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CONTRIBUTION OF COMPTON SCATTERING IN MULTIPLE ENERGY BRAIN SPECT USING ^{67}Ga

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INTRODUCTION

To reconstruction a quantitative image in SPECT using Ga-67, it is important to subtract the counts of scatter contribution photons from those of photons acquired with a scintillation camera. The scatter subtracted data can yield a quantitative SPECT image by performing an attenuation correction for the scatter subtracted data which consist of primary photons. We attempted to improve the image quality of brain SPECT using Ga-67, in which the radiation field arising from the complex geometry of the skull bone and soft tissue was administered with the radioisotope emitting photons of four different energies (93keV, 184keV, 300keV, and 394keV) . In the Ga-67 SPECT study, Compton photons by high-energy primary photons enter the energy window of the low-energy photopeak, leading to an increased count in this photopeak window. The count is also affected by Compton photons resulting from low-energy primary photons.

In our study, We developed a Monte Carlo simulation code to determine the relative contribution of Compton-scattered photons to the three energy-windows set at 93keV, 184keV and 300keV. Simulation cylindrical phantoms consisting of water and calcium have been used [1] . Our experimental phantom comprised an elliptical skull bone model, consisting of $CaPO_3$ (85%), $CaCO_3$ (10%), $MgCO_3$ (1.5%) and many other minor constituents. In this model, the measurement geometry is strictly prescribed so that the MEGP collimator is assumed to be a hexagonal . Using this simulation code we accurately determine the contribution of higher-energy photons.

METHOD

In our model of the brain SPECT Ga-67, we assumed the four photopeak energies to be 93keV, 184keV, 300keV and 394keV. Figure 1 shows the elliptical skull bone phantom used in the simulation. In this phantom, the distributions of activity per Bq is uniform in water. In the simulation, the Monte Carlo (Monte Carlo N-Particle Transport Code System : MCNP4B) method was used to calculate the energy spectrum at various values for bone thickness, bone density and projection angle. In the simulation, the skull bone thickness was varied from 0.0∼2.0 cm, bone density was set to 1.50g/cm^3, 1.70g/cm^3 or 1.90g/cm^3, and the angle was set to 0 degree, 45 degree, or 90 degrees. The simulation was performed separately for 93keV, 184keV, 300keV and 394keV in each case, and specified window was obtained by integrating the energy spectrum. We assumed that the acquisition efficiency of the scintillation camera used for detection 100%. To examine the energy resolution (FWHM) of the scintillator, we used Ga-67 photons with energies of 93keV, 184keV and 300keV, which correspond to 12%, 9.2% and 8.5% of the photopeak energy, respectively. We considered Compton scattering, coherent scattering, and the photoelectric effect to determine the interaction of the photons with water. In addition, we compared the photon cross-section data obtained by 「mcplib02」 simulation method with the evaluated nuclear data file. The histories of 100 000 000 samples were used to calculate of probability distributions of absorbed energy caused by four energies. Using this simulation code we accurately determined the contribution of higher energy photons to each of the three energy windows.

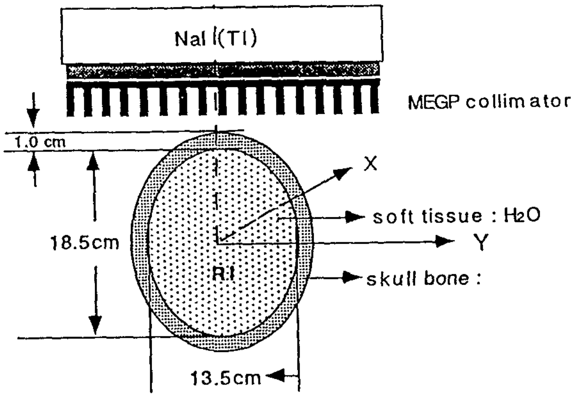

Fig.1 Geometry of the computed simulation at angle.

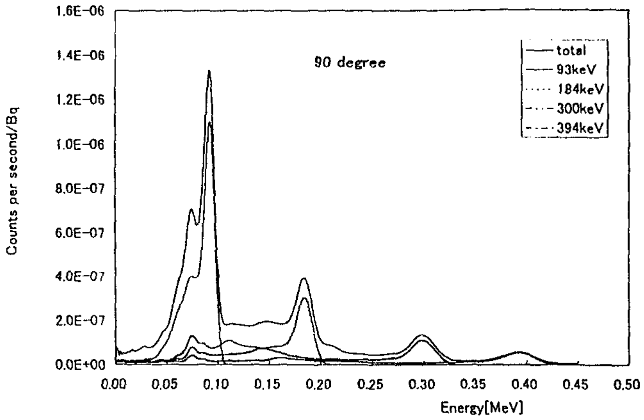

Fig.2 The energy spectra of the Ga-67 in skull phantom

RESULTS

Figure 2 shows the results of the simulation using the skull bone phantom at 90 degrees. In this figure, the energy spectra of the primary photons, Compton scattered photons, and total photons are clearly shown. The projection angle is graphically shown in Figure 2 . The projection data of the primary photons, total photons and Comptons scatter contribution were acquired with a 20% window centered at each photopeak energy (93keV, 184keV, 300keV) as shown in Figure 3(a)(b). The results showed that the relative contribution depended on the photon energy, the thickness of skull and its width of radiation source, but howed little relationship with bone density. For example, at a skull thickness of 1.0 cm and a bone density of 1.70 g/cm^3, the relative contribution of higher-energy photons to the lowest energy window set at a width of 20% was approximately 0.16 at a 93keV energy window, 0.33 at a 184keV energy window and 0.14 at a 300keV energy window. Based on these results, for the 100 000 000 histories, the relative error of 93keV-rays was approximately 0.74%.

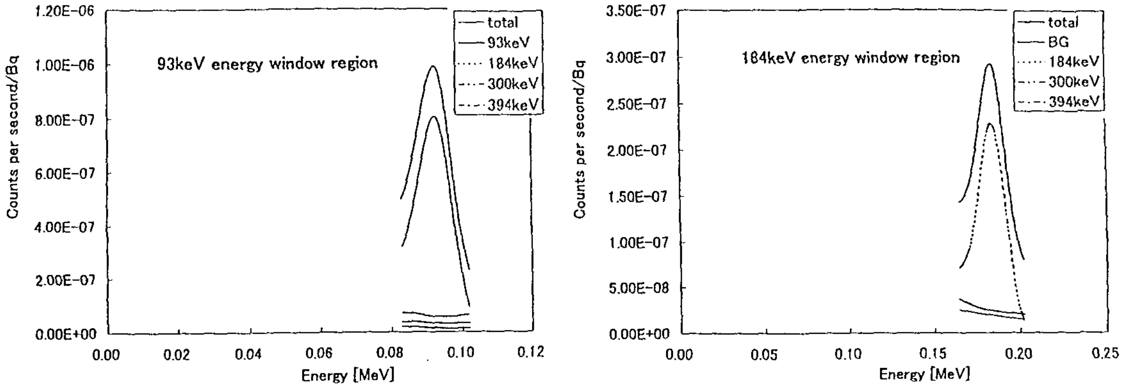

Fig. 3 The number of scatter contribution detected by energy window width 20%
(a): 93keV (b) 184keV.

DISCUSSION

A Monte Carlo (MCNP4B) simulation was performed to estimate scattered photons generated in brain SPECT using Ga-67. To accurately estimate the counts of primary photons, an energy spectrum measured with three narrow energy windows for each projection data is required. In most clinical cases, however, it is impossible to measure the energy spectrum accurately, and therefore it is hard to estimate the counts of the primary photons accurately due to the contribution of noise. The Compton scatter contribution varies depending on photon energy, the thickness of skull and object size. Based on present results, the image quality of brain SPECT using Ga-67 can be significantly improved by correcting for Compton scattering due to higher-energy photons which are determined by the Monte Carlo simulation code.

CONCLUSION

In conclusion, the contribution of the three energy window in the energy spectra of the counts of the Comton scattered photons in brain SPECT using Ga-67 study was shown by simulation. The results showed that the shape of the energy spectra depended on the photon energy, thickness of skull bone, object size, and projection angle. In clinical cases, it becomes more difficult to count low energy photos as depth increase. Thus TPEW (triple peak energy window : TPEW) [2] method becomes increasingly useful in brain measurements using Ga-67.

We are currently investigating quantitative methods to correct for sacttered photons in order to further improve the image quality in SPECT.

References

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2) Hatakeyama R, Zhiqiang HU, Tagawa N, Moriya T : Algebraic Reconstruction of Brain SPECT Images with Triple Energy.:Technical Report IEICE. 98 (135) 43-49, 1998