Pre-exposure effect of low-dose $^{16}O^{8+}$ or γ-rays on testicular endocrine of mice*

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Abstract The testes of the B6C3F$_1$ hybrid strain mice were irradiated with 0.05 Gy of $^{16}O^{8+}$ ion /^{60}Co γ-ray as the pre-exposure dose, and were then irradiated with 2 Gy of $^{16}O^{8+}$ ion/^{60}Co γ-ray as challenging irradiation dose at 4 h after pre-exposure. The results show that irradiation of mouse testes with 2 Gy of $^{16}O^{8+}$ion or ^{60}Co γ-ray significantly diminished mouse body mass, testis mass and serum testosterone. However, pre-exposure with a low-dose (0.05 Gy) significantly reduces this kind of effect. The relative biological effectiveness of $^{16}O^{8+}$ ion was calculated with respect to ^{60}Co γ-ray for the induction of reduction in body mass, testis mass and serum testosterone to be 1.71, 1.81 and 1.42, respectively.

Keywords $^{16}O^{8+}$ion, Pre-exposure with low-dose , Endocrine capacity, Mouse testes, Adaptive response

1 Introduction

Many studies have showed that ionizing radiation with low-dose could induce adaptive response to harmful effects of subsequent high-dose irradiation exposure in various systems of the body.[1~3] Most of these studies were performed with X-rays or γ-rays. Comparing with X or γ-rays, the track of a heavy ion is complex, energy is deposited not only by the primary interaction but also by secondary electrons that may travel considerable distance from the core. This heavy ion with high linear energy transfer (LET) and high relative biological effectiveness (RBE) is also significantly more deleterious on the cellular or molecular level than low LET ionizing irradiation, such as X-rays or γ-rays. Hence, the aim of the present study is to investigate whether pre-exposure of mouse testes with a low dose (0.05 Gy) of $^{16}O^{8+}$ ion could alleviate the harmful effect on testicular endocrine capacity induced by subsequent a high-dose (2 Gy) irradiation.

2 Materials and methods

2.1 Animals

B6C3F$_1$ hybrid strain male mice (9 weeks average age) provided by Lanzhou Institute of Biological Products were used under identical breeding conditions. They were divided randomly into each group with seven animals.

2.2 Irradiation procedure

The mouse was positioned in a chamber which was fixed on the irradiation equipment at the Heavy Ion Research Facility in Lanzhou.[4] The abdomen (12 mm diameter centered the scrotum) of mouse was irradiated with $^{16}O^{8+}$ ion beam at energy 60 MeV/u and LET 70 keV/μm in the water generated from HIRFL, with high or low dose. The remainder of the body was shielded with lead plate. The acquisition of data was automatically accomplished using a microcomputer during irradiation. Doses of the beams were determined with air ionization chamber. ^{60}Co γ-ray irradiation on animal's abdomen were performed by a FTC-50H model ^{60}Co teletherapy machine (Shanghai Nuclear Equipment Factory), at a source to surface distance (SSD) of 75 cm, with high or low dose. Each kind of testes irradiation ($^{16}O^{8+}$ ion or ^{60}Co γ-ray) was divided into four groups as shown in Table 1. The challenging irradiation was performed at 4 h after pre-exposure.

2.3 Assay of body mass, testis mass and serum testosterone

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On the 35th day after irradiation, body masses of mice were recorded and the blood samples were collected by veinal sinus behind socket of eyeball. Then, the animals were killed by cervical dislocation, both the testes from each animal were dissected and weighted immediately. Serum testosterone was measured by ^{125}I-testosterone radioimmunoassay medical kit from China Institute of Atomic Energy Research.

3 Results and discussion

The effects of pre-exposure of mouse testes with a low-dose (0.05 Gy) of $^{16}O^{8+}$ ion or ^{60}Co γ-ray on body mass, testis mass and serum testosterone induced by subsequent a high-dose (2 Gy) irradiation are shown in Table 1. Irradiation of mouse testes with 2 Gy of $^{16}O^{8+}$ ion or ^{60}Co γ-ray significantly diminished mouse body mass, testis mass and serum testosterone. The RBE values of $^{16}O^{8+}$ ion was calculated with respect to ^{60}Co γ-ray for the induction of reduction in body mass, testis mass and serum testosterone to be 1.71, 1.81 and 1.42, respectively. Testosterone is the androgen produced by testicular interstitial cells—Leydig's cells, which play important roles in maintaining spermatogenesis, stimulating development of male reproductive organs and promoting the protein synthesis. Reduction in testicular testosterone production induced by high dose irradiation is due to the altering of endocrine function of Leydig's cells and other interstitial elements by affecting steroid biotransformations in these cells[5,6], which further results in diminishing of body mass and testis mass. Moreover, these effects were observed more obviously in group irradiated by $^{16}O^{8+}$ ion than in that irradiated by ^{60}Co γ-ray, suggesting that heavy ion irradiation is more deleterious to tissues than γ-ray.

Table 1 Effects of pre-exposure of mouse testes with a low dose (0.05 Gy) of $^{16}O^{8+}$ or ^{60}Co γ-ray on body mass, testis mass and serum testosterone induced by a subsequent high dose (2 Gy) irradiation

Group	Body mass/ g	Mass loss/ %	Testis mass/ g	Mass loss/ %	Serum testosterone/ nmol·L^{-1}	Percentage decrease/%
Control	35.30±1.79	0	0.212±0.007	0	1.83±0.22	0
$^{16}O^{8+}$(Gy)						
0.05	35.52±2.05	0	0.213±0.008	0	1.86±0.23	0
2	29.10±1.94[a]	17.6	0.054±0.010[a]	74.4	1.02±0.18[a]	44.3
0.05+2	34.66±1.83[c]	1.8	0.200±0.008[c]	5.6	1.70±0.20[c]	7.1
^{60}Co(Gy)						
0.05	36.49±1.88	0	0.220±0.009	0	1.92±0.17	0
2	31.67±1.87[b]	10.3	0.125±0.008[a]	41.2	1.45±0.16[b]	20.8
0.05+2	34.93±1.69[d]	1.1	0.204±0.007[c]	3.5	1.84±0.17[c]	0

Data represent mean±SEM, n=7. The differences among data of individual groups were performed with the analysis of variance (ANOVA). (a) P <0.001 vs control; (b) P <0.01 vs control; (c): P <0.001 vs 2 Gy group; (d): P <0.01 vs 2 Gy group

As shown in Table 1, pre-exposure of mouse testes with a low-dose (0.05 Gy) significantly alleviated reductions in body mass, testis mass and serum testosterone induced by a subsequent high-dose (2 Gy) irradiation. The mechanism of increased radioresistance induced by low-dose irradiation is unknown still. Increase in SOD activity and decrease in lipid peroxide level induced by low-dose ionizing irradiation suggest that the enhance of antioxidative defense capacities induced by low-dose irradiation[7,8] may be associated with this mechanism , which inhibits the oxidative damage of cell membrane lipid, proteins and nucleic acids during high-dose ionizing irradiation.[9,10]

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