Development of neutron irradiation field for cells and small animals using cyclotron-based epithermal neutron source

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Introduction: In order to evaluate the effect of boron compounds, it is necessary to confirm the cell killing effect on cells and the antitumor effect on tumor-bearing small animals by thermal neutron irradiation. An irradiation field almost equivalent to the neutron intensity used in the clinic is required. Therefore, in this study, we are studying the method of forming thermal neutron irradiation field to cells and small animals using cyclotron-based neutron source (C-BENS). The dose rate was evaluated about thermal neutron irradiation field combining C-BENS and thermal neutron moderator. Based on the comparison with the dose rate of the KUR Heavy Water Neutron Irradiation Facility (HWNIF) that used for basic research, the validity of the irradiation field was examined.

Materials and methods: C-BENS consists of a 30 MeV cyclotron with 1 mA proton beam, a beam transport system, a beryllium target, and a moderator. Since C-BENS can only generate epithermal neutrons for clinical use, in order to irradiate cells and small animals with thermal neutrons, it is necessary to moderate epithermal to thermal neutron energy region at the beam exit. Since small animal irradiation needed to be performed in the air, a 20 mm thick PMMA was inserted into the collimator and enriched ^{6}LiF with a 100 mm hole in the center was placed behind the PMMA to reduce the dose to the whole body of the mouse. In order to increase the thermal neutron flux intensity, a 40 mm thick PMMA with a diameter of 100 mm as a reflector was placed behind the irradiation position corresponding to the tumor of the mouse.

On the other hand, as a method of performing cell irradiation, cell tubes were set in a water phantom. The collimator diameter was 150 mm, and a 200 mm square water phantom was installed. The thermal neutron flux at a depth of 30 mm was measured by gold activation methods.

Results: In the mouse irradiation field, the thermal neutron flux was 4.8 x 10^{8} (n/cm^{2}/s). The physical dose of fast neutrons was about 2.5 times higher than the mixed mode of HWNIF. For example, in the irradiation using BPA, it was confirmed that the irradiation was able to be performed because the contribution of the boron dose was large.

On the other hand, the thermal neutron flux at 30 mm depth of the water phantom for cell irradiation was 1.6 times higher than HWNIF. The fast neutron dose was also about 1.6 times higher. When the fast neutron dose per thermal neutron flux was evaluated, the irradiation field of the cells was almost equivalent to HWNIF.

Conclusion: We examined the irradiation fields of cells and small animals using C-BENS and thermal neutron moderator. The irradiation field evaluated this study showed that irradiation to cells and small animals was possible.