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Effect of Detector Parameters on the Image Quality of Compton Camera for 99mTc

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The Compton camera, which uses a new concept of collimation, i.e., electronic collimation, has a bright future as a medical imaging device considering its simplicity and inherent 3D image capability. Currently, however, the spatial resolution of the Compton camera is not sufficient for medical imaging. In this study, we investigated the effect of various parameters in Compton camera on image quality by using a general purpose Monte Carlo simulation package GEANT4. This study focused on the low energy gamma source, 99mTc, which emits 140 keV gammas. This study modeled a Compton camera which consists of two plane-type position-sensitive detectors: a double-sided silicon strip detector (DSSD, 5 x 5 x 0.15 cm3) as scatterer and a 25-segmented germanium detector (25-SEGD, 5 x 5 x 2 cm3) as absorber. The distance between the scatterer and absorber is 5 cm. This study modeled a 99mTc point source at 6 cm from the scatterer. The Compton camera was modeled very realistically in this study including all the details of the Compton camera such as Doppler energy broadening, detector energy resolution, detector segmentation, energy discrimination, etc. This study used the PENELOPE physics model in GEANT4 to accurately model the Compton scattering including atomic binding effect and Doppler energy broadening. The energy resolution of the scatterer and absorber detectors was simulated based on the measured data, but assuming ideal Gaussian distribution of the peak in the energy spectrum. The developed model simulates 20 keV and 10 keV energy discrimination level for the scatterer and absorber, respectively. Our result shows that segmentation of the detectors (especially, the 25-SEGD detector) significantly affects the spatial resolution of the Compton camera (FWHM = 1.7 cm for a point source). The Doppler energy broadening and detector energy resolution results in FWHM of 0.8 cm and 0.9 cm, respectively. The energy discrimination of the detectors was found to significantly affect both the sensitivity and spatial resolution. Our result suggests that a higher energy gamma source (e.g., 18F emitting 511 keV annihilation photons) should be used for Compton camera imaging. The use of higher energy gamma sources will significantly improve the spatial resolution of the Compton camera, nearly eliminating the effect of Doppler energy broadening and detector energy discrimination. It will also significantly reduce the effect of the detector energy resolution. The detector segmentation should be reduced down to a few mm or less to achieve the spatial resolution of 0.5 cm required in medical imaging. We believe that the 25-SEGD detector should be replaced with a more sophisticated detector such as a double-sided strip germanium detector or a stack of DSSD detectors.

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