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Alteration of Life Span of Mice Chronically Exposed to 2.45 GHz CW Microwaves

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Female CD1 mice were exposed from the thirty-fifth day of age for the remainder of their lives to 2.45 GHz, CW-microwave radiation at a power density of 3 or 10 mW/cm^2 (SAR = 2.0 or 6.8 W/kg). Exposures took place 1 h/day, 5 day/week in an anechoic chamber at an ambient temperature of 22 °C and a relative humidity of 50%. There were 25 animals in each exposure group, and an equal number of controls were concurrently sham exposed. The average life span of animals exposed at 10 mW/cm^2 was significantly shorter than that of sham-exposed controls (572 days vs. 706 days; P = .049; truncation >20%). In contrast, the average lifespan of the animals exposed at 3 mW/cm^2 was slightly, but not significantly, longer (738 days) than that of controls (706 days). ©1994 Wiley-Liss, Inc.*

Key words: CW microwaves, mice, longevity

INTRODUCTION

Few studies have been reported on the effects of chronic microwave exposure on the life span of experimental animals. An analysis of the data of Prausnitz and Süsskind [1962], who exposed mice intermittently to 9.27 GHz microwaves for 59 weeks, revealed a significant increase in the life span of the exposed animals [Preskorn et al., 1978; Kirk, 1984]. Spaulding et al. [1971] found no significant difference in the life span of mice intermittently exposed to 800 MHz microwaves for 35 weeks, although the microwave-exposed animals did live slightly longer on average than the controls (664 vs. 645 days). In a more recent study, Chou et al. [1992] reported a slight but insignificant increase in the life span of rats exposed near-continuously for 25 months to 2450 MHz, pulse-modulated microwaves. In an in utero study by Preskorn et al. [1978], increased survival times were found for rats exposed four times during developmentally critical periods to intense, complexly modulated, 2450 MHz microwaves.

The effects of chronic microwave exposure on life span need to be considered when establishing microwave exposure guidelines for the general population. Our study was designed to analyze the effect of chronic exposure on the life span of mice.

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MATERIALS AND METHODS

The animals used in our study were CD-1 female mice that were 30 days of age when received. They were allowed 5 days to acclimatize to their new surroundings before exposures began. During a microwave or sham exposure they were located in individual plastic containers (6 × 6 × 7 cm) as described by Berman et al. [1978] in foamed polystyrene frames in a 5 × 5 array.

The animals were exposed in a tapered anechoic exposure system modified from that of Guy [1979]. The exposure system was described in detail by Ali and Well [1983]. Briefly, the sides of the exposure chamber were lined with a ceramic, highly absorbing material, and the floor was covered with a pyramidal absorber. The inside of the chamber was lined with foamed polystyrene for environmental control. The sham-exposure chamber was also lined with foamed polystyrene, and it was the same size as the exposure chamber. The outside of the sham-exposure chamber was covered with aluminum so the ambient electromagnetic background in the sham and exposure chambers would be similar. The 2450 MHz microwave generator was a 250 watt CW source with a magnetron of a type commonly used for diathermy and like applications.

One group of 25 animals was exposed at a power density of 10 mW/cm^2 (SAR = 6.8 W/kg); an equal number of animals were concurrently sham exposed. Approximately 1 year later, exposures were begun on another group of 25 animals for whom all parameters were identical to those used with the first group except that the animals were exposed at a power density of 3 mW/cm^2 (SAR = 2.0 W/kg). These animals were obtained from the same supplier and were the same age when received and when exposures were started as the animals in the first group. All other exposure conditions were identical to those of the first group of animals except that exposures began 1 h later (i.e., immediately after the 10 mW/cm^2 exposure was completed). Again, an equal number of animals was concurrently sham exposed.

The animals were housed 12–13 animals per cage in a room with an ambient temperature of ~23 °C, and the cages were placed side by side during the time the animals were not being exposed.

The daily exposures were continued until fewer than two animals (10%) in each group were survivors. In each group, the day of demise of each animal was recorded. During the study, when an animal died, another animal was substituted in its position in the exposure chamber to maintain uniformity of the microwave-dose distribution. Data on the replacement animals were not included in the formal analysis of findings. Because the study was designed to be as non-intrusive as possible, the only other measurement that was made was a weekly weighing of surviving animals.

The mortality data were analyzed by the Logrank test (SAS Institute, Cary, NC) for the 50% survival data and for the evaluation of differences in survival times.

RESULTS

Life span data for the two microwave-exposed groups as compared with the sham-exposed animals are shown in Table 1. The animals exposed at 10 mW/cm^2 had a mean life span of 572 days; those exposed at 3 mW/cm^2 had a mean life span of 738 days. The mean lifespan of the total group of sham-exposed animals was 706 days. Because exposure of animals at 3 mW/cm^2 began at a different time from that of animals exposed at 10 mW/cm^2, the data in the two sham-exposed groups

TABLE 1. Life Span Data of Mice Exposed to 2.45 GHz (CW) Microwaves for 1 h Daily, 5 Days a Week at 3 or 10 mW/cm² (SAR 2.0 or 6.8 W/kg) Beginning at the Thirty-Fifth Day of Age†

	50% survival time (days)
Microwave exposed mice (10 mW/cm²) N = 24	571.7*
Microwave exposed mice (3 mW/cm²) N = 25	738.0
Sham exposed mice N = 50	706.2

*$P = .049$ vs. sham-exposed mice.

†The number of days that elapsed from date of birth until half the animals in each group had expired defines 50% survival time.

were analyzed for equality. The statistical analysis indicated that they were essentially identical ($P > .60$). Because of the evidence of equality, and because they were exposed at the same time for approximately half the study, the data of the two sham-exposed groups were pooled for the analysis of survival times.

Figure 1 shows survival curves for the two groups of exposed rats and the sham-exposed controls. The mean life span of animals exposed to microwaves at 10 mW/cm² was significantly shorter than that of the sham-exposed controls ($P = .049$), but the difference between animals exposed at 3 mW/cm² and sham-exposed animals was not significantly different ($P = .50$).

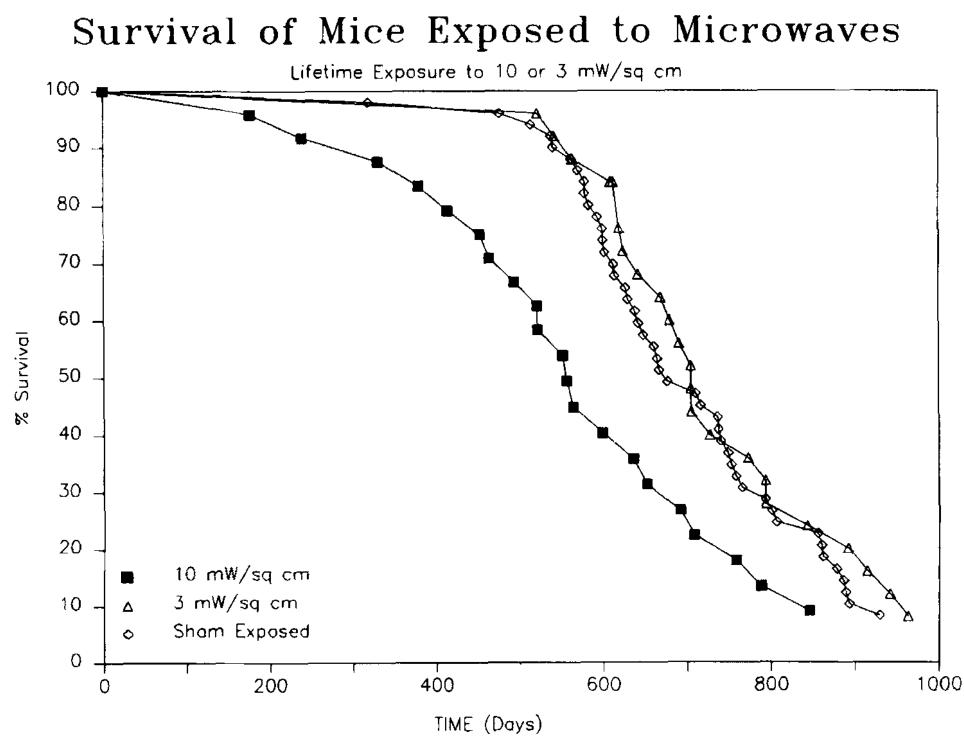

Fig. 1. Survival curves of mice during lifetime exposure to 2.45 GHz (CW) microwaves for 1 h daily, 5 days a week, at 3 or 10 mW/cm² (SAR = 2.0 or 6.8 W/kg) beginning at the thirty-fifth day of age.

DISCUSSION

The results of our study differ substantially from the results of three studies in which the life span of murine animals was analyzed following exposure to microwaves. The results of one of those studies [Prausnitz and Süsskind, 1962] showed a significant increase of life span of mice, but the other two [Spaulding et al., 1971; Chou et al., 1992] reported no statistically significant differences in survival times of rats—although the microwave-exposed animals in both studies lived slightly longer than did their respective controls.

There were several differences among the three longevity studies as well as between those studies and ours. The study by Prausnitz and Süsskind [1962] was one of two in which the mouse was the experimental animal. However, a different frequency (9270 MHz) was used, which would produce a different absorption pattern, as most of the microwave energy would be deposited more superficially than in the present study. Another difference is that the microwaves were pulsed in their study as opposed to the use of CW fields in our study. They also used a higher power density (100 mW/cm^2) and a much shorter daily exposure time (4.5 min). The calculated SAR of 40 W/kg in their mice was also much higher than that used by us, and it resulted in a significant, if brief, period of thermal stress: An exposure produced an average rise in body temperature of 3.3 °C. A previous study in our laboratory [Liddle et al., 1987] indicated that mice exposed at 10 mW/cm^2 in our chamber would show a rise of rectal temperature near 0.8 °C.

In the study of mice by Spaulding et al. [1971] a different frequency from ours was also used (800 MHz), which would result in a different (deeper) penetration of microwave energy. Their power density was also higher (43 mW/cm^2, with an estimated SAR of 12.9 W/kg); the daily exposure duration was longer (2 h) than that in our study. Another difference between their study and ours is that the exposures were conducted for 35 weeks rather than for the life span of the animals. They reported that the microwave-exposed animals lived longer (664 vs. 645 days) but that the difference was not statistically significant.

The third study reported on the effect of chronic microwave exposure on life span was reported by Chou et al. [1992]; rats were exposed in a circularly polarized waveguide to pulse-modulated, 2450 MHz microwaves for 21.5 h/day for 25 months. In their study, the animals were exposed at a much lower power density of 0.48 mW/cm^2 (SARs ranged downward in the study as the animals grew, from 0.04–0.15 W/kg). Thus, the species, modulation, type of exposure (in a waveguide), exposure time (21.5 h/day), and power density (lower) were all considerably different from the parameters of our study. Chou et al. reported a small, positive, but statistically insignificant difference in the life span of the microwave-exposed animals as compared with their sham-exposed animals.

The animals exposed at 10 mW/cm^2 in our study received a moderately thermalizing level of microwaves, but the SAR (6.8 W/kg) is below the resting specific metabolic rate of 8 W/kg reported for the mouse [Durney et al., 1978], and it is below the 10–12 W/kg level that resulted in a reduction in the metabolic rate of mice [Gordon, 1984]; therefore, the amount of additional heating of the mouse in a 2450 Mhz field at 10 mW/cm^2 would not normally be considered an appreciable thermal stress. However, because there was a significant (>20%) decrease in the average lifespan of the animals exposed at 10 mW/cm^2, the possibility exists that this relatively modest amount of additional heating was indeed stressful to the mice, either in toto or from an unequal distribution of thermalizing energy—or from both. The possibility also exists that the microwaves produced some other type of physical, biological or psychophysiological insult that, because the animals were chronically exposed, was detrimental to them.

The significant reduction in life span of approximately 20% indicates that chronic, intermittent exposure to a 2450 MHz field at 10 mW/cm^2 may be detrimental to the mouse. We find it of interest that the animals exposed at 3 mW/cm^2 actually lived longer on average than did the sham-exposed animals (738 vs. 706 days, a difference of 32 days) although the ~ 5% difference is not statistically significant.

Our results indicate that an intermittent, lifelong exposure at a moderately high power density of microwave radiation (10 mW/cm^2) can result in a decrease in the mean life span of mice. The data also indicate that there is no such detrimental effect when the exposure level is approximately one-third as high.

REFERENCES

Ali JS, Weil C (1983): "Radiofrequency Radiation Exposure Facilities for Bioeffects Research." EPA-600/2-83-018, March (NTIS PB83-229591), 54 pp.

Berman E, Kinn JB, Carter HB (1978): Observations of mouse fetuses after irradiation with 2.45 GHz microwaves. Health Phys 35:791–801.

Chou C-K, Guy AW, Kunz LL, Johnson RB, Crowley JJ, Krupp JH (1992): Long-term, low-level microwave irradiation of rats. Bioelectromagnetics 13:469–496.

Durney CH, Johnson CC, Barber PW, Massoudi H, Iskander MF, Lords JL, Ryser DK, Allen SJ, Mitchell JC (1978): "Radio-Frequency Radiation Dosimetry Handbook," 2nd Ed. Brooks Air Force Base, TX, USAF SAM Publication SAM-TR-78-22.

Gordon CJ (1984): Thermal physiology. In Elder JA, Cahill DF (eds): "Biological Effects of Radiofrequency Radiation." EPA-600/8-83-026F, pp 4-1–4-28. Available as report PB-85-120-848 from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

Guy AW (1979): Miniature anechoic chamber for chronic exposure of small animals to plane-wave microwave fields. J Microw Power 14:327–338.

Kirk WP (1984): Life span and carcinogenesis. In Elder JA, Cahill DF (eds): "Biological Effects of Radiofrequency Radiation." EPA-600/8-83-026F, pp 5-106–5-111. Available as report PB-85-120-848 from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

Liddle CG, Putnam JP Lewter OH (1987): Effects of microwave exposure and temperature on survival of mice infected with *Streptococcus pneumoniae*. Bioelectromagnetics 8:397–404.

Prausnitz S, Süsskind C (1962): Effects of chronic microwave radiation on mice. IRE Trans Biomed Electron 9:104–108.

Preskorn SH, Edwards WD, Justesen DR (1978): Retarded tumor growth and augmented longevity in mice after fetal irradiation by 2450-MHz microwaves. J Surg Oncol 10:483–492.

Spaulding JF, Freyman RW, Holland LM (1971): Effects of 800 MHz electromagnetic radiation on body weight, activity, hematopoiesis and life span in mice. Health Phys 20:421–424.