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Monte Carlo simulation of a stand-up type whole body counter using different sized BOMAB phantoms

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1. Introduction

In radiation emergency situations, there is a possibility of internal contamination. Therefore, it is necessary to assess internal contamination level to determine the need for medical intervention [1]. Whole Body Counter (WBC) is used to measure incorporated radioactive materials inside the human body. Also, WBC is standard in vivo method and used for preparedness of response to radiological emergencies [2]. To operate this equipment correctly, proper energy and efficiency calibrations must be performed [3]. WBC is usually calibrated using a Bottle Manikin ABsorber (BOMAB) Phantom, which is the industrial standard [4].

The problem occurs when the subjects to be measured have different physical characteristics (height or weight) from a phantom used in calibration [5]. In radiation emergency situations, this problem is expected to worsen because there are special populations whose physical characteristics are different from reference male, for example children and women.

The aim of this study is to resolve this problem by simulating counting efficiency of different sized BOMAB phantoms using Monte Carlo techniques.

2. Methods and Results

The WBC used in this study is FASTSCAN (Canberra, CT USA, 2250). FASTSCAN is stand-up type and uses two NaI(Tl) detectors configured in a linear array on a vertical axis. The WBC uses large area NaI(Tl) detectors (7.6 cm × 12.7 cm × 40.6 cm). Detector is shielded in all straight-line directions by 10 cm of low background steel and total weight is 4800 kg.

BOMAB phantom is a standard phantom for the calibration of whole body counting systems [4]. BOMAB phantom is composed of 10 cylinders. The part for head, chest and pelvic region is elliptical cylinder and the part for leg, thigh, neck and arm is circular cylinders. Different sized BOMAB phantom was used to simulation: 4 years old, 10 years old, reference female and reference male. The phantom size was based on data contained in ICRP Pub. 23 [6].

Monte Carlo simulations were performed with MCNPX (v.2.7.0). Energies chosen for simulation represent radionuclides used in calibrations. The radionuclides were ^{109}Cd, ^{57}Co, ^{139}Ce, ^{203}Hg, ^{113}Sn, ^{137}Cs, ^{88}Y and ^{60}Co. Each photon energy was independently run for each BOMAB phantom size. The geometry of the WBC and the different sized BOMAB phantom is shown in Fig. 1. Lower and upper detectors are located in 68 cm to 108.6 cm and 126.1 cm to 166.7 cm respectively. F8 tally was used to calculate counting efficiency. The number of photons used in simulations was 10^7 and relative error was less than 2%. The photons that interact with two NaI(Tl) detectors were tallied and the array efficiency was obtained by summing each detector efficiency.

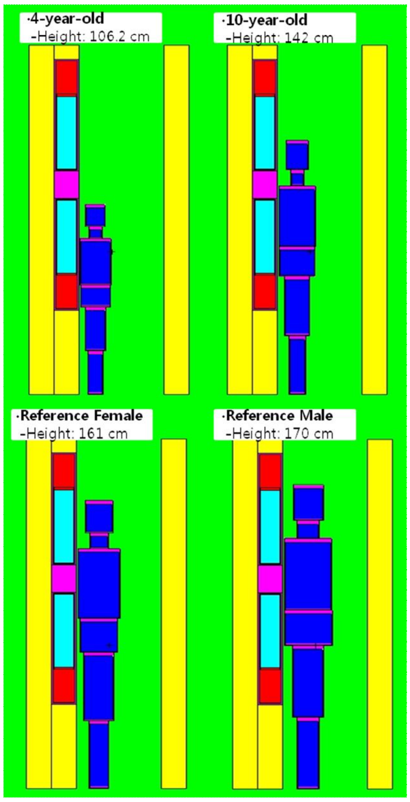

Fig. 1. Geometry of the WBC and the different sized BOMAB phantoms used for the Monte Carlo simulations.

The counting efficiencies of the BOMAB phantoms as a function of photon energy are shown in Fig. 2. The counting efficiency depended on phantom size and photon energy. These data show that the effect of phantom size on the counting efficiency is large at the lower photon energies.

This stand-up type WBC has linear geometry, so the effect of phantom size on counting efficiency is different from other study on counting efficiency of WBC [7]. In previous study, as the phantom size gets smaller, the counting efficiency increases due to the decrease in self-attenuation of the emitted photons. On the other hand, in this linear geometry WBC, 10-year-old phantom is more efficient than 4-year-old phantom because the photon emitted from 4-year-old phantom is hard to reach to upper detector. And reference female phantom becomes more efficient than 4-year-old phantom at energy above 662 keV because self-attenuation of the emitted photons gets lessening in high photon energy area.

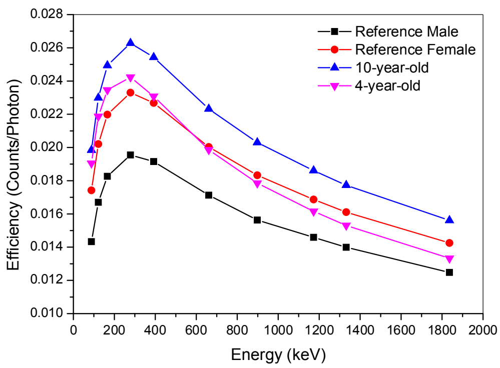

Fig. 2. Counting efficiency of the stand-up type whole body counter for different sized BOMAB phantoms as a function of photon energy.

The ratio of the counting efficiency of a different sized phantom to the reference male sized phantom is shown in Fig. 3. And it shows the effect of phantom size on counting efficiency.

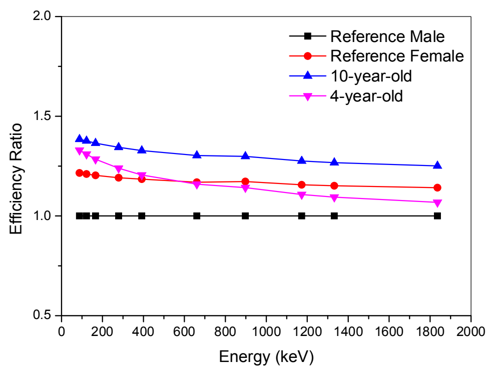

Fig. 3. Ratio of the counting efficiency of a different sized phantom to the reference male sized phantom as a function of photon energy.

These data show that if the counting efficiency of reference male was applied to measurement of person whose body is smaller than the reference male, activity estimation will be up to 1.38 times higher than true value.

3. Conclusions

The counting efficiency response of the WBC has been modeled for different sized four BOMAB phantoms using MCNPX. The stand-up type WBC has different efficiency response on phantom size since this WBC has different geometry from other scanning-type or non-linear geometry WBC.

In emergency monitoring situations, it is important to estimate activity of various sized persons. Therefore, it is necessary to apply appropriate counting efficiency according to person size. Further investigations are needed to optimize methodology for measuring small object in the stand-up type WBC.

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