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TECHNICAL NOTE

STUDIES ON THE BIOLOGICAL EFFECTS OF MICROWAVE IRRADIATION OF THE DOG AND RABBIT

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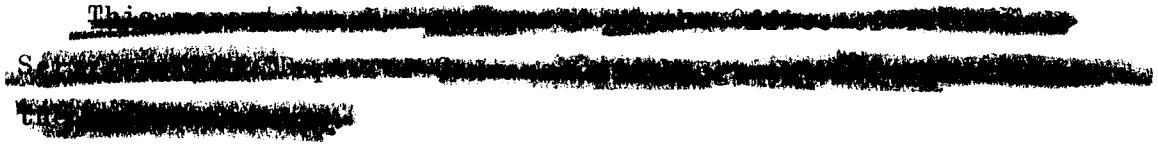

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ABSTRACT

This report describes a biomedical investigation into the potential hazards of electromagnetic radiations. Studies were conducted on dogs exposed to 100 and 165 mw/cm^2 energies of 2800 mc pulsed microwave for periods varying from two to six hours. Emphasis is placed on the characterization of the physiological changes of microwave exposure in the dog and rabbit, preliminary study of changes in hemodynamics as correlated with temperature change, behavior of the circulating blood elements, description of superficial burns on skin surfaces, as well as preliminary observations on isolated physiologic and cytologic processes.

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STUDIES ON THE BIOLOGICAL EFFECTS OF MICROWAVE IRRADIATION OF THE DOG AND RABBIT*

INTRODUCTION

The current increasing use of microwave generators by the armed services plus the progressive development of greater power densities at a variety of frequencies demands an immediate investigation into the potential hazards of such electromagnetic radiations. Also necessary is a careful study of the pathological changes which occur following such exposures. The most urgent demands are (1) to detect and characterize the damaging effects of both acute and chronic nature caused by such exposures, (2) to establish, if possible, a lethal change in terms of timed exposure at specific power densities, and (3) to establish a tolerance or safe exposure level for individuals working with such generators similar to those already determined for noxious agents and ionizing radiations. The above mission is now being directed toward a biomedical approach with study of related physiological and pathological phenomena.

Review of the literature yields almost no information of value which was useful in initiating these studies. At the outset it was decided that (1) the selected animal should be more comparable to man in size and in possession of similar heat regulatory mechanisms, (2) the selected species should have well defined parameters of physiologic behaviour in which observations on a single animal would be pertinent, (3) the exposures should be in free space and of a type possible in a hazardous situation in the human, and (4) because of the great variability in present physical measurement techniques, consistency in biological behaviour would indicate presence of a uniform exposure.

*Based on work done by the University of Rochester School of Medicine & Dentistry, Dept. of Radiation Biology for USAF under RADC Contract AF30(602)-1813 dated 1 March 1958.

The microwave frequency assigned to this study was set at 2880 megacycles, of pulsed type. The dog was selected as the most ideal animal to be used in these studies, although for special and confirmatory investigations certain exposures of the rabbit would be carried out.

As a portion of the effort in achieving standardized measurement techniques, a series of phantoms have also been constructed. Comparative measurement of power in mw/cm^2 and actual energy absorbed in calories under both static and dynamic conditions has been initiated. A portion of this effort is also directed toward development of apparatus and accessories in which physiologic changes can be directly measured without interference in the microwave field. As is indicated in the following account of research in progress, all present measurements on animals have been made either at the start and finish of exposures, or by intermittent stopping of the exposure for the time of the measurement. For accurate assay of the hemodynamic which form a primary role in heat loss and exchange, methods of continuous measurement of physiologic events are imperative.

Another facet of this study has been directed toward a possible demonstration of athermal effects of microwave exposure. To this end, a series of combined exposures of microwave and ionizing irradiation have been initiated. To date, microwaves have been used as a stressing effect on animals (dogs) exposed to sublethal and lethal dosages of Cobalt-60 irradiation four or 11 days earlier. Other combinations such as Co-60 after microwave and simultaneous Co-60 and microwave have not been initiated. It must be emphasized from the hazard viewpoint that microwave exposure can be additive on previously existing subclinical abnormalities -- particularly those of cardiovascular type. To this end, a series of experiments have been conducted on dogs which have survived lethal exposures of ionizing irradiation administered a number of years (two to four) previously and in which histological but not clinical effects of vascular damage of varying degree are present.

With the standarization of the experiment and the production of specific physiological abnormalities and pathological defects (burns) on a consistent basis, it has become possible to embark on a controlled series of pathological investigations. While these are only preliminary in nature, a number of findings have been demonstrated which may correlate with observed physiologic change, and, as such, direct the nature of subsequent experiments.

One of the more important aspects of this study has been the ability to observe the normal unanesthetized animal during the exposure as well as through the recovery and post-recovery phases. The exposures are or can be of long duration; the physiologic changes show us that immediate lethality so common in previous experiments does not occur. As will be noted, certain rather unusual effects have been observed which form a framework for the planning of future experiments. One of these in point can be mentioned. Animals which die from high-dosage microwave exposure resemble physiologically those acutely incapacitated and dying from supralethal ionizing irradiation (CNS death). Pathological assay of such groups may indicate a thermal as well as ionizing injury in the CNS death due to high-dosage ionizing radiation exposures.

In the following account, emphasis is placed on the characterization of the physiological changes of microwave exposure in the dog and rabbit, preliminary study of changes in hemodynamics as correlated with temperature change, behaviour of the circulating blood elements, description of superficial burns on skin surfaces, as well as preliminary observations on isolated physiologic and cytologic processes. In most instances the number of animals in the groups is sufficient to allow for estimate of the hazard situation. Uniformity of response is the best index of a uniform challenge to all animals in spite of the fact that rotation during exposure was not carried out. From the present series one can arrive at a rough estimate of tolerance in terms of power measured in air (dose and time) provided that a fixed or specific

threshold of thermal or heating effect does not exist. It is possible on a thermal basis that this threshold does exist at the point where the cooling or heat loss mechanism becomes insufficient to correct for the total impact in absorbed calories. Up to this point no abnormal physiologic process can occur, but beyond it (in terms of heat impact vs. heat loss) damage can occur in rapid sequence.

One other possibility should be broached in a review of the observed data. Certain of the thermal or athermal effects resulting from microwave exposure may be of beneficial rather than of detrimental types. As such, the observed damaging effect as seen in the animal may be reduced by a variable amount. Certain experiments are being considered in an attempt to demonstrate this overall concept.

METHODS

This project is a cooperative effort between personnel of the Medical Division of the University of Rochester School of Medicine and Dentistry, Department of Radiation Biology and those of the Rome Air Development Center. At the Rochester laboratory mongrel dogs carefully standardized as to age, sex and weight are kept for a holding period to insure good health. In view of the fluid changes which occur during and after exposure, these animals are kept on a constant food and water intake for a minimum of one week prior to exposure. They are then transported to the Verona site (115 miles) in a station wagon, rested overnight and exposed on the following day. Most animals are returned to Rochester the night of exposure except for those which are held at Verona for chronic or daily exposure. The distance of transport together with weather conditions sharply limits the number of exposures which can be conducted.

The source of r-f power is a radar set AN/MPS-14 operating at a frequency of 2800 megacycles and producing in excess of 2000 watts of average power. The pulse type emission utilizes a two-microsecond pulse width and a 360/sec pulse repetition frequency.

The power densities available in the exposure chamber vary between the limits of 1.2 watts/cm^2 to less than 50 milliwatts/cm^2 depending upon distance from the antenna. In order to estimate the power distribution across the animal's body, contour lines of equal intensity have been measured. Analysis of the graphs indicates a relatively uniform field across the animal's body with the energy at the periphery differing by less than 20 per cent from that at the center. Because of the intense r-f fields existing in the chamber it is impractical to perform measurements under high power conditions; therefore, a system has been devised whereby the power density at an arbitrary distance from the antenna is related to the power fed to the antenna.

To simplify the determination of the power density and aid in the interpretation of data, a microwave "free space" room was constructed for animal exposures. The exposure room, approximately 7' x 7' x 15', is lined with commercial microwave absorbing material. According to the absorbing material manufacturer, a maximum of two per cent of the energy will be reflected from the surface of the absorber. Under these conditions, it is felt that we have approximately a "free field" for all practical purposes.

Initially, attempts were made to expose trained animals supported in a nylon sling. It was soon realized that this was impractical inasmuch as the unanesthetized dog, no matter how well trained, would immediately struggle as soon as the higher power densities necessary to produce physiologic effect were applied. As a solution, an all plexiglass cage was constructed to confine the animal during exposure. This was made of such a size that the limits of the cage were within the 80 per cent continuous exposure lines as measured in air by standard techniques. The material proved to have excellent dielectric properties and structural strength, with excellent transmission and tolerable distortion from diffraction of the radiation. During exposures it was noted that the animal preferred to remain at the outer limits of the field so that the dosage as indicated at each exposure level

is undoubtedly on the high rather than low level. Rotation is not used. With the maximum penetration of ± 3 cm and the absorption of the major portion of the dose in this area of surface, the total amount of surface area can not be stated with surety. However, since animals were free to turn to any desired position, and were observed to do so, it is considered that rotation is not necessary. The development of bilateral chest burns in all cases is best explained by a uniform exposure on both sides of the thorax.

With the success of the initial plexiglass single cage, a double separated cage of the same overall size limit was constructed. Although increased reflection of radiation undoubtedly occurs, the advantage in combined exposure studies of one animal together with his control may outweigh the defects of reflection and diffraction.

Dogs were exposed at two power densities (100 mw/cm^2 and 165mw/cm^2) for different durations of time. Clinical and laboratory tests are performed before and after exposure. During exposure continuous observations of his response are recorded. Animals are placed in the cage for a 15-minute period prior to exposure during which rectal temperatures are made at five-minute intervals. If temperature is constant, exposure is started. Following exposure, rectal temperatures are recorded at 5, 15, 30, 45 and 60 minutes. Blood for hematological examination is obtained by jugular puncture within one minute after cessation of power. Following exposure the animal is observed for general appearance, alterations in behaviour and gait and desire for water. Superficial neurological examination sufficient to characterize motor or reflex changes is performed. Animals used in these studies include:

1. Normal healthy dogs of both sexes.
2. Normal dogs exposed to 200 or 400 r whole body gamma radiation from a Cobalt-60 source four or 11 days prior to microwave exposure.

3. Dogs from groups of animals receiving X or gamma irradiation at the LD/50-90 level several months to 3 years prior to the microwave exposure. These animals are designated in this report as survivors.
4. Normal rabbits. Some of these animals are used for studies of antibody production and decay rates.

Exposures to both dogs and rabbits are reported as either high power (165 mw/cm^2) or medium power (100 mw/cm^2).

Laboratory methods are those used in routine studies. Specific methodology for fat absorption and red cell life is given in those special sections of the report where pertinent.

Pathological techniques include gross examination including opening of the skull, microscopic study with hematoxylin-eosin as standard and special connective tissue, fat and nerve tissue stains where indicated.

RESULTS

Detailed observations under fixed experimental conditions are described for 27 normal dogs, 11 dogs receiving 400 r of Co-60 irradiation plus subsequent microwave, and eight survivors receiving ionizing radiation from two months to several years previously.

The general clinical behaviour of the dogs can be described as follows. Shortly after being placed in the field, panting is noted. As exposure continues the rate increases and may stabilize only to increase again as temperature rises. Salivation occurs in many dogs, the amount increasing with the duration of exposure. Most animals display increased activity varying from restlessness to extreme agitation. At times the animal rests at the extreme end of the cage as if sensing that the energy being transmitted is of less intensity there. In all but extreme instances, the dogs remain responsive and oriented throughout exposure. Marked vasodilatation to the extent of acrocyanosis develops over skin and mucous membranes. Toward the end of exposure (4-6 hours at 100 mw/cm^2 or 2 hours at 165 mw/cm^2) weakness develops particularly

in more active animals with occasional stumbling, collapse of a leg and falling. In extreme cases, perhaps of agonal type, the dog becomes prostrate. Either death ensues or slow gradual recovery follows.

Upon removal from the cage abnormalities in equilibrium are noted. Rectal temperature is increased. An increased desire for water is present in all but extreme cases in which water is refused.

Exposure of rabbits to 165 mw/cm^2 produces an extremely violent reaction which may progress to death at the end of 40 minutes of exposure. Within five minutes at this power level violent reaction developed to the extent that four of six rabbits escaped (or better erupted) through the bars of the cage by 25 minutes. Peripheral engorgement of all vessels yielded an acrocyanotic picture. In the remaining two animals at 40 minutes, the ears had developed a "fried or cooked appearance." Rectal temperatures by 20 minutes had reached 8°F. above control levels. Dogs over a corresponding period showed little change. Subsequently 10 rabbits were exposed to 100 mw/cm^2 for one hour. All animals became immobile or prostrate with definite weakness of extremities. Three rabbits died in a shock-like state preceding demise. None of these animals developed cutaneous burns although peripheral vessels were markedly engorged.

TEMPERATURE RESPONSES

As indicated in Table I and again in Figure 1, the maximum temperature rise of 5.1°F. occurred in dogs exposed to 165 mw/cm^2 for a three hour period. Dogs exposed for six hours at 100 mw/cm^2 showed a 3° elevation. At two hours at 165 mw/cm^2 a rise of 3.4° was noted. In the ionizing irradiation survivors and acutely Co-60 irradiated groups the elevation was similar. Unexplained is the comparative lack of response (+ 1.4) in the five animals irradiated with 400 r Co-60 and given six hours of microwave four to 11 days later.

As mentioned earlier, rabbits exposed to 165 mw/cm^2 for 40 minutes developed temperature elevation as high as + 11° F. over basal determinations. Those receiving 100 mw/cm^2 achieved elevations up to +10°F. (Figure 1).

The temperature recovery of all animals was recorded. These are shown in Figure 1. The temperature recovery curve assumes an exponential form with the high-power exposed dogs in which the pre-exposure level or below is reached within a period of one hour. To make recovery rates of various experiments more comparable, the data were plotted on semi-log paper. Review of these curves, Figure 2, indicates that dogs exposed to the high power level for two or three hours recover more rapidly than do those exposed to medium power for six hours. This may indicate a secondary process or breakdown in temperature regulation which occurs within the final period of the exposure. It is interesting that recovery of rabbits from the near lethal 100 mw/cm^2 one-hour exposure parallels the pattern for the dog for the same power level but for a six-hour exposure. It would be useful if this temperature recovery pattern for a species could be stated for comparative purposes, i.e. one-hour at 100 mw/cm^2 for the rabbit is equal to six hours at 100 mw/cm^2, etc.

Until the present, it has been impossible to record the pattern of temperature rise throughout the exposure period, but with instrument procurement and development, this task now becomes feasible.

Attempted correlation of temperature rise in these animals with weight, sex, age and body surface area as measured by standard formulae has produced entirely negative results.

Temperature changes were also recorded in four dogs which died during or immediately after exposure. By excising the organ and plunging a thermometer probe deep into the interior at periods between 15 and 60 minutes after death, it was noted that the liver, gall bladder, urinary bladder and heart were three to four degrees Fahrenheit higher than the rectal temperature taken at the same

time. Stomach and lungs were two degrees Fahrenheit higher while temperatures of testes and anterior chamber of the eye were six degrees lower than simultaneous rectal temperatures.

HEMATOLOGIC EFFECTS

Changes in hematocrit are shown in Tables I and III. Of importance is the observation in the sham irradiated animal in which a significant change in hematocrit, extending up to 24 hours after exposure, is noted. This factor of change following animal handling is very important in the interpretation of all blood findings as directly attributable to the process or agent under study.

The most marked increase in the hematocrit occurs in animals exposed for three hours at the 165 mw/cm^2 level; changes at the 165 mw/cm^2 for two hours and the 100mw/cm^2 for six hours are almost identical. Dilution toward pre-exposure levels or below occurs immediately following exposure and at the 24-hour period is apparently complete. Deducting the changes observed in the sham irradiated groups it is shown that the reduction is uniform in all groups with residual change remaining in groups having the higher exposures. Certain pilot experiments (not shown) indicate that animals exposed to high power for one hour and low for two hours tend to reduce or dilute the hematocrit. This adds further confirmation to this analysis.

Of interest are certain of the special groups studied. In the 400 r Co-60 (gamma) dogs an immediate post-exposure reduction of hematocrit of five and six per cent is noted. Since some specific vascular change is suspected to follow ionizing irradiation, it may be that this is the first specific evidence to be shown. As indicated in Table II (one week after exposure), this reduction is exaggerated to -19 and -21 respectively. This may reflect further sequestration of red cells, hemorrhage, plus some lack of erythrocyte formation.

Leukocyte changes are of interest. The changes as seen in the immediate 100 mw/cm^2 dogs are negligible. Those at the 165mw/cm^2

level show an initial decrease at the two hour period, an increase at the three hour time. The gradual increase in all groups at the 24-hour level at a time when the hematocrit has diluted down may reflect minor tissue damage. At the one week period, normal values have returned except in the three hour 165 mw/cm^2 animals and in the Co-60 irradiated. In the latter instance, the depression is typical of the depression seen in the Co-60 irradiated controls. The cause of the depression in the three hour 165 mw/cm^2 animals is not understood.

OTHER OBSERVATIONS

Other observations are recorded in Tables I and II. Hematuria occurred sporadically in the first one to three day period. Akinesis with motor weakness paralleled the amount of exposure occurring in two of 10 dogs at 100 mw/cm^2 six hours, three of 10 at 165 mw/cm^2 two hours, and six of seven at 165 mw/cm^2 for three hours. No persistence of symptoms up to one week was noted except in burned animals. No weight changes were noted. Deaths have occurred in all series, but are most common in the ionized microwave animals. From the data presented on control Co-60 dogs at 400 r and Co-60 microwave at six hours 100 mw/cm^2 and two hours 165 mw/cm^2 it would suggest that the injuries are definitely additive. Further experimentation along this line will be necessary for more definitive conclusions.

In periods of observation up to nine months for the dog and four months for the rabbit, no cataracts of any type have developed.

BURNS

A unique finding previously mentioned is the development of superficial burns on various portions of the body but more commonly on <u>both</u> sides of the rib cage. These are well illustrated in the accompanying photographs and legends. A latent period of as much as five to six days following exposure may elapse, at which time the entire area sloughs away leaving a deep clean area identical

in appearance with a third-degree burn. Prior to sloughing away, the central portion appeared to devitalize with development of a process suggesting a dry gangrene. Of 46 dogs exposed, seven developed burns. Most were on the chest (bilateral) but others have occurred on the neck and head, the latter being smaller in type. Healing without infection occurred in all except the survivor (ionizing irradiation) group where considerable suppuration was observed. To date no scarring or keloid development is noted. Among the survivor dogs there was also noted a delay in the appearance of the burns by as much as several days, and healing even without infection was extremely slow. Pathological examination of burn site areas resembles those of a typical third-degree burn. The mechanism of production of these areas is unknown but the possibility of a standing wave being produced by reflection off the skeletal elements is considered.

SPECIAL TESTS

A number of tests of fat absorption from the gut using carefully standardized Iodine-131 labelled fat have been performed. In an initial series of determinations a two-hour delay in fat absorption from the gut was present in an animal exposed to 165 mw/cm^2 for two hours eight days previously. This gradually returned toward normal although an initial delay continues to persist even after the 20th day.

Assay of thyroid function by measurement of the biological decay rate of Iodine-131 indicated a significant increase in activity seven days after exposure to 165 mw/cm^2. This would correlate with the period of maximum tissue injury. Direct exposure of the thyroid gland to a small 2800-megacycle continuous-wave generator produced no effect after a 30-minute exposure.

Preliminary observations on red cell life have been made using the Chromium-51 labelling technique. Results from the study of four animals with microwave alone, Co-60 irradiation and Co-60 plus microwave indicate a definite reduction in red cell life after Co-60 alone. A similar reduction occurs after Co-60 plus microwave and no reduction in controls, and with microwave alone. Since some

of these experimental groups contain only four animals, tabulation of data will not be included until sufficiently large samples are studied.

Certain other observations are pertinent and may suggest future experiments. Female animals exposed at any level develop labial engorgement, vaginal secretion and attraction for male. This phenomenon will occur, regress between exposure and recur again. Whether this is a true or false heat is not known as the length of periods of engorgement, etc. vary with the animal and with the exposure.

Bone obtained from animals dying of microwave appear to be changed in structure to the extent that it is difficult to decalcify. Time has not permitted a closer study of this problem, but suitable techniques such as X-ray diffraction and electron microscopy are available.

PATHOLOGICAL EFFECTS

Animals dying from microwave exposure develop rigor mortis almost immediately. One animal dying some hours after exposure and after cooling of the body also developed almost instant rigor. As to whether this is a common finding in death from heat exposures is unknown.

The following are preliminary gross observations which have been made.

The outstanding necropsy finding in all animals has been generalized congestion of nearly all organs, particularly the liver, spleen, kidneys, and lungs. Other organs showing slight to moderate congestion included the testes, brain, pancreas, heart and gastrointestinal tract. The blood itself was generally darker red than normal and seemed to have little or no tendency to clot. The gastrointestinal tract of most animals appeared cyanotic and the mucosa of the small intestine in particular showed scattered areas of inflammation and hemorrhage.

A program of extensive histopathologic study of animals

exposed to microwaves has been initiated.

SUMMARY AND CONCLUSION

Studies have been conducted on dogs exposed to 100 and 165 mw/cm^2 energies of 2800 megacycle pulsed microwave for periods of time varying from two to six hours. Observations are reported on 27 normal dogs, 11 dogs receiving 400 r of Co-60 gamma irradiation, and eight survivors of lethal ionizing irradiation from X-ray or Co-60. Observations on 16 rabbits at these levels are given.

The clinical behaviour of the dog irradiated with 2800 megacycle microwave is reported. Certain findings from the rabbit study are given.

Maximum temperature elevation and physiological heating effect was seen in normal dogs exposed to 165 mw/cm^2 for a two-hour period. A lesser effect was noted in the 100 mw/cm^2 for a six-hour exposure. Occasional lethality is encountered. Observations suggest the possibility of a thermal threshold below which no deleterious effects are noted. Elevation of temperature is accompanied by an increase in hematocrit, variations in leukocyte count and bizarre neurological findings.

Temperature increase is proportional to the amount and duration of power. Recovery of all groups is exponential, particularly in those animals exposed to the high (165 mw/cm^2) power. Occasional rebound to levels lower than the pre-exposure level is noted. Certain deeper tissues and organs accumulate or store heat to much greater degree than do external organs.

Dogs previously exposed and clinically recovered from the acute phase of ionizing irradiation injury appear to be more sensitive to the effects of microwave exposure than do normal dogs.

Dogs exposed to 400 r of gamma (Co-60) irradiation four to 11 days prior to microwave show an immediate reduction rather than an increase in hematocrit. This may be related to a vascular defect. Although size of the animal groups is small, some additive effect

of acute Co-60 and 2800 megacycle microwave may be presumed.

A characteristic third-degree type of burn has been produced on the chest, neck or head of seven of 46 animals. These are described and illustrated in many phases of recovery. Delay in appearance of burns and slow healing was characteristic of the radiation survivors.

Certain defects in fat absorption and thyroid function are indicated in pilot experiments.

Rabbits are much more sensitive to microwave exposure and may not be a good species for experimental study due to a poor temperature regulating mechanism.

Preliminary observations on pathological findings are given.

In periods of observation of up to nine months for the dog and four months for the rabbit, no cataracts of any type have been produced.

TABLE I

RESPONSE OF DOGS TO MICROWAVE EXPOSURE - IMMEDIATE

Power Level	100 mw/cm^2		165 mw/cm^2			
Duration of Exposure	6 Hours		2 Hours			3 Hours
Previous History	Normal	Co-60 400 r	Normal	Co-60 Survivor	Co-60 400 r	Normal
Number of Dogs	10	5	10	8	6	7
Temp. change ° F	+ 3.0	+ 1.4	+ 3.4	+ 3.4	+ 3.8	+ 5.1
WBC % (Total)	+ 3.1	+ 3.8	-18.2	-15.8	-16.7	+22.5
Polys	+25.7		+14.0			+22.2
Lymphs	-49.4		-21.0			-27.1
Hct.	+ 3.0	- 5.0	+ 3.1	+ 9.9	- 6.0	+14.5
Glucose % change			- 6.8	+ 4.3		
Hematuria	2	3	0	3	1	1
Akinesia	2	1	3	0	2	6
Death	1	0	1	1	0	1

TABLE II

RESPONSE OF DOGS TO MICROWAVE EXPOSURE - DELAYED 1 WEEK

Power Level	100 mw/cm^2		165 mw/cm^2				Control
Duration of Exposure	6 Hours		2 Hours			3 Hours	
Previous History	Normal	Co-60 400 r	Normal	Co-60 Survivor	Co-60 400 r	Normal	Co-60 400 r
Number of Dogs	10	5	10	8	6	7	6
WBC % (Total)	+ 3.2	-78.5	- 1.8	+12.4	-86.1	-23.1	-68.2
Polys						+15.6	
Lymphs						-21.7	
Hct. % change	- 3.1	-19.7	- 4.5	- 5.5	-21.0	- 3.9	-10.1
Burns	1		0	3	1	1	
Pain Abdominal or Joint	1		0	1	0	1	
Weight change	--		--			--	
Death	0	2	0	1	6	0	1

TABLE III

HEMATOLOGIC CHANGES IN DOGS EXPOSED TO MICROWAVES

Time After Exposure	% Change Hematocrit				
	Sham	100 mw/cm^2 6 hr.	165 mw/cm^2 2 hr.	Survivor 165 mw/cm^2 2 hr.	165 mw/cm^2 3 hr.
0	- 4.6	+ 3.0	+ 3.1	+ 9.9	+ 14.5
15 min.	- 8.4	+ 3.3	+ 0.6	+ 4.4	+ 14.0
24 hr.	-10.2	- 3.9	- 7.5	+ 0.9	+ 2.3
48 hr.	---	- 2.7	- 5.7	- 1.7	+ 10.7
1 wk.	- 4.2	- 3.1	- 4.5	- 5.5	- 3.9

TABLE IV

HEMATOLOGIC CHANGES IN DOGS EXPOSED TO MICROWAVES

Time After Exposure	% Change WBC				
	Sham	100 mw/cm^2 6 hr.	165 mw/cm^2 2 hr.	Survivors 165 mw/cm^2 2 hr.	165 mw/cm^2 3 hr.
0	- 3.7	+ 3.1	- 18.2	- 15.8	+ 22.5
15 min.	---	---	---	---	---
24 hr.	+10.2	+80.3	+ 15.3	+ 77.3	+ 96.3
48 hr.	---	+10.4	- 3.1	+ 28.4	+ 30.6
1 wk.	+ 5.1	+ 3.2	- 1.8	+ 12.4	- 23.1

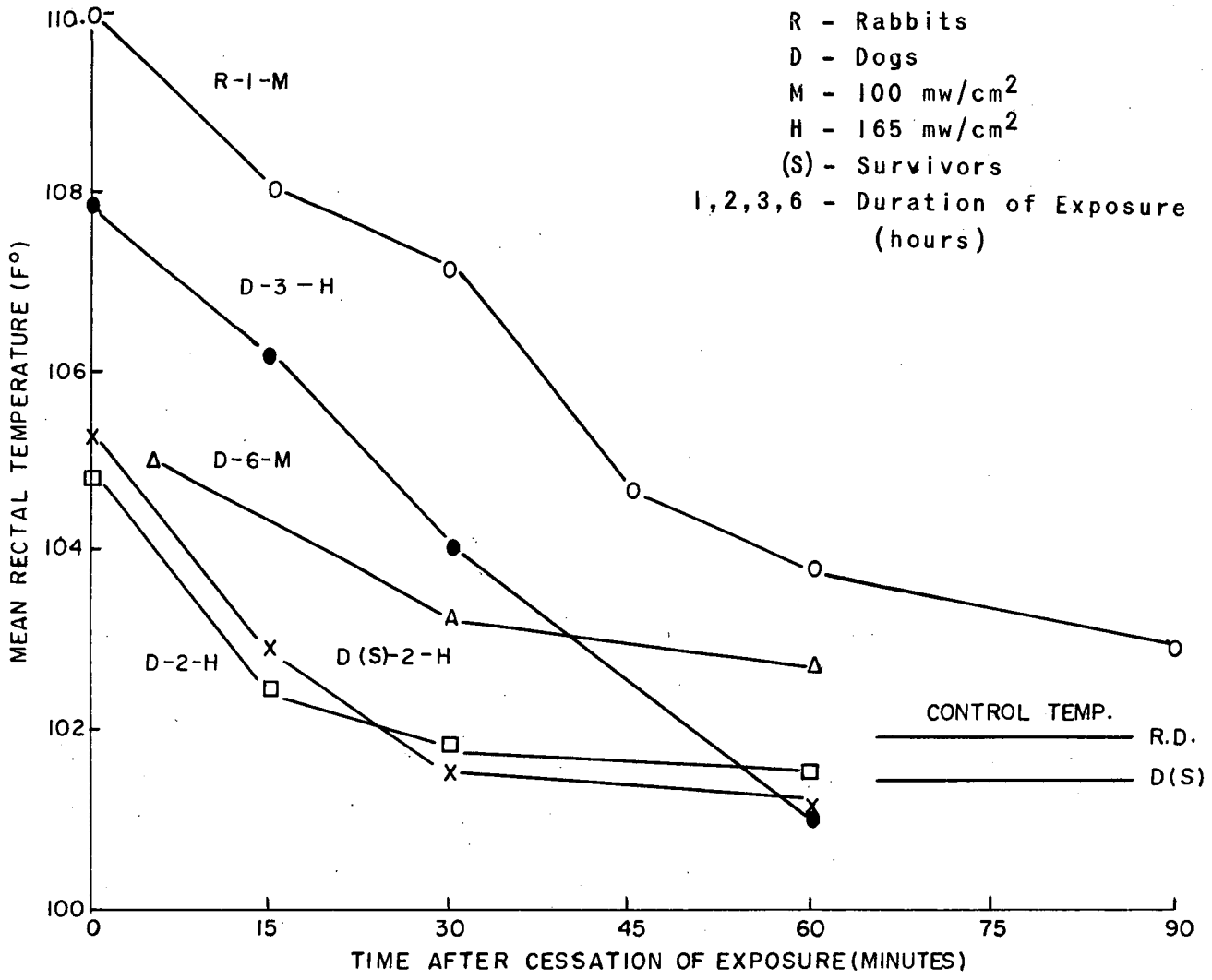


Figure 1. Rectal Temperature Recovery Among Animals Exposed to Microwaves

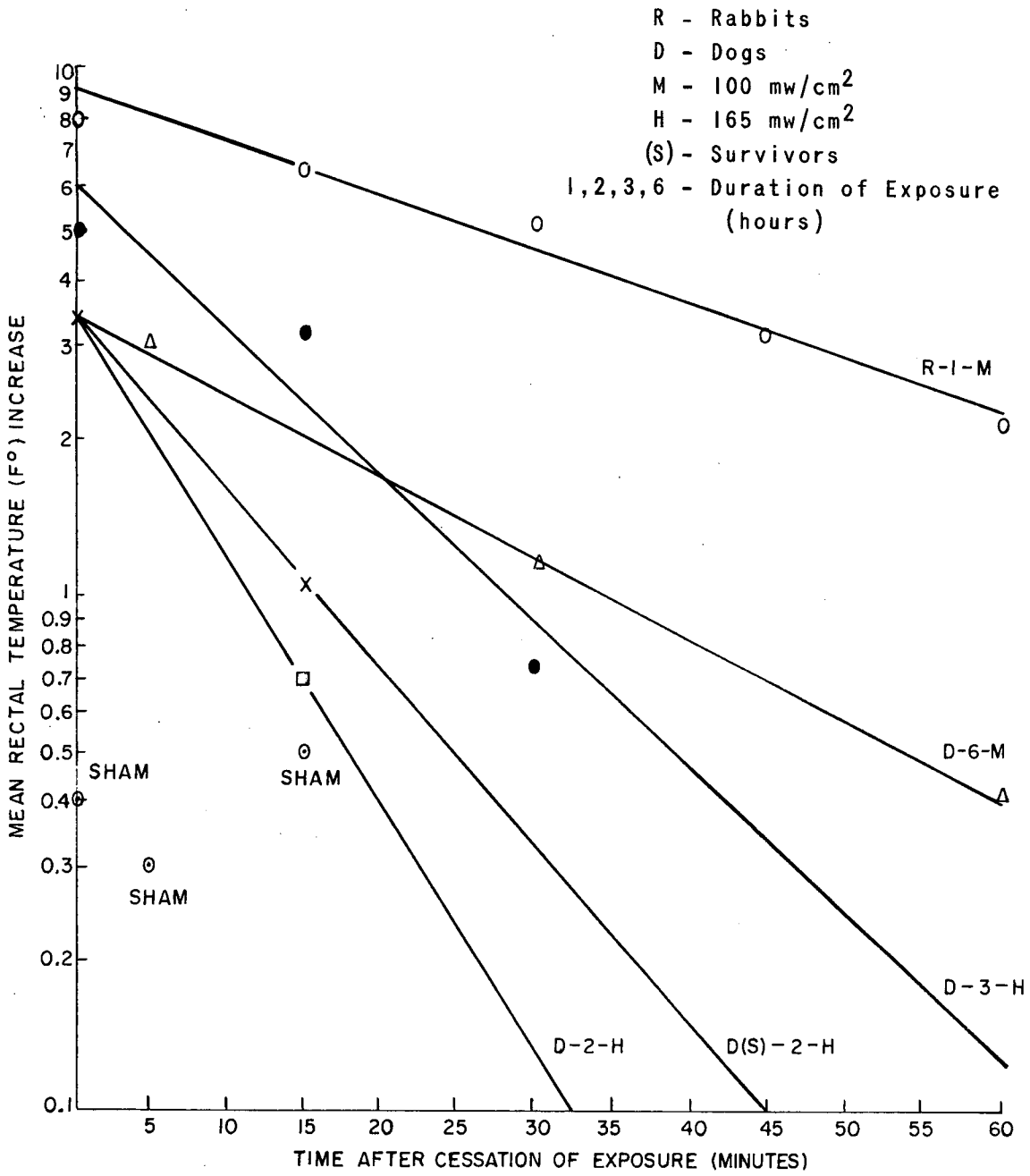


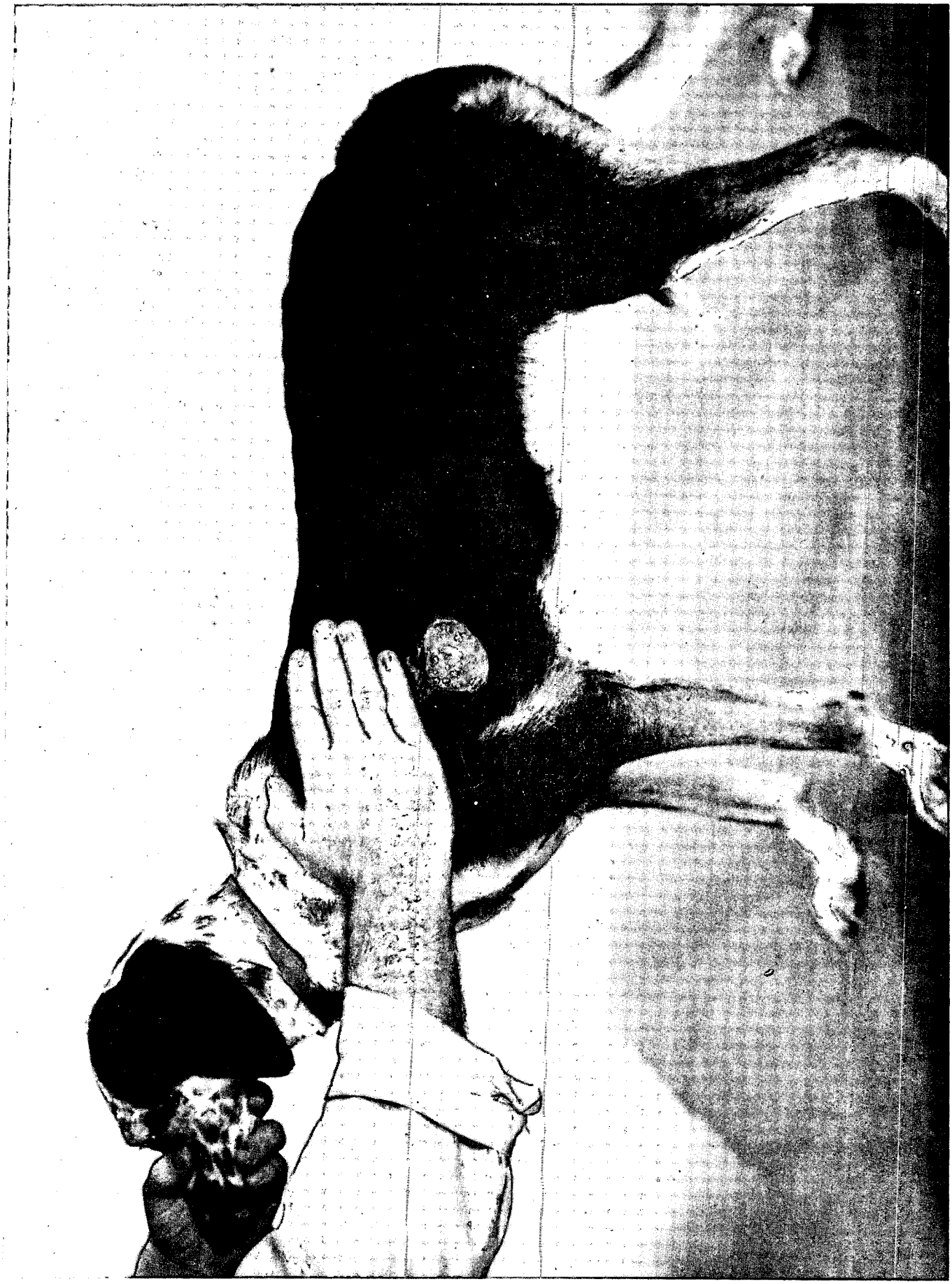
Figure 2. Rectal Temperature Recovery After Microwave Exposure

DOG #4260 (NORMAL)

Exposed to 2800 mc microwaves - 100 mw/cm^2 for 6 hours - 7/8/58

Lesion first noted 5 days after exposure

Photographed - 7/14/58 - 6 days after exposure



DOG #4260 (NORMAL)

Exposed to 2800 mc microwaves - 100 mw/cm^2 for 6 hours - 7/8/58

Lesion first noted 5 days after exposure

Photographed - 7/14/58 - 6 days after exposure

DOG #3169 (SURVIVOR)

Exposed to 2800 mc microwaves - 165 mw/cm^2 for 2 hours - 11/5/58

Lesion first noticed 12 days after exposure

Photographed - 11/21/58 - 16 days after exposure

DOG #3169 (SURVIVOR)

Exposed to 2800 mc microwaves - 165 mw/cm^2 for 2 hours - 11/5/58

Lesion first noted 16 days after exposure

Photographed - 11/21/58 - 16 days after exposure

DOG #3169 (SURVIVOR)

Exposed to 2800 mc microwaves - 165 mw/cm^2 for 2 hours - 11/5/58

Lesion first noted 12 days after exposure

Photographed - 12/3/58 - 28 days after exposure

DOG #3169 (SURVIVOR)

Exposed to 2800 mc microwaves - 165 mw/cm^2 for 2 hours - 11/5/58

Lesion first noted 16 days after exposure

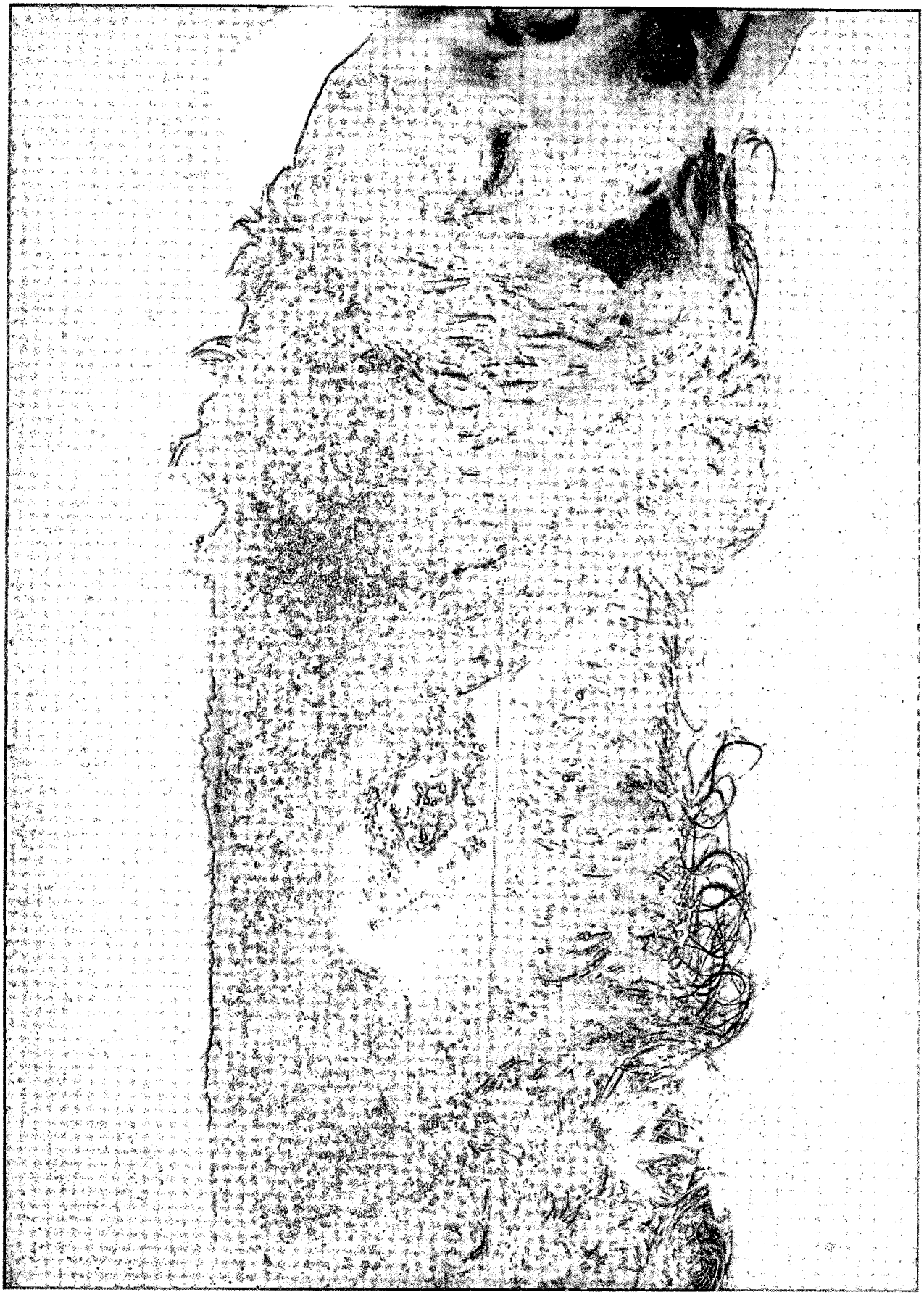
Photographed -12/3/58 - 28 days after exposure

DOG #3169 (SURVIVOR)

Exposed to 2880 mc microwaves - 165 mw/cm^2 for 2 hours - 11/5/58

Lesion first noted 12 days after exposure

Photographed 12/16/58 - 41 days after exposure

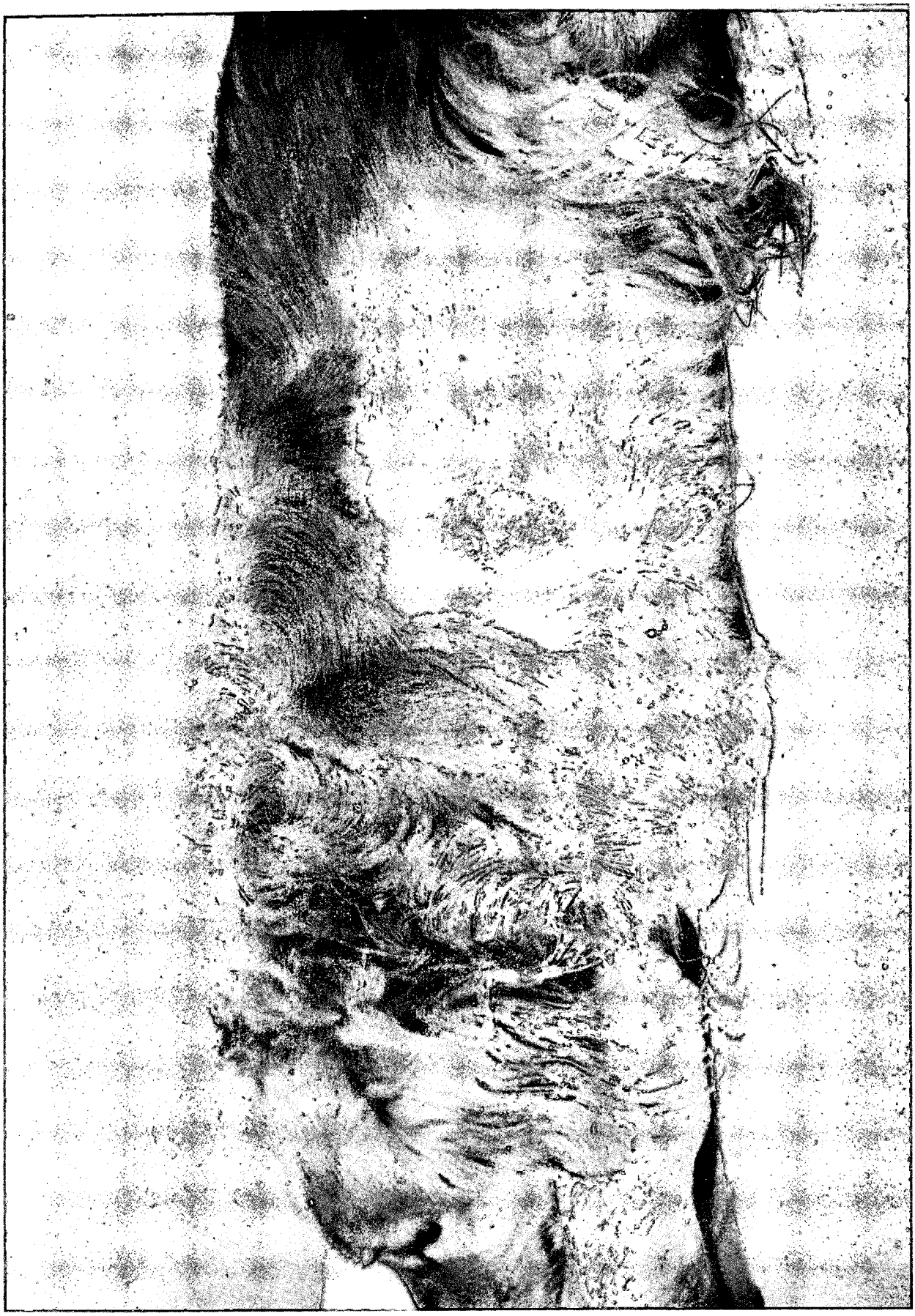


DOG #3169 (SURVIVOR)

Exposed to 2880 mc microwaves - 165 mw/cm^2 for 2 hours - 11/5/58

Lesion first noted 16 days after exposure

Photographed 12/16/58 - 41 days after exposure



DOG #4217 (NORMAL)

15 min. (165 mw/cm^2) microwave - 5/2/58

30 min. (165 mw/cm^2) microwave - 5/23/58

30 min. (165 mw/cm^2) microwave - 5/28/58

30 min. (165 mw/cm^2) microwave - 6/5/58

2 hours (165 mw/cm^2) microwave - 9/25/58

2 hours (165 mw/cm^2) microwave - 9/26/58

2 hours (165 mw/cm^2) microwave - 9/29/58

Lesion first noted 1 week after last exposure

Photographed - 10/10/58

4217 - Multiple exposures - 165 mw/cm^2

DOG #4039 - RECEIVED 400 r Co-60 10/10/58

165 mw/cm^2 for 2 hours microwaves - 10/21/58

165 mw/cm^2 for 2 hours microwaves - 10/22/58

165 mw/cm^2 for 2 hours microwaves - 10/23/58

165 mw/cm^2 for 2 hours microwaves - 10/24/58

165 mw/cm^2 for 2 hours microwaves - 10/27/58

165 mw/cm^2 for 2 hours microwaves - 10/28/58

165 mw/cm^2 for 2 hours microwaves - 10/29/58

Photographed - 10/29/58 - when lesion was first noted

Dead - 10/30/58

4039 - Multiple exposures (165 mw/cm^2) 11 d. p Co^{60}

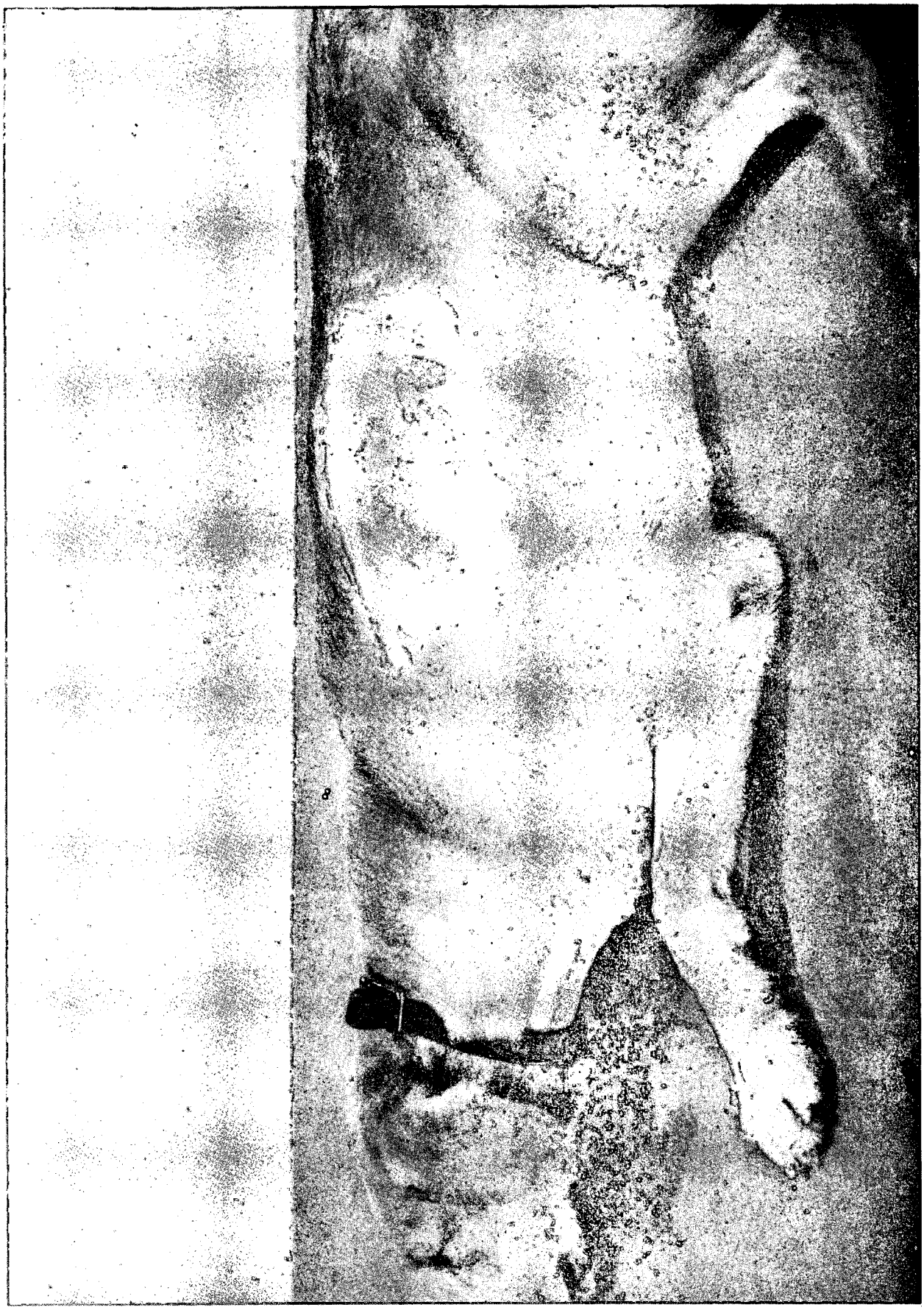
DOG #3288 (SURVIVOR)

Exposed to 2880 mc microwaves - 165 mw/cm^2 for 2 hours - 11/18/58

Lesion first noted 3 days after exposure

Photographed - 11/21/58 - 3 days after exposure

Dead - 11/22/58



AD-212110

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This report describes a biomedical investigation into the potential hazards of electromagnetic radiations. Studies were conducted on dogs exposed to 100 and 165 mw/cm^2 energies of 2800 mc pulsed microwave for periods varying from two to six hours. Emphasis is placed on the characterization of the physiological changes of microwave exposure in the dog and rabbit, preliminary

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