INTRODUCTION

There has been increasing public concern about the adverse health effects of human exposure to electromagnetic waves. In the radiofrequency and microwave (MW) ranges, elevated temperature (1–2 °C) resulting from energy absorption is known to be a dominant factor inducing adverse health effects such as heat exhaustion and heat stroke. Whole-body average specific absorption rate (SAR) is used as a measure of human protection for MW whole-body exposure. Thresholds are based on the fact that MW exposure of laboratory animals in excess of approximately 4 W/kg has revealed a characteristic pattern of thermoregulatory response. Peak spatially averaged SAR is used as a metric for localized exposure, but the rationale for the use of SAR as a metric for local exposure has been challenged, especially with respect to local and systemic physiological responses, including change in blood perfusion.

In order to obtain some insight on the effect of localized exposure, our group has conducted exposures of rats. Our previous studies had failed to show blood flow changes in pial microcirculation in the brain of rats locally exposed to 1,439 MHz RF even at 4.8 W/kg brain averaged SAR (e.g., [1]). On the contrary, a recent study reported that the blood flow in the human brain increased after the exposure to pulse-modulated 900 MHz RF at 0.27 W/kg brain averaged SAR [2]. In the present study, we simulate the exposure scenario of the measurement in [3] in order to investigate the time course of temperature elevation due to microwave exposure.

MODELS AND METHODS

Male Sprague-Dawley rats (4 weeks old) were used in the experiment. The rats were anesthetized with an intramuscular injection of ketamine (100 mg/kg) and xylazine (10 mg/kg), and with a subcutaneous injection of pentobarbital (12.5 mg/kg). The core temperature was maintained at 36±0.4°C in sham exposure using a heating pad (42°C) to avoid the reduction in basal metabolism under anesthesia. The heads of the animals were fixed in a stereotaxic apparatus and locally exposed to 1,457 MHz microwave emitted from an “8”-shaped loop antenna. The exposure duration was six minutes. This exposure setup is shown in Fig. 1. For computing EM absorption in the rat, the Finite-Difference Time-Domain (FDTD) method was used. Then, the temperature variation was computed by solving the bioheat equation along with the SAR computed by the FDTD method.
RESULTS

In order to get the balance between the basal metabolism rate under anesthesia, heat transfer from the body to the air and from the heating pad, the reduction in basal metabolism rate was computationally estimated as 40% of the nominal. Then, the blood perfusion rate was reduced by the same factor, since it has been reported that the blood perfusion rate is approximately proportional to the basal metabolic rate. Figure 2 shows measured and computed time course of temperature elevation in the rectal and dura mater of rats for brain averaged SAR of 167 W/kg (whole-body SAR of 15.9 W/kg). As seen in Fig. 2, a reasonable agreement was observed between measured and computed temperature elevations. One of the reasons for the difference in rectal temperatures by less than 20% would be attributed to the difference of weight between exposed rats and the numeric phantom. The difference between measured and computed temperatures in the dura mater may be caused by the air temperature. Specifically, air temperature was assumed as a constant in our computation, while the air temperature around the dura mater of the head may be elevated due to radiation.

SUMMARY

We have developed an electromagnetic-thermal computational model for rats exposed to microwaves. The validity of the computational model was confirmed via the comparison between computed and measured temperature elevation profiles.

REFERENCES