GENETIC EFFECTS OF IRRADIATION ON EARLY MORTALITY IN SWINE[1]

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MAMMALIAN studies in radiation genetics have been confined principally to mice. The major emphasis has been on the nature and rate of changes at specific sites in the chromosomes (RUSSELL and RUSSELL 1959). Genetic effects of neutron radiation on the longevity of the first generation offspring have been reported (RUSSELL 1957). The work with swine was undertaken to extend the mammalian studies to another species. This report deals with the average effect of paternal irradiation on survival at birth and during the first three weeks of postnatal life. Corresponding effects on weight are given elsewhere (WILLHAM and Cox 1962).

MATERIALS AND METHODS

The parents of the offspring studied in this experiment represented the Duroc and Hampshire breeds and were purchased when approximately six months of age from farms in Iowa. The testes of one half of the 46 males used were given 300r of X rays in a single dose at a rate of 100r per minute. Details of the treatment and the pattern of sperm production following exposure have been reported (WILLHAM and Cox 1961).

The males were held for at least five months after exposure before they were mated. This period permitted the germinal epithelium to recover from the initial effects of radiation and insured that the sperm utilized were irradiated as premeiotic cells. Exposed and comparable unexposed males were bred to untreated females of the same breed. Two groups of females were used. One group produced 68 litters (33 control, 35 irradiated) in the spring of 1960 and 54 litters (25 control, 29 irradiated) in the fall of 1960. A second group produced 148 litters (77 control, 71 irradiated) in the fall of 1960 and 92 litters (47 control, 45 irradiated) in the spring of 1961. Females producing two litters were mated so that one litter was by a control male and the other by an irradiated male. A random choice was made on whether a control or irradiated male was used to produce the first litter.

Litters were farrowed and raised in separate eight ft by 16 ft pens. The individuals that were dead when the litter was first found were examined for evidence of respiration. If the lungs indicated that no respiration had occurred, these individuals were classed as dead at birth otherwise they were considered

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to have died during the first day. Individuals showing any obvious signs of decomposition indicating that death occurred sometime prior to birth were classed as regressing fetuses. The afterbirth was examined for the remains of these late fetal deaths. Daily mortality records were kept for each litter.

RESULTS AND DISCUSSION

The average litter size at birth based on all pigs found in 182 control and 180 irradiated litters was 10.3 and 10.4, respectively. The proportion of all births classified as regressing fetuses were 0.052 and 0.046 in the control and irradiated groups, respectively. Daily mortality rates based on the average number alive during various intervals of time are shown in Table 1. The rate at birth includes the individuals which gave no evidence of respiration. Regressing fetuses were not included. The percent of the total number born, excluding regressing fetuses, that survived to 21 days was 78.5 and 72.6 in the control and irradiated groups, respectively. The percentage of males in the control group was 51.0 at birth and 50.0 at 21 days and in the irradiated group it was 50.4 at birth and 49.5 at 21 days.

Mortality rates in Table 1 are higher among the progeny of irradiated males compared with progeny of control males in all but one of the intervals studied. The litter size at birth and presumably the prenatal mortality, a small fraction of which is reflected in the number of regressing fetuses, were not substantially different in the two groups. The number of males at birth and at 21 days showed no large disparity between the two groups.

Difficulties confront a judgment of the statistical significance of the observed differences between the two groups. If the survival of each individual could be considered as an independent event, then a chi-square test of the relationship between paternal irradiation and mortality would be appropriate. In the present study such a test indicates that the difference in total mortality to 21 days is highly significant ($P < .01$). However, while each individual is the test of irradiation on a single paternal gamete, the survival of littermates is correlated by their common environment and genotype. This fact does not bias the observed difference but does exaggerate the level of significance obtained by a chi-square test. Another method was used to determine the strength of the evidence for a real difference between the two groups. The procedure is based on a type of

TABLE 1

Daily mortality rates at various ages among the first generation from control and irradiated males

	Birth	Age in days 0–1	1–2	2–3	3–4	4–5	5–21
Offspring from control males (1770 born)	0.0605	0.0373	0.0182	0.0166	0.0215	0.0139	0.0046
Offspring from irradiated males (1782 born)	0.0803	0.0584	0.0150	0.0293	0.0267	0.0217	0.0054

randomization test. In the present work a difference in various criteria of survival has been observed between two groups of litters, 182 from control males and 180 from irradiated males. Considering the litter as the basic unit the randomization test asks how many times differences as large or larger than those observed would be obtained if the 362 litters were divided at random into two groups of similar size to those in the experiment. A sample of 200 random partitions were obtained from the (362!)/(180!)(182!) possible arrangements of the litters into two such groups. Various criteria were evaluated for each partition and compared with the values observed in the actual experiment.

The mortality was studied in three age intervals. The first included the individuals born dead or dying in the first day. The second included those dying after the first day but before the sixth day. The third included those dying in the remaining 16 days of the period studied. The observed differences between the average daily mortality rate (control minus irradiated) for the three intervals were +0.0434, +0.0056, +0.0008, respectively. For the first interval equal or larger differences were found in three of the 200 random partitions of the litters. For the second and third interval equal or larger differences were found in 26 and 79 of the 200 partitions, respectively. The total mortality to 21 days differed by 5.9 percent between the control and irradiated groups in the actual experiment. A difference this large was found in only one of the 200 random partitions.

These results support the hypothesis that paternal irradiation affects survival during the first three weeks of postnatal life. They provide good evidence for a real difference in mortality at birth and during the first day, somewhat less convincing evidence for a difference between day one and six and very little evidence for a difference after day six. However, the difference between the irradiated and control group is positive for each interval studied and the only limiting factor to establishing the case in the later intervals could be the volume of data involved. The graph in Figure 1 showing the relationship between the logarithm of the mortality rate and the logarithm of the day at the midpoints of the age intervals studied supports the above argument. This relationship has been shown in other work (Cox 1962) to be roughly linear before puberty. The slopes of the two lines in Figure 1 are quite similar while the intercepts at the first interval differ. In the 200 random partitions mentioned previously, 82 instances were found where the slopes differed more than observed in the actual experiment. However, no cases were found where the intercepts differed as much as those observed in the actual experiment.

The results indicate that random genetic changes, presumably point mutations induced in the spermatogonia of the males, reduced the probability of survival in the early postnatal life of the first generation offspring. Such detrimental effects on fitness have been observed in many other adapted cross-fertilized species and are logical consequences of random changes in genetic material that has a history of natural selection. The results agree generally with RUSSELL and RUSSELL (1959) where, based on over 12,000 litters, a 3.8 percent reduction in litter size at weaning was found in mice following 300r paternal exposure. Pa-

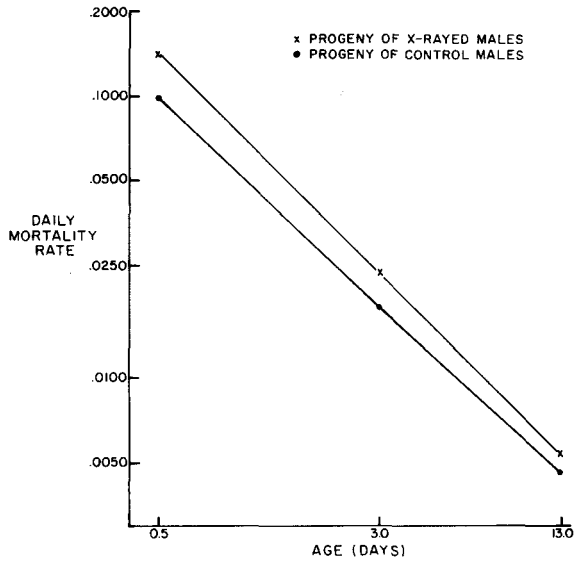

FIGURE 1.—Relationship of the daily mortality rate and age. Rate and time plotted on logarithmic scale.

ternal irradiation did not increase prenatal mortality as measured by the average litter size at birth. This somewhat unexpected result might arise from an excess of fertilized ova and a limited number of implantation sites. Thus, early preimplantation losses from induced mutations could be compensated for by reduced competition for available sites.

SUMMARY

Survival at birth and over the first three weeks of postnatal life was studied in 182 and 180 litters of pigs from control and irradiated sires, respectively. The paternal exposure of 300r had no clear influence on litter size at birth or on sex ratio in the first generation. However, the percentage of the total born that survived to three weeks was reduced from 78.5 percent in the controls to 72.6 percent in the irradiated group. The effect is apparently the result of detrimental mutations induced in the spermatogonia of the exposed males.

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