

TANAKA-1: Present status of physical dosimetry of BNCT

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The dose evaluation of BNCT needs to be divided into the following four components based on the interaction of neutrons with different energies with material.

1. The gamma dose due to primary gamma rays emitted from a neutron-generating target/ a moderator and secondary gamma rays produced by the capture reaction of $^1\text{H}(\text{n},\text{g})^2\text{H}$ between thermal neutrons and hydrogen, which are constituent elements in tissues.
2. The hydrogen dose due to recoil protons produced by the elastic scattering reaction of $^1\text{H}(\text{n},\text{n}')\text{p}$ of epithermal and fast neutrons with hydrogen.
3. The nitrogen dose due to protons and recoil ^{14}C generated by the capture reaction of $^{14}\text{N}(\text{n},\text{p})^{14}\text{C}$ of thermal neutrons with nitrogen.
4. The boron dose due to charged particles generated by the capture reaction of $^{10}\text{B}(\text{n},\alpha)^7\text{Li}$ between thermal neutrons with ^{10}B .

In order to evaluate the above doses, it is necessary to derive a neutron spectrum when a treatment beam is incident on a water phantom simulating a human body. The neutron energy in the irradiation field of BNCT ranges from 10^{-9} to several tens MeV, and it is difficult to measure it over the entire energy range. Evaluation of neutron energy spectrum is performed in combination with neutron transport calculation using nuclear data by Monte Carlo simulation.

By injecting the treatment beam into the water phantom, epithermal neutrons are moderated into thermal neutrons. Obtaining thermal neutron flux distribution in a water phantom is important for deriving nitrogen dose and boron dose. The thermal neutron flux distribution is mainly evaluated using the activation method (Mn, Au, Cu). Moreover, TLD etc. are used for the measurement of the gamma ray dose distribution.

Next, the absorbed dose at each position is calculated by using the KERMA factor. Further, by using the twin ionization chamber method, it is possible to measure the neutron dose including the fast neutrons and the gamma ray dose in the water phantom. It is important to evaluate the validity of the simulation using the results of these dosimeters.

Measurement of neutron spectrum under the condition of free air without water phantom is necessary to acquire radiation source information for treatment planning system and to compare beam performance with other facilities. In the case of an accelerator neutron source, the nuclear reaction data between the neutron generating target and charged particles is needed, and it is important to verify the validity of the neutron spectrum from the target. The therapeutic beam is designed to reduce the number of fast neutrons and gamma rays as much as possible, and the neutron spectrum of the epithermal neutron beam generated from the moderator is evaluated using multiple activation foils and Bonner spheres. It is possible to evaluate the quality of neutron beam by the microdosimetry method using a tissue-equivalent proportional counter.

During commissioning of accelerator-based neutron sources, the thermal neutron flux distribution in the water phantom is used to verify the radiation source data of the treatment planning system. Data of thermal neutron flux distribution and gamma ray dose in the water phantom obtained during commissioning are used during QA.

In the treatment planning, the neutron spectrum and the gamma ray dose at each position are calculated, and after the neutron physical dose is converted by KERMA factors, the RBE equivalent dose is derived using the relative biological effectiveness for each neutron energy region and the kind of boron compounds.

In addition to the conventional BNCT dosimetry, we will introduce the BNCT dosimetry that includes a neutron spectrometer that uses a special moderator that has been recently developed, and a neutron detector that combines a small scintillator and a quartz optical fiber.