International Journal of Natural Sciences: Current and Future Research Trends (IJNSCFRT)
ISSN (Print) , ISSN (Online)

https://ijnscfrtjournal.isrra.org/index.php/Natural_Sciences_Journal/index

Influence of Different Doses of Radiation on the Behavior and Memory of Black and White Rats

Marine Nikolaishvili[a*], Tea Museliani[b], Gogi Jikia[c], Marine Nebieridze[d]

[a,b,c,d]*Ivane Beritashvili Center of Experimental Biomedicine, Tbilisi, Georgia*
[a,b,d]*European University, Tbilisi, Georgia*
[a]*Email: mantskavamaka@bk.ru*

Abstract

This paper presents the results of a study of black and white rats. The aim of this work was to study the dependence of the individual radiosensitivity of white and black rats, which were cross-bred and named Ratus Ratus-Georgia. Comparative radiosensitivity of white Wistar rats and black rats was studied under general irradiation in sublethal doses (5, 7 and 9 Gy). Radiosensitivity was determined by the cumulative functions of survival, the spectrum of changes in a number of ethological parameters, the content of serotonin and catecholamines in various brain structures. The survival rate of white and black rats is associated with changes in the content and distribution of biogenic amines in various brain structures, as well as with a decrease in locomotor and orientation-exploratory activity, on the one hand, and an increase in emotionality and stereotypical activity, on the other. After irradiation at doses of 5, 7, and 9 Gy, the regression coefficients of the dependence of the type of survival functions on the radiation dose in black rats are significantly higher than in white rats. The change in the mortality rate per unit change in the radiation dose depends on the synthesis of serotonin and on the number of sulfhydryl groups, the deficiency of which is one of the important factors for white rats. The data obtained suggest that after irradiation of rats in sublethal doses, the change in radiosensitivity is caused not only by the consequences of radiation injury, but also by the activation of the serotoninergic system during restitution after radiation injury. On the other hand, the higher radiosensitivity of white rats compared to black rats is associated with a low content of serotonin, thiols, melanin, and some other biologically active substances, which are endogenous radioprotectors that determine individual radio-resistance.

Keywords: white and black rats; biogenic amines; sulfhydryl groups; survival; open field.

1. Introduction

The current global escalation of changes in behavior and radiosensitivity is associated with natural and anthropogenic changes in the environment and with general adaptation processes of a phenotypic nature.

---

* Corresponding author.

This problem is being actively studied at all levels of the organization of biological systems, including humanitarian and social aspects. This explains the great interest of natural and social scientists in the study of neurobiological and social determinants of behavior. Currently, the most reasonable is the so-called. "Serotonin deficiency concept" of behavior manifestation. It can be provoked or stopped both by various specific pharmacological agents and by a variety of non-specific stressful effects associated with the modification of the activity of the serotoninergic system. Based on these general assumptions, one would expect that white and black rats would differ in radiosensitivity. This work is devoted to the experimental verification of this assumption in order to reveal the dependence of individual radiosensitivity and behavior.

2. Materials and methods

Experimental animals

The experiments were carried out on white rats, male Wistar rats and black rats weighing 250-270 g. Animals were bred and raised to the desired condition in the nursery of our Center and kept in the same conditions of care and free access to food and water.

Criteria for assessing radiosensitivity

The radiosensitivity was assessed by quantitative analysis and comparison of the dynamics of their mortality and average life expectancy after irradiation at various doses. Ethological parameters determined by the so-called “open field” method and conditioned reflex tests of the so-called “active” and “passive” avoidance were used as behavioral comparison criteria.

Neurochemical research

The total quantitative content of synaptic and extra synaptic noradrenaline (NA), dopamine (DF) and serotonin (5-HT) in the brain was determined by the method of highly sensitive liquid chromatography.

Development of a conditioned passive avoidance reaction

The conditioned passive avoidance reaction (CPAR) was developed in rats using the method of Essman W.B., Alpern H.P. [8] The chamber in which the experiments were carried out consisted of two chamber - light and dark, which were connected by a 5x6 cm hole. The development of the CPAR was carried out as follows. A rat was placed in the light chamber (12x20 cm), which, noticing the hole, immediately passed into a dark chamber, the floor of which was electrified. The rat received a one-time electrical stimulus (30V) that was delivered intermittently for 5 seconds. The development and retention of passive avoidance memory was checked after 20 minutes, 2 hours, the next day. If the animal did not pass from the light chamber to the dark one within one minute, then the production of passive avoidance reaction was considered preserved.

Irradiation

The total irradiation of animals was carried out on a paired RUM-17 unit under the following conditions: voltage 230 kV, current strength 15 mA, filters 0.5 mm Cu + 1.0 mm Al, skin focus distance - 60 cm, power 4.5 Gy/min, dose: 5.0, 7.0 and 9.0 Gy.

Data processing algorithms and statistical procedures

The whole complex of statistical analysis was carried out using standard and special programs implemented in the operating environments "MATLAB-6" and "STATISTICA-5".

3. Results

In this series of experiments, 15 black and white rats were tested for each of the following doses: total irradiation in sublethal doses (5.0, 7.0 and 9.0 Gy). Experiments have shown that a one-time total irradiation at a dose of 5 Gy in white rats causes a decrease in the average life span, while black rats die on average within 90.2 + 1.1 days after irradiation. The differences are statistically significant with a high probability. A similar picture is observed in the entire range (7 and 9 Gy) of doses used. (see Table 1).

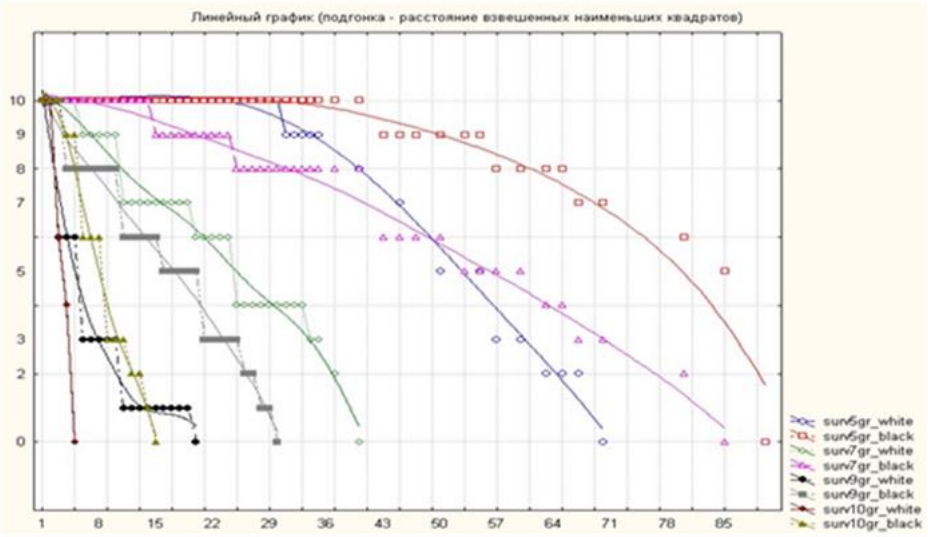

Figure 1: Total irradiation in sublethal doses of rats (5.0, 7.0 and 9.0 Gy).

To clarify the neurochemical aspects of radiosensitivity in white and black rats, the quantitative distribution of NA and 5- HT, as well as the ratio between them in white and black rats, was studied. Experiments have shown that in white rats the amount of 5-HT in the structures of the brain is statistically significantly less than in black rats.

Table 1: Distribution of biogenic amines in the brain structures in white and black rats μg / g**.**

Biogenic amines	The frontal part of hemisphere		The parietal part of hemisphere		Hippocampus	
Noradrenaline	W 0.453±0.01	B 0.488±0.024	W 0.368±0.023	B 0.377±0.016	W 0.648±0.028	B 0.612±0.032
	$\Delta_{Б-ч}$ +7.7%		$\Delta_{А-Б}$ +2.4%		$\Delta_{А-Б}$ –5.6%	
Dopamine	0.405±0.01	0.435±0.011	0.520±0.012	0.574±0.021	0.878±0.025	0.928±0.029
	$\Delta_{А-Б}$ +7.4% P <0.05		$\Delta_{А-Б}$ +10.4% P<0.05			
Serotonin	0.352±0.01	0.429±0.01	0.366±0.019	0.454±0.019	0.554±0.031	0.704±0.017
	$\Delta_{А-Б}$ +17.9% P<0.001		$\Delta_{А-Б}$ +19.4% P <0.001		$\Delta_{А-Б}$ +21.3% P <0.001	

Numerous experimental data indicate that sulfhydryl groups of endogenous substances are involved in weakening the primary processes of radiation injury. It is also known that sulfhydryl groups are included in the active center of many enzymes, they are necessary to ensure normal permeability of cell membranes, play an important role in the redox processes of the cell, etc. Therefore, the distribution of non-protein and total sulfhydryl groups in the brain of white and black rats was studied. Experiments have shown that the content of non-protein and total sulfhydryl groups in the brain in white rats is lower than in black ones. Statistical processing of the data obtained indicates the reliability of the differences noted (see Table 3).

Table 2: Content of sulfhydryl groups μM / g tissue M ± m white and black rats (n = 30).

SH-groupd	White rats	Black rats	Average difference
Non-protein sulf-	1.03 ±0.123	1.70± 0.109	0.67 ±0.161 P< 0.05
Total sulf- hydrilic	33.00 ± 1.220	37.16± 1.440	4.16± 1.151 P< 0.05

The development of a conditioned passive avoidance reaction in white and black rats was studied in the Essman and Alpern chamber. Experiments have shown that total irradiation at sublethal doses (5.0, 7.0 and 9.0 Gy) affects the formation and maintenance of passive avoidance in white rats, namely, it causes difficulties in animals and suppresses the development of a passive avoidance reaction in white rats, but does not affect black (CPAR observation - 3 months).

Thus, the results of the study give the right to state that in white rats the metabolism of some endogenous

radioprotective substances occurs differently than in black rats, and there are differences in the distribution of the content of biogenic amines (BA), and non-protein and total sulfhydryl groups of the brain. Probably, these differences determine, at least, those mechanisms that ultimately determine the differences in radiosensitivity and in the behavior of CPAR in white and black rats. The following experiments, carried out in the "open field," showed that the general pattern, namely, the number of translocations in white rats is 2 times less than in black rats (26.2±15.4 and 60.29±10.03, respectively) tentative research activity (9.14±4.07 and 15.08□4.46, respectively); as well as emotional-motivational behaviors in the "open field" in white and black animals statistically significantly differ in the number of grooming (2.57±1.82 and 4.25±1.86 and in the percentage of this time from the total testing time (0.86±0 , 73 and 6.17±3.9) and by the number of urinations and boluses (0.42±0.75 and 2□0.85). This indicates that neuroanatomical structures and neurochemical mechanisms are associated with the organization of the behavior of white and black rats. This is confirmed by the data of studies of the content, distribution and ratio of a number of biogenic amines in key neuroanatomical structures involved in the organization of behavior (see Table 4) and in the distribution of thiols.

Table 3: Behavior of white and black rats in the "open field"**.**

		Average and std. deviations		Wilks' lambda	p-level <
		White rats	Black rats		
1	Locomotor activity (m)	26,2±15,4	60,29±10,03	0.20	0.00089
2	Time of locomotor activity (s)	36,4±16	71±14,92	0.26	0.02
3	Average time of locomotor activity	0,82±0,07	0,85±0,07	0.25	0.009
4	Number of vertical standings	9,14±4,07	15,08±4,46	0.16	0.00005
5	Time of vertical standings (s)	7.74±6,86	11,8±3,72	0.23	0.004
6	Average time of vertical standings (s)	0,59±0,21	0,8±0,25	0.21	0.001
7	Amount of grooming	2,57±1,82	4.25±1,86	0.24	0.007
8	Time of grooming (s)	3,02±3	22.721±17.4	0.26	0.01
9	Average time of grooming (s)	0,86±0,73	6.17±3.9	0.22	0.002
10	Number of boluses	0,42±0,75	2±0,85	0.22	0.002

4. Discussion

Summarizing the above, we can state that, contrary to the expected, white rats are more sensitive to radiation than black ones. This is most likely related to the general metabolic status of black rats. In white rats, the specific spectrum of the content and distribution of biogenic amines in various structures of the brain, thiols and other biologically active substances participating in the determination of individual radio-resistance is low, which affects the development of a conditioned passive avoidance reaction [6-8,10,15, 21.22].

5. Conclusion

The revealed facts can, to a certain extent, be explained within the framework of the serotonin deficiency concept of the genesis of radiosensitivity and behavior.

Acknowledgments

Society of Rheology, 405133029; Popularization of Rheology Science Program (PRSP); Project "Georgian Reality: The sustainability of scientific research during the Covid-19 pandemic".

Reference

[1]. Graevskaya E.E., Parkhomenko I.M., Kudryashov Yu.B. // The role of endogenous substances in the creation of a fund of increased radioresistance. Communication 2. On the radio-protective effect of serotonin and mexamea on mammalian cells cultured in vitro. Radiobiology. 1974; 14(1):S.74-77.

[2]. Goncharenko E.N., Antonova S.V., Gorskaya T.G., Kaplya S.A., Mineeva M.F. // The role of endogenous substances in the creation of a fund of increased radioresistance. Communication 15. On the participation of serotonin in the formation of radioresistance. Radiobiology. 1981; 21(4):S.588-590.

[3]. Kudryashov Y.B., Goncharenko E.N., Antonova S.V., Akhalaya M.Ya., Bayzhumanov A.A., Shestakova S.V. // Study of the effect of sublethal doses of ionizing radiation on the endogenous background of radioresistance. Radiation Biology and Radioecology. 1997; 37(3):S.372-376.

[4]. Nadareishvili K.Sh, Iordanishvili GS,. Nikolaishvili M.I. Melitauri N.N. // Influence of parachlorophenylalanine on the distribution of biogenic amines and free amino acids in the structures of the brain. Bulletin of the Academy of Sciences of the Georgian SSR (Biologist Series). 1995; 21(1-6):S.202-207.

[5]. M.M.Nikolaishvili, G. S. Iordanishvili, T. V. Museliani, I. N. Maisuradze, G. M. Dzhikia, S. I. Zenaishvili. Radiosensitivity and aggressive behavior of rats. International conference Physiological mechanisms of regulation of the body's activity. Jubilee conference dedicated to the 130th anniversary of the birth of academician L.A. Orbeli. Yerevan 0028, Armenia

[6]. Sobolev FS, Zhamsaranova SD, Goncharenko EN, Kudryashov Yu.B. // The role of endogenous substances in the creation of a fund of increased radioresistance. Communication

[7]. Study of the effect of serotonin on the formation of lipid oxidation products in microsomes of the mucous membrane of the small intestine. Radiobiology. 1974. T. 14, No. 3, S. 353-355.

[8]. Dobrzyńska M.M., Czajka U. // Male-mediated developmental toxicity in mice after 8 weeks'exposure to low doses of X-rays. Int. J. Radiat. Biology. 2005 V. 81, N 11. P. 793 - 799

[9]. Essman W.B. Alpern H.P. Psychol. Rept. v14, p731-740, 1964

[10]. Popova N.K., Naumenko V.S., Plyusnina I.Z., Kulikov A.V. // Reduction in 5-HT1A receptor density, 5-HT1A mRNA expression, and functional correlates for 5-HT1A receptors in genetically defined aggressive rats. J Neurosci Res. 2005 Apr 15; 80 (2): 286-92.