CYTOGENETIC STUDY OF THE BONE MARROW AND PERIPHERAL BLOOD LYMPHOCYTES OF MONKEYS EXPOSED TO PROLONGED GAMMA-IRRADIATION

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The study of the harmful action of low-power ionizing radiation on animals is a topical direction in modern radiobiology [1, 3, 4, 8]. A study of the mutagenic activity of prolonged irradiation is particularly interesting. The first information about the cytogenetic after-effects of prolonged experimental irradiation of monkeys was obtained by the present writers for bone marrow cells [7]. The raised level of chromosomal aberrations in a proliferating tissue in the early period after irradiation was due mainly to symmetrical chromosomal exchanges. The question accordingly arises of the need to study the chromosomal apparatus in irradiated animals in different kinds of somatic cells, differing in their level of cellular proliferation, for the intensity of cell proliferation is known to play an important role in the cytogenetic effects of radiation [1].

EXPERIMENTAL METHOD

Bone marrow cells and peripheral blood lymphocytes of eight rhesus monkeys aged 2-7 years (four females and four males) served as the test object. After a general clinical examination, four monkeys were irradiated with gamma-rays from a ^{137}Cs source. The dose rate was 3.87 μA/kg, the duration of irradiation 15 h 30 min, and the total radiation dose was 7.97 Gy ($LD_{50/60}$).

The cytogenetic investigations on the monkeys were carried out after normalization of the principal clinical and hematologic parameters. Material for cytogenetic analysis was taken 4, 30, and 33 months after the end of irradiation. Treatment of the bone marrow and production of the chromosomal preparations followed the method in [6]. The peripheral blood lymphocytes were cultured as in [10] and chromosomal aberrations were analyzed by the usual method [2]. The experimental results at each time of observation were presented in the form of the total number of aberrations obtained in two or three irradiated monkeys.

EXPERIMENTAL RESULTS

Data on the frequency and types of chromosomal aberrations in the experimental monkeys are given in Table 1. The spontaneous levels of chromosomal aberrations in the bone marrow cells and peripheral blood lymphocytes of the control monkeys were 0.89 ± 0.46 and 1.33 ± 0.35 respectively. In monkeys surviving after prolonged low-power irradiation, the number of chromosomal aberrations in the bone marrow and peripheral blood lymphocytes was higher than in the control ($p < 0.01$) for 33 months. However, the frequency of chromosomal aberrations in the peripheral blood lymphocytes was higher throughout the period of observation than in bone marrow cells, and the difference was most significant 4 months after irradiation ($p = 0.01$). In the late period, the differences in the number of chromosomal aberrations in the tissues studied decreased sharply mainly due to weakening of the effect in the peripheral blood compared with the early stage of observation (4 months). The number of chromosomal aberrations in the peripheral blood 30 and 33 months after irradiation still remained higher than in the bone marrow, but the difference at these times was no longer statistically significant. The total number of chromosomal aberrations and the percentage of aberrant cells in the bone marrow of the irradiated monkeys and also in the peripheral blood did not differ significantly ($p > 0.05$).

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TABLE 1. Chromosomal Aberrations in Bone Marrow (A) and Blood Lymphocytes (B) of Monkeys after Prolonged Irradiation

Time after irradiation, months	Tissue	Number of cells studied	Acentric fragments		Asymmetrical chromosomal exchanges		Symmetrical chromosomal exchanges		Aberrations	
			single	paired	dicentrics	centric rings	translocations	pericentric inversions	total	per 100 cells
Control	A	500	3	1	0	0	0	0	4	0,89±0,46
	B	600	3	1	0	0	2	0	6	1,43±0,35
4	A	160	3	5	1	1	7	4	22[a]	13,75±2,72
	B	305	11	32	28	2	24	22	119	39,02±2,79
30	A	165	2	1	0	1	10	5	19	11,52±2,48
	B	160	3	3	1	2	11	7	27	16,88±2,96
33	A	260	1	1	0	1	8	17	28	9,28±1,8
	B	280	1	2	1	3	20	16	44[b]	15,71±2,17

Legend. a) Including one chromatid exchange, b) including one interstitial deletion.

Comparative analysis of the types of chromosomal aberrations showed that in the irradiated monkeys, unlike in the control, these were mainly symmetrical chromosomal exchanges: chromosomal translocations and pericentric inversions (Table 1). The number of single and paired fragments also was increased 4 months after irradiation. The difference compared with the control was statistically significant ($p < 0.01$). Asymmetrical chromosomal aberrations were extremely rare in the bone marrow of the irradiated monkeys. Among 160 metaphases analyzed 4 months after irradiation only one cell with a dicentric chromosome was found, and at each time of the experiment there was one cell with a centric ring.

By contrast with the bone marrow, in the peripheral blood 4 months after irradiation, there was a considerable increase not only in the number of acentric fragments, but also in the number of asymmetrical chromosomal exchanges (dicentric chromosomes) as well as aberrations of the symmetrical chromosomal exchange type (Table 1). In particular, a large number of single and paired fragments, significantly more than normally, was observed during the 4 months after irradiation. Dicentrics in the peripheral blood lymphocytes of the irradiated monkeys mainly had one pair of fragments, although simultaneously with these, there were also dicentrics with two pairs of fragments or without them. At each time of the experiment, centric rings also were found in the peripheral blood.

To sum up, prolonged low-power gamma-irradiation possesses high mutagenic activity, manifested in various types of somatic cells. The principles observed can be explained by the absence of a threshold, as a result of which any dose of radiation causes a proportional number of mutations [2]. The cytogenetic aftereffects of radiation in different tissues of irradiated monkeys between 4 and 33 months after irradiation differ quantitatively and qualitatively. The total number of chromosomal aberrations in the peripheral blood is higher than in the bone marrow, especially in the early period after exposure, and aberrations of an unstable type last longer, until 33 months at least. The results are thus evidence that even in the late period after irradiation, a certain number of peripheral blood lymphocytes will be commencing the first mitoses, in good agreement with the aftereffects of radiation on groups of the population surviving radiation loads of different kinds [5, 9, 11-13].

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