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RELATIVE BIOLOGICAL EFFECTIVENESS OF 31 MEV ELECTRONS, ^{60}CO GAMMA-RAYS AND 200 KVP X-RAYS MEASURED BY THE REGRESSION RATE OF SPLENIC WEIGHT IN MICE

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The relative biological effectiveness of 31 MeV electrons and ^{60}Co gamma-rays for 200 KVp X-rays as standard was determined. As indicator, the regression rate of the splenic weight of the mouse 120 hours after whole body irradiation was adopted.

When 200 KVp X-rays were chosen as standard, the relative biological effectiveness of 31 MeV electrons was 0.64 at 50% splenic regression rate and 0.72 at 60%, while that of ^{60}Co gamma-rays was 0.79 at 50% splenic regression rate and 0.78 at 60%.

INTRODUCTION

The purpose of this study is to compare the biological effectiveness of electron rays of 31 MeV betatron, gamma-rays of ^{60}Co and X-rays of 200 KVp deep therapy.

METHODS AND MATERIALS

1) *Material:* Female mice of ICR strain, 4 weeks old, were obtained from the breeding colony at the Japan Central Laboratory. Those were fed with CE-1 (feed stuff) and water for 4 weeks at our laboratory until the average body-weight became 27.2 $\pm$ 3.6 gr. About 250 mice were used.

2) *Irradiation:* Whole body irradiation[2) 9)] was performed. Two boxes having eight acrylite compartments for gamma-rays and X-rays irradiation, and three compartments for electron rays irradiation were prepared. Each mouse was placed compactly in the compartment for minimizing the amount of extraneous air space around the body. Irradiations were performed with sufficiently large fields and a maximum amount of back and side scatter[5)]. For convenience of irradiation the dose was selected from 200 to 500 rads for 200 KVp X-rays, and from 300 to 700 rads for ^{60}Co gamma rays and 31 MeV electrons. The irradiation condition was as follows.

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	200 KVp X-rays (h. v. l. 1.54 mm Cu)	^{60}Co gamma-rays	31 MeV electrons
Source-skin distance	58 cm	75 cm	100 cm
Field size	17 × 17 cm	16 × 16 cm	10 × 10 cm
Intensity	50 rads/min	50 rads/min	250 rads/min

3) *Measurement of dose:* The dose during irradiation was checked by inserting an integrating ionization chamber of Radocon (No. 601 for 200 KVp X-rays, No. 606 for ^{60}Co gamma-rays and No. 607 for 31 MeV electrons). The Radocon dosemeter was also calibrated with the Victoreen condenser r-meter[14]. The conversion factor was adopted from exposure dose (R) to absorbed dose (rads), and was 0.95 for 200 KVp X-rays, 0.97 for ^{60}Co gamma-rays[1) 6) 8) 12)] and 0.85[6)] for 31 MeV electrons.

RESULTS

The mice were sacrificed in the fifth day[3) 16)] after irradiation, and the weight of the spleen was measured. The regression rate $\left(\frac{a-b}{a}\right)$ was computed for each group irradiated, where a is the average weight of the spleen of control mice and b the average splenic wegiht of the mice irradiated. Thus, the mean weight loss of the spleen of each group was expressed as a percentage of the unirradiated controls, and the value was plotted by the rectangular coordinate system. After arrangement of the data, the method of least squares was applied to fit three straight lines[3)], corresponding to the different conditions of irradiation — namely 200 KVp X-rays, ^{60}Co gamma-rays and 31 MeV electrons (Fig. 1).

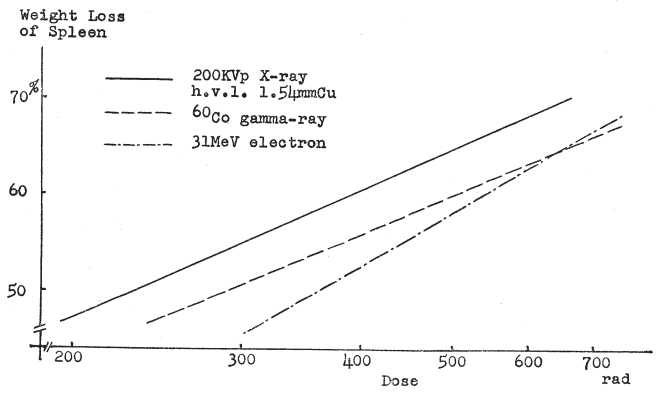

FIG. 1. Relationship between dose and regression rate of splenic weight after irradiation

The equations of the individual lines became

for 200 KVp X-rays, $y = 19.1\ x - 53.9$

for ^{60}Co gamma-rays, $y = 17.6\ x - 49.8$

for 31 MeV electrons, $y = 22.3\ x - 79.9$

From these equations, the doses, which brought about 50% and 60% weight loss of spleen, were determined. Next, the relative biological effectiveness of ^{60}Co gamma-rays and 31 MeV electrons were calculated, with the condition of 200 KVp X-rays to be 1.0.

The result was as follows:

weight loss of spleen	200 KVp X-rays	^{60}Co gamma-rays	31 MeV electrons
50%	230 rads	290 rads	360 rads
	(1.00)	(0.79)	(0.64)
60%	390 rads	495 rads	535 rads
	(1.00)	(0.78)	(0.72)

DISCUSSION

As the experimental technique is relatively easy[16], and the results considerably reliable, the regression rate of splenic weight after irradiation of mice has often been chosen as an indicator of radiation effect. However, it should be noted[3)5)16], that there are some weak points in this method. The necessity arises to use relatively large numbers of animals, while weight loss does not depend solely on the absorbed dose of the spleen, but partly due to abscopal effects after irradiation of high dose. Moreover, as the fifth day weight depends on both recovery and injury, especially with low-dose levels, the distribution of splenic weight becomes wide. In order to remove these

TABLE 1. Relative biological effectiveness of ^{60}Co gamma-rays reported, with 200-250 KVp X-rays chosen as standard

material	indicator	R.B.E.	author	
mouse	splenic weight-loss	0.7-0.8	Irie[4]	1965
mouse	splenic weight-loss	0.87	Urata[18]	1960
mouse	splenic weight-loss	0.79	Morita *et al.*	1966
mouse	testicular weight-loss	0.76	Hayakawa *et al.*[3]	1964
mouse	lethal effect	0.61	Okamura *et al.*[10]	1963
mouse	lethal effect	0.85	Sinclair[14)15]	1962
mouse	lethal effect	0.85	Paterson *et al.*[11]	1957
mouse	lethal effect	0.78	Narabayashi[7]	1966

TABLE 2. Relative biological effectiveness of electron rays reported, with 200-250 KVp X-rays chosen as standard

material	indicator	R.B.E.	source	author	
mouse	splenic weight-loss	0.5-0.7	15 MeV	Irie[4]	1965
rat	splenic weight-loss	0.77	15 MeV	Inst. Radiol.[17] Univ. Rom	1958
mouse	splenic weight-loss	0.64-0.72	31 MeV	Morita *et al.*	1966
mouse	testicular weight-los	0.87	15 MeV	Okamura *et al.*[10]	1963
mouse	lethal effect	0.74	30 MeV	Zuppinger[21]	1960
mouse	lethal effect	0.79	35 MeV	Schulz[13]	1963
mouse	lethal effect	0.74	18 MeV	Narabayashi[7]	1965
rabbit	skin reaction	0.6-0.7	30 MeV	Zuppinger[21]	1960
human	skin reaction	0.6-0.7	30 MeV	Veraguth[19]	1961

defects, as many mice as possible were used in this study. Though the conversion factor applied to electron beam varies with employed machine, in this report the value of 0.85 was used as the conversion factor[6].

When our value of relative biological effectiveness is compared with those of other previous reports (Table 1 and 2), it can be concluded that the relative biological effectiveness of 31 MeV electrons is considerably lower than 200 KVp X-rays and not higher than that of ^{60}Co gamma rays. The result was matched with analogous results of other authors.

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