Characterization of Scattered Radiation in Helical CT Geometries using Monte Carlo simulations

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1. Introduction

Scattered x-ray photons caused by interactions between incident x-ray photons and object (mainly patient in diagnosis computed tomography (CT) or radiography system) severely degrade the quality of x-ray projections [1,2,3], and also affect to the radiation workers in the hospital. Therefore, it is necessary to figure out the effects of scattered x-ray photons in radiation imaging systems, 3-dimensional distribution of scattered photons are particularly important since it includes spatial characteristics of scattered photons. If this distribution has a regular patterns, scatter kernel can be obtained and further correct those from x-ray projections. Moreover, it could be utilized to protect radiation workers during CT diagnosis.

In this point, we have investigated how the scattered photons are distributed in 3-dimensional space. The effects of ASG (anti-scatter grid) to block the scattered photons are also investigated [4].

2. Methods and Materials

The particle tracking feature in MCNP (Version 5, RISCC, Oak Ridge, TN, USA) Monte Carlo simulation code has been used to trace scattered photons passing through the detector surface, and ASG if there is. Fig. 1 (a) describes the Monte Carlo simulation geometry for helical CT. To mimic a human chest for CT scanning, 24 cm thick water phantom [5] has been used which supposed to be equivalent chest thickness of 70 kg patient. Patient thickness consideration on scattering was also characterized by performing simulations with various water phantom thickness (10 cm to 50 cm).

In a clinical environment, a great part of radiography imaging systems adopting ASG since it rejects scattered x-ray photons efficiently. However, it is truth that septum in ASG blocks primary photons in a certain fraction which require more patient exposure to achieve high quality images. Therefore, it is necessary to characterize the effects of ASG. Fig. 1 (b) shows the description of ASG in which 57 modules of single ASG with 16 × 64 array were butted in an arc way and which is put on the surface of CT detector. Single ASG module of 16 × 64 pixel array is shown in Fig. 1 (c) and (d), the pitch between each septum, *p* is approximated to be 1 mm. The thickness of each septum, *t* is 100 μm, so that the effective pixel size is 0.9 × 0.9 mm^2. The height of septum, *h* is 20 mm and the consisting material is tungsten. To block the scattered x-ray, each septum in single ASG module was designed to be tilted with angle θ so that the primary x-ray can only approach the detector surface as shown in the Fig. 1 (d).

Incident x-ray photons are assumed to arrive at a center of water phantom top surface which correspond to a pencil beam x-ray. It is also designed that the primary x-ray photons which didn't interact with water phantom are blocked completely by a thick septum located at the center of ASG and is not arrived at the detector surface. Therefore, it can be assumed that detected photons are all from the scattered photons.

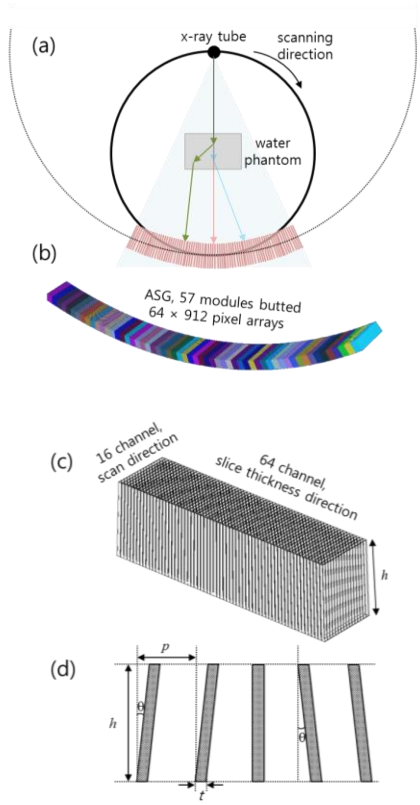

Fig. 1. Monte Carlo simulation geometry to investigate a spatial distribution of scattered x-ray photons and the effect of ASG on the surface of CT detector. (a) shows the helical CT geometry. The position of x-ray source, human chest equivalent water phantom and anti-scatter grid are shown. (b) shows the butted ASG modules in an arc way. In the (c) and (d), each ASG module has a 16 × 64 channels with 20 mm of thickness, h. The pixel size, p is 1 × 1 mm^2, the thickness of each septum, *t* is 100 μm, and the material is tungsten.

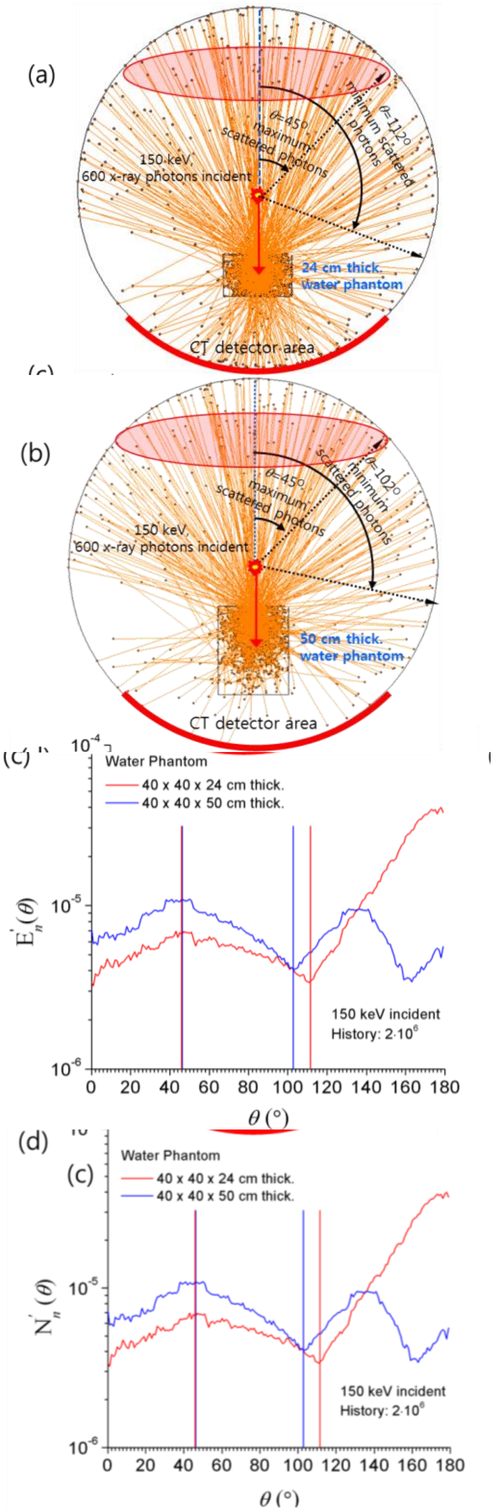

Fig. 2. Distribution of scattered x-ray photons, (a) and (c): 2-dimensional distribution of scattered photons, bc) and (d): 1-dimensional profile of scattered x-ray photon in phi direction in (a)

3. Result and Summary

Figure 2 shows the distribution of scattered x-ray photons obtained by Monte Carlo simulation. (a) and (b) shows the 2-dimensional distribution of scattered photons and (c) and (d) shows the 1-dimensional profile of scattered photons in phi direction with two different water equivalent patient thickness and 150 keV monochromatic x-ray photons.

From the results, the scattered photons cannot be ignorable in CT detector area. In addition, amount of back scattered x-ray photons is also considerable so that it can affects the radiation worker.

We investigated the effect of scattered x-photons caused by interaction between incident x-ray photons and object (mainly patient). For the study, the particle tracking feature of Monte Carlo simulation code has been used. It is shown that a substantial amount of x-ray photons were scattered in a water phantom which will affect to an image quality in helical CT. Therefore, it is highly important to understand the characteristics of scattered photons. Detailed result such as the role of ASG, SPR and KC will be announced later.

ACKNOWLEDGEMENTS

This work was supported by Samsung electronics and Radiation Technology R&D program through the National Research Foundation of Korea funded by the Ministry of Science, ICT & Future Planning.

REFERENCES

[1] J. M. Boone, and J. A. Seibert, "An analytical model of the scattered radiation distribution in diagnostic radiology," Med. Phys., Vol. 15, No. 5, pp. 721-725, 1988.

[2] W. Yao and K. W. Leszczynski, "An analytical approach to estimating the first order x-ray scatter in heterogeneous medium", Med. Phys. Vol. 36, No. 7, pp. 3145-3156, 2009.

[3] E. P. Rührnschopf and K. Klingenbeck, "A general frame work and review of scatter correction methods in cone beam CT. Part 2, Scatter estimation approaches", Med. Phys., Vol. 38, No. 7, pp. 4296-844, 2000.

[4] M. Endo and H. Miyazaki, "Magnitude and effects of x-ray scatter in a 256 slice CT scanner," Med. Phys., Vol. 33, No. 9, pp. 3359-3367, 2006.

[5] W. Huda, E. M. Scalzetti, and M. Roskopf, "Effective doses to patients undergoing thoracic computed tomography examinations", Med. Phys., Vol. 27, No. 10, pp. 838-844, 2000.