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Biological Dosimetry of the Irradiation Emitted by NG-12I Neutron Generator

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Abstract. The aim of the present work was to carry out biological dosimetry of the irradiation generated by NG-12I system implementing the stem hemopoietic cells survival in CBA mice with the use of the test of exogenous colony formation. The rate of relative biological effectiveness (RBE) for radiation of NG-12I system, defined as a ratio of equal effective doses (in our research we used D_0), amounted to 1.53 for an acute neutron irradiation and 3.05 for a fractionated neutron irradiation. Obtained data allows defining a total dose and one fraction dose of a neutron irradiation of NG-12I system for the complex photon-neutron therapy of oncological patients.

Introduction

In accordance with current radiobiological concepts, the cell survival following the exposure to ionizing radiation depends on both cell radiosensitivity and external factors, especially on cellular oxygenation. Tumors are known to contain fraction of different hypoxic cells, and this fraction becomes noticeable even when the tumor size is approximately 1 cm^3. Hypoxia significantly reduces tumor sensitivity to radiation therapy. One of the possible ways to overcome tumor hypoxia is the use of radiation therapies, biological action of which hardly depends on tissue oxygenation. Fast neutron radiotherapy just concerns to such type of radiation therapy. Fast neutron radiotherapy has proven to be an effective form of treatment in a selected subset of tumors (salivary gland tumors, sarcomas, and locally-advanced prostate cancer), but has not proven to be more beneficial than conventional photon irradiation for the majority of tumor types upon which it has been tested. [1-3].

Clinical trials using 14 MeV neutron beam for mixed photon-neutron radiotherapy of cancer patients have been being carried out at the Ural Neutron Therapy Center since November, 1999. About 990 patients with head and neck tumors received fast neutron radiation therapy. The use of high-energy neutron beam (14 MeV) of NG-12I neutron generator for treating primary and recurrent malignant tumors demonstrated higher efficacy in comparison to conventional radiotherapy of advanced radioresistant tumors [4].

High cancer incidence rate in the Urals region and a large clinical experience in the field of integration of nuclear medicine and standard radiation therapy (1000 patients) indicate that further clinical studies of the efficacy of neutron therapy using new radiation therapy regimens are both reasonable and necessary.

The purpose of the study was to carry out dosimetry studies of neutrons emitted by NG-12I neutron generator according to the survival criterion of hematopoietic stem cells in CBA mice using exotest method in order to optimize further treatment in the Ural Neutron Therapy Center [5].

Materials and methods

The patients of The Center of Neutron Therapy of the Chelyabinsk Region Cancer Centre were receiving the photon-neutron therapy with the use of ELLIT-80 therapeutic gamma-ray unit with the dose rate of 2.51 Gy/min and gamma-ray field non-uniformity of no more than 10%, and NG-12I neutron generator with the average energy of neutrons of 10.5 MeV, the neutron dose rate of 11.5 cGy/minute, and field non-uniformity of no more than 15%.

The upgrade of NG-12I neutron generator required the determination of RBE for optimized radiation therapy of cancer patients. In the experimental study, relative biological effectiveness (RBE) of neutrons was investigated using substrates of stem cells from 750 CBA mice. Cell survival following the radiation exposure was calculated by intervals between fractions. The D_0 values for CFUs in the bone marrow of CBA mice were 0.6 Gy and 0.65 Gy for single acute neutron radiation and for fractionated neutron radiation, respectively. This indicates the absence of recovered radiation-induced injuries after the fractionated neutron radiation [6,7].

The value of the relative biological effectiveness (RBE), determined as the ratio of equally effective doses (in the study we used D_0), was 1.53 for acute fast neutron radiation and 3.05 for fractionated neutron radiation.

Results

Figure 1 and 2 show the decrease of a dose-effect curve slope for fractionated gamma-radiation in relation to that for acute gamma-radiation. The data obtained was used for the regression analysis of the dependence of stem cell survival on the radiation dose. For this purpose, the exponential model was used. Based on the estimated criteria of the exponential model, the D_0 value was calculated.

The experiment showed that value D_0 of spleen colony forming units (CFUs) in the bone marrow of CBA mice was 0.88, for single acute gamma-irradiation, and 1.99 Gy, for fractionated gamma-irradiation, thus indicating the presence of post-irradiation recovery processes, as it can be seen in the Fig.1.

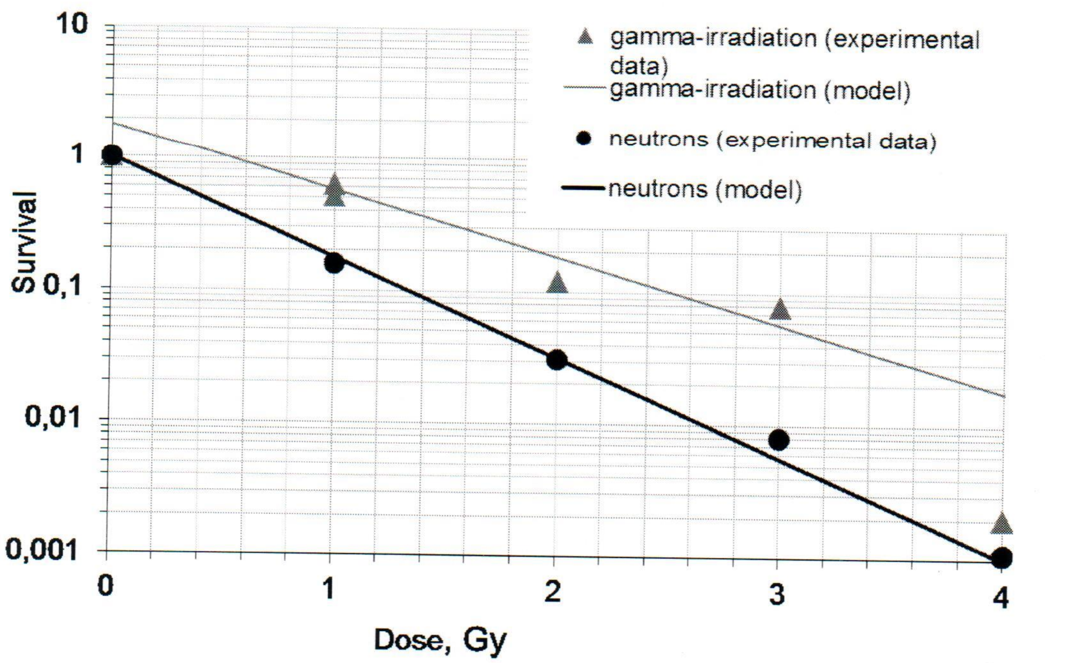

Fig.1. CFU-S survival in CBA mice marrow vs. acute and fractionated irradiation dose

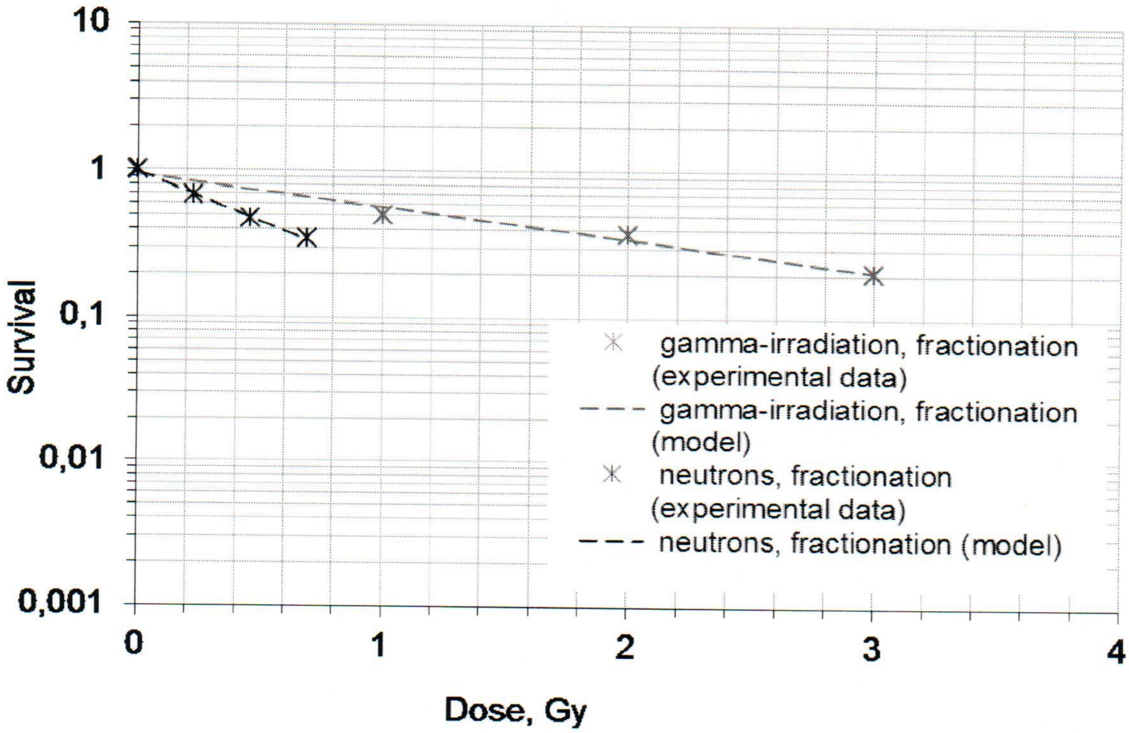

Fig.2. CFU-S survival in SBA mice marrow versus acute and neutrons-irradiation dose

Results obtained after completing the biological experiment became a wonderful "tool" for combined photon-neutron therapy optimization techniques. According to the biological dosimetry data of NG-12I neutron beam and long-term results of combined photon-neutron therapy, the experts suggested the following regimen of mixed photon-neutron therapy with an increase (up to 28%) in neutron contribution to the total radiation therapy dose (28.8 iso-Gy vs. 14.4 iso-Gy according to the previously suggested combined photon-neutron therapy program in case of malignant head and neck tumors with unfavorable prognosis).

Conclusion

The analysis of biological experiment results showed that for the new specifications of NG-12I beam, fractionated irradiation did not lead to the increase in the dose-effect rate. Based on the analysis of the previous schedule of mixed photon-neutron therapy (Ural Neutron Therapy Center clinical experience), the expediency of individual approach to the increase in neutron radiation contribution to neutron and combined photon-neutron therapies is going to be proved. The data obtained allow us to use neutron therapy more effectively both alone and in combination with photon therapy in treatment of cancer patients.

References

[1] M. Catterall, Fast neutrons in the Treatment of Cancer, Catterall, Moscow, 1979.

[2] T.W. Griffin, Fast neutrons head and neck cancer, Chichester, Washington, 1985.

[3] M.H. Maor, R.D. Errington, R.J. Caplan, Fast-neutron therapy in advanced head and neck cancer: a collaborative international randomized trial, Int. J. Radiat. Oncol. Biol.Phys. 3 (1995) 599-604.

[4] Vazhenin A.V. Ural Neutron Therapy Center. RAMN Publishing, Chelyabinsk, 2008 (in Russian).

[5] I.A. Gulidov, Y.S. Mardynsky, A.F. Tsib, A.S. Sysoev, Nuclear reactors neutrons in malignant neoplasms treatment, Medical Radiological Scientific Center of the Russian Academy of Medical Sciences, Obninsk, 2001.

[6] L.I. Musabaeva, Radiation therapy with fast neutrons of average 6.0 MeV of radioresistant malignant growths, Abstracts of thesis in medical science (in Russian), Leningrad, 1991.

[7] L.I. Musabaeva, Fast Neutrons in Oncology, NTL Publishing House (in Russian), Tomsk, 2000.