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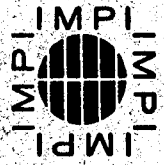

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Gamma-Aminobutyric Acid Metabolism in Rats Following Microwave Exposure*

G. H. Zeman, R. L. Chaput†, Z. R. Glaser, and L. C. Gershman††,‡

ABSTRACT

The metabolism of the inhibitory neurotransmitter gamma-aminobutyric acid (GABA) was studied in rats chronically exposed to 2.86 GHz microwaves at an incident power level of 10 mW/cm² or acutely exposed to incident power levels of 40 or 80 mW/cm². No changes occurred in whole brain GABA levels or in the activity of the enzyme which synthesizes GABA, L-glutamate decarboxylase, following these exposures. These results indicate that brain GABA metabolism was not affected by exposure to microwave radiation.

Introduction

Animals chronically exposed to microwave radiation at relatively low power levels have been reported to show signs of behavioral [5] and neurochemical [8] effects and acute exposure to higher power levels has been reported to result in other neurologic manifestations, such as convulsions [1,4]. The inhibitory neurotransmitter gamma-aminobutyric acid (GABA) and the enzyme which synthesizes GABA, L-glutamate decarboxylase, (E.C.4.1.1.15) (GAD), play an important role in regulation of neuronal activity in the brain [9]. Alterations in the metabolism of this neurotransmitter occur in rat brain after exposure to ionizing radiation [2], and have been implicated in the etiology of various convulsive disorders [3,11]. It is possible, therefore, that altered GABA metabolism is involved in the reported response of animals to microwave exposure. In view of the current controversy concerning biological effects of microwave exposure, and the sparsity of information on precise mechanisms involved, we feel it appropriate to report the results of our experiments, which indicate that alterations in brain GABA metabolism do not occur following exposure to microwave radiation.

Microwave irradiation conditions. Male Sprague-Dawley rats were constrained in individual Plexiglas containers (3″ x 3″ x 7.5″) in which holes had been

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drilled for ventilation. The individual containers were housed in a carrier so that the long axis of each container was perpendicular to the direction of propagation of the incident radiation. The rats were irradiated in groups of eight for the chronic exposures and singly for the acute exposures, with at least one empty container placed in the carrier directly above and below each group of rats.

The radiation source* produced 2.86 GHz microwave radiation with a pulse duration of 1 μsec, a pulse repetition rate of 500 sec^{-1}, and 600 kW peak power (300 watts average power). The source radiated into a lighted and ventilated screened chamber lined with anechoic material, through a waveguide transmission line and standard gain horn antenna. The animals in the container-carrier were placed in the chamber at a distance from the antenna where the incident power density was of the desired value. Power densitiess were measured with a Ramcor Densiometer• in place of the animals. In all exposures the animals were in the far field portion of the incident beam. The measured power densities agreed well with those calculated from the source output, antenna gain and the distance from the antenna.

Control rats for all experiments were treated identically to experimentals, including sham irradiation in a chamber similar in construction and adjacent to the exposure chamber. The temperatures of randomly selected animals were measured immediately upon removal of the animals from the exposure chamber, using a Digitec Model 251A (United Systems, Inc.) digital thermometer with a calibrated rectal probe. During the time between exposures both control and exposed animals were maintained in the exposure laboratory. Additional groups of rats of appropriate age and weight, housed in separate facilities, are referred to as unstressed controls.

Chronic exposures. In the first experiment, rats weighing 200-250 g were chronically exposed to incident power levels of 10 mW/cm^2 for 8 hours per day (8:00 a.m. to 4:00 p.m.) for either 3 or 5 days. On the day after the last day of irradiation, approximately 18 hours after termination of the exposure, the rats were decapitated. The heads were immediately immersed in liquid nitrogen, with subsequent storage at -80°C until time of assay. In the second chronic exposure experiment, rats weighing 85-105 g were exposed to incident power levels of 10 mW/cm^2 for 4 hours per day (10:00 a.m. to 2:00 p.m.), 5 days per week (Monday through Friday) for either 4 or 8 weeks. These rats were decapitated immediately following the final exposure period, and the heads frozen and stored as described above.

Acute exposures. Acute exposures were conducted as described above except that the power output from the radiation source was increased and the distance from the antenna to the animals was decreased to provide exposure to incident power levels of either 40 or 80 mW/cm^2 for 20 or 5 min., respectively. The rats (250-300 g) were decapitated immediately after exposure, and the heads frozen and stored as in the chronic exposure experiments.

GABA and GAD Determinations. The frozen brain tissues were excised and GABA and GAD extracts prepared. GABA concentrations were determined enzymatically by the method of Scott and Jakoby (1959) and GAD activity

* Manson Laboratory, Inc., Stanford, Connecticut, Model 275, 2.5 megawatt modulator, driving a Raytheon 4J3 Pulse magnetron.

• Serial No. D27-8, and receiving horn antenna Serial No. 27-8

was determined by an isotopic assay similar to that employed by Roberts and Simonsen (1963) as modified by Wilson *et al.* (1972). The details of the extraction and assay procedures have been previously reported [2].

Results and Discussion

The rats chronically exposed to an incident power level of 10 mW/cm² showed only moderate signs of heat stress. During exposure, rectal temperature (sampled randomly) did not rise significantly above those of control rats. There were no significant differences in whole brain GABA levels or GAD activity between the irradiated and appropriate unstressed control and sham irradiated rats after exposures of either 3 or 5 days or 4 or 8 weeks (Table I).

TABLE I

WHOLE BRAIN GABA LEVELS AND GAD ACTIVITY IN RATS CHRONICALLY EXPOSED TO INCIDENT POWER LEVELS OF 10 mW/cm² MICROWAVE RADIATION AT 2.86 GHz. DATA ARE PRESENTED AS THE MEAN ± S.E.M. FOR THE NUMBER OF ANIMALS INDICATED IN PARENTHESES. UNSTRESSED CONTROLS WERE NOT ANALYZED FOR THE 8 WEEK EXPOSURES.

	8 hour day		4 hour day	
	3 days	5 days	4 weeks	8 weeks
GABA (μmole/g)	Duration of exposure			
Unstressed controls	2.09 ± 0.08(11)		2.27 ± 0.04(7)	
Sham controls	2.17 ± 0.08(8)	2.08 ± 0.10(8)	2.30 ± 0.11(7)	2.42 ± 0.11(7)
Exposed	2.18 ± 0.08(8)	2.12 ± 0.08(8)	2.32 ± 0.08(7)	2.40 ± 0.14(8)
GAD activity (μmole/g per h)				
Unstressed controls	10.7 ± 0.5(8)		12.3 ± 0.8(6)	
Sham controls	8.9 ± 0.7(4)	11.7 ± 0.3(4)	10.5 ± 0.6(7)	12.9 ± 0.7(7)
Exposed	9.3 ± 0.9(4)	11.6 ± 0.4(4)	10.2 ± 0.7(5)	11.1 ± 0.4(6)

The rats exposed to incident power levels of 40 mW/cm² for 20 min. showed signs of general hyperthermia, i.e., panting, salivation, increased defecation and urination, and fatigue. Those exposed to incident power levels of 80 mW/cm² showed similar but somewhat more severe symptoms. All rats remained conscious during these exposures and none showed signs of convulsions. Rectal temperatures were not obtained for these rats since they were killed immediately after exposure. However in other groups of rats similarly exposed to incident power levels of either 40 or 80 mW/cm², rectal temperatures rose no more than 3.0°C above the control level of 35.6°C. These acute exposures also had no apparent effect on whole brain GABA levels or GAD activity (Table II).

TABLE 2

WHOLE BRAIN GABA LEVELS AND GAD ACTIVITY IN RATS ACUTELY EXPOSED 40 OR 80 mW/cm². DATA ARE PRESENTED AS THE MEAN ± S.E.M. FOR THE NUMBER OF ANIMALS INDICATED IN PARENTHESES. GAD ACTIVITY WAS NOT ANALYZED FOR THE 80 mW/cm² EXPOSURES.

Treatment	GABA (μmole/g)	GAD (μmole/g per h)
Unstressed controls	2.27 ± 0.04(7)	12.3 ± 0.8(6)
Sham controls	2.31 ± 0.11(4)	13.3 ± 1.2(3)
40 mW/cm² for 20 min	2.28 ± 0.07(4)	12.1 ± 0.6(4)
80 mW/cm² for 5 min	2.28 ± 0.07(8)	

These data indicate that chronic exposure to incident power levels of 10 mW/cm² or acute exposure to incident power levels of 40 or 80 mW/cm² of 2.86 GHz microwave radiation does not alter normal GABA metabolism in rat brain. Since biochemical determinations were conducted using whole brain homogenates we cannot rule out the possibility that the exposures induced regional metabolic alterations or impairment of the physiological role of GABA. However, whole brain determinations of both GABA levels and GAD activity have previously served as sensitive indicators of other central nervous system disorders [2, 3, 10]. We conclude therefore that any central nervous system effects induced by microwave exposures similar to those employed in this study cannot be explained on the basis of altered GABA metabolism.

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