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Modeling High Energy (I-131) Pinhole Collimator for Small Animal Gamma Camera by Monte Carlo Simulation

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1. Introduction

In medical nuclear imaging, I-131 takes important role in not only the diagnostic image, but also the quantitative evaluation in nuclear medicine therapy. However, due to the relatively high energy peak of I-131[364 keV (82 %), 326 keV (0.27 %), 503 keV (0.36 %), 637 keV (7.18 %), 643 keV (0.22 %), 723 keV (1.77 %)], it is difficult to construct high resolution, high sensitivity preclinical gamma camera. Especially, 637 keV, 723 keV energy, penetration and scattering occur in relatively high possibility. In this manner, penetration and scattering of high energy gamma ray in collimator degrades image quality fatally. According to the characteristics, it is essential to design collimator which can minimize the degrading factor, and preserve the gamma ray for imaging at the same time. In this study, we designed and simulated the structure of pinhole collimator for a small animal high energy gamma camera by Monte Carlo simulation (GATE 6.0). In this model, the diameter, channel length of pinhole and the thickness of collimator are the main issue for determining the system sensitivity. Thus, in this study, we observed the difference in the number of photons on the scintillator which pass through the collimator that determined by those three factors.

2. Methods and Material

In this study, a point source is set as 1mm diameter, and describe the variation of energy peaks [364 keV (82 %), 326 keV (0.27 %), 503 keV (0.36 %), 637 keV (7.18 %), 643 keV (0.22 %), 723 keV (1.77 %)]. The total activity is 0.1mCi (3,700,000 Bq). For collimator material, tungsten (W) is selected. It is appropriate to high energy radiation shielding material because of its high density (ρ = 19.24gm/㎥) and atomic number(Z = 74). To fix the magnification as 1:1, the distance between collimator center to scintillator surface and to source center is equalized.

2.1 Parameter of Pinhole Collimator & Design

The simulation is executed with three parameters, collimator thickness, pinhole diameter and pinhole channel length. 20~50 (mm) collimator thickness, 0.5, 1, 2, 4 (mm), pinhole sizes and 2.4~3.6 (mm) channel length are selected independently to simulate the collimation efficiency. When these parameters are changing separately and the distances set certain value, the field of view (FOV) is also varying. But in this simulation the aim is examine the collimator efficiency, the distance parameters are fixed. The diameter of pinhole on collimator surface is calculated by this equation 1. 50x50x50 (mm) NaI(Tl) scintillator is used to count whole photons regardless of the energy.

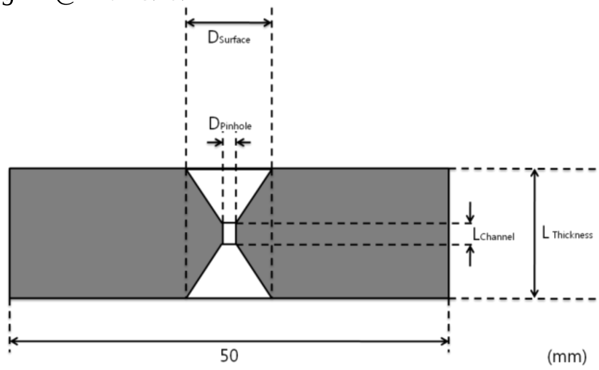


Fig. 1. Cross-section of collimator.

$$D_{Surface} = \frac{L_{Thickness} \times D_{Pinhole}}{4 \times L_{Channel}} \quad (1)$$

3. Results

3.1 Sensitivity on Channel length and Collimator thickness

Figure 1 shows the number of photons detected on scintillator due to the collimator thickness and pinhole channel length pinhole channel length changes from 2.4 mm to 3.6 mm, the minimum count rate, in 0.5 mm diameter of pinhole, 0.05 % is achieved when the channel length is 3.6 mm and collimator thickness is 50 mm. The maximum count rate, in same diameter of pinhole, 0.37 % is achieved when the channel length is 2.4 mm and collimator thickness is 20 mm. Moreover, when collimator thickness is 20 mm, 0.35 % of count rate is showed on average. As collimator thickness are varied from 30 mm, 40 mm, and 50 mm, counting rate of quantum efficiency are shown as 0.17 %, 0.12 %, and 0.07 % respectively. In case of 1mm diameter of the pinhole, the minimum count rate 0.22 % is achieved when the channel length is 3.6 mm and collimator thickness is 50 mm. The maximum count rate 0.69 % is achieved when the channel length is 2.4 mm and the collimator thickness is 20 mm. Moreover, when collimator thickness is 20 mm, 0.56 % of count rate of quantum efficiency is showed on average. As collimator thickness are varied from 30 mm, 40 mm, and 50 mm, counting rate of quantum efficiency are shown as 0.41 %, 0.34 %, and 0.29 % respectively.

3.2 Sensitivity on Pinhole diameter & Collimator thickness

The number of photon depends on the diameter of pinhole and thickness of collimator. And figure 2 shows the tendency. When pinhole channel length become longer, generally count rate is also increase. And over 2 mm diameter, increase tendency of counts are slower

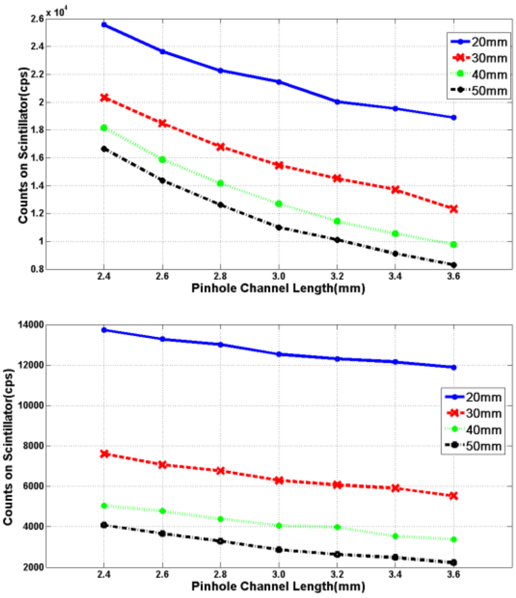
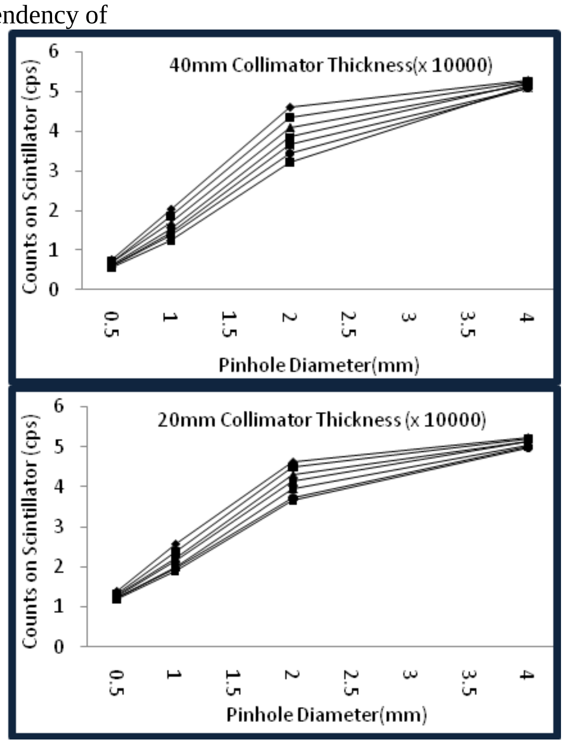


Fig. 2. 0.5 mm & 1 mm Count rate difference due to collimator thickness and channel length

than before. This phenomenon appears when channel length is short and collimator thickness is thin. Moreover, the thicker collimator shows bigger difference of count rates by the channel length.

3. Conclusions

In regard of average count rate of quantum efficiency, the value of 0.5 mm pinhole diameter is effective because of the variation is not large. But in 1 mm pinhole values, variation between different channel lengths on average count rate is relatively large. As a result, it is not reliable to use average count rate as a represents. When pinhole channel length become longer, generally count rate of quantum efficiency is also increase. And over 2 mm diameter, increase tendency of



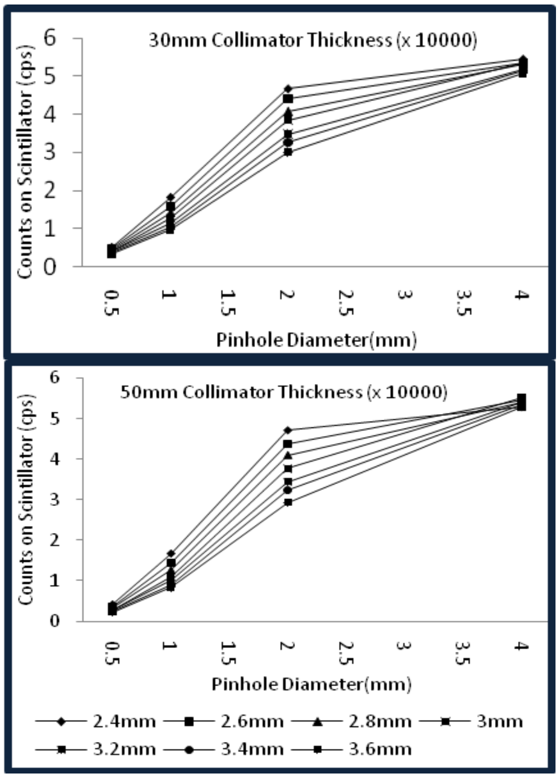


Fig 3. The number of photon depends on the diameter of pinhole and thickness of collimator

counts are slower than before. This phenomenon appears when channel length is short and collimator thickness is thin. Moreover, the thicker collimator shows bigger difference of count rates by the channel length.

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