14.1 MEV FAST NEUTRON EQUIVALENCE OF WHOLE-BODY X-IRRADIATION FOR THE GROWTH DELAY OF MICE

By

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マウスの成長遅延からみたX線に対する14.1 MeV 速中性子当量

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2種の放射線すなわち 180kVpX線および14.1 MeV 速中性子線が，この実験に使用された．照射した4週令の幼若雄マウスの体重における成育遅延と，照射後3日目における体重差がそれぞれ比較された．同程度の成育遅延および照射後3日目に同様の体重差を示すに必要な 180kVpX線にたいする14.1MeV 速中性子線のRBEとして，それぞれ2.21および1.68をえた．

Introduction

It is well established that irradiation brings about whole-body weight loss in growing animals[1]. Nims and Sutton reported that weight loss is a function of dose[2]. Nims and Lewis has used growth delay of animals as a biological dosimeter[3]. They irradiated young rats and the growth delay curve which dropped temporarily immediately after exposure and later recovered to the preirradiation weight level was drawn. The thermal neutron equivalence of whole body X-irradiotion was then studied.

In their report the period of time for irradiated animals to recover to their preirradiation weight, designated as growth delay, was found to have a linear relationship to irradiation dose. In this paper the utility of growth delay for the determination of fast neutron equivalence to whole body X-irradiation is presented, using young mice. When mice are used instead of rats, there is the advantage that mice are smaller than rats in size for irradiation and thus the difference in posterior and anterior doses is also smaller for mice than rats. However, how remarkable is the decrease in mouse body weight after irradiation? Is dose a linear function in growth delay?

The growth delay curve of mice following exposure was not identical to that of rats.

Therefore, a method which differed slightly from Nims-Lewis' was employed to ascertain whether a linear function exists in growth delay.

Experiments

For experiments on growth delay it is necessary that the growth rate of the animal is constant. That is, growth curve should be linear. For this experiment CF#1 male mice were used. The growth curves of CF#1 male and female are shown in Fig. 1. The growth rate of mice increases after the age of 3 weeks and decreases after the age of 6 weeks, and the linearity of male is superior to that of female. Such charateristics in the growth curve are also seen on the other strains[4]. It is, therefore, desirable to use male animals which are 4 weeks in age. Male mice born in a constant-temperature room (20–25°C), weaned at 3 weeks age, housed 5 to a cage, and weighing of 12.5±2 g were selected at the age of 4 weeks and irradiated.

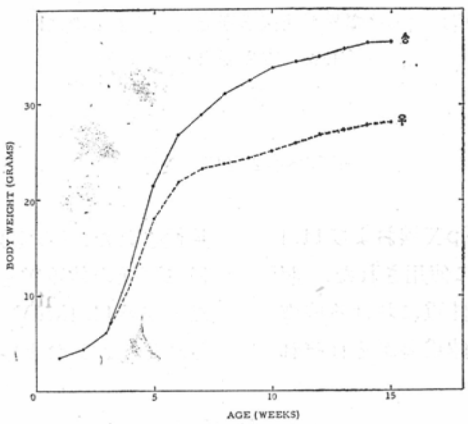

Fig. 1. Growth curves of CF# 1 male and female mice.

Uda and Akamatsu[5] reported on the variation of body weight within one day. They fed mice for 4 hours a day and weighed the mice before and after feeding. According to their paper the excellent constancy in body weight for all test mice was obtained. Author tested this method on young mice, but—4/15 of the male and 6/15 of the female—died in a week. This method was found to be too severe and not proper for young mice. Therefore, mice in this experiment had free access to water and prepared solid food, CA-1, of Zikken Dōbutsu Chūō Kenkyūsho (Central Laboratory of Experimental Animals). Mice were weighed at about 11.00 a.m. daily after exposure. A total of 20~25 mice was irradiated to each dose.

The X-ray source used was a deep therapy machine* operated at 25 mA and 180 kVp with filters of 0.5 mm Cu+0.5 mm Al (HVL: 1.26 mm Cu). Under this condition the dose rate was approximately 50 r/min. when the animals were placed 65 cm vertically

* Model KXC-18-2 manufactured by Tōkyō Shibaura Electric Co.

under the target of the X-ray tube. For the exposure box, a plastic box having twelve pie-shaped sectors was used. For the measurement of the X-ray dose received by the animals, a chamber of radocon** which would give the dose and dose rate was placed in one of the remaining vacant sectors of the exposure box at a point corresponding to the mid-position of the mouse's body.

A T(d,n) reaction type neutron source generator was operated at 150 kV for fast neutron irradiation. A metallic 3 layer round case in which a plastic tube, 10 cm in height and 3 cm in diameter to accommodate mice could be inserted to was set around the target. A description of this apparatus was made in detail in a previous paper[6]. 5 to 10 mice were irradiated at the same time in the interior layer of the set revolving at right angle to the target prop. The distance from the target to the mid-position of a mouse's body was 5 cm, and the dose rate was 3~10rads/min. Though there is some difference in the dose rates, it has been reported, that under the same neutron dose the dose rate dependency is extremly low[7]. The measurement of neutron flux was made by a scintillation counter whose head was placed 1 m from the target. This measurement method was converted from sulfur activation method. When sulfur is irradiated with neutron, S(n,p) P^{32} reaction develops. A tablet of sulfur was placed at a position which corresponds to the mid-position of mouse's body. In order to ascertain the quantity of neutron flux at such a position, the yield of P^{32} produced by the above reaction could be obtained by the G.M. counter. A scintillation counter was operated during the same irradiation. Then the relation between the count shown by the scintillation counter and the yield of the P^{32} could be obtained[8]. From this relation we could determine the quantity of neutron flux only by reading the scintillation counter.

Control mice which were 4 weeks old and in the period of rapid growth did not show any boy weight loss though placed in a similar exposure box.

Results and Discussion

Nims and Lewis has employed the growth delay of young rats after irradiation as a biological dosimeter[3]. Their growth delay curve showed a cuneo-form after irradiation. The base lines of the cuneo-triangles drawn as growth delay were plotted to irradiation doses. It has a linear function to dose.

In the case of X-ray irradiaion of low doses loss of body weight and death as a result of hematopoietic injury are remarkable about 15 days after irradiation. So-called gastro-intestinal injury appears a few days after irradiation. As the comparison of later cases, that is early injuries, was considered in this experiment, the survivors 10 days after irradiation were subjects for the calculation of average weights. As seen in Fig. 2, the body weight curves did not show the cuneo-form except at high doses. For this experiment, it is, therefore, difficult to apply the method of Nims and Lewis without modiffication. The straight line after returning to the normal growth rate was extended to the

** Model 575 manufactured by the Victoreen Instrument Co.

*** Model NS-H manufactured by Tōkyō Shibaura Electric Co.

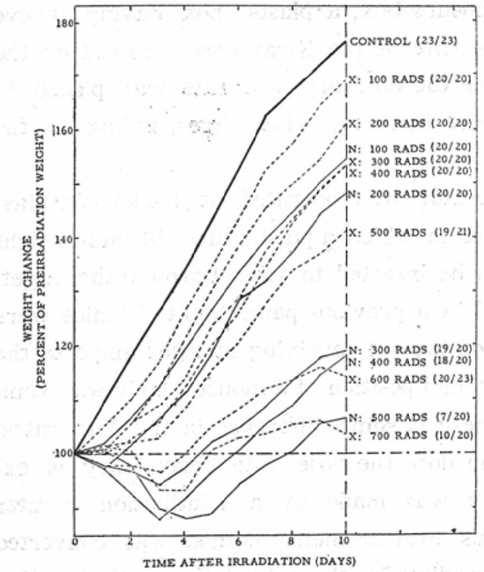

Fig. 2. Body curves after irradiation for 10 day survivors. The number of survivors is indicated in parentheses.

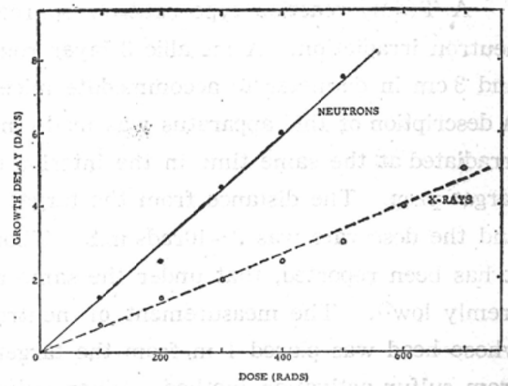

Fig. 3. The relationship of growth delay to the degree of exposure for young mice.

base line. The distance from the intersection to the original point was considered to be growth delay. Growth delay and dose have a linear relationship within the dose range experimeted as shown in Fig. 3. The equations and the RBE of 14.1 MeV neutron to 180 kV X-ray which cause the same degree of growth delay are as follow:

X-rays $Y = 0.0067X$

Neutrons $Y = 0.0148X$

Growth delay in mice RBE $= \eta_x^n = 2.21$

Depending on the dose and the kind of radiations some mice die from about 3 days after irradiation. When the mice which died were excluded from the experimental group, only the effect on the surviving mice which have a strong recovering power would likely appear in the body weight observations. It is desirable to observe the effects inclusive of both those which die and those which recover. Comparison of body weight on the third day following irradiation is considered to be significant because the body weight at such time wouid express the generalized effect of mice which die and of mice which recover and the difference in their body weights would be most predominant at such time. In fact, Storer et al.[9], and Woodward and Rothermel[10] have also compared the body weights of mice irradiated with thermal neutrons and X-rays on the third day after irradiaton. Fig. 4 shows the change in mice body weights until the third day after irradiation, that is, until some of the mice begin to die. As shown in Fig. 5 there is a linear relationship between the body weight difference and dose within the given dose range. The equations and the RBE of 14.1 MeV neutron to 180 kVp X-ray which bring about the same degree of body weight reduction are following:

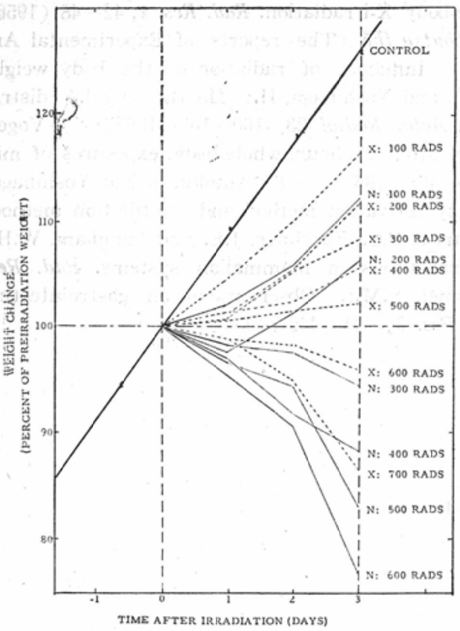

Fig. 4. Body weight curves for 3 days after irradiation.

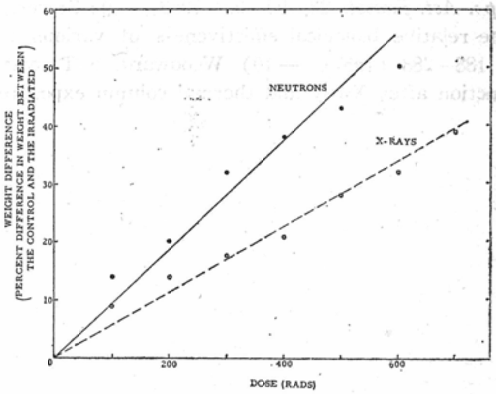

Fig. 5. The relationship of weight difference to the degree of exposure on the third day after irradiation.

X-rays $Y = 0.056X$

Neutrons $Y = 0.094X$

Body weight reduction in mice RBE $= \eta_x^n = 1.68$

A value 1.3 as the RBE of $LD_{50/30}$ of 4 weeks age male mice was estimated in this experiment. This will be described in detail in a subsequent paper. It is interesting that the RBE of the growth delay or body weight reduction is higher than that of $LD_{50/30}$. This suggests that in mice the body weight reduction appears relatively more strongly than lethality in neutron irradiation in comparison with X-ray irradiation. The reason for this will be a subject of further study in the future.

Summary

Two kinds of radiations, that is 180 kVp X-rays and 14.1 MeV neutrons, were used in this experiment. Four weeks old young male mice were irradiated and the growth delay according to body weights and body weight reductions on the third day after exposure were compared. The RBE of 14.1 MeV neutron to 180 kVp X-ray which brought about the same degree of growth delay and the same degree of body weight reduction on the third day after irradiadiation were found to be 2.21 and 1.68 respectively.

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