SAKURAI-1: Treatment planning for BNCT - from the experience of the reactor-based BNCT -

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Since the world's first clinical study of boron neutron capture therapy (BNCT) was performed using a research reactor at Brookhaven National Laboratory (BNL) in USA in 1951, more than one thousand and three hundreds BNCT studies were performed using research reactors in the world during almost seventy years as of May 2020. In the early days, BNCTs with thermal neutron irradiation were performed for malignant brain tumors. Especially in Japan, the thermal-neutron-irradiation BNCTs had been performed for brain tumors with craniotomy till 2002. In 1987, the thermal-neutron-irradiation BNCT for malignant melanoma was started in Japan. The application of the treatment planning in BNCT has started in 1994, when BNCTs with epi-thermal neutron irradiation were started for brain tumors in USA. The application of BNCT was enlarged by the epi-thermal-neutron-irradiation BNCTs with treatment planning. The applications were started for head and neck tumors in 2001, and for body-trunk tumors such as lung tumors, liver tumors, etc. in 2005. Recently, the applications were started for Paget's disease, angiosarcoma, breast cancer, etc.. In this report, the historical background and present status of treatment planning for BNCT is introduced, from the experience of the reactor-based BNCT.

In the reactor-based BNCT, the following treatment-planning systems had been used; "NCTPlan" developed by Massachusetts Institute of Technology (MIT), Harvard University and Comisión Nacional de Energía Atómica (CNEA) (used by MIT in USA, CNEA in Argentine, etc.), "SERA" developed by Idaho National Laboratory and Montana State University (used by BNL in USA, VTT in Finland, KURNS in Japan, etc.), "JCDS" developed by Japan Atomic Energy Agency, and "THORplan" developed by National Tsinghua University. Moreover, "Tsukuba-Plan" by University of Tsukuba, etc. are under development as systems applicable to the accelerator-based BNCT. Monte Carlo method is applied as the simulation method in all of these treatment-planning systems. The simulation geometry is made based on the diagnostic images by X-ray CT and/or MRI, and GTV is defined by referring to the images by ^{18}F-FBPA-PET. The inter-verification for the used nuclear-data-libraries, and the standardization for the pixel size, slice interval and slice thickness of the used diagnostic-images, are considered to be necessary.

According to the application enlargement of BNCT, various treatment protocols and treatment-planning techniques were studied. Multi-fractional and/or multi-directional irradiation is applied for some kinds of tumor and body-part, in addition to the conventional one-fractional and one-directional irradiation. The epi-thermal neutron irradiation with bolus is also applied mainly to the superficial tumors spread over relatively large area, such as meningioma, angiosarcoma, Paget's disease, etc.. The standardization for the techniques with multi-fractional and multi-directional irradiation, and bolus is considered to be necessary. The critical organs are diversified, such as oral mucosa, lung, liver, alimentary canal mucosa, etc., in addition to brain and skin. For the tolerant dose, the peak dose is used for serial organs, but the averaged dose is used for parallel organs such as lung and liver. The proper evaluation for the composition and density of the critical organs, relative biological effectiveness (RBE) and compound biological effectiveness (CBE) is important, and the standardization of the values for these parameters is considered to be necessary.