP ANTENNA ON THE CEREBRAL MICROCIRCULATION IN RATS.

H. Masuda[1], **A. Ushiyama**[2], **K. Wake**[3], **S. Watanabe**[4], **M. Taki**[5], **C. Ohkubo**[6]

[1]*Department of Physiological Hygiene, National Institute of Public Health, Tokyo 108-8638, Japan. E-mail: msd@niph.go.jp*

[2]*As (1) above, but E-mail: ushiyama@niph.go.jp.*

[3]*Electromagnetic Compatibility Research Section, Communications Research Laboratory, Tokyo 184-8975, Japan. E-mail: kana@crl.go.jp.*

[4]*As (3) above, but E-mail: wata@crl.go.jp.*

[5]*Department of Electrical Engineering, Graduate School of Engineering, Tokyo Metropolitan University, Tokyo 192-0397, Japan. E-mail: taki@eei.metro-u.ac.jp.*

[6]*As (1) above, but E-mail: ohkubo@niph.go.jp.*

ABSTRACT

A cranial window method modified for our experiment enabled to observe the cerebral microcirculation including the hemodynamic changes, the leukocyte behavior, and the blood-brain barrier(BBB) function during pre- and post-exposure to radio-frequency electromagnetic fields (EMF) with a loop antenna in rats. No noticeable changes in the BBB function, the diameter of venule, and the number of sticking leukocyte were recognized under the present conditions due to EMF exposure. However, further investigation of plasma velocity and the number of rolling leukocyte, which were partially altered after due to EMF exposure, are needed.

INTRODUCTION

Biological effects of radio-frequency electromagnetic fields(EMF) on the blood-brain barrier (BBB) function has been extensively studied in experimental animals. Most of these studies, however, have been performed by the histological or morphological investigations due to postmortem examination. Besides these, little information are available about the

*This study was financially supported by the committee to Promote Research on the Possible Biological Effects of Electromagnetic Fields, Ministry of Pablic Management, Home Affairs, Posts and Telecommunications, Japan.

exposure effects of EMF on cerebral microcirculation. A closed cranial window (CW) method have been widely used among many researchers as a beneficial method to investigate the cerebral microcirculation including BBB function [1]. We partially modified this method for evaluating the exposure effect to EMF on the cerebral microcirculation. Our previous results from acute exposure effects of EMF using a monopole antenna showed that no noticeable changes have been recognized due to EMF exposure [2]. The present study aims to investigate the acute exposure effect of EMF on the cerebral microcirculation in rats using the loop antenna that enabled more local exposure to the brain than the monopole antenna does.

MATERIAL AND METHODS

Nineteen male Sprague-Dawley rats (B.W. 426±19 g) were used in the study. Both CW implantation and the intravital-microscopic observation were performed under anesthesia with a cocktail (100mg/kg i.m.) of Ketamine hydrochloride and Xylazine hydrochloride (10:1, w/w). EMF exposure system consisted of a small anechoic chamber and a loop antenna. The head of rat was positioned 2mm under the loop antenna and was locally exposed to 1,439MHz electromagnetic near-field TDMA (time division multiple access) signal for PDC (Personal Digital Cellular, Japanese cellular telephone standard) system. The intensity of EMF exposure was controlled by average specific absorption rate (SAR) of the brain at 0.2, 2.0, and 7.5W/kg as shown in Table 1. The EMF exposure duration was 10 minutes. After exposure to EMF, the animal's head was immediately positioned in a stereotactic frame for microscopic observations. The exposure for 10 min and the observation for 20 min were performed sequentially from 0.2W/kg SAR. The pial microcirculation within a CW was investigated by a fluorescent microscope equipped with an SIT camera and a confocal scanning laser microscope. In order to measure hemodynamic changes, plasma velocities, leukocyte behavior and BBB-function, two-types of fluorescent dye and fluorescent microparticles were administered via the tail vein. Results are given as means±s.e. mean. The statistical analysis was performed by Student's *t*-test or ANOVA.

RESULTS

In order to investigate the detail of hemodynamic changes and leukocyte behavior in the pial venule, each parameter was separately measured at postcapillary venule (8-30μm) and collecting venule (31-50μm).

Table 1. The value of average SAR in the present experiment

Input	0.015	0.15	0.57	(W)
brain SAR	0.2	2.0	7.5	(W/kg)
whole body SAR	0.0097	0.097	0.36	(W/kg)

Hemodynamic Changes

The values of vessel diameters did not significantly change between pre- and post-exposure at any SAR values. The maximal plasma velocity in the collecting venule was significantly decreased($p<0.01$) due to EMF exposure at2.0W/kg SAR, however, there were no significant changes in postcapillary venule due to EMF exposure at any SAR values.

Permeability of BBB

In order to evaluate the permeability of BBB due to exposure, sodium-fluorescein was administered after each exposure. Extravasation of sodium-fluorescein from the pial venule was measured with the confocal scanning laser microscopy. In all measurement points, the fluorescent intensity profile did not change at any SAR values. FITC-Dx was administered before EMF exposure in order to detect the extravasation of dye during exposure. The fluorescence in the brain surface within pial microcirculation was measured with the fluorescent microscopy until the end of experiment. However, there was no significant difference between sham group and exposure group in the fluorescent intensity at any SAR values.

Leukocyte Behavior

The numbers of sticking and rolling leukocyte to the pial venular endothelia were measured. The number of sticking leukocyte did not significantly different between pre- and post-exposures. The number of rolling leukocyte tended to decrease corresponding to increasing SAR values. The number in the collecting venule at 0.2W/kg SAR was significantly decreased($p<0.05$) compared with those of pre-exposure.

DISCUSSION AND CONCLUSION

In the present experiment, we used a loop antenna for more local EMF emission to the rat brain. The average whole body SAR was less than 1/20 of the average brain SAR. The average whole body SAR used in the present study keeps below the level that may cause thermal effect due to EMF exposure.

No extravasations of both sodium-fluorescein and FITC-Dx from the pial venul were observed following EMF exposure at any SARs. This indicates that no disruption of the BBB function have been recognized due to EMF exposure emitted from the loop antenna which agrees with our previous results using the monopole antenna [2]. An increase of sticking leukocytes to the pial venuler endothelia is closely related to induce to the disruption of BBB [3]. In the present experiment, the number of rolling cell decreased due to EMF exposure at 0.2W/kg SAR, however, it was also found that there were no changes in the number of the sticking leukocyte after exposure of EMF at any SARs. This finding may support a hypothesis that EMF exposure does not disturb BBB function.

The plasma velocity of the collecting venule significantly decreased at 2.0W/kg SAR. However, the venular diameter, which is associated with the change of a blood flow, was not affected at any SARs. Thus, further studies on this dissociation are needed.

Whereas the number of sticking leukocyte did not change after EMF exposure, the number of rolling leukocyte tended to decrease corresponding to the increase in brain SAR. However, no significant differences were recognized between the values of pre- and post-exposures, except for the values obtained from collecting venule at 0.2W/kg SAR. In this study, we may need to consider a temporal effect of anesthesia, for one experimental sequence was 110 min from the beginning to the end. The changes in rolling counts and plasma velocity may be affected with the depth of anesthesia.

In conclusion, the results suggested that no noticeable changes in the BBB function, the venular diameter, and the number of sticking leukocyte under the present EMF exposure conditions. However, a temporal effect may relate with the changes of plasma velocity and rolling leukocyte counts. Further investigations are required.

REFERENCES

[1] W.G. Mayhan, “Regulation of blood-brain barrier permeability,” *Microcriculation*, 8, pp89-104, 2001.

[2] H. Masuda, K. Wake, S. Watanabe, M. Taki, and C. Ohkubo, “Acute effects of local exposure to radio-frequency electromagnetic fields on the cerebral microcirculation in rats,” *BEMS 2001*, P-51, pp.139-140, June 2001.

[3] W.G. Mayhan, “Leukocyte adherence contributes to disruption of the blood-brain barrier during activation of mast cells,” *Brain Research*, 869, pp.112-120, 2000.