A Study on the Derivation of Specific Absorbed Fraction Based on Reference Korean Organs

Jung hoon kim, Sang Won Shin, Jooho Whang
Dep. of Nuclear Eng. College of Advanced Technology, Kyung Hee Univ.,
Sochen-ri, Giheung-eup, Yongin-si, Gyeonggi-do, 449-701, rdt111@hanmail.net

1. Introduction

In case of internal radioactive contamination caused by the inhalation, ingestion, administration or percutaneous injection of radionuclides, it is necessary to evaluate adsorbed dose resulting from radiation exposure. The evaluation for internal absorbed dose and distribution of radio nuclides is defined depending on radioactive properties of source organ, quantity of radioisotope in the organ, physical disintegration, and type of radiation or energy emitted upon radioactive decay. These principles allow us to calculate specific absorbed fraction in each internal organ and evaluate internal absorbed dose in a little easier and more convenient manner[1,2]. In this study, conventional specific absorbed fraction was derived using MIRD-type phantom as mathematical one based on reference western. The specific absorbed fraction derived with MIRD-type phantom is based on the reference western, so if it is blindly applied to Koreans who typically show difference in the weight, position and configuration of internal organs from western's ones, we may fall into the error of over- or underestimation upon deriving specific absorbed fraction.

Thus, in this study, we determined specific absorbed fraction in total 9 internal organs on the basis of reference Korean using the reconstruction of mathematical MIRD-type phantom and Monte Carlo method, in the assumption that source region is identical with target region.

2. Methodology and Results

2.1 Basic Concepts of Absorbed Dose

A generic equation for the absorbed dose in an organ is:

$$D = \frac{k\tilde{A}\sum_{i} n_i E_i A_i}{m} \quad (1)$$

where D = absorbed dose (rad or Gy), $\tilde{A}$: cumulated activity (μCi h or MBq s), n_i: number of particles with energy Ei emitted per nuclear transition, Ei: energy per particle(MeV), Φi: fraction of energy absorbed in the target, m: mass of target region (g or kg), and k: proportionality constant(rad g/μCi h MeV or Gy kg/MBq s MeV). The term 'cumulated activity ($\tilde{A}$)' is given to the area under the time-activity curve for a source organ or region. Specific absorbed fraction means the value of absorbed fraction divided by the mass of target region[3].

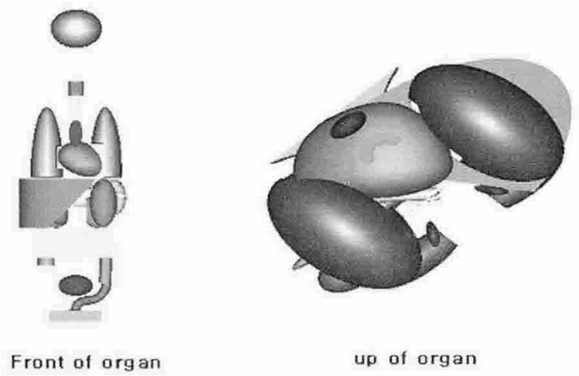
2.2 Makeup of MIRD-Type Phantom

In addition, human internal organs were made up into ellipse, cone, plane, cylinder, etc. by means of MIRD-type phantom, and each internal organ was expressed in 3-dimensional space using 2-dimensional mathematic equation. Basic data on MIRD-type phantom reflected reference person as suggested by ICRP-23. The makeup of mathematic phantom of MIRD Pamphlet No. 5 simulated erected human body. Solid figure was simulated in 3-dimensional space using orthogonal coordinates system. Z axis was specified from the feet of phantom in the direction of head, X axis was specified from the right to left direction, and Y axis was specified from front to rear direction respectively. The dimension of each axis was expressed in centimeter(cm). The generalized equation of mathematical phantom can be expressed as shown in Eq. 2. [1,4]

$$(\frac{x}{A_T})^2 + (\frac{y}{B_T})^2 \le 1, 0 \le Z \le C_T \quad (2)$$

2.3 Simulation of Mathematical Phantom for Each Internal Organ

In this study, mathematical phantom was simulated as shown in this figure in order to derive specific absorbed fraction appropriate for reference Korean by modifying MIRD-type human phantom as mathematical one, on the basis of reference Korean as suggested by Radiation Health Research Institute [5].



[Figure 1] The principal organs of the adult Phantom

The mathematical phantom embodied human body into three parts to derive the specific absorbed fraction of photon by means of Monte Carlo method. Human hands, trunk and pelvis comprised an elliptical cylinder, feet and legs comprised a circular cone, neck and head constituted an ellipse, and the top of head constituted an elliptical plane, respectively.

2.4 Calculation by Monte Carlo Method

With regard to the internal organs of mathematical human model(phantom) used in this study, their mass and build were determined on the basis of standard data collected from Korean adult men. In this study, the substances comprising internal organs were the ones as suggested by Report TM-8331, which was published by Oak Ridge National Laboratory(hereinafter called 'ORNL'). Here, it was assumed that lung, bone or skeleton and other organs consist of soft tissues, and their density is $0.296 g/cm^3$, $1.40 g/cm^3$ and $1.04 g/cm^3$ respectively. On the other hand, Monte Carlo particle transport code(NTRAN) was applied to calculating the quantity of photon transport and energy. For effective comparison with existing data, 9 internal organs were established as source and target region respectively, and the photon energy was subdivided into 10 steps to derive specific absorbed fraction by each internal organ.

2.5 Results

Source and target organs were set up as total 9 internal organs to derive specific absorbed fraction in each organ. Derived results were compared with conventional data such as MIRD Pamphlet No. 5 and TM-8381 report(Oak Ridge). It was found that the internal organs of reference Korean weighed less than those of reference western, but this result is possibly attributed to volume or mass of each internal organ. If body and organs weigh little, their absorbed fraction reaches low level, while their specific absorbed fraction reaches relatively high level, which is calculated through dividing absorbed fraction by the weight of organs.

As a result of comparing three data altogether, there were almost similar tendencies in specific absorbed fraction, but the values derived by reference Korean amounted to higher level across most energy regions.

Moreover, source organs had a tendency to absorbing relatively high energy in the low energy region because of its short photon range, while they showed relatively low absorption energy because of different transmit power near and in high energy region.

3. Conclusion

In this study, we simulated a mathematical phantom based on reference Korean adult man, and Monte Carlo method was applied to derive specific absorbed fraction. In the value of absorbed fraction, MIRD5 and ORNL showed relatively higher level than reference Korean. On the contrary, the mathematical phantom based on reference Korean adult man showed higher level of specific absorbed fraction. This may be attributed mainly to difference resulting from weight of organs and size of trunk, which all comprised phantom under simulation. The variation of specific absorbed fraction is possibly associated with medium substances, photon range and transmit power. The specific absorbed fraction derived through this study may be used as basic data for evaluating internal exposure dose, and also help make a quantitative evaluation of any potential internal exposure that may occur in the field of nuclear medicine.

Acknowledgement

This work was financially supported by MOCIE through IERC program.

REFERENCES

[1]Walter S. Snyder, Mary R. Ford, and Gordon G.Warner. "Estimates of Specific Absorbed Fractions for Photon Sources Uniformly Distributed in Various Organs of a Heterogeneous Phantom". MIRD Pamphlet No 5, revesed (1978).

[2]Pat B. Zanzonico " Internal Radionuclide Radiation Dosimetry: A Review of Basic Concepts and Recent Developments", J Nucl Med 2000;41:297-308

[3] M.G. Stabin, M Tagesson, S.R. Thomas, M. Ljungberg, S.E. Strand. "Radiation dosimetry in nuclear medicine". Applied Radiation and Isotopes 50(1999)73-87.

[4] M. Cristy and K.F. Eckerman. "Specific Absorbed Fractions of Energy at Various Ages from Internal Photon sources". ORNL/TM-8381 (1987).

[5]hanyang university "formulation of the reference Korean for radiation protection puropses" ITRS/TR-2004(2004).