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Segmentation Effect of the Absorber Detector on the Imaging Resolution of a Compton Camera

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1. Introduction

Compton camera, which is a novel radiation imaging device based on Compton kinematics and gamma-ray tracking, uses electronic collimation and has several advantages over the current imaging devices in nuclear medicine and molecular imaging [1-4]. Currently, however, the imaging resolution of the Compton camera is not sufficient for medical imaging applications which require ~5 mm (= FWHM) of resolution. In a previous study [5], we found that the segmentation of the component detectors, especially the absorber, is the main detector parameter which dominantly affects the imaging resolution of the Compton camera. To this end, this study quantifies the variation of the imaging resolution of the Compton camera as a function of the interaction position resolution of the absorber. The simulation study was performed by using the GEANT4 simulation toolkit [6].

2. Methods and Results

2.1 Method

The Compton camera (Fig. 1) considered in this study is composed of two planar type position-sensitive detectors, i.e., a double-sided silicon strip detector (DSSD, 5x5x0.15 cm^3) as scatterer and a 25-segmented germanium detector (25-SEGD, 5x5x2 cm^3) as absorber [7]. The scatterer determines the location of the Compton scattering and the deposited energy in the scatterer, while the absorber determines the location and energy of the absorbed photon in the absorber. The interaction positions in these detectors must be determined as accurately as possible in order to increase the resolution of a Compton camera.

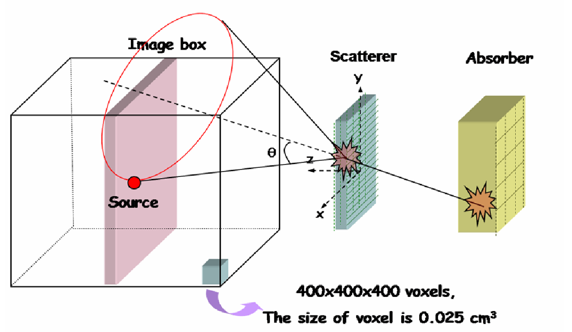

Fig. 1. Diagram of the Compton camera with a back-projected cone for image reconstruction

The scatterer, which has 16 orthogonal strips on each side, has the interaction position resolution of 0.3x0.3x0.15 cm^3 and, therefore, hardly affects the imaging resolution of the Compton camera. On the other hand, the segment size of the absorber is relatively large (i.e., 1x1x2 cm^3), which significantly deteriorate the imaging resolution of the Compton camera.

In this study, the imaging resolution of the Compton camera was quantified as a function of the interaction position resolution of the absorber, by using the GEANT4 detector simulation toolkit. Considered are five different cases in the segmentation of the planar direction or XY direction (i.e., 5x5 segmentation, 10x10 segmentation, 16x16 segmentation, 20x20 segmentation, and 32x32 segmentation) and five different cases in the axial direction or Z direction (i.e., 2 cm Δz, divided into 2, 4, 10, 20 identical segments), totaling 25 cases.

The simulation of the Compton camera was performed under the following conditions. A point source of ^{18}F, which is widely used for positron emission tomography (PET), is located at 6 cm from the surface of the scatterer. The inter-detector distance, between the scatterer and absorber detectors, is 5 cm. The imaging resolution of the Compton camera is evaluated in terms of full width at half-maximum (FWHM) of the Compton image for the point source.

2.2 Results

Figure 2 shows the imaging resolution of the Compton camera for different segmentations of the absorber. The result shows that the imaging resolution of the Compton camera is significantly improved with the improvement of the interaction position resolution of the absorber. If the interaction position resolution of the absorber is improved to 16x16 segmentation in the planar direction (i.e., Δx = Δy = 0.3 cm) and 4 segmentation in the axial direction (i.e., Δz = 0.5 cm), the imaging resolution of the Compton camera is improved from 9.2 mm FWHM, which is the imaging resolution of the current system, to 5.1 mm FWHM.

Figure 3 compares the Compton camera images, which were reconstructed with weighted backprojection algorithm, for the case of the current system (5x5 segments with Δz = 2 cm) and the case of the improved system (16x16 segments with Δz = 0.5 cm). The result show the imaging resolution of the Compton camera is significantly improved by increasing the position resolution of the absorber to the mentioned level.

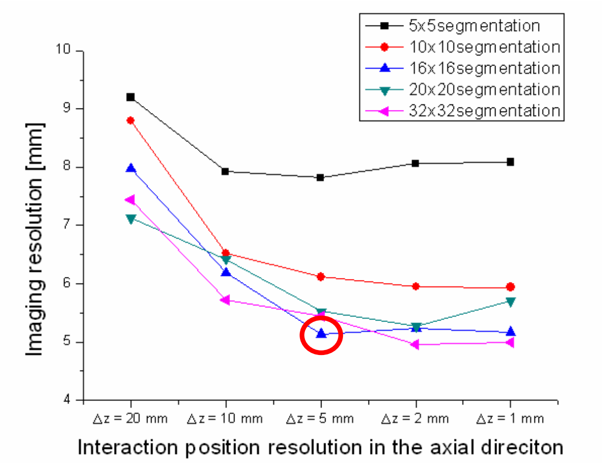

Fig. 2. Imaging resolution of the Compton camera for different segmentations of the absorber

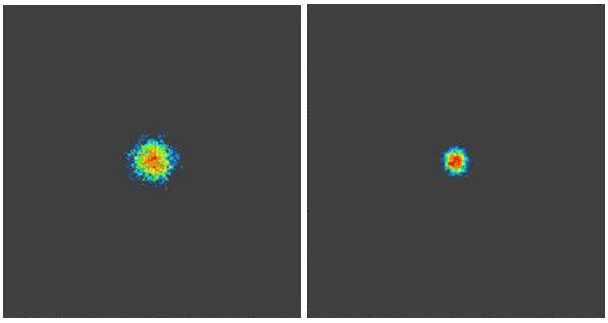

Fig. 3. Compton camera images for the case of current system (left) and the improved system (right)

3. Conclusion

Detector simulation was performed with the GEANT4 simulation toolkit to quantify the effect of the segmentation of the absorber on the imaging resolution of the Compton camera. The results shows the imaging resolution of the Compton camera can be significantly improved by using the absorber which has much segment size, i.e., 16x16 segmentation in the planar direction and 4 segmentation in the axial direction.

The result shows how much we need to improve the interaction position resolution of the absorber in the actual measurement to achieve the imaging resolution required in medical applications. Theoretically, for higher imaging resolution, we need to determine the interaction positions in the absorber as precisely as possible. This will, however, result in higher cost in terms of time, expense, and efforts. In addition, if the segmentation of the detector has less influence than the other detector parameters such as Doppler energy broadening and the energy resolution of the detectors, any additional efforts to increase the position resolution of the absorber will not be necessary.

Acknowledgement

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