Progress in NUCLEAR SCIENCE and TECHNOLOGY, Vol. 1, p.549-551 (2011)

ARTICLE

Efficiency Calibration of Bed Type Whole Body Counter Using Monte Carlo Simulations and Application to Intake Estimation of ^{131}I

Jeong-In KIM*, Byoungil LEE, Hoon CHOI, and Young-Khi LIM

Radiation Health Research Institute 388-1, Ssangmoon-dong Dobong-gu Seoul 132-703 Korea

Efficiencies of a bed type whole body scanning detector were calculated by Monte Carlo simulations. A commercially available RMC-II phantom was modeled for simulated calibration. Except for low gamma energy region, the simulation results were well matched with those of measurements. The efficiencies for measurement of I-131 intake were also calculated considering the changing of retention fraction of thyroids and whole body by the time after intake. As time passes, the intake can be overestimated by more than 50% if it was calculated using the efficiency for whole body.

KEYWORDS: whole body counter, calibration, internal dose, phantom, Monte Carlo calculation

I. Introduction

To accurately evaluate worker's internal doses, it is important to estimate the intake of radioactive materials properly. Generally, whole body counters (WBC) are used for the detection of high energy (> 200 keV) gamma ray emitters inside a human body. This equipment cannot measure the intake directly. So, the users should know the relations between measured values and intake. To know these relations, the calibration should be done using standard sources and proper phantoms represent the human body. A Bottle Manikin Absorption phantom (BOMAB)[1] is recommended for the calibration of WBC, but it is difficult to handle and takes long time. For these reasons, commercially developed phantoms are used for convenience. One of these phantoms, an RMC-II (Canberra) is widely used. This phantom can be used for the calibration to thyroids, lungs and gastro-intestinal tract as well as whole body with suitable location of a vial of standard mixed radioactive sources.

In case of the intake I-131 which has tendency to be deposited mainly on thyroids of the victims, proper measures should be taken rapidly after the intake evaluation. However, it is difficult to apply the efficiency calibration factors (ECF) of a WBC to I-131 due to the change of organ retention fractions by the time. So, the ECF of whole body may be used for conservative evaluation.

In this study, Monte Carlo simulations were carried out to calculate the efficiency of a widely used bed type whole body scanning detector. Efficiency measurements were also done for the verification. Then, the I-131 intake was estimated by considering the change of organ retention fractions in short period after intake to verify the application of an ECF of whole body to I-131 intake.

II. Materials and Methods

1. Modeling of RMC-II Phantom

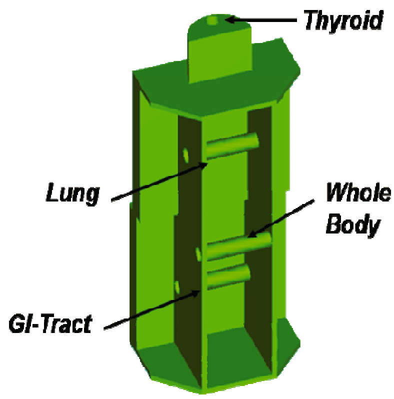

Fig. 1 Modeling of an RMC-II whole body counter calibration phantom by MCNPX

For the Monte Carlo calculations, an RMC-II phantom was modeled by MCNPX[2] which is a general purpose Monte Carlo radiation transport code designed to track many particle types over broad ranges of energies. The efficiency response with this phantom was designed to replicate the ANSI N 13.30 phantoms[3] (Livermore Lung, BOMAB total body and thyroid). **Fig. 1** shows the modeling of an RMC II phantom which has 4 holes correspond to each of calibration geometries for a single 20ml liquid scintillation vial source

2. Modeling of Whole Body Counter

The bed type whole body scanning detector (ACCUSCAN, Canberra) at Radiation Health Research Institute was also modeled. There is one HPGe (GC4019) detector equipped in the middle of the WBC to measure the gamma ray with its energy from the body. In the measurements, the bed moves by 2 m from the end line of one side to the other side.

The iron shields of each side and structures which cannot influence on detector response were ignored. **Fig. 2** shows the MCNP modeling of whole body counting with RMC-II phantom.

*Corresponding Author, E-mail: neogen21@khnp.co.kr

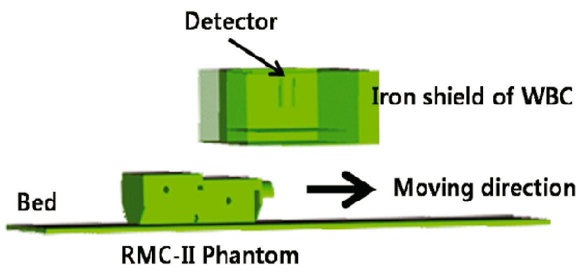

Fig. 2 Modeling of a whole body counting with RMC-II

3. Monte Carlo Calculation

For the calculation of calibration efficiencies for 4 regions, a standard mixed source whose energies are 122 keV, 166 keV, 279 keV, 392 keV, 662 keV, 898 keV, 1173 keV and 1332 keV (correspond to CO^{57}, Ce^{139}, Hg^{203}, Sn^{113}, Cs^{137}, Y^{88}, CO^{60} respectively) was inputted to be located in the middle of each holes of the phantom.

The F8, pulse height tally in MCNPX, which provides the energy distribution of pulse created in a detector by radiation was used for response of the germanium detector.

In the real measurement, the WBC scans a human body continuously. However, there is a limitation on simulating continuous movement with MCNPX. For the alternative method, the detector was put in different places and averaged over 21 points by 10cm intervals.[4)]

Table 1 Intake retention fraction of stable Iodine and I-131

Day	Stable Iodine		ICRP 78	I-131	
	W. B	Thyroids	Thyroids	W. B	Thyroids
0.75	6.12×10^{-1}	5.66×10^{-2}	-	5.99×10^{-1}	5.54×10^{-2}
0.5	4.60×10^{-1}	9.70×10^{-2}	-	4.41×10^{-1}	9.29×10^{-2}
0.75	3.61×10^{-1}	1.20×10^{-1}	-	3.38×10^{-1}	1.12×10^{-1}
1	2.98×10^{-1}	1.31×10^{-1}	1.20×10^{-1}	2.73×10^{-1}	1.20×10^{-1}
1.25	2.66×10^{-1}	1.37×10^{-1}	-	2.30×10^{-1}	1.23×10^{-1}
1.5	2.27×10^{-1}	1.40×10^{-1}	-	1.99×10^{-1}	1.23×10^{-1}
1.75	2.07×10^{-1}	1.41×10^{-1}	-	1.78×10^{-1}	1.21×10^{-1}
2	1.92×10^{-1}	1.42×10^{-1}	1.20×10^{-1}	1.61×10^{-1}	1.19×10^{-1}
2.25	1.81×10^{-1}	1.42×10^{-1}	-	1.49×10^{-1}	1.17×10^{-1}
2.5	1.73×10^{-1}	1.42×10^{-1}	-	1.39×10^{-1}	1.14×10^{-1}
2.75	1.66×10^{-1}	1.41×10^{-1}	-	1.31×10^{-1}	1.11×10^{-1}
3	1.61×10^{-1}	1.41×10^{-1}	1.10×10^{-1}	1.24×10^{-1}	1.09×10^{-1}
4	1.60×10^{-1}	1.40×10^{-1}	9.90×10^{-2}	1.06×10^{-1}	9.90×10^{-2}
5	1.46×10^{-1}	1.39×10^{-1}	9.00×10^{-2}	9.47×10^{-2}	9.01×10^{-2}
6	1.46×10^{-1}	1.38×10^{-1}	8.20×10^{-2}	8.62×10^{-2}	8.21×10^{-2}
7	1.44×10^{-1}	1.37×10^{-1}	7.40×10^{-2}	7.85×10^{-2}	7.47×10^{-2}
8	1.43×10^{-1}	1.36×10^{-1}	6.80×10^{-2}	7.15×10^{-2}	6.80×10^{-2}
9	1.43×10^{-1}	1.35×10^{-1}	6.20×10^{-2}	6.56×10^{-2}	6.19×10^{-2}
10	1.43×10^{-1}	1.33×10^{-1}	5.60×10^{-2}	6.01×10^{-2}	5.59×10^{-2}

Histories (10^8) were applied to reduce relative error < 5%. Relative error is defined to be on estimated SD of the mean divided by the estimated mean. Results with errors < 10% are generally reliable in Monte Carlo calculation.[2)] The results by Monte Carlo calculations compared with those by real measurements.

4. Calibration for I-131 Intake Measurement

Intake retention fractions of I-131 in early stage of intake were calculated and tabulated in **Table 1** using the intake retention fractions provided by ICRP 78[5)] and Charles et al.[6)]

In the real situation, it is almost impossible to apply the change of retention fraction to calibration due to the lack of suitable sources and phantoms. In the Monte Carlo calculation, this type of calibration can be achieved simply by scattering sources and adjusting the intensities. So, the efficiencies to whole body and thyroids in every 6 hours after intake of I-131 were obtained

III. Results and Discussion

Figure 3 shows the calculated efficiencies to 4 regions of RMC-II phantom. Because the probability of photon energy transfer to the detector crystal decreases as the photon energy increases, the efficiencies become lower at high photon energy regions, which is general phenomenon in gamma spectroscopy.

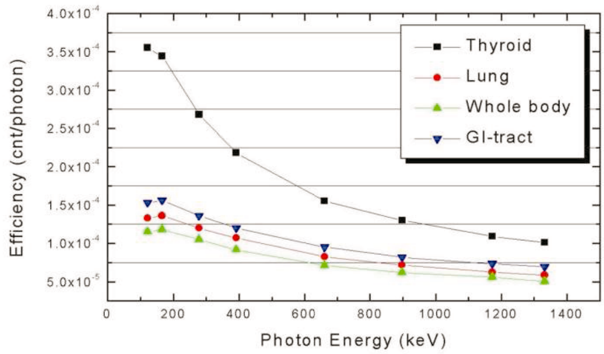

Fig. 3 Calibration efficiencies of the whole body counter for 4 regions calculated by MCNPX

Table 2 Comparison of the calibration efficiencies by MCNPX with measured values.

Energy (keV)	MCNPX/Actual			
	Thyroid	Lung	W. B	GI-tract
122	1.37	1.33	1.17	1.47
166	1.07	1.13	1.10	1.09
279	1.02	1.13	1.14	1.06
392	1.03	1.13	1.02	1.01
662	1.04	1.06	1.01	1.07
898	1.06	1.14	1.07	1.06
1173	1.06	1.15	1.03	1.06
1332	1.06	1.12	1.11	1.11

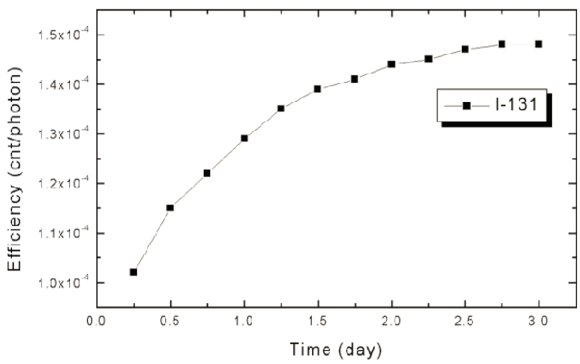

Fig. 4 The change of calibration efficiencies by the time after intake of I-131

Table 2 shows that the agreement was more than 90% between experimental scanning and simulation above 150 keV photon energy range. The I-131 gamma ray energy is 365 keV and there are no significant differences between simulations and measurements for both thyroid and whole body.

The results of efficiency calibration for I-131 intake using the retention fraction of whole body and thyroids were shown in **Fig. 4**. These calculated efficiencies correspond to the efficiencies between thyroid and whole body at 365 keV in Fig 3. In early stage of intake, the efficiency is similar to that of whole body because I-131 in a body does not move to thyroids directly but passes into whole body. As time passes, I-131 moves to thyroids but some portion of it still remains in whole body. So, the efficiency cannot reach the value of thyroid at 365 keV in **Fig 3**. Therefore, the efficiency increases gradually and becomes saturated by the time. So, the results showed that the intake of I-131 measured using whole body calibration efficiency can be overestimated about 50% as time increasing. In the same manner, it can be underestimated by applying the efficiency for thyroid.

IV. Conclusion

Efficiencies of a WBC were calculated by Monte Carlo methods and the results were verified by the real measurements. The efficiencies for measurement of I-131 intake were also calculated considering the changing of retention fraction of thyroids and whole body by the time after intake. As time passes, the intake can be overestimated by more than 50% if it was calculated using the efficiency for whole body.

References

1) American National Standard, Specifications for the Bottle Manikin Absorption Phantom, ANSI/HPS N 13.35(1999).
2) Denise B. Pelowitz, MCNPX User’s manual Version 2.6.0, LA-CP-07-1473(2008).
3) American National Standard, Performance Criteria for Radiobioassay, ANSI/HPS N 13.30(1996).
4) Gary H. Kramer, Linda C. Burns, and Steven Guerriere, "Monte Carlo Simulation of a Scanning Detector Whole Body Counter and The Effect of BOMAB Phantom Size on The Calibration," *Health Phys.*, 83, 4, 526-533(2002).
5) ICRP, Individual monitoring for internal exposure of workers replacement of ICRP publication 54, Internal Commission on Radiological Protection, ICRP Publication 78(1997).
6) Charles A. Potter, "Intake Retention Fractions Developed from Models Used in The Determination of Dose Coefficients Developed for ICRP Publication," *Health Phys.*, 83, 5, 594(2002).