

(C/a)

2014 Has this paper been referenced in your Newsletter bibliography?

Glaser

Bob

Absence of Ocular Pathology after Repeated Exposure of Unanesthetized Monkeys to 9.3-GHz Microwaves*



R.D. McAfee†††, A. Longacre, Jr.††, R.R. Bishop††, S.T. Eldert†††, J.G. May†††, M.G. Holland†††† and R. Gordon††††

ABSTRACT

Unfettered monkeys (*Macaca mulatta*) have been trained to expose the face and eyes to pulsed microwave radiation at a frequency of 9.31 GHz and an average power density of 150 mW/cm². Performance of an operant response required the monkeys to maintain the head within the field of the radiation source. Twelve monkeys were individually irradiated during 30 to 40 sessions and then were observed for a period of one year. No deleterious effects such as cataracts have been observed.

INTRODUCTION

Microwave radiation is alleged to produce acute and chronic illness [1, 2]. The radiation may be continuous wave (CW), such as produced by some microwave ovens, or pulsed radiation of high peak power as produced by radar equipment. Formation of cataracts is one pathology ascribed to microwave irradiation. This claim is based on human medical data and on results of experiments on animals. Many of the allegations may be criticized on the grounds that medical observations are uncontrolled and retrospective [3], and that experimental studies have generally been based on anesthetized rabbits [1, 2]. Data are available which reveal that cataracts can be produced in anesthetized rabbits by microwaves at field strengths that do not produce cataracts in unanesthetized rabbits under otherwise identical conditions [4].

It has frequently been suggested that repeated exposure to microwaves and other radio-frequency (RF) radiations can produce deleterious effects, including cataracts in human beings, at power densities well below the maximal permissible exposure (MPE) recommended by the American National Standards Institute (ANSI). The pertinent ANSI document [5] states that incident RF radiation at frequencies from 10 MHz to 100 GHz should not exceed 10 mW/cm² and that this level should be reduced considerably if the testes and eyes are irradiated. The authors of the ANSI publication also recognized that information was not available to determine if irradiation at or below an average power density of 10 mW/cm² would be more harmful if delivered in short pulses of high peak power.

Long-term studies of primates without anesthesia but after multiple exposures to radiation at high peak power have not been reported and are the objectives of a continuing investigation that we report on here.

METHODS AND MATERIALS

Twelve monkeys (*Macaca mulatta*) were irradiated individually without restraint or anesthesia during 30 to 40 sessions, and were observed for a period of one year for signs of ocular pathology. The monkeys were trained to face a microwave-horn antenna, thereby accurately positioning the eyes, face and head within the microwave beam. Serving as an operandum-feeder was a hollow quartz-glass mouthpiece that could be depressed by the animal's lips; depression closed a switch that made apple juice available as a reward for lever pressing — and simultaneously activated a microwave generator, if required in the experimental protocol.

* Manuscript received August 22, 1978.
† Research Service, Veterans Administration Hospital, 1601 Perdido Street, New Orleans, LA, 60146, U.S.A.
†† School of Engineering, Department of Electrical Engineering, University of New Orleans, Lakefront, New Orleans, LA, 70122, U.S.A.
††† Department of Psychology, University of New Orleans, Lakefront, New Orleans, LA, 70122, U.S.A.
†††† Department of Ophthalmology, Tulane University Medical Center, 1430 Tulane Avenue, New Orleans, LA, 60112, U.S.A.

mail stop #151

The monkeys were housed in two groups, each of which comprised one male and five females (along with infants) in a family cage. Attached to each cage was an operant chamber that could be entered through a guillotine door. The chamber and the home cage were partitioned into two equal sections so that a monkey, once in the chamber, could not return to the home cage. The chamber contained an apparatus that consisted of 1-m² acrylic panel with two foot holds 1 m above ground, a left-hand support, a right-hand lever, and the hollow, quartz-glass mouthpiece that was centrally located 0.3 cm below a 20-cm² opening covered by Mylar film (0.5-mm thick) through which the microwave beam passed without measurable distortion or reflection. Both the cage (3.65 m x 3 m x 2 m) and the chamber (3.65 m x 1.50 m x 2 m) were of chain-link construction and both were located in an isolated area of a pine forest at the Delta Regional Primate Research Center, Covington, Louisiana, U.S.A.

An adjacent building housed the microwave generator, the instrumentation to control schedules of reinforcement and irradiation, and the recorders of timing and lever pressing. When the drinking tube was pressed forward to close a switch, a timer operated and microwave irradiation could be initiated. Only then did lever pressing produce a reward of 0.1 ml of apple juice on a 20% variable-ratio schedule of reinforcement (VR-5).

Microwave radiation was generated by a Model AN/CPN-6 radar (Radio Research Instrument Co., Inc., Norwalk, Conn., 06850) that operated at 9.31 GHz. It produced a 0.5- μ s pulse at a peak power of 40 kW. The pulse-repetition rate (PRR) was controlled by varying the frequency of the modulation pulse to the magnetron with a General Radio Unit Pulse Generator, Type 1217B. The PRR was set at 1050 Hz, which resulted in radiation at an average power density of 150 mW/cm² at the locus of a monkey's head, which was 15 cm from the aperture of a standard gain horn (6.0 x 4.9 cm, E-field vertically polarized). The average power of delivered radiation was measured by a Hewlett Packard Meter (439A) and a Sensor Model 8481A meter that were connected to a 16-dB fixed-calibration attenuator and a calibrated 20-dB directional coupler. The average power density was calculated from power measurements made with the Hewlett-Packard instrumentation or was directly measured by a Narda (Narda Microwave Corp., Plainview, N.Y.) Model 8315 broad-band power meter and Model 8321 isotropic probe placed in the position of the monkey's head. In order to prevent damage to the Narda probe, the peak power output of the microwave pulse was attenuated 20 dB with the calibrated directional coupler. The peak power of the 0.5- μ s pulse at this location in the absence of attenuation is approximately 300 W/cm².

The microwave field within the exposure chamber was surveyed with a field probe that was connected to the Hewlett-Packard sensor and meter. Standing waves were found to be present at the rear of the cage but not within 15 cm of the horn antenna. Field strength fell off less than 1 dB 3 cm from the center of the microwave beam and less than 3 dB 6 cm from the center. The measurements revealed no trough in the microwave field at the locus where a monkey placed its head. An estimation of reflected power was obtained in the following ways: First, an integral meter on the CPN-6 transmitter read 5.5 milliamperes when operated at a PRR of 1050 Hz and in the absence of the monkey's head. When a monkey placed its head in the field this reading was reduced to 5 ma. And second, measurements of reflected power by the calibrated directional coupler and the Hewlett-Packard instrumentation indicated a 0.5-dB drop in power when the monkey positioned itself to operate the operandum-feeder. In the absence of a more realistic model, a 150- or a 200-ml volume of physiological saline in a foamed polystyrene cup was placed at the locus of irradiation. At a PRR of 1050 Hz for 15 minutes, a 3- $^{\circ}$ C Δ T (above ambient temperature) was obtained in the 150-ml volume and a 2- $^{\circ}$ C Δ T in the 200-ml volume. Allowing for heat loss, the rate of energy coupling to the saline models was at least 15 mW/g.

Drinking water was available *ad libidum* in the family cages. The monkeys were fed Purina Monkey Chow at 0800 and at 1500 hours in excess of what they would eat within a 15-minute period. At 0830 the cages were cleaned and remaining food was removed. The operant sessions began at 1100 hours and continued until 1500 hours. The order of entry to the operant chamber was recorded daily. Infants often entered an operant chamber with their mothers and nursed during the mother's operant behavior or climbed about the cage. The social and sexual behavior of the monkeys was observed during this period as was the status of their health.

Six adult members of one family group (II) were irradiated during 30 to 40 daily sessions while six animals of the other group (I) acted as controls. During a second set of sessions the order was reversed. Except for occasional (normal) blinking, the monkeys' eyes were open during irradiation. Some of the sessions were missed by an individual monkey because of parturition or of injury unrelated to irradiation and for this reason some monkeys were irradiated for fewer than 40 sessions, but none less than 30. The irradiation sessions occurred Mondays through Fridays. Occasionally a day or two was missed because of inclement weather. Preceding and following each of the 40 sessions, animals of both groups were given ocular examinations under light anesthesia with a slit-lamp biomicroscope. An additional group of 75 monkeys that was kept in outdoor cages at the Delta Regional Primate Research Center and was used for breeding purposes only, was also examined. Monkeys of this group will eventually provide data on incidence of cataracts in an unirradiated population of animals of approximately the same age as the irradiated monkeys.

Prior to irradiation, family Groups I and II and the larger group of 75 monkeys were examined using the slit-lamp biomicroscope. No cataracts were observed in any animal.

RESULTS AND DISCUSSION

Table I shows the total time spent operating the operandum-feeder, i.e., it was total time of depression during sessions with and without irradiation. As mentioned previously, some sessions were missed and some monkeys varied considerably in the time they would spend at the operandum-feeder with or without irradiation. The estimated total of incident energy to the face of each rhesus is shown in the last column of Table I. At the date of the latest examination (August 4, 1978) no cataracts or corneal lesions were observed.

Table 1 Operant Responding Time and Facial Irradiance

Family Group	Monkeys Designation and Sex	Total Time Spent		Total Incident Energy in kJ/cm ²
		at Operandum Radar off	(minutes) Radar on	
	(1)	(2)	(3)	(4)
I	26M	326	665	179.55
	93F	377	512	138.24
	40F	552	630	170.10
	37F	470	550	148.50
	36F	267	628	169.56
	35F	486	654	176.58
II		(3)	(2)	
	34F	613	631	170.37
	27M	470	305	82.35
	28F	502	496	133.92
	38F	656	475	128.25
	30F	582	554	149.58
	29F	525	294	79.38

- (1) Listed in approximate daily order of entry into operant chamber.
- (2) Time accumulated between November 3, 1976 and January 4, 1977.
- (3) Time accumulated between May 2, 1977 and August 11, 1977.
- (4) Total incident energy in kJ/cm² assuming a projected facial area of 30 cm².

$$\text{For monkey 26M; } 665 \text{ min } (0.15 \frac{\text{W}}{\text{cm}^2}) (30 \text{ cm}^2) (\frac{60 \text{ sec}}{\text{min}}) (\frac{1}{1000}) = 179.55 \text{ kJ/cm}^2.$$

The social behavior of the monkeys is being observed during this study. The experimenter did not interact with monkeys except to open and close the entry and exit doors to the operant chamber. Dominance behavior of individual animals (e.g., entry of the dominant animal first) was observed and remained unchanged during the course of these experiments. Grooming behavior would be interrupted by entry to the operant chamber and was resumed when an animal was returned to the home cage. The success of mating behavior was noted visually and verified by the fecundity of the females. Eleven infants have been born of monkeys that were being irradiated when impregnated and while carrying the fetus. The offspring have been examined by Primate Center veterinarians and no abnormalities have been found. The fecundity of animals of Groups I and II does not appear significantly different from other breeding groups of similar age that are living in outdoor gang cages at the Delta Regional Primate Center. Behavior of both the mother and of the family group toward infants has been exemplary and no infant has been injured by an adult. The general health status of both groups of monkeys is excellent and the findings of this continuing study of microwave-irradiated monkeys does not support the hypothesis upon which this study was based: That frequently-repeated exposure to pulsed microwave irradiation at 150 mW/cm² is a health hazard. We do not imply that we have proved the null hypothesis. We shall continue to search diligently for signs of deleterious effects of microwave irradiation.

ACKNOWLEDGEMENTS

The authors thank Drs. Robert Wolf and Christian Abee of the Delta Regional Primate Research Center, Covington, Louisiana, for veterinary care and advice. The research was performed at the Delta Regional Primate Research Center, Covington, Louisiana 70433. The editorial assistance of Dr. Don R. Justesen is gratefully acknowledged.

Supported by the Medical Research Service of the Veterans Administration.

REFERENCES AND NOTES

- 1 Three readily available proceedings of symposia provide access to the voluminous literature on microwave effects: (1) *Biological Effects of Microwave Radiation*, Stephen F. Cleary, Ed., 1970 (BRH/DBE 70-2) Library of Congress Catalog Card Number 76-607340; (2) *Biological Effects of Nonionizing Radiation*, Paul E. Tyler, Ed., Annals of the New York Academy of Sciences Volume 247, 1975; (3) *Biological Effects of Electromagnetic Waves: Selected Papers of the USNC/URSI Annual Meeting — volume I and II*, Curtis C. Johnson and Moris L. Shore, Eds., 1976 HEW Publication (FDA) 77-8011 (available from the Superintendent of Documents U.S. Government Printing Office, Washington, D.C., 20402, Stock No. 017-015-00125-3).
- 2 For many pertinent literature citations, congressional hearings, and media expose of microwave effects see also *The Zapping of America: Microwaves, Their Deadly Risk and The Coverup* by Paul Brodeur, W.W. Norton & Co., Inc., New York, 1977.
- 3 See particularly Milton M. Zaret in references 1 and 2 above. For a contrary opinion see Budd Appleton, *ibid* and in *Archives of Ophthalmology* 93:257, 1975. See also Zaret in *N. Y. State J. Med.* 74:2032, 1974 and following "Letters of Comment Pro and Con."
- 4 Daily L. Jr., K.G. Wakim, J.F. Herrik, E.M. Parkhill and W.L. Benedict. The Effects of Microwave Diathermy on the Eye of the Rabbit. *Am. J. Ophthalmology*, 35:1001, 1952.
- 5 "Safety Level of Electromagnetic Radiation with Respect of Personnel." American National Standards Institute (ANSI C95. 1-1974). Published by Institute of Electrical Electronics Engineers, 345 E. 47th Street, New York, N.Y. 10017.