

Microwave Radiation and Its Effect on Response to X-radiation

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R. A. E. THOMSON, M.T., SOL M. MICHAELSON, D.V.M., and JOE W. HOWLAND, M.D.

Dogs were exposed to simultaneous microwave (2800 Mcycles/sec, 100 mW/cm²) and x-ray (250 KVP, 1656 R, 4.6 R/min) exposure, or to the same x-ray exposure nine months after a total of 90 hours of multiple microwave exposure. Mortality was greater in animals treated with microwaves, and was most marked following simultaneous microwave and X-irradiation. Deaths were hemopoietic in nature. Survival appeared best in dogs showing minimal leukocyte and neutrophil changes immediately after X-irradiation. Hematocrit, erythrocyte sedimentation rate, reticulocyte, rectal temperature, body weight, food and water consumption changes are presented. Microwave treatment can modify the response to X-irradiation, and its effect appears related to the total microwave exposure, duration of microwave exposure, rectal temperature response, time interval before X-irradiation, total X-irradiation and X-ray dose rate. Modification of ionizing radiation injury at the hematopoietic level is indicated.

Ramcor Densimeter was used to determine the average power level in the exposure cage.

X-radiation was from a Picker X-ray unit, operated at 250 KVP, 5 ma, with no filter added. Half value layer was 0.25 mm Cu. Air dose rate measured with a Victoreen R meter in the center of the exposure cage was 4.6 R/min.

The animals received for six hours (1) X-radiation; (2) simultaneous microwave and X-radiation; or (3) X-radiation nine months after a total of 90 hours of microwave exposure, of which the microwave exposure was limited to six hours a day. The microwave and X-ray beams intersected at a 90° angle in the center of the cage.

Hematologic studies were done on blood obtained by jugular venipuncture. Rectal temperature was determined using an electronic thermometer with a thermistor probe. Water and commercial dog food were provided ad libitum except during exposure. Food and water consumption and body weight changes were noted. The animals were observed for 60 days following exposure.

THERE IS EVIDENCE that microwaves are capable of altering the response to ionizing radiation. Modification of the leukocytic, neurologic and lethal effects of ionizing radiation have been reported.^{2,4,7} The studies reveal less acute effects from x or gamma irradiation in animals treated with microwaves. In investigation of the response to simultaneous microwave and X-irradiation, in which modification of the leukocyte response was observed, lethality did not result from the X-ray dose used. This study was undertaken to determine the effect of simultaneous microwave and X-irradiation at a lethal X-ray dose level. The response to X-irradiation after numerous exposures to microwaves was also investigated.

RESULTS

Lethality from 1656 R whole body X-irradiation was 30 per cent in normal dogs, 70 per cent in dogs X-irradiated nine months after microwave exposure totalling 90 hours, and 100 per cent in dogs subjected to microwaves during X-ray exposure (Table I). Simultaneous X-ray and microwave irradiated dogs had the shortest mean survival time (11 days). Survival time for the microwave pre-treated dogs appeared bimodal; four deaths 12 to 13 days, and three deaths 21 to 25 days after X-ray exposure. Non-microwaved dogs died 11 to 17 days after X-irradiation.

Leukocyte changes immediately after X-ray exposure are listed in Table II. Lymphocytes decreased 70 to 80 per cent from the pre-exposure level in all dogs. Total leukocyte count was slightly decreased in dogs that survived X-irradiation, and in the microwave pre-treated dogs that died 21 to 25 days post-exposure. Microwave

MATERIALS AND METHODS

Male and female dogs, of mixed breeds, one to five years of age, were exposed individually in a Plexiglas cage, 20 x 20 inches and 23 inches high, in an anechoic chamber 7 x 7 feet and 15 feet long.

Microwave frequency was 2800 Mcycles/sec, pulse rate 360 per second with a 2 microsecond pulse width, and average power level, 100 mW/cm². A Model 1250

From the Department of Radiation Biology and Biophysics, The University of Rochester, School of Medicine and Dentistry, Rochester, New York.

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This certifies that the investigations described in this paper were conducted according to the "Rules Regarding Animal Care" as established by the American Physiological Society.

Opinions expressed in this paper are those of the authors and do not represent the official views of the U.S. Air Force.

TABLE I. 60 DAY LETHALITY IN DOGS FOLLOWING 1656 R WHOLE BODY X-IRRADIATION

Exposure	Lethality		Survival Time (Days)		Mean
X-ray	3/10	30%	11, 12	17	13.3
X-Ray 9 Months Post Microwave Exposure	7/10	70%	12, 12, 12, 13	21, 23, 25	16.9
Simultaneous Microwave and X-ray	5/5	100%	9, 9, 11, 11	15	11.0

TABLE II. LEUKOCYTE COUNT IMMEDIATELY BEFORE AND AFTER 1656 R WHOLE BODY X-IRRADIATION

No. of Dogs	Group	Survivors		Count x 10 ³ per cu. mm.		Lymphocytes		
		Total Leukocytes		Neutrophils		Post		
		Pre	Post	Pre	Post	Pre	Post	
7	I	10.38 ± 1.16 ^a	9.44 ± 3.52	6.09 ± 0.92	7.70 ± 3.00	3.23 ± 0.99	0.84 ± 0.31	
3	II	8.52 ± 1.06	6.80 ± 1.08	5.43 ± 1.26	5.46 ± 1.02	2.03 ± 0.68	0.70 ± 0.12	
		Non-Survivors						
	Survival Time (Days)	Group						
3	11-17	I	9.37 ± 1.47	9.44 ± 4.77	5.80 ± 1.33	7.99 ± 4.58	2.70 ± 0.48	0.79 ± 0.09
3	21-25	II	10.17 ± 1.08	7.87 ± 1.16	5.29 ± 0.45	6.17 ± 0.99	4.30 ± 1.31	1.13 ± 0.23
	12-13	II	10.14 ± 0.93	15.46 ± 0.86	5.38 ± 1.66	13.88 ± 0.89	3.29 ± 0.74	0.68 ± 0.38
5	9-15	III	9.13 ± 2.19	13.53 ± 5.09	4.60 ± 1.91	11.56 ± 5.10	3.34 ± 0.59	0.94 ± 0.50

^a Mean ± Standard Deviation of the Mean
 Group I Normal X-Irradiated
 Group II X-Irradiated 9 Months After Microwave Exposure
 Group III Simultaneous Microwave and X-Irradiation

pre-treated and simultaneous irradiated animals that survived 12 to 13 days, and 9 to 15 days had a moderate leukocytosis, and a marked increase in neutrophils. Leukocyte count was essentially unchanged, and the neutrophils slightly increased in the normal dogs that succumbed to X-irradiation. Most of the animals had an increase in band-form neutrophils (stabs) immediately after X-irradiation. Dogs that died had a rapid and continuous depletion of white cells from 24 hours after X-irradiation until death. Survivors had a similar rapid decrease in leukocytes from one to seven days after X-irradiation (Figure 1). The leukocyte count on day seven ranged from 10 to 20 per cent of the pre-exposure value. It remained at this level until 30 days after exposure. Between 30 and 60 days post-exposure the total leukocyte count gradually increased, and at 60 days it was approximately 60 per cent of the pre-exposure value. In the microwave pre-treated animals the neutrophil count was relatively unchanged up to one day after X-ray exposure. Normal animals had a mild increase in neutrophils immediately after X-irradiation. Thereafter, the neutrophil response in both groups of animals was similar in pattern to that of the total leukocyte count. Negligible changes in lymphocyte values occurred from the markedly depressed level evident at one day after X-irradiation.

Normal and microwave pre-treated dogs that survived X-radiation had a gradual decrease in hematocrit, increased sedimentation rate, and reticulocytopenia for 30 days after exposure, followed by recovery toward the initial values (Figure 2). The increase in sedimentation rate was more marked and of longer duration in normal X-irradiated dogs. Reticulocyte count was depressed for two to three weeks following X-ray exposure. At 42 and 60 days after exposure reticulocyte counts exceeded the initial value. Increased nucleated erythrocyte level was present four weeks post-X-radiation. Changes in these hematologic parameters, from the pre-exposure level, were much greater in the animals that did not survive X-irradiation, and indications of recovery were absent.

Rectal temperature immediately after exposure was increased in the simultaneous microwave and X-irradiated dogs, and decreased in the other X-irradiated animals (Figure 3). Non-survivor animals were hyperpyretic for one or more days prior to death. Animals that survived

were pyretic between 15 and 25 days after X-irradiation. Varying increases in water consumption, and de-

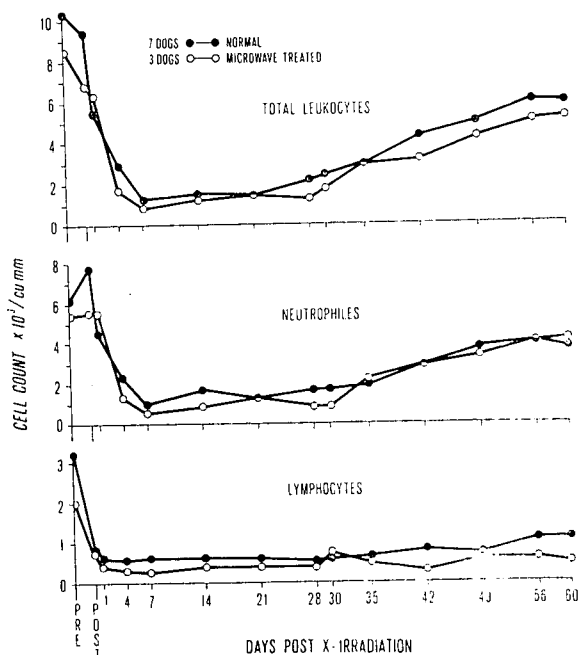


Fig. 1. Response of dogs that survived 1656R whole body X-irradiation.

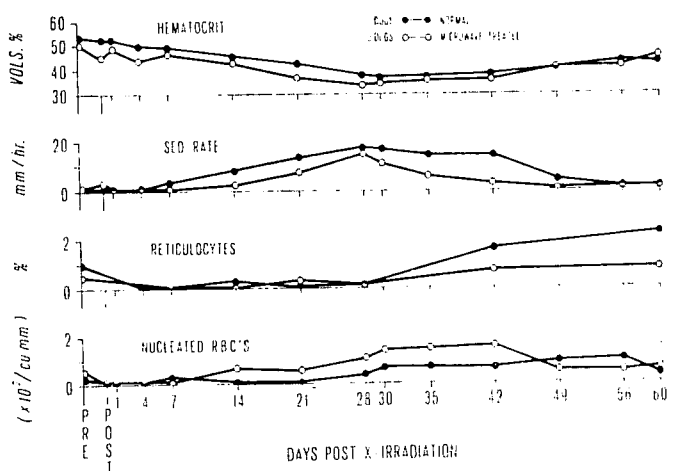


Fig. 2. Response of dogs that survived 1656R whole body X-irradiation.

creased food intake during the first 24 hours after exposure were evident in animals that died following X-irradiation. Water intake was most marked following combined irradiation. Anorexia of two to nine consecutive days duration preceded death. None of the animals abstained from drinking water. Food consumption was

markedly diminished during the initial 24 hours after X-irradiation in animals that survived. During this period water intake differed little from the pre-exposure value in the non-microwaved dogs. In the microwave pre-treated dogs it was decreased.

Emesis occurred in 60 per cent of the dogs mostly during or within three hours after any of the three types of exposures conducted. The maximum per cent body weight loss that resulted following X-irradiation was similar among non-survivors (Table III). Body weight loss, in animals that survived, was greatest during the third week after X-irradiation. The normal dogs lost more weight than the microwave pre-treated dogs.

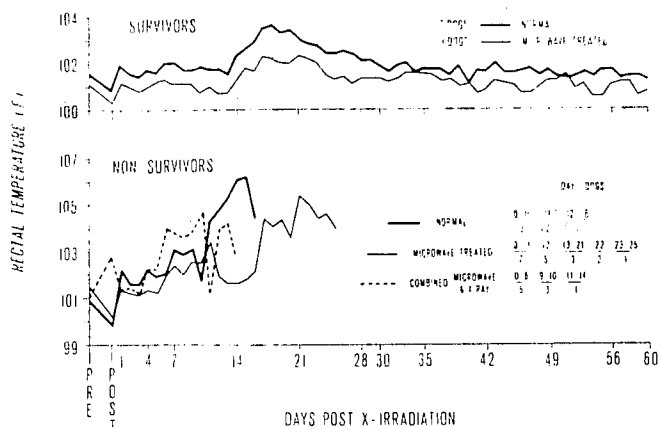


Fig. 3. Response of dogs exposed to 1656R whole body X-irradiation.

DISCUSSION

It is apparent from Table I that microwave treatment can increase the lethal effects of X-irradiation. This is very evident following combined microwave and X-irradiation. The increase in body temperature immediately following combined microwave and X-irradiation results from heating of the animal by microwaves (Figure 3). Absorption of microwave energy in tissue results in the heating of the medium.⁵ Hurley and Joslin¹ found enhancement of X-radiation effects when heating and X-irradiation of mice was administered simultaneously. Such a response has been hypothesized by Selawry, et al.,⁶ in a review of the combined effect of heat and ionizing radiation.

The increased lethality in animals that received X-irradiation nine months after microwave exposure suggests that the microwave treatment caused a change in the animals that made them respond differently from normal animals. Differences in response between microwave treated and normal animals following ionizing radiation have been observed.^{2,4,7} In such studies lethality was less in microwave treated than in normal animals. When the lethality response in this study is examined closely, it is evident that of the microwave treated animals only those with the least number of consecutive microwave exposures, in accumulating 90 hours of exposure, survived X-irradiation (Figure 4). The exposures ranged from a single exposure up to a maximum of five consecutive exposures. The relation of each type of exposure (single, two consecutive, etc.) to the total number given, is expressed as per cent of the total microwave exposure. Fewer consecutive exposures comprised the microwave exposure groupings for animals that survived 21 to 25 days, than for the animals that died

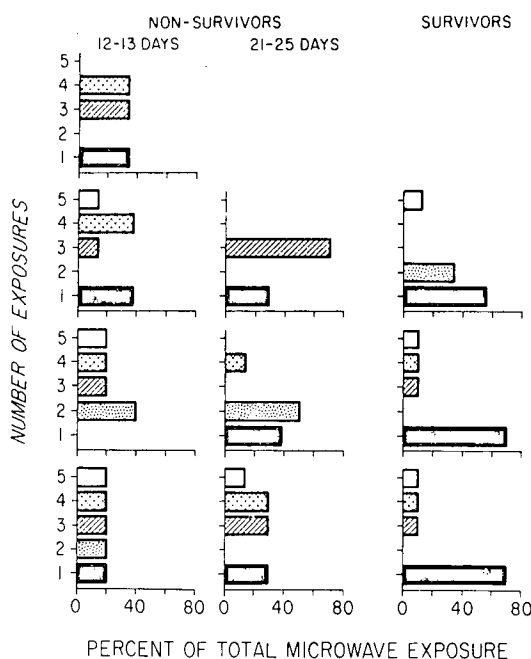


Fig. 4. Relationship of microwave exposure and lethality following X-irradiation.

TABLE III. MAXIMUM BODY WEIGHT LOSS (%) AFTER 1656 R WHOLE BODY X-IRRADIATION

Treatment	Survivors			Non-Survivors		
	No. of Dogs	Mean Initial Body Wt. (Kg.)	Maximum Wt. Loss (%)	No. of Dogs	Mean Initial Body Wt. (Kg.)	Maximum Wt. Loss (%)
No Pre-Treatment	7	13.28 (10.95-19.10)	12.4±1.97 ^a	3	11.65 (11.07-11.99)	14.8±1.52
Microwaves 9 Mos. Pre-X-Irradiation	3	12.77 (10.58-13.95)	8.2±0.40	7	12.04 (8.16-21.10)	17.4±1.86
Simultaneous Microwave and X-Irradiation	—	—	—	5	12.35 (8.68-17.39)	17.9±1.33

^a—Mean ± Standard Error of the Mean
()—Range