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# *Effects of Electromagnetic Radiations on Physiologic Responses*

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**Studies were performed on dogs exposed to 1240 Mc/sec pulsed microwaves, at a field intensity of 50 mW/cm², six hours per day for five consecutive days. Some dogs with additional exposures were included. For comparison, dogs previously irradiated with 1000 kVp X-rays (50 R/min) either to the whole-body (300 R) upper-body (1900 R) or lower-body (900 R) were exposed to microwaves in a similar manner. Alterations in cardiopulmonary, thyroid and erythropoietic function of normal dogs and greater sensitivity of X-irradiated dogs to microwaves are noted. In general, these studies indicate that repeated exposure to 1240 Mc/sec microwaves at 50 mW/cm², can produce functional changes in the dog which if extrapolated to man would be indicative of homeostatic insufficiency and decrement in performance capability even though overt incapacitation may not take place. Whether thermal, non-thermal, or both of these are the contributing factors in the response to microwave exposure, there are sufficient experimental and human survey evidence to indicate that microwave exposure results in alteration in compensatory and homeokinetic mechanisms of the body. The effects of microwave exposure at 50 mW/cm² in the normal animal should alert us to the caution that has to be exerted when any consideration is given to raising the presently accepted maximum permissible exposure of 10 mW/cm².**

SINCE WORLD WAR II increased interest has developed in the biologic effects of microwaves as related to potential hazards to man. Considerable experimental work on animals and clinical evaluations in man have been undertaken in the U.S.A. and the U.S.S.R.

Although suggestions of altered physiologic function among individuals exposed to radar have appeared in the literature, there is a paucity of experimental evidence to implicate microwave exposure as a causative factor in such impairment of functional capacity.

In the course of study of biologic effects of 1240 Mc/sec pulsed microwaves, experimental evidence of altered physiologic function has been obtained.

## MATERIALS AND METHODS

The animals used in these studies were short-haired dogs of mixed breed. Males and females between 9 and 18 kg. body weight were selected. The ages were estimated to be between 1 and 5 years. All animals were quarantined for at least 30 days during which they were immunized against distemper and hepatitis. When indicated by fecal examination, appropriate anthelmintic therapy was instituted. The dogs were housed singly in comfortable cages. Water was available at all times. A commercial kennel ration was fed once daily.

Dogs were individually exposed in a Plexiglas cage 20 × 20 inches and 23 inches high. The cage was situated on a Plexiglas table in an anechoic chamber, 7 × 7 feet and 15 feet long. A 1240 Mc/sec (AN/FPS-8) pulsed microwave generator (360 pulses/sec, 2 microsecond pulse width) was used for exposure.

Power measurements were made using a Ramcor Model 1200 densitometer. The microwave field pattern was relatively uniform, with the energy at the periphery of the cage differing by less than 20 per cent from that at the center.

Twenty-one dogs were exposed at 50 mW/cm² field intensity, 6 hours a day for 5 consecutive days. One dog was exposed over a two- and another over a four-week period.

To investigate the response of X-irradiated animals to microwaves, additional groups of dogs were irradiated with 1000 kVp X-rays (50 R/min) either to the whole-body (300 R), upper (1800 R) or lower-body (900 R) at various times before microwave exposure. Ten dogs were exposed to microwaves without previous X-irradiation. Of the dogs that were X-irradiated before microwave exposure, 4 received whole-body, 4 upper-body, and 3 lower-body X-irradiation.

In addition, data on 1-131 uptake are presented for 8 dogs that received one exposure for 6 hours at 100 mW/cm² and one dog that received daily (5x/wk) six hour exposure over a two-week period.

All physiologic function and hematologic studies were performed by standardized and accepted techniques.

## RESULTS

Per cent body weight loss which is a reflection of insensible water loss and serves as an index of the thermal burden imposed on the animal is indicated in Table I.

In normal dogs, there was a smaller loss in body weight as microwave exposures were repeated. Among whole-body and lower-body X-irradiated dogs body weight loss was greater than in normal dogs during the first exposure to microwaves. The weight loss was less during subsequent exposures. In upper-body X-irradiated dogs weight loss was less than in normal dogs initially, but became greater as the exposures

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

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were repeated. In all dogs exposed to microwaves there was a progressive decline in pre-exposure rectal temperature as the exposures were repeated (Table I.). Increase in rectal temperature during exposure was less in the X-irradiated dogs than in normal dogs.

All whole-body X-irradiated dogs and two of three upper-body X-irradiated dogs vomited once during microwave exposure. Retching unaccompanied by vomiting was noted once during microwave exposure in the latter group of animals. Such a response was not observed in normal or lower-body X-irradiated dogs.

In two dogs studied 17 days after multiple exposure to 1240 Mc/sec, 50 mW/cm², blood volume was slightly increased from pre-exposure values of 83.58 and 83.68 cc/kg to 106.36 and 100.00 cc/kg. These results are indicated in Table II with other data from 2800 Mc/sec exposure.

Some hematologic changes were variable, however, indices of erythropoietic function such as hematocrit, reticulocytes, hemoglobin content, plasma Fe-59 clearance and red cell uptake determinations revealed the influence of microwave exposure on such responses. Total leukocyte count, absolute neutrophil, red blood cell and erythrocyte sedimentation rate values were not remarkable. Reticulocyte and lymphocyte levels, indicated significant microwave effects (Table III). As exposures were repeated, there was a progressive de-

TABLE I. EFFECT OF MICROWAVES[a] ON BODY WEIGHT LOSS AND RECTAL TEMPERATURE

| X-Radiation[b] | Microwave Exposure Number | % Body Weight Loss | Rectal Temperature (F) Pre | Rectal Temperature (F) Post |
|---|---|---|---|---|
| Control (sham irradiated) | 1 | 3.22±0.22[c] | 101.7±0.16 | 101.8±0.31 |
| | 3 | 2.69±0.14 | 100.8±0.16 | 102.0±0.14 |
| | 5 | 2.51±0.13 | 100.6±0.17 | 101.5±0.16 |
| Whole-Body 300 R (MAD) | 1 | 3.52±0.42 | 101.8±0.27 | 101.6±0.38 |
| | 3 | 2.83±0.45 | 101.3±0.20 | 101.4±0.50 |
| | 5 | (2.67—2.87) | 101.0±0.29 | 101.6±0.33 |
| Upper-Body 1800 R (MAD) | 1 | 2.52±0.13 | 102.6±0.48 | 101.4±0.24 |
| | 3 | 2.54±0.47 | 100.6±0.16 | 101.4±0.19 |
| | 5 | (2.39—2.65) | 100.7±0.65 | 101.4±0.60 |
| Lower-Body 900 R (MAD) | 1 | 3.85±0.33 | 101.8±0.25 | 101.8±0.14 |
| | 3 | 3.67±0.43 | 101.0±0.38 | 101.3±0.22 |
| | 5 | 3.44±0.40 | 100.7±0.36 | 101.4±0.08 |

a – 1240 Mc/sec pulsed. 50 mW/cm² 6 hrs/day, 5 days
b – 1000 kVp X-rays 55 R/min
c – Mean ± standard error
( ) – Individual determinations on two dogs

TABLE II. EFFECT OF MICROWAVES ON BLOOD VOLUME

| Exposure | | Dog | Blood Volume (cc/kg) Control | Time after exposure 10 min. | 2 days | 17 days |
|---|---|---|---|---|---|---|
| 1240 Mc/sec 50 mW/cm² | 6 hrs. (Multiple) | V-3 | 83.58 | — | — | 106.36 |
| | 6 hrs. (Multiple) | V-50 | 83.68 | — | — | 100.00 |
| 2800 Mc/sec 165 mW/cm² | 2 hrs. morphine premedication | 4404 | 83.63 | 70.07 | 114.46 | — |
| | 40 min. pentobarbital anaesthesia | 4085 | 100.30 | 74.06 | 104.58 | — |

TABLE III. EFFECT OF MICROWAVES[a] ON RETICULOCYTES AND LYMPHOCYTES

| X-Radiation[b] | Microwave Exposure Number | Reticulocytes Pre | Reticulocytes Post | Lymphocytes Pre | Lymphocytes Post |
|---|---|---|---|---|---|
| Control (sham irradiated) | 1 | 6.00±1.10[c] | 4.87±2.13 | 2.56±0.52 | 2.14±0.42 |
| | 3 | 3.62±1.86 | 4.63±3.80 | 2.52±0.10 | 1.88±0.25 |
| | 5 | 3.42±1.08 | 2.00±0.56 | 2.84±0.35 | 2.15±0.11 |
| Whole-Body 300 R (MAD) | 1 | 4.68±3.05 | 6.15±4.86 | 0.95±0.06 | 1.13±0.12 |
| | 3 | 4.24±2.20 | 4.00±2.01 | 0.73±0.09 | 1.16±0.17 |
| | 5 | 2.54±1.71 | 0.47±0.25 | 0.87±0.13 | 1.05±0.18 |
| Upper-Body 1800 R (MAD) | 1 | 7.05±3.19 | 5.32±1.52 | 1.11±0.09 | 1.15±0.58 |
| | 3 | 4.80±2.65 | 4.06±1.55 | 1.49±0.37 | 1.61±0.45 |
| | 5 | (2.00—2.34) | (4.42—4.74) | 1.29±0.25 | 1.06±0.54 |
| Lower-Body 900 R (MAD) | 1 | 6.12±3.76 | 5.28±2.17 | 1.52±0.21 | 1.40±0.27 |
| | 3 | 4.37±0.48 | 3.54±1.38 | 1.52±0.52 | 0.95±0.36 |
| | 5 | 2.46±0.34 | 2.84±1.58 | 1.64±0.59 | 1.49±0.41 |

a—1240 Mc/sec pulsed, 50 mW/cm² 6 hrs/day, 5 days
b – 1000 kVp X-rays 55 R/min
c—mean ± standard error
( )—individual determinations on two dogs

TABLE IV. EFFECT OF MICROWAVES[a] ON HEMOGLOBIN AND HEMATOCRIT

| X-Radiation[b] | Microwave Exposure No. | Hemoglobin (Gm/100cc) Pre | Hemoglobin (Gm/100cc) Post | Hematocrit (Vol%) Pre | Hematocrit (Vol%) Post |
|---|---|---|---|---|---|
| Control (sham irradiated) | 1 | 15.7± 0.17[c] | 15.3± 0.25 | 56.0±0.46 | 53.3±0.54 |
| | 3 | 15.2± 0.40 | 15.0± 0.32 | 54.3±2.01 | 51.6±1.93 |
| | 5 | 14.7± 0.26 | 14.5± 1.17 | 52.4±1.74 | 50.1±2.24 |
| Whole-Body 300 R (MAD) | 1 | 14.9± 0.38 | 14.4± 0.43 | 51.6±1.8 | 51.1±1.30 |
| | 3 | 14.4± 0.43 | 14.4± 0.43 | 50.1±2.4 | 51.5±3.00 |
| | 5 | 14.3± 0.60 | 14.3± 0.60 | 49.7±2.09 | 49.2±2.8 |
| Upper-Body 1800 R (MAD) | 1 | 15.1± 0.31 | 14.8± 0.14 | 53.1±1.23 | 50.9±1.53 |
| | 3 | 15.3± 0.32 | 14.8± 0.25 | 54.9±1.20 | 51.1±1.39 |
| | 5 | (14.0—15.0) | (14.0—15.0) | 52.5±0.58 | 49.5±1.89 |
| Lower-Body 900 R (MAD) | 1 | 15.0± 0.50 | 14.8± 0.17 | 51.8±0.60 | 50.0±2.02 |
| | 3 | 14.5± 0.00 | 14.0± 0.28 | 50.3±0.93 | 49.3±1.20 |
| | 5 | 14.2± 0.33 | 14.3± 0.44 | 49.0±1.23 | 48.7±1.92 |

a—1240 Mc/sec pulsed, 50 mW/cm² 6 hrs/day, 5 days
b—1000 kvp X-rays 55 R/min
c—mean ± standard error
( )—Individual determinations on two dogs

cline in the reticulocyte level in normal and X-irradiated dogs. Lymphocytes in normal dogs decreased during exposure to microwaves while in whole-body X-irradiated dogs there was an increase. Changes in upper and lower-body X-irradiated dogs were variable.

In normal dogs, hematocrit and hemoglobin content decreased during exposure to microwaves and declined progressively as the exposures were repeated (Table IV). In general the X-irradiated dogs responded in a similar manner but were not as labile.

Seventeen days after 1240 Mc/sec, 50 mW/cm², multiple microwave exposure, incorporation of Fe-59 in red cells was more rapid, and maximum amount of Fe-59 incorporated was higher than was noted prior to microwave treatment (Figure 1).

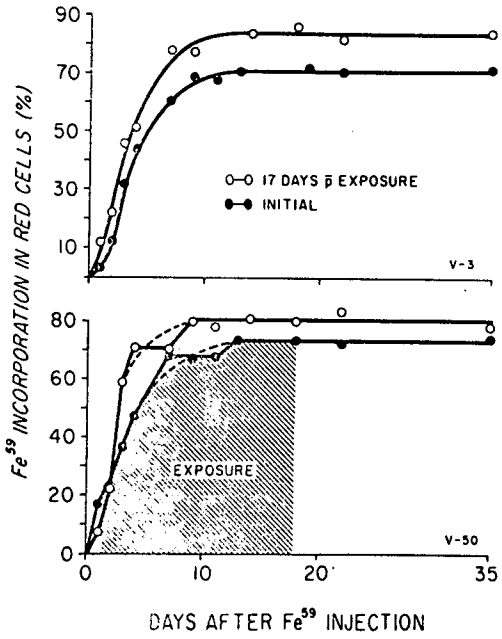

Fig. 1

Fe-59 clearance and uptake studies were done on two dogs, one eighteen days after 138 hours of microwave exposure (50 mW/cm², 6 hours per day), the other at ten days after 60 hours of exposure. When results were compared with data for normal dogs, it appears that Fe-59 initial plasma clearance half-time may be prolonged in dogs exposed to microwaves (Table V). Maximum incorporation of Fe-59 occurred earlier in microwave treated dogs. The maximum degree of Fe-59 incorporation in red cells in the microwave treated dogs was in the upper limits of the normal range.

Hematologic data for these two dogs reveal a decrease in hemoglobin, red cell count, hematocrit and reticulocytes. In the one dog that received 23 exposures, reticulocytosis developed during the third week of exposure. With the increase in reticulocytes, the

TABLE V. FE-59 CLEARANCE AND UPTAKE VALUES

| Dogs | 22 Normal | V-23[a] | V-45[b] |
|---|---|---|---|
| Initial Plasma Clearance Half-Time (Min.) | 85±26.0[c] | 126 | 126 |
| Time for 50% Maximum Incorporation (Days) | 2.6± 0.7 | 2.8 | 2.8 |
| Time for 90% Maximum Incorporation (Days) | 6.8± 1.9 | 7.8 | 5.1 |
| Time for Maximum Incorporation (Days) | 15.0± 5.6 | 12.5 | 10.0 |
| Maximum Degree of Fe-59 Incorporation in Red Cells | 77.1± 8.0 | 83.0 | 85.0 |

a - Dog V-23—10 Days p̄ 60 hrs. 1240 Mc/sec, 50 mW/cm² Exposure
b - Dog V-45—18 Days p̄ 138 hrs. 1240 Mc/sec, 50 mW/cm² Exposure
c - Mean ± Standard Deviation

TABLE VI. EFFECT OF MICROWAVES[a] ON SERUM PROTEINS AND PLASMA CHLORIDES

| X-Radiation[b] | Exposure Microwave Number | Total Proteins Gm/100cc | | Plasma Chlorides mEq/L | |
|---|---|---|---|---|---|
| | | Pre | Post | Pre | Post |
| Control (sham irradiated) | 1 | 6.90±0.14[c] | 6.95±0.12 | 109.6±1.9 | 121.3±2.4 |
| | 3 | 6.53±0.15 | 6.60±0.14 | 110.7±2.6 | 117.6±1.7 |
| | 5 | 6.43±0.09 | 6.30±0.15 | 111.5±2.9 | 116.2±2.8 |
| Whole-Body 300 R (MAD) | 1 | 7.30[d] | 7.30 | 110.3±2.5 | 122.6±0.8 |
| | 3 | (6.70—7.30) | (7.45—7.55) | 113.3±1.8 | 122.4±2.7 |
| | 5 | 7.10 | 7.20 | 117.3±2.8 | 122.0±2.2 |
| Upper-Body 1800 R (MAD) | 1 | 6.37±0.67 | 6.13±0.09 | 117.6±2.4 | 121.4±5.4 |
| | 3 | 5.83±0.07 | 6.07±0.03 | 113.0±0.6 | 119.5±4.1 |
| | 5 | 5.73±0.09 | 5.77±0.03 | 113.4±4.3 | 121.0±6.9 |
| Lower-Body 900 R (MAD) | 1 | 6.40±0.10 | 6.43±0.27 | 109.8±1.6 | 119.8±1.7 |
| | 3 | 6.10±0.26 | 6.30±0.45 | 110.4±1.4 | 125.0±2.5 |
| | 5 | (6.10—6.30) | (6.60—6.70) | 114.2±4.4 | 121.6±5.4 |

a—1240 Mc/sec pulsed, 50 mW/cm² 6 hrs/day, 5 days
b—1000 kvp X-rays 55 R/min
c—mean ± standard error
d—Single determination
( )—Individual determinations on two dogs

decrease in hemoglobin, red cell count and hematocrit became less apparent. Reticulocytosis noted at one to seven days following the last microwave exposure, rapidly declined to below the initial exposure level.

Repeated exposures to microwave resulted in decreased plasma total protein and increased plasma chlorides (Table VI). During each microwave exposure there was a significant increase in plasma chlorides.

There was a tendency towards increase in total protein during each exposure.

Venous $Co_2$ content was mildly decreased during microwave exposure, and as the microwave exposures were repeated there was a smaller difference between pre- and post-exposures values.

Thyroid I-131 uptake increased between 4 and 25 days after microwave exposure in normal, and whole-body X-irradiated animals (Table VII). Between 173 and 194 days after microwave exposure there was no increase in I-131 uptake values from the pre-exposure level. In one upper-body X-irradiated dog there was increased uptake 11 days after microwave exposure (90 days after X-irradiation). In two other upper-body X-irradiated dogs, one had a normal uptake 12 days after microwave exposure (49 days after X-irradiation); the other had a decreased uptake 33 days after microwave exposure (83 days after X-irradiation).

TABLE VII. $I^{131}$ UPTAKE AFTER ELECTROMAGNETIC RADIATION

| Exposure | Dog Number | % Uptake (24 hrs) | | | Days Post Exposure | | |
|---|---|---|---|---|---|---|---|
| | | (1) Pre Exposure | (2) Post X-ray | (3) Post Micro-waves | (2) Post X-ray | (3) Post Micro-waves | |
| Microwaves[a] | 5460 | 18 | — | 40 | — | 4 | — |
| | 5363 | 21 | — | 16 | — | 194 | — |
| X-ray[b] Whole Body 300 R (MAD) + Microwaves[a] | 5470 | 23 | — | 34 | — | 18 | (90) |
| | 5364 | 24 | — | 33 | — | 25 | (90) |
| | 5159 | 18 | 20 | 20 | 10 | 173 | (260) |
| | 4938 | 18 | 17 | 12 | 10 | 180 | (260) |
| X-ray[b] Upper Body 1800 R (MAD) + Microwaves[a] | 5627 | 15 | — | 30 | — | 11 | (90) |
| | 5160 | 21 | — | 22 | — | 12 | (49) |
| | 5634 | 20 | 22 | 10 | 32 | 33 | (83) |

a=1240 Mc/sec pulsed 50 mW/cm²; 6 hrs/day; 5 consecutive days
b=1000 kvp 55 R/min
( )=days after X-rays for 3rd determination

In view of the fact that there is an indication of altered thyroid function after microwave exposure, I-131 uptake studies were performed in dogs that had been exposed to microwaves 2-3 years previously. The results of these determinations are indicated in Tables VIII and IX.

## DISCUSSION

In earlier studies it was noted that exposure to 2800 Mc/sec pulsed microwaves at a flux density of 100 or 165 mW/cm² resulted in hematologic and hemodynamic responses suggestive of "stress", possibly due to a pituitary-adrenal effect.[7] Studies performed in rats exposed to 2450 and 10,000 Mc/sec at 25 and 70 mW/cm² also indicated a hemodynamic response to microwave exposure.[10]

It has been suggested that exposure to microwaves of low intensity which do not produce any appreciable thermal effect may produce functional changes in the nervous and cardiovascular systems.[1,2,9] Effects on the nervous system include changes in excitation and inhibition relationships of the cerebral cortex.

Cardiovascular changes such as arterial hypotension, bradycardia, sinus arrhythmia, lengthening of the conduction time in the heart, reduction of the amplitude of the spikes of the ECG are noted.

The occurrence of retching and vomiting during microwave exposure at 1240 Mc/sec suggests a central nervous system effect. Central nervous system effects of microwaves have been suggested in observations made during exposure of dogs and rabbits exposed to 2800 Mc/sec microwaves, and have also been noted by others.[4,5,6]

The prolongation in Fe-59 initial plasma clearance half-time and the earlier maximum incorporation of Fe-59 in the red blood cells indicates an effect of microwaves on the bone marrow. Studies on 2800 Mc/sec, microwave treated dogs indicated a depression of total erythropoietic activity of the bone marrow, with altered productive erythropoietic activity dependent on microwave field intensity and duration of exposure.[8] After 50 mW/cm² for 9 hours with no apparent temperature increase, red blood cell Fe-59 uptake remained relatively depressed and returned to normal 3 months after exposure.

In dogs X-irradiated after microwave exposure there was a decrease in plasma iron levels associated with depressed total erythropoietic activity. This is in contrast to comparably X-irradiated dogs without previous microwave exposure in which there is an increase in plasma iron level in conjunction with suppressed total erythropoietic activity.[11]

These results indicate the lability of the bone marrow to microwave exposure and should alert us to further study of this response not only as an early effect, but also from the aspect of potential late manifestations.

Plasma chloride, and total serum protein changes during microwave exposure indicate alterations in body water and/or electrolyte kinetics. Fluid balance shifts have also been noted in dogs exposed to 2800 Mc/sec microwaves.[7]

The changes in blood $CO_2$ content possibly reflect impaired pulmonary gas exchange. Arterial blood oxygen desaturation in dogs exposed to 2800 Mc/sec, and effects on respiration in dogs and rabbits exposed to 2800 Mc/sec microwaves and rats exposed to 2450 and 10,000 Mc/sec microwaves, have been noted.[6,10]

Thyroid gland enlargement with increased I-131 uptake has been reported among individuals working with UHF generators.[12] Disturbance in thyroid function has also been noted in dogs exposed to 2800 Mc/sec microwaves.[3] The present observations of increased thyroid activity after microwave exposure may be due to increased TSH from the hypophysis which is consistent with the earlier suggestion of microwave induced stimulation of hypothalmic-hypophyseal activity.[7]

Previous experience with 2800 Mc/sec microwaves has shown that residual effects from ionizing radiation are revealed by increased susceptibility to the induced hyperthermia which could be attributed to alteration

TABLE VIII. THYROID $I^{131}$ UPTAKE IN DOGS 881-985 DAYS AFTER MICROWAVE EXPOSURE

| Time after $I^{131}$ Injection (Hours) | Percent Uptake | |
|---|---|---|
| | Normal Dogs 8 | 1280 mW/cm² 100 mW/cm² Single Exp. (8) |
| 24 | 24.9±2.3* | 30.0±1.5 |
| 48 | 29.0±3.2 | 35.9±2.5 |
| 72 | 30.3±2.5 | 38.5±2.2 |

*mean ± std error of the mean

TABLE IX. THYROID $I^{131}$ UPTAKE IN DOGS EXPOSED TO MICROWAVES

| NORMAL | | | | | MICROWAVE EXPOSURE | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Dog number | Days between tests | % Uptake (hours) 24 | 48 | 72 | Dog number | Days after exposure | % Uptake (hours) 24 | 48 | 72 | 1280 Mc/sec |
| V-9 | Initial | 25.0 | 31.2 | 33.0 | 5385 | 724 | 33.6 | 43.6 | 46.6 | 20 |
| | 56 | 25.3 | 31.9 | 33.8 | | 920 | 26.1 | 31.9 | 35.6 | mW/cm² |
| V-11 | Initial | 23.7 | 26.7 | 25.6 | 5405 | 929 | 32.5 | 40.8 | 42.3 | 100 |
| | 112 | 25.2 | 24.6 | 25.2 | | 986 | 23.3 | 34.1 | 35.5 | mW/cm² |
| V-12 | Initial | 24.4 | 29.5 | 29.1 | 5262 | 952 | 34.7 | 36.7 | 37.0 | 100 |
| | 120 | 22.6 | 23.0 | 22.5 | | 1051 | 22.6 | 23.0 | 22.5 | mW/cm² |
| V-4 | Initial | 23.7 | 17.3 | 25.0 | 5401 | 928 | 30.7 | 41.4 | 44.4 | 100 |
| | 140 | 14.8 | 15.9 | 11.9 | | 1065 | 19.4 | 23.3 | 23.7 | mW/cm² |

in the vascular system or damage to the hypothalamus, The results of the present study also indicate the sensitivity of X-irradiated animals to microwaves. Differences in body weight loss during microwave exposure between upper and lower-body X-irradiated animals indicate alteration in hemodynamic and/or pulmonary function, since body weight loss during microwave exposure is due to insensible water loss through the combined effects of the respiratory and cardiovascular systems.

Lymphocyte changes during microwave exposure provide an interesting adjunct to the effects of microwaves. As indicated in Table III, generally, during microwave exposure of the normal dog, there is a decrease in lymphocytes in contrast to a granulocyte increase. Whole-body X-irradiated dogs, however, have a marked increase in lymphocytes unrelated to granulocyte level alteration during microwave exposure. In upper or lower-body X-irradiated dogs in which lymphocyte level has returned to slightly below normal the response to microwaves is more comparable to normal dogs. Apparently the X-irradiated dogs with a depressed lymphocyte level can respond to the stress of microwaves by a transient marshalling of lymphocytes. This may also be indicative of microwave effects on the hypothalamus, which it is believed, plays a part in regulating leukocyte levels.[9]

Although the results of the present studies reflect the physiologic response of the organism to the thermal burden imposed by microwave exposure acting as a nonspecific stress, it has been suggested that the stress stimulus from microwaves comes not only from the thermal receptors of the skin, but also from other sensory skin receptors. Under comparable conditions, microwave irradiation causes a more intense flow of afferent impulses and more intense stimulation of hypothalamic-hypophyseal activity than thermal effects.[9] The apparent adaptation to repeated microwave exposures is also referrable to stimulation from skin receptors.

In general, these studies indicate that repeated exposure to 1240 Mc/sec microwaves at 50 mW/cm$^2$, can produce functional changes in the dog which if extrapolated to man would be indicative of homeostatic insufficiency and decrement in performance capability even though overt incapacitation may not take place. This study also reveals the inability of X-irradiated animals to maintain homeokinesis during microwave exposure.

Whether thermal, non-thermal, or both of these are the contributing factors in the response to microwave exposure, there is sufficient experimental and human survey evidence to indicate that microwave exposure results in alteration in compensatory and homeokinetic mechanisms of the body.

The effects of microwave exposure at 1240 Mc/sec, 50 mW/cm$^2$ in the normal animal should alert us to the caution that has to be exerted when any consideration is given to raising the presently accepted maximum permissible exposure of 10 mW/cm$^2$.

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