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Double photon coincidence crosstalk reduction method for multi-nuclide Compton imaging

Compton imaging is one of promising imaging methods in nuclear medicine. This method is based on Compton kinematics [1] and can visualize a wide range of gamma-ray energy. Therefore, the multi-nuclide imaging capability of Compton imaging was reported in previous research [2]-[4]. A problem in multi-nuclide imaging is crosstalk artifacts on the reconstructed images of low-energy gamma-rays [5]. Sakai et al. demonstrated a crosstalk reduction method using a dual energy window (DEW) scatter correction in Compton imaging, and the artifacts could be eliminated by the DEW method [5]. In this research, we demonstrated the double photon coincidence method as another crosstalk reduction method. In the previous research, we have applied the double photon coincidence method to Compton imaging and Pb-collimation-based imaging [6]-[8]. Some nuclides emit two or more gamma-rays through metastable intermediate levels. By detecting the coincidence of Compton events, the position of a nuclide can be determined at an intersection of Compton cones. Herein, we utilized the coincidence method to reduce crosstalk caused by gamma-rays from other nuclides. By detecting coincidence between photo-absorption events and Compton events (Figure 1), the crosstalk can be reduced although the position of a nuclide cannot be determined.

We have developed a ring-type Compton imaging system, which consists of eight Compton cameras (Figure 2 (a)). A Compton camera comprises a scatterer and an absorber, which are 8×8 array of high-resolution type GAGG scintillators coupled with 8×8 array of silicon photomultipliers. The pixel sizes of a scatterer and an absorber are 2.5 mm × 2.5 mm × 1.5 mm and 2.5 mm × 2.5 mm × 9 mm, respectively. Charge signals from SiPMs were processed by the dynamic Time over Threshold (dToT) method in parallel and converted from analog signals to digital signals of the time width [9]. These digital signals were acquired by a field-programmable gate array (FPGA, Xilinx Artix7) based data acquisition (DAQ) system with 1.0-ns accuracy as list-mode data. The intrinsic time resolution of this system is approximately 50 ns. For the demonstration, approximately 0.2 mL of 111InCl3 (0.73 MBq) and 177LuCl3 (7.3 MBq) were dispensed into 0.5 mL micro tubes, individually (Figure 2 (b)). Both nuclides are double photon emitters and used in nuclear medicine. 111In emits cascade gamma-rays with energies of 171 keV and 245 keV with 84.5 ns time constant. 177Lu emits cascade gamma-rays with energies of 208 keV and 113 keV with 0.5 ns time constant. The measurement time was approximately 12 hours. In analysis, coincidence events between a scatterer and an absorber were extracted as Compton events used for Compton imaging. Moreover, coincidence events of a Compton event and a photoelectric effect event (171 keV gamma-ray events for 111In, 113 keV gamma-ray events for 177Lu) were extracted to reduce crosstalk. Time windows were ±100 ns for 177Lu and from -50 ns to 250 ns for 111In.

Figure 3 shows energy spectra of sum of deposited energies in the scatterer and the absorber. By taking double photon coincidence, the background Compton events were reduced and peaks of 245 keV or 208 keV Compton events can be clearly seen. The signal-to-background ratio (SBR) and absolute detection efficiencies were shown in Table 1. SBRs were calculated as the ratio of the number of Compton events that are used for reconstruction with energy selection in Compton events that are not used for reconstruction. SBRs were approximately 1.4 ˜ 1.8 times increased although the detection efficiencies of double photon coincidence method were ˜10ˆ2 smaller than those of single photon method.

In this research, we demonstrated the double photon coincidence method to reduce crosstalk by taking coincidence of a photoelectric absorption event and a Compton event. Background events were reduced in the spectra of sum of deposited energies in the scatterer and the absorber and SBRs were increased. This coincidence method is useful to reduce the crosstalk. We will report the detail including imaging results in conference.

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