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PERFORMANCE OF TRAINED BEAGLES AFTER SUPRALETHAL DOSES OF RADIATION

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

FOREWORD
(Nontechnical summary)

For a broad range of supralethal doses of ionizing radiation, the postirradiation performance of trained monkeys, miniature pigs, and rats follows a rather well-defined pattern. Within seconds to minutes after exposure, a transient period of performance decrement occurs. Functional capabilities gradually improve so that the animals are generally performing satisfactorily within 1 hour after irradiation. Later, a rapid irreversible decline in performance leads to complete incapacitation and death.

When righting reflex and clinical symptoms were used to evaluate gross performance capabilities of untrained beagle dogs after irradiation, no obvious temporary debilitation was detected. Instead, the dogs' physical ability progressively worsened and the animals became completely incapacitated shortly before death. Unlike the other animal species which had been required to perform specific tasks so that their response could be objectively evaluated, the dog's performance was only subjectively evaluated. It was possible, therefore, that trained dogs would also show a pronounced but temporary performance decrement shortly after irradiation.

Nine beagles were trained by shock avoidance conditioning to work a discrimination problem cued by visual and auditory stimuli. The animals received 5200- to 17,600-rad midline tissue doses of pulsed mixed gamma-neutron radiation, and their postirradiation performance was evaluated.

The results indicate that the response of trained dogs to supralethal doses of radiation is different from that of monkeys, miniature pigs, and rats. Sustained

periods of temporary performance decrement did not occur in dogs during the first 60 minutes after doses of 11,900 rads or less; however, random, brief periods of performance decrement were frequent. Animals that received 17,600 rads experienced a severe irreversible performance decrement within 1 hour after irradiation. At doses below 10,000 rads dogs performed at or near preirradiation levels for several days after irradiation. Later, a rapid decline in performance led to complete incapacitation and death. At doses of 10,000 to 12,000 rads most animals performed at or near preirradiation levels for only a few hours. Thereafter, a rapid, irreversible decline in performance led to complete incapacitation and death.

ABSTRACT

Nine beagle dogs were trained by shock avoidance conditioning to work a discrimination problem cued by visual and auditory stimuli. The animals received 5200- to 17,600-rad midline tissue doses of pulsed mixed gamma-neutron radiation, and their postirradiation performance was evaluated. During the first 60 minutes after irradiation, random, brief periods of performance decrement frequently occurred. Dogs that received less than 10,000 rads performed at or near preirradiation levels several days until they became permanently incapacitated shortly before death. After doses of 10,000 rads or more most dogs performed satisfactorily for only a few minutes to hours. Their condition then worsened precipitously and the dogs died shortly thereafter.

I. INTRODUCTION

For a broad range of supralethal doses of ionizing radiation trained monkeys, miniature pigs, and rats experience a period of transient performance decrement shortly after irradiation.[2-4] Functional capabilities subsequently improve so that the animals are generally performing satisfactorily within 1 hour after irradiation. Later, a rapid irreversible decline in performance occurs and is followed by incapacitation and death.

When righting reflex and clinical symptoms were used to evaluate gross performance capabilities of untrained beagles after irradiation, no temporary debilitation was detected.[1,5] Instead, a progressive decline in the dogs' physical ability occurred which ultimately led to complete incapacitation shortly before death.

Since the dog's performance had only been subjectively evaluated, it was possible that the animal's ability to perform a learned task would, as in the other species, fall off temporarily almost immediately after irradiation. To test this possibility, nine trained beagles were given doses of 5200 to 17,600 rads, and their postirradiation performance was evaluated.

II. PROCEDURES

The subjects were nine male AKC registrable beagles. They were 1-1/2 to 3 years old and weighed 8 to 12 kg at the time of irradiation.

The dogs were trained to briefly flex the appropriate forelimb on cue. The animals were placed in the testing box shown in Figure 1 where only the head was firmly restrained by an adjustable yoke. The front paws were strapped to metallic grid keys which, when manipulated, actuated electrical circuits that served to record

forelimb flexing. The keys also functioned as the electrodes for the shock avoidance conditioning.

A high (1125 Hz) and a low (450 Hz) frequency tone from a 2-inch diameter speaker directly above the dog's head provided the auditory cues, and a 12-volt incandescent light in front of each key provided the visual cue. The dogs were trained to flex the right forelimb in response to the light in front of the right key and the high frequency tone and to flex the left forelimb in response to the light in front of the left key and the low frequency tone.

The cues were started at the beginning of each 8- or 10-second trial. If the dog responded correctly by flexing the appropriate forelimb within 6 seconds, it avoided electrical shock, and the cues were terminated. The remainder of the trial

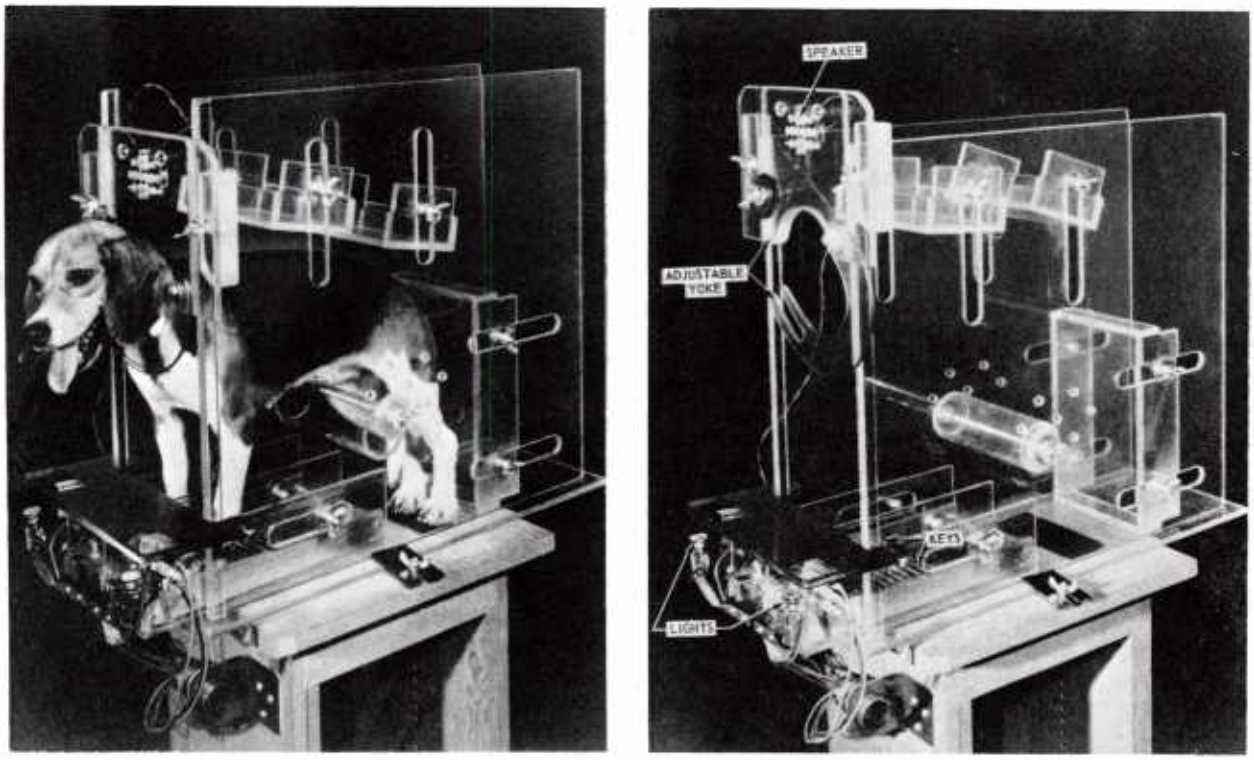

Figure 1. Beagle testing box

served as a rest period. When the dog responded incorrectly by flexing the wrong forelimb, the cues were terminated, and a 1/2-second electrical shock was applied through the grid key to the paw of the forelimb that should have been flexed. If, after 6 seconds, the dog did not respond (scored as an omission) the cues were turned off and an electrical shock was delivered.

Each dog was trained until its performance reached a steady-state level. Eight dogs achieved a 90 percent or more correct response steady-state level; one dog performed consistently at the 85 percent correct response level but was retained in the study. Each animal performed at its steady-state level for approximately 2000 trials before irradiation. These were given in 100-trial sessions over 10 days.

Beagle performance before irradiation is shown in Table I. After the animals' performance levels had been established, omissions were rare.

The dogs were easily distracted by sudden changes in their surroundings. Note the slight decline in base-line performance of most animals when transferred from the training room to the exposure room. In spite of differences in the duration of training, the data in Table I indicate that the animals were equally well trained.

The dogs were exposed unilaterally to the left side to a pulse of mixed gamma-neutron radiation from the AFRRI-TRIGA reactor.[5] Midline tissue doses to the head were 5200 to 17,600 rads. During irradiation the dogs were held in the Plexiglas testing box (Figure 1). The animals were positioned so that the brain center line was 60 or 100 cm from the vertical reactor core center line. All doses were calculated by previously reported methods.[3]

Table I. Beagle Training and Performance before Irradiation

Dog #	Steady-state performance* before irradiation		Preirradiation base-line performance† in training room			Exposure room
	Total time (days)	Total number of trials	Number of trials	Percent correct response ± S.D.	Latency ± S.D. (seconds/trial)	Percent correct response
1	20	2600	2600	94.8 ± 4.0	0.93 ± 0.204	95.6
2	46	7100	2000	98.9 ± 1.1	1.37 ± 0.260	95.6
3	54	7800	2100	97.0 ± 3.0	0.58 ± 0.104	97.0
4	47	5800	2100	95.7 ± 4.13	0.380 ± 0.082	92.0
5	19	1900	1900	94.8 ± 3.1	0.607 ± 0.149	92.0
6	7	1800	1800	96.1 ± 1.5	0.682 ± 0.114	89.0
7	18	2500	2500	85.1 ± 9.90	0.126 ± 0.066	84.0
8	65	10,900	3050	97.4 ± 2.10	0.388 ± 0.098	88.6
9	19	3400	2800	94.1 ± 3.11	0.348 ± 0.121	96.0

* 85% correct response for dog 7; 90% correct response for all other dogs
† Values based on the last trials performed before irradiation

Within 1 hour before irradiation the animals were tested in the exposure room for from one to three 100-trial sessions. After irradiation the dogs were tested in 100-trial sessions starting at 0, 20, and 40 minutes postirradiation. Thereafter, they were tested at least once a day until death. Several dogs that received higher doses were also tested at additional times during the first 6 hours after irradiation.

III. RESULTS

Postirradiation performance data for each of the nine dogs are illustrated in Figure 2. Each bar represents the results of a test session which lasted for the times shown on the abscissa. For the two dogs that received 5200 rads, the test session immediately after the pulse consisted of a series of 70 trials. All other test sessions in this study consisted of a series of 100 trials.

For the first 60 minutes after irradiation correct responses were also averaged over 10-trial sessions. These values are shown by the data points on the solid lines.

Beagle performance and clinical symptoms for the first hour after irradiation are summarized in Table II. For purposes of this study, performance decrement was defined as "slight" for 70 or 80 percent correct response and "severe" for 60 percent correct response or less.

As shown by Figure 2, dogs that received doses of 11,900 rads or less generally performed well during the initial 60 minutes after irradiation, whereas dogs that received 17,600 rads experienced severe irreversible performance decrement within 1 hour after irradiation. This is clearly shown by the data in Table II; the dogs that received 17,600 rads had a marked increase in the number of 10-trial sessions with performance decrement compared to dogs that received 11,900 rads or less.

Although dogs 4 (7,800 rads), 5 (10,200 rads), 6 (10,200 rads), 7 (11,900 rads), and 9 (17,600 rads) showed signs of an early transient performance decrement within 15 minutes after irradiation, only dog 9 experienced decrement severe enough to be construed as incapacitation. Further, only dogs 5, 6, and 9 had severe decrement in two or more consecutive 10-trial sessions. At lower doses the severe decrement generally occurred during periods of vomiting; at higher doses, severe decrement also occurred during periods of convulsions.

As shown in Figure 2, the dogs performed quite well for several days (48-72 hours) after 5200- and 7800-rad doses. After doses of 10,200 rads or more, severe central nervous system damage (convulsions) was evident in most dogs, and a rapid decline in performance occurred within a few hours after irradiation.

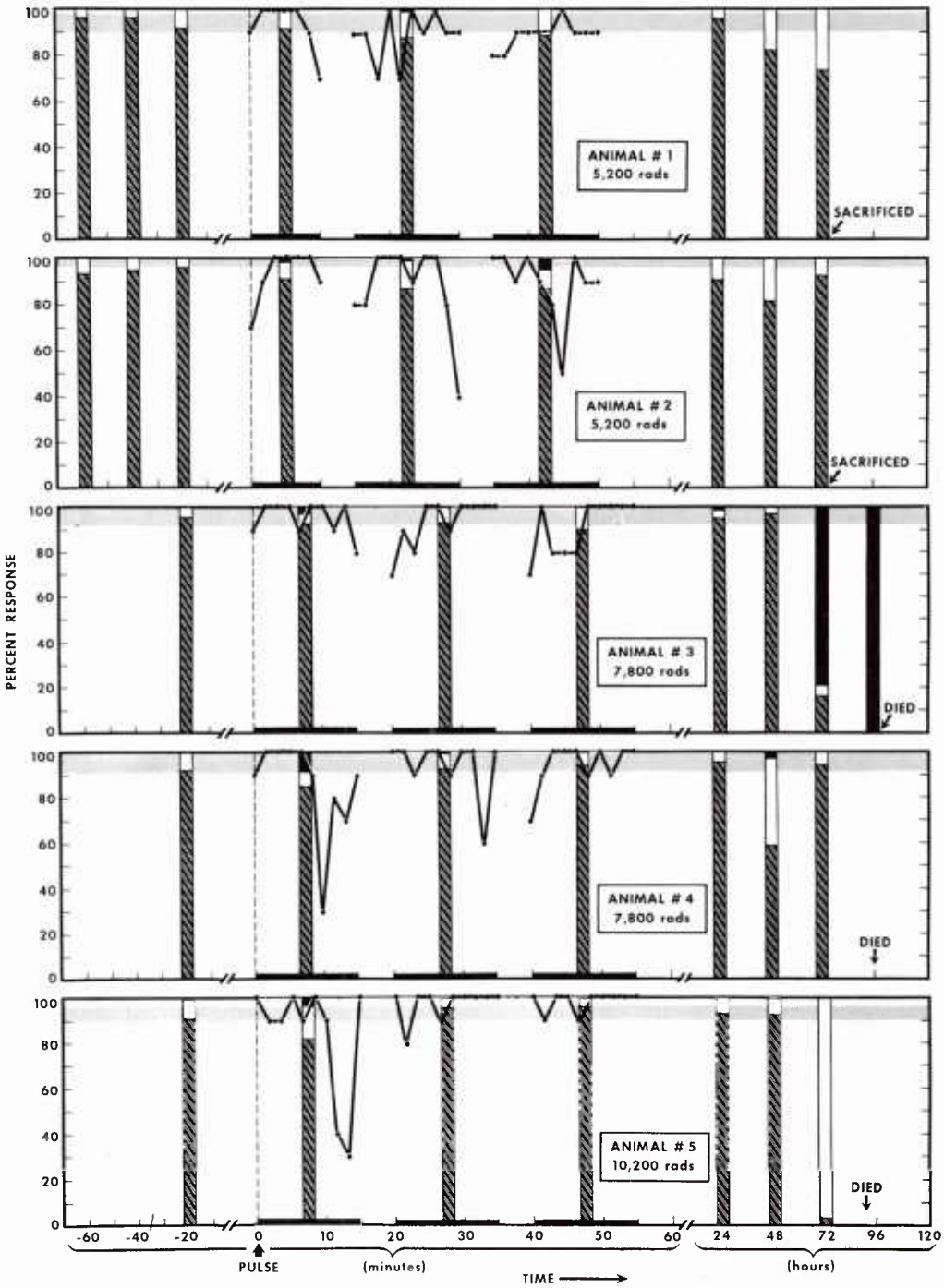

Figure 2. Beagle performance after irradiation. Each vertical bar represents the average performance for each test session: ▨ correct and ▯ incorrect responses; ▮ omissions. Each data point is an average of a 10-trial session. The standard deviation around the mean of the preirradiation base-line performance is indicated by the shaded area.

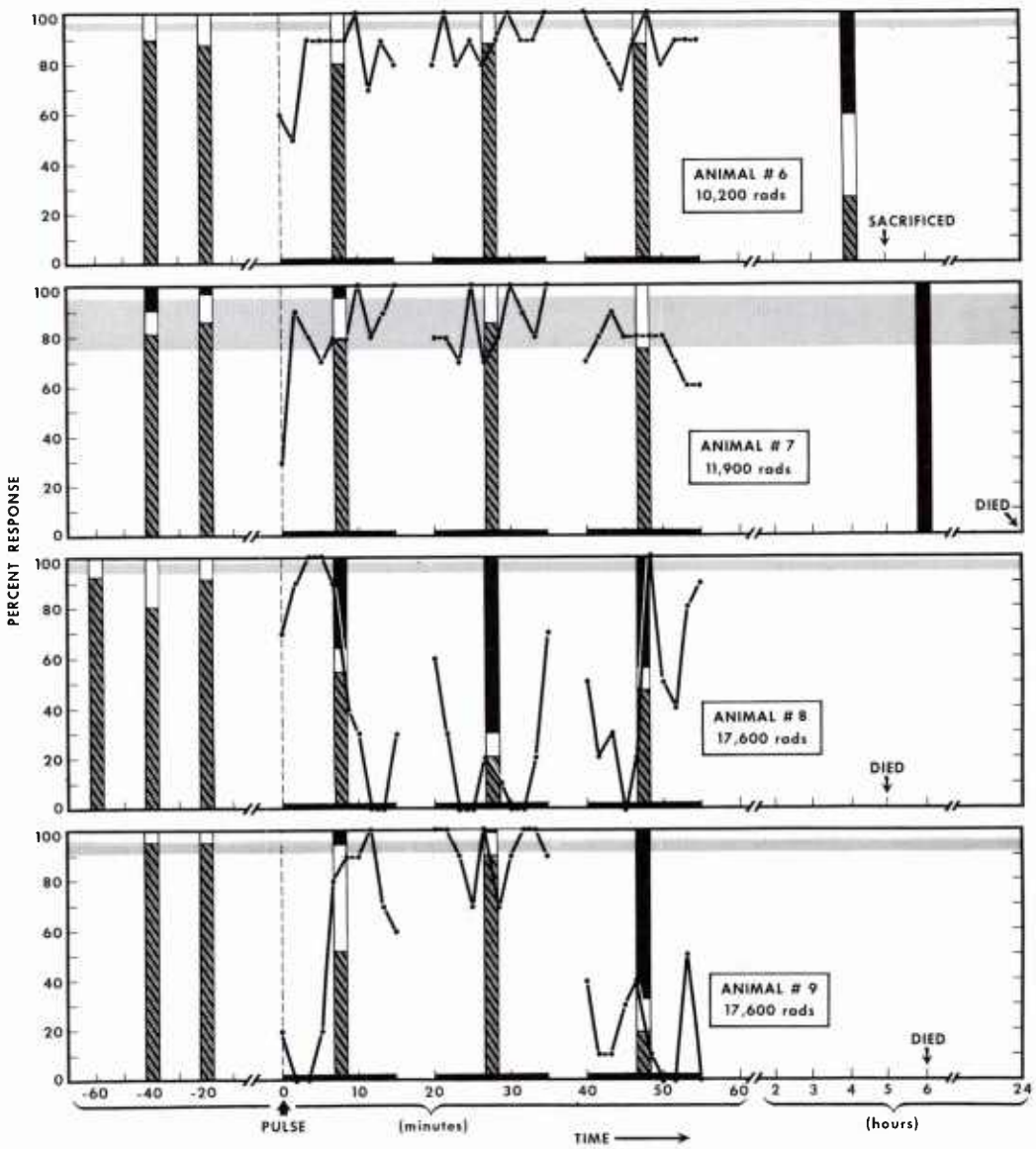

Figure 2 (continued)

Table II. Beagle Performance and Clinical Symptoms during the First Hour after Irradiation

Dog #	Midline tissue dose (rads)	Severe performance decrement (P.D.) ≤ 60% correct response			Number of 10-trial sessions with any P.D.*	Onset of vomiting (minutes)	Onset of convulsion (minutes)
		Time of severe P.D. (minutes)	Percent correct response during severe P.D.	Number of 10-trial sessions with severe P.D.			
1	5200	None	--	0	5	11	None
2	5200	30-32 45-47	40 50	2	7	10	None
3	7800	None	--	0	7	12	None
4	7800	10-12 33-35	30 60	2	5	10	None
5	10,200	12-15	35	2	3	7	None
6	10,200	0-4	55	2	10	30	60
7	11,900	0-2 54 →	30 60	3	8	None	~120
8	17,600	8-35 40-52	16 30	21	24	10	38
9	17,600	0-7 15-17 40 →	10 60 19	15	19	8	40

* < 90% correct response for all dogs except dog 7 which was < 80%

The onset of complete incapacitation varied among dogs from a few hours to as long as 1 day before death.

IV. DISCUSSION

The pattern of trained beagle performance after irradiation is generally consistent with the results of Pitchford[5] and Block et al;[1] a definite early transient performance decrement was not consistently evident.

Although nearly all dogs experienced random periods of early performance decrement, these periods generally lasted only 1 to 3 minutes; they were not prolonged as was characteristic of the temporary debilitation observed in the trained monkeys, miniature pigs, and rats.

The decline in performance observed in a few of the dogs immediately after irradiation (Figure 2) may have been related to the noises involved in reactor operation. These dogs appeared distracted and usually responded incorrectly or omitted several consecutive trials. This transient performance decrement was not associated with the severe clinical symptoms (convulsions, coma, shock, etc.) that consistently occurred during the temporary performance decrement experienced by irradiated monkeys, pigs, and rats. When convulsions did occur in the dog, the animal could no longer perform and died shortly thereafter.

The dogs generally performed quite well until they were unable to stand in the testing box. At doses below 10,000 rads this occurred 3 to 4 days after irradiation and within 1 day of death. At higher doses, the early incidence of convulsions prevented satisfactory performance even though many of the dogs appeared to be alert and tried to perform while convulsing. The dogs performed reasonably well between the convulsive episodes; note the cyclic performance pattern shown by dog 8, Figure 2. Unlike monkeys, pigs, and rats, the dogs never appeared to lose consciousness until they became comatose a few hours before death.

Although three of the dogs were sacrificed, the survival time data that were obtained in this study agree reasonably well with survival time data obtained by Pitchford[5] and Block et al.[1]

V. CONCLUSION

The response of trained dogs to supralethal doses of radiation is quite different from that of trained monkeys, miniature pigs, and rats. No sustained early temporary performance decrement was found; instead, very brief periods of performance decrement occurred randomly throughout the first 60 minutes after irradiation. At doses below 10,000 rads the animals continued to perform at or near satisfactory levels for several days after irradiation. Thereafter, a rapid decline in performance led to complete incapacitation within 1 day of death. When the dose exceeded 10,000 rads, central nervous system damage was obvious (convulsions), and the animals experienced severe decrement within 1 hour after irradiation; a few hours later, a rapid, irreversible decline in performance led to complete incapacitation and death.

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13. ABSTRACT

Nine beagle dogs were trained by shock avoidance conditioning to work a discrimination problem cued by visual and auditory stimuli. The animals received 5200- to 17,600-rad midline tissue doses of pulsed mixed gamma-neutron radiation, and their postirradiation performance was evaluated. During the first 60 minutes after irradiation, random, brief periods of performance decrement frequently occurred. Dogs that received less than 10,000 rads performed at or near preirradiation levels several days until they became permanently incapacitated shortly before death. After doses of 10,000 rads or more most dogs performed satisfactorily for only a few minutes to hours. Their condition then worsened precipitously and the dogs died shortly thereafter.

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