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Feasibility Study on Current-mode SPECT for B-10 Concentration Estimation in Boron Neutron Capture Therapy

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Boron neutron capture therapy (BNCT) is a promising method to treat invasive cancers. In BNCT, medicine including boron-10 (B-10) which will be delivered to cancer tissue is injected into blood vessel. With the neutron absorption reaction of B-10, two charged particles, i.e., alpha particle and Li-7, are emitted. Because the ranges of these charged particles are similar to the size of a cell, canter cells are killed by neutron irradiation. For the estimation of B-10 concentration, prompt gamma rays with 0.478 MeV in energy emitted by Li-7 are utilized. The background gamma rays, however, prevent from measuring 0.478 MeV gamma rays at the BNCT treatment facility: high flux neutrons create 2.2 MeV gamma rays by H(n, gamma)D reactions and accompanied 0.511 MeV annihilation gamma rays. For the measurement of 0.478 MeV gamma rays by photon counting method, a very thick collimator is necessary as demonstrated in Ref. [1].

For overcoming high rate background gamma rays and obtaining B-10 concentration image, we have been studying the feasibility of current-mode single-photon emission computed tomography (SPECT) with applying the principle of a "transXend"detector, which we have invented for energy-resolved X-ray computed tomography [2]. In this method, all the gamma rays are measured as electric current. After unfolding analysis, a gamma ray energy spectrum is obtained.

Because the number of annihilation gamma rays is proportional to the one of 2.2 MeV gamma rays, total number of 0.478 and 0.511 MeV gamma rays is obtained first, and the number of 0.478 MeV gamma rays, which is proportional to the B-10 concentration, is estimated.

A phantom used in the calculation was 18 cm diameter 20 cm high water with 5 cm diameter cancer with various B-10 concentrations. In the simulation study, the gamma ray energy spectrum induced by neutron reactions was calculated by PHITS code [3]. The transXend detector consisted of four TlBr segmented detectors with 5×5×10 mm3. The electric currents measured by each segmented detector were estimated. With unfolding analysis and applying a neural network method, images of B-10 concentration distribution in the phantom were shown.

[1] T. Kobayashi, et al., Med. Phys., 27, 2124 (2000).
[2] I. Kanno, et al., J. Nucl. Sci. Technol., 45, 1165 (2008).
[3] T. Sato, et al., J. Nucl. Sci. Technol., 50, 913 (2013).

Primary authors: Prof. KANNO, Ikuo (Kyoto University); Mr NISHIMATSU, Daisuke (Kyoto University)

Presenter: Prof. KANNO, Ikuo (Kyoto University)

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