CURRENT STATUS OF THE DEVELOPMENT OF COMPACT ACCELERATOR-BASED NEUTRON SOURCE DEVICES FOR BORON NEUTRON CAPTURE THERAPY IN THE WORLD

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Boron neutron capture therapy (BNCT) has attracted attention in recent years as a treatment for intractable cancers. To perform this therapy, a high-intensity neutron source is required. Hence, clinical trials of BNCT have been conducted using research reactors so far. The recent remarkable advances in technology for the compact accelerator-based neutron source enabled us to realize the “accelerator-based BNCT” instead of the “reactor-based BNCT”. When the accelerator based BNCT is realized, patients become to be able to receive the therapy in hospitals in the world. In addition, the device can be regulatory approved, allowing BNCT to change from the clinical study stage to the insurance treatment stage.

At present, many development projects for the accelerator based BNCT are in progress worldwide. However, the major specifications of the device, such as the type of accelerator, the energy of charged particles, and the neutron target material, have not yet been optimized. Thus, various approaches for the accelerator-based neutron source are being carried because the combination of several devices constructing an accelerator-based neutron source has not been optimized. For the type of the accelerator, cyclotron, linac, and electrostatic accelerator have been adopted. Regarding target material, beryllium or lithium are being combined. Fig.1 shows a schema of accelerator based BNCT device.

Japan is ahead in this field of R&D, commercial-based treatment devices are being produced. The top runner of the development is Sumitomo Heavy Industry Co. They have succeeded to manufacture a cyclotron-based epithermal neutron source for BNCT named "Neu-Cure". The device adopted beryllium as a target material. Three devices had been installed in hospitals and institutes in Japan, clinical studies for head-and-neck cancer and malignant brain tumor had been implemented. The first clinical study for head-and-neck cancer had been conducted at Kyoto University by using a Neu-Cure in 2012. The clinical study of Phase 1 and Phase 2 had been conducted until 2019, and finally, the device had been regulatory approved in 2020. At present BNCT against recurrent head-and-neck cancer became to be received with the insurance medical care system in Japan. It is expected that the device will be approved for recurrent malignant brain tumor and malignant meningioma also in the near future. In National Cancer Center Hospital in Tokyo, a clinical study for superficial cancer including malignant melanoma is being currently performed by using a linac-based neutron source manufactured by CICS Co. a venture company for BNCT. This device combines lithium as a neutron target material and is the only device that combines a linac as a proton accelerator in the lithium target devices. iBNCT project team headed by University of Tsukuba has been developed a demonstration device of a linac-based BNCT device named “iBNCT001”. For accelerator of iBNCT001, a linac consists of an RFQ and a DLT has been adopted. The device accelerators protons of average current of 2 mA to 8 MeV and generate neutrons by irradiating the protons to a thin beryllium target. The results of several characteristic measurements indicated that the device has generated currently the highest intensity neutrons in the accelerator based BNCT device. Non-clinical test just began to perform using the device in the Autumn of 2021. The project team plan to conduct clinical study with actual patient as soon as possible based on the results of the non-clinical test. Nagoya University is also developing an electrostatic accelerator-based neutron source.

Outside Japan also, many developments for the accelerator based BNCT device are being carried out. Neutron Therapeutic Inc. as a venture company in the USA has been developed an electrostatic accelerator based BNCT device, and the first device has been installed in Helsinki University hospital in Finland and clinical study by using the device is planned. The second device of the company is being installed currently to a private hospital in Japan. TAE life science, a venture company in the USA is also developed an electrostatic accelerator-based neutron source for BNCT. They have a very international activity. In the development of the device, they have employed basic technology of an accelerator in Russia. And the first treatment device is being installed in China. The clinical study using this device is expected to begin in the near future. The second device of TAE has been announced to be installed in an institute in Italy. In addition, unique devices for accelerator based BNCT device is also being developed in Argentina, South Korea, and Chine, respectively.

In this presentation, an overview of BNCT and its history will be given briefly, and the developments for the accelerator based BNCT device that are currently being implemented around the world and the future prospects of the field will be introduced.

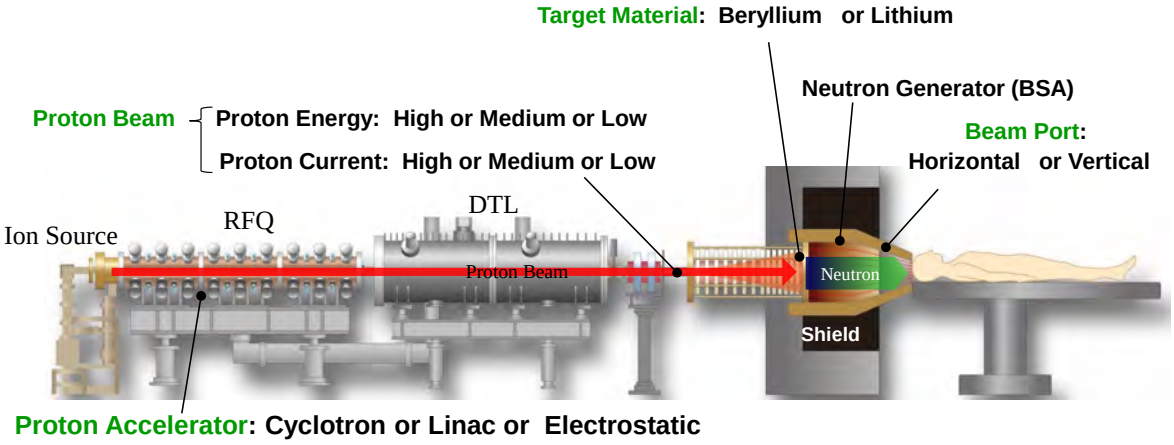

Fig.1 Shema of accelerator-based neutron source device for BNCT