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PERFORMANCE OF MINIATURE PIGS AFTER PARTIAL BODY IRRADIATION

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Armed Forces Radiobiology Research Institute
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PERFORMANCE OF MINIATURE PIGS AFTER PARTIAL BODY IRRADIATION

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FOREWORD
(Nontechnical summary)

Incapacitation has been observed in monkeys, dogs, and miniature pigs that received supralethal, pulsed doses of ionizing radiation. Over a fairly wide range of such doses, the pig and the monkey experienced a period of early transient incapacitation (ETI) from which they recovered to perform satisfactorily for several hours. ETI was not observed in the dog; after the onset of incapacitation, the dog's condition declined continually without improvement.

Either head shielding or trunk shielding alleviated or prevented the symptoms of ETI for the monkey. Head shielding prevented early onset of incapacitation in the dog, but trunk shielding did not. The purpose of this study was to determine whether head or trunk shielding would alleviate or prevent early incapacitation in irradiated miniature pigs.

Thirty-two miniature pigs (males, females, and barrows) were trained by shock avoidance conditioning to traverse a two-chambered shuttlebox. Eight unshielded pigs (whole-body exposed) received midline tissue doses (MTD) of about 13,000 rads of pulsed, mixed gamma-neutron radiations to the head and trunk. Eight head-shielded and eight trunk-shielded pigs received doses to the unshielded part of the body that were equivalent to the doses received by unshielded animals. Four trunk-shielded pigs received 6[illegible] rads to the head, and four others received 3000 rads to the head. The MTD behind the shield (at the middle of the head or trunk) was less than 7 percent of the MTD to the same point without the shield in place. Postirradiation performance was evaluated.

In the 13,000-rad dose groups, ETI or immediate, permanent complete incapacitation (PCI) occurred in all of the unshielded pigs and in seven of the eight trunk-shielded pigs. The other trunk-shielded pig did not suffer ETI, but its early post-irradiation performance was far below preirradiation levels. One head-shielded pig suffered ETI, which appeared to be due to paralysis of the hind legs. Three head-shielded subjects seemed slightly ataxic for 5 to 10 minutes after irradiation, but they continued to perform at acceptable levels by avoiding shock at least 90 percent of the time. ETI also occurred in the four trunk-shielded pigs that received 6000 rads to the head and in one of the four that received 3000 rads.

In the 13,000-rad dose groups, two unshielded pigs and one trunk-shielded pig suffered immediate PCI. Survival times of 4 hours or less were observed in both groups. Early deaths (within 4 hours) did not occur among the head-shielded pigs nor among the trunk-shielded pigs that received lower doses. However, all trunk-shielded animals that escaped the early death had longer survival times than comparable head-shielded or unshielded animals.

It appears, therefore, that radiation damage within the head is the primary cause of early death, ETI, and early PCI in irradiated pigs, and head shielding would help prevent these phenomena. However, trunk shielding would be expected to extend the survival and effectiveness of irradiated pigs if early death does not occur.

ABSTRACT

Thirty-two miniature pigs were trained by shock avoidance conditioning to traverse a two-chambered shuttlebox. Eight unshielded pigs (whole-body exposed) received midline tissue doses (MTD) of about 13,000 rads of pulsed, mixed gamma-neutron radiations to the head and trunk. Eight head-shielded and eight trunk-shielded pigs received doses to the unshielded part of the body that were equivalent to the doses received by unshielded animals. Four trunk-shielded pigs received 6000 rads to the head, and four others received 3000 rads to the head. MTD behind the shield (at the middle of the head or trunk) was less than 7 percent of the MTD to the same point without a shield in place. Postirradiation performance was evaluated. All unshielded pigs suffered early transient incapacitation (ETI) or immediate, permanent complete incapacitation (PCI); several early deaths (within 4 hours) occurred among these animals. Head shielding prevented ETI, immediate PCI, and early deaths, but trunk shielding did not. However, trunk-shielded subjects that escaped the early death performed and survived longer than most head-shielded or unshielded pigs. ETI occurred in all of the trunk-shielded pigs that received 6000 rads and in one of four that received 3000 rads; however, early deaths did not occur and survival times were much longer than those previously reported for unshielded pigs that received comparable doses.

I. INTRODUCTION

Incapacitation has been observed in monkeys,[2] dogs,[3] and miniature pigs[4] that received supralethal, pulsed doses of ionizing radiation. Over a fairly wide range of such doses, the pig and the monkey experienced a period of early transient incapacitation (ETI) from which they recovered to perform satisfactorily for several hours. ETI was not observed in the dog; after the onset of incapacitation, the dog's condition declined continually without improvement.

Head shielding and trunk shielding alleviated or prevented the symptoms of ETI for the monkey.[5] Head shielding prevented early incapacitation in the dog, but trunk shielding did not.[4] The purpose of this study was to determine whether head or trunk shielding would alleviate or prevent early incapacitation in irradiated miniature pigs.

II. PROCEDURE

The subjects were trained miniature pigs (male, female, and barrow) of the Hormel-Hanford strain. At the time of exposure they weighed between 30 and 40 kg and were about 21 cm thick at the shoulder.

Thirty-two subjects were irradiated individually with the AFRRI-TRIGA reactor operated in the pulsed mode.[3] Eight unshielded pigs (whole-body exposed) received midline tissue doses (MTD) of about 13,000 rads of pulsed, mixed gamma-neutron radiations to the head and trunk. Eight head-shielded and eight trunk-shielded pigs received doses to the unshielded part of the body that were equivalent to the doses received by unshielded animals. Four trunk-shielded pigs received 6000 rads to the head and four others received 3000 rads to the head.

Each pig was restrained in a Plexiglas box and positioned with its left side toward the reactor core. The pig's center line was about 79 cm from the vertical core center line, and appropriate shielding of the type previously described[4] was in place. Immediately after exposure, the pig was released into a shuttlebox for performance testing.

Midline tissue doses to the head and trunk of each animal were calculated based on measurements in a pig cadaver (Figure 1). Depth-dose distributions in the pig cadaver are presented in Figures 2-4. Dosimetry methods were similar to those used in other experiments.[4,5] The midline tissue dose behind the shield (at the middle of the head or trunk) was less than 7 percent of the midline tissue dose to the same point without a shield in place. The whole-body exposures were

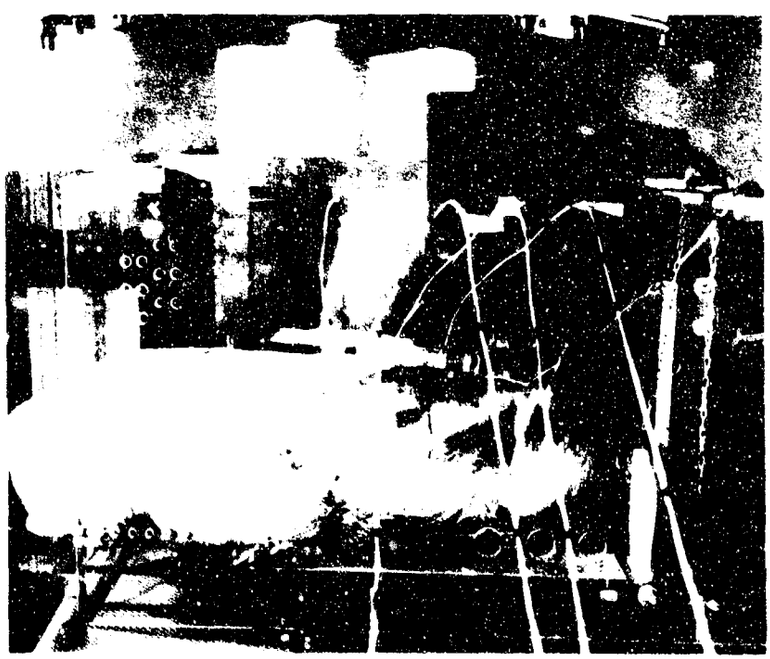

Figure 1. Array for depth-dose measurements in head-shielded pig cadaver

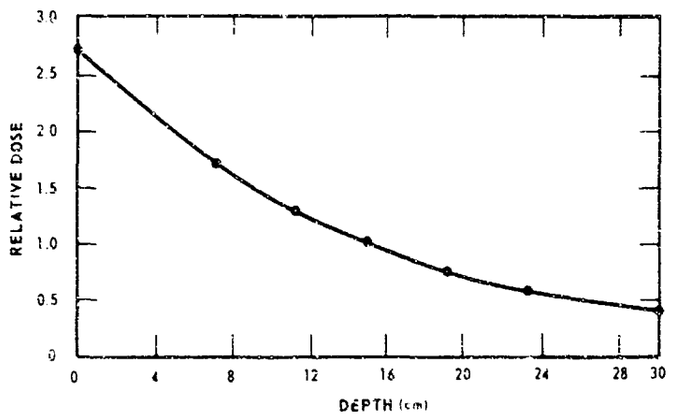

Figure 2. Horizontal depth-dose distribution through trunk of pig cadaver

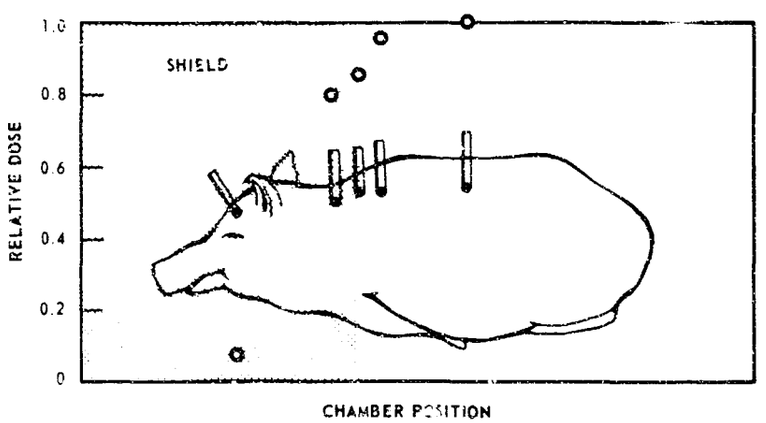

Figure 3. Longitudinal midline tissue dose distribution in head-shielded pig cadaver

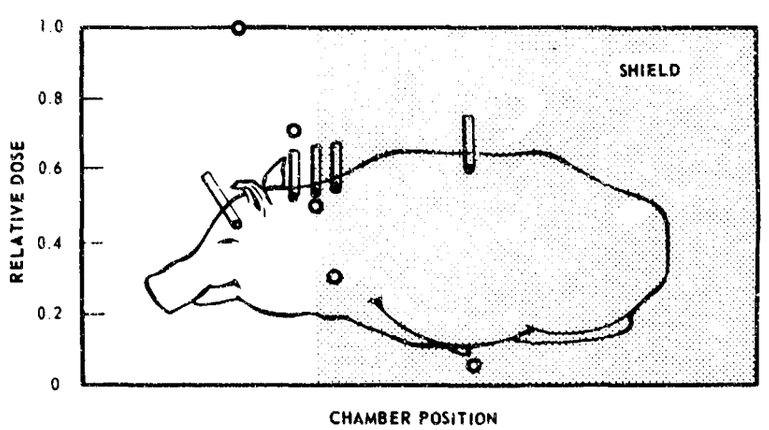

Figure 4. Longitudinal midline tissue dose distribution in trunk-shielded pig cadaver

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The pigs were trained by shock avoidance conditioning to traverse a two-chambered shuttlebox. The task is more completely described in another report.[1] Each trial lasted 15 seconds; beginning with the presentation of appropriate cues, the trial sequence allowed 6 seconds to avoid shock by traversing the shuttlebox, 3 seconds to escape from the shock by traversing the box, and 6 seconds to rest. Each subject was trained to a proficiency of at least 90 percent avoidance before it was irradiated.

Each postirradiation test period consisted of 10 trials. Test periods were initiated in the exposure room at 0, 3, 6, 9, 12, 15, 20, 25, 30, 35, 40, and 45 minutes after exposure. The pig was then removed from the exposure room and tested again at 1, 2.5, and 4 hours postexposure and every 2 hours thereafter until death.

III. RESULTS

Results are summarized in Tables I through V. The subject was considered to have suffered ETI if there were any convulsions or if the pig was unable to avoid or escape for several consecutive trials.

Among the pigs receiving 13,000 rads, ETI or immediate, permanent complete incapacitation (PCI) occurred in all of the unshielded pigs and in seven of the eight trunk-shielded pigs; all of these animals suffered convulsions during the early part of ETI. The other trunk-shielded pig did not suffer ETI, but its early performance was far below preirradiation levels (85 avoidances for 130 trials after exposure,

Table I. Postirradiation Performance of Unshielded Pigs (13,000 rads)

Pig number	First hour performance (130 trials)			Length of ETI (minutes)	Survival time (hours)	Last performance (hours)	Length of PCI (hours)
	Number of avoidances	Number of escapes	Avoidances and escapes				
1	30	8	38	30	3	2	1
2	92	5	97	9	19	12	7
3	69	14	83	12	16	11	5
4	81	6	87	12	32	26	6
5	0	0	0	no recovery	3	none	
6	0	0	0	no recovery	0.5	none	
7	0	2	2	45	20	12	8
8	46	20	66	20	4	3	1

Table II. Postirradiation Performance of Head-Shielded Pigs (13,000 rads)

Pig number	First hour performance (130 trials)			Length of ETI (minutes)	Survival time (hours)	Last performance (hours)	Length of PCI (hours)
	Number of avoidances	Number of escapes	Avoidances and escapes				
1	*	*	*	*	109	96	13
2	125	5	130	none	88	80	8
3	129	1	130	none	19	13	6
4	118	11	129	none	28	24	4
5	129	1	130	none	25	17	8
6	121	7	128	none	32	21	11
7	121	9	130	none	33	30	3
8	84	6	90	12	95	92	3

* Pig was not released until 10 minutes postexposure. No indication of any type of early incapacitation.

Table III. Postirradiation Performance of Trunk-Shielded Pigs (13,000 rads)

Pig number	First hour performance (130 trials)			Length of ETI (minutes)	Survival time (hours)	Last performance (hours)	Length of PCI (hours)
	Number of avoidances	Number of escapes	Avoidances and escapes				
1	85	14	99	none *	124	110	14
2	0	0	0	no recovery	0.45	none	
3	3	12	15	35	112	51	61
4	69	2	71	15	111	96	15
5	92	7	99	6	119	104	15
6	51	13	64	20	146	94	52
7	82	20	102	3	132	116	16
8	8	19	27	15	0.75	0.6	

* No ETI, but performance was below acceptable levels

Table IV. Postirradiation Performance of Trunk-Shielded Pigs (6,000 rads)

Pig number	First hour performance (130 trials)			Length of ETI (minutes)	Survival time (hours)	Last performance (hours)	Length of PCI (hours)
	Number of avoidances	Number of escapes	Avoidances and escapes				
1	88	32	120	5	236	165	71
2	101	13	114	5	191	144	47
3	125	3	128	1	214	167	47
4	64	8	72	20	285	190	95

Table V. Postirradiation Performance of Trunk-Shielded Pigs (3,000 rads)

Pig number	First hour performance (110 trials)*			Length of ETI (minutes)	Survival time (hours)	Last performance (hours)	Length of PCI (hours)
	Number of avoidances	Number of escapes	Avoidances and escapes				
1	107	2	109	none	359	284	75
2	83	18	101	3	312	283	29
3	94	6	100	none	310	282	28
4	107	3	110	none	280	257	23

* Pigs were removed from exposure room early because there was very little evidence of ETI

compared to 100 percent avoidances in preirradiation testing). One head-shielded pig suffered ETI without convulsions; its failures were apparently due to temporary paralysis of its hind legs. Three head-shielded pigs seemed slightly ataxic for 5 to 10 minutes after irradiation, but they did perform at acceptable levels. ETI also occurred in the four trunk-shielded pigs that received 6000 rads to the head and in one of the four trunk-shielded pigs that received 3000 rads to the head.

After receiving 13,000 rads, two unshielded pigs and one trunk-shielded pig suffered immediate PCI. All other pigs in this experiment either performed continously at acceptable levels for some time after irradiation or they recovered to perform satisfactorily after experiencing ETI. All pigs experienced PCI before death. For some pigs, the onset of PCI appeared to be delayed by head shielding

or trunk shielding. PCI appeared to last longer in trunk-shielded animals than in head-shielded or unshielded animals. PCI lasted several hours in the trunk-shielded pigs that received 6000 or 3000 rads.

Survival times of 4 hours or less were observed among unshielded and trunk-shielded pigs that received 13,000 rads to the head. These early deaths did not occur in head-shielded pigs of the 13,000-rad dose group nor in trunk-shielded pigs that received lower doses. Among the unshielded subjects in the high dose group, four survived 4 hours or less and four survived between 16 and 32 hours. Five of the head-shielded subjects survived between 19 and 33 hours and three survived between 88 and 109 hours. Two of the trunk-shielded pigs survived less than 1 hour after exposure, and the survival times of the other six ranged from 111 to 146 hours. Among the trunk-shielded pigs receiving lower doses, mean survival times were 231 hours for the 6000-rad group and 315 hours for the 3000-rad group.

IV. DISCUSSION

The results of this study indicate that radiation damage to the head is the primary cause of the early death and early incapacitation observed in pigs. Among the pigs receiving 13,000 rads to the head, ETI accompanied by convulsions and some early deaths occurred whether the trunk was shielded or not. Furthermore, ETI occurred in one trunk-shielded pig that received only 3000 rads to the head. The latter finding is similar to earlier results[1] which indicate that ETI can occur after whole-body exposures if the head receives between 2500 and 4000 rads. By contrast, head shielding prevented convulsions and early deaths in all pigs, and ETI occurred in only one of eight animals.

Since one head-shielded pig did suffer temporary paralysis and three others were temporarily ataxic after irradiation, it may be that early incapacitation due to physical disability would occur in head-shielded pigs receiving higher doses to the trunk.

It appears that head shielding or trunk shielding can extend survival and effectiveness of irradiated pigs. Head shielding prevented early deaths, but the unshielded pigs that escaped early death lived and performed about as long as most head-shielded pigs. Trunk shielding did not completely prevent early deaths in the highest dose group, but the trunk-shielded subjects that escaped early deaths performed and survived longer than unshielded or head-shielded pigs. There were no early deaths among the trunk-shielded pigs that received lower doses, and these pigs performed and survived much longer than unshielded pigs that received comparable doses in another study.[1]

Head shielding offered some protection to dogs,[4] monkeys[5] and miniature pigs that received supralethal doses of pulsed mixed gamma-neutron radiations. Early death was prevented in all three species and early incapacitation was either absent or less severe when the head was shielded. Head shielding extended the survival time of dogs, but this effect was less apparent in head-shielded pigs or monkeys.

Trunk shielding seems to be generally less beneficial than head shielding for all three species. There appeared to be no benefit to dogs from trunk shielding, and ETI and early deaths did occur in some trunk-shielded pigs. However, trunk shielding prevented early deaths among irradiated monkeys, and the pigs and monkeys that escaped early deaths did live longer than most head-shielded or unshielded

subjects. Trunk shielding reduced the probability of ETI in monkeys, but, if a trunk-shielded monkey did suffer ETI, it was more severe than in the head-shielded monkey.

Some caution must be observed in comparing the three animal species. The response of unshielded animals varies among species, and different tasks and different doses were used in studying the three species. Furthermore, the head or trunk of the dog or pig could be more effectively shielded than the head or trunk of the monkey. It was necessary to work with large source dimensions and short source-to-animal distances in all three studies. The smaller size of the monkey, compared to that of the dog or pig, made it more difficult to shield one part of the body while irradiating another. It appears that more experiments should be completed using other radiation sources with which the monkey's head or trunk can be more effectively shielded. In addition, physiological and biochemical changes should be studied in all three species to help elucidate the mechanisms involved.

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13. ABSTRACT

Thirty-two miniature pigs were trained by shock avoidance conditioning to traverse a two-chambered shuttlebox. Eight unshielded pigs (whole-body exposed) received midline tissue doses (MTD) of about 13,000 rads of pulsed, mixed gamma-neutron radiations to the head and trunk. Eight head-shielded and eight trunk-shielded pigs received doses to the unshielded part of the body that were equivalent to the doses received by unshielded animals. Four trunk-shielded pigs received 6000 rads to the head, and four others received 3000 rads to the head. MTD behind the shield (at the middle of the head or trunk) was less than 7 percent of the MTD to the same point without a shield in place. Postirradiation performance was evaluated. All unshielded pigs suffered early transient incapacitation (ETI) or immediate, permanent complete incapacitation (PCI); several early deaths (within 4 hours) occurred among these animals. Head shielding prevented ETI, immediate PCI, and early deaths, but trunk shielding did not. However, trunk-shielded subjects that escaped the early death performed and survived longer than most head-shielded or unshielded pigs. ETI occurred in all of the trunk-shielded pigs that received 6000 rads and in one of four that received 3000 rads; however, early deaths did not occur and survival times were much longer than those previously reported for unshielded pigs that received comparable doses.

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