HIROSAKI UNIVERSITY

Radiation Environment and Medicine 2017 Vol.6, No.2 108–111

REM
Radiat Environ Med

Technical Data

Utilization of Monte Carlo Particle Transport Simulation Code on Radiation Emergency Medicine at Hirosaki University

Kazuki Iwaoka[1]*, Masahiro Hosoda[2], Takakiyo Tsujiguchi[2], Minoru Osanai[2], Shinji Tokonami[1] and Ikuo Kashiwakura[2]

[1]*Institute of Radiation Emergency Medicine, Hirosaki University, 66-1 Honcho, Hirosaki, Aomori 036-8564, Japan*
[2]*Hirosaki University Graduate School of Health Sciences, 66-1 Honcho, Hirosaki, Aomori 036-8564, Japan*

Received 17 April 2017; revised 16 June 2017; accepted 26 June 2017

In 2015, Hirosaki University was designated as an Advanced Radiation Emergency Medicine Center and a Nuclear Disaster Medical Care/General Support Center; it thus offers critical medical treatment in radiation emergencies. The extent of radiation damage to human organs and tissues depends on radiation exposure levels. The Monte Carlo particle transport simulation code is used in radiation emergencies to estimate the radiation exposure levels. At Hirosaki University, the latest version of the Particle and Heavy Ion Transport Code System (PHITS), developed under collaboration between the Japan Atomic Energy Agency, the Research Organization for Information Science and Technology, and the High Energy Accelerator Research Organization is employed as the Monte Carlo particle transport simulation code for use in radiation emergency situations. The PHITS can estimate absorbed energy using computational materials. In this paper, practical use of the PHITS in emergency situations is demonstrated. At Hirosaki University, the PHITS will continue to be utilized for the dose calculation during emergency situations while it is updated to its latest version.

Key words: Monte Carlo particle transport simulation code, emergency medicine, dose estimation

1. Introduction

A number of radiation accidents related to research and development of atomic energy and nuclear technology have occurred globally, such as mishandling of a source, improper use of radiation generators, in addition to serious incidents and the unintended release of emissions into the environment[1)]. It is necessary to ensure the provision of adequate medical treatment during future possible incidents. In 2015, the Nuclear Regulation Authority (NRA) designated Hirosaki University as a national center in Japan for, 1) Advanced Radiation Emergency Medicine and as a 2) Nuclear Disaster Medical Care/General Support Center[2)]. Hirosaki University thus has the responsibility of providing frontline medical treatment in radiation emergencies. A number of nuclear facilities are located in the area around Hirosaki University (i.e. in Aomori Prefecture), and therefore, if a radiation or nuclear accident occurs at any of these facilities, Hirosaki University will be the last port of call offering treatment to exposed people.

Radiation damage to organs and tissues depend on radiation exposure levels. Therefore, if someone is exposed to high levels of radiation, it is important to accurately estimate the radiation exposure level[3-5)]; this

*Kazuki Iwaoka: Institute of Radiation Emergency Medicine, Hirosaki University, 66-1 Honcho, Hirosaki, Aomori 036-8564, Japan
E-mail: iwaoka@hirosaki-u.ac.jp

Table 1. Conditions for demonstration of dose calculation

Item	Calculation condition
Source	Type: point source
	Position: left hand
	Emission direction: 4 π sr
	Energy: 1MeV
	Particle: photon
Material	Phantoms: adult man (1.76 m, 73 kg)[13]
	Others: void
Calculation	History: 1000000
	Batch: 10
	Travel space of particles: X = 100, Y = 50, Z = 200 cm
	Statistical uncertainty: standard deviation among batches
Drawing	ParaView[12]

Meanings of each parameter in calculation are described in the Phits's manual[8]

is currently performed using approaches based on physical dosimetry and biological dosimetry. Physical dosimetry is performed by measuring radiation emitted from radionuclides deposited in the body (e.g., whole body counter) or by using the Monte Carlo particle transport simulation code with exposure conditions such as source intensity and geometry. Biological dosimetry is performed by measuring the variety of biological samples in the exposed person (e.g., Analysis of chromosomal aberrations in peripheral blood lymphocytes)[6]. When biological samples cannot be immediately obtained, or local radiation exposure occurs in an emergency situation, particle transport simulation is thus effective for estimating the dose. This paper presents the outline of the particle transport simulation employed for dose estimation in radiation emergency situations at Hirosaki University and demonstrates the same.

2. Particle transport simulation code at Hirosaki University

The Particle and Heavy Ion Transport Code System (PHITS) was developed under collaboration between the JAEA (Japan Atomic Energy Agency), RIST (Research Organization for Information Science and Technology), and KEK (High Energy Accelerator Research Organization)[7-10], and was employed as the Monte Carlo particle transport simulation code at Hirosaki University. The PHITS (version 2.88) is composed using FORTRAN and can simulate the transport of particles such as nucleons, photons, and electrons by using nuclear reaction models and nuclear data libraries. The 2D and 3D figures shown in simulated results are described using code ANGEL[11] or ParaView[12]. For immediate evaluation, the PHITS works well with a common note computer, although using a high-performance computer is more effective because of the higher computation speed. DICOM (a standard for handling, storing, printing, and transmitting information in medical imaging) image data of computed tomography (CT) scans, which include individual body information such as a person's physical size and the constitution of their organs and tissues, can be converted to PHITS format files, and the PHITS can thus estimate the extent of influence on the basis of individual physical size and organs/tissues constitution. In addition, the standard deviation is calculated as the statistical uncertainty in the PHITS, using variances between the tally results of each batch and the history.

3. Demonstration of dose calculation

A particle transport simulation using the PHITS was given as an example here, where the absorbed energy of human handling sources was calculated. For convenience, the shape of the source was assumed as the point source, the energy and type of radiation released from the source were assumed to be 1 MeV and photon, respectively, and the direction of the photon from the source was assumed as 4 π sr. A male adult reference computational phantom[13] was used as a virtual human body in the PHITS, and the material in spaces other than those which the phantom occupies was assumed as void. A region width (resolution) of X, Y, and Z was set up as 0.5 cm, respectively. Results from these expediency conditions with other configurations (Table 1) are shown in Figures 1 and 2. A unit of MeV/incident was used as the unit of absorbed energy in Figures 1 and 2 in relation to the PHITS algorithm used in the mesh of X, Y, and Z. Results indicated the distribution of energy deposition in the body. It was determined that absorbed energy near the source (hand) was higher and that it decreased further away from the source (hand). Results of this distribution are useful to determine the type of medical treatment required for local radiation exposure. Although results in

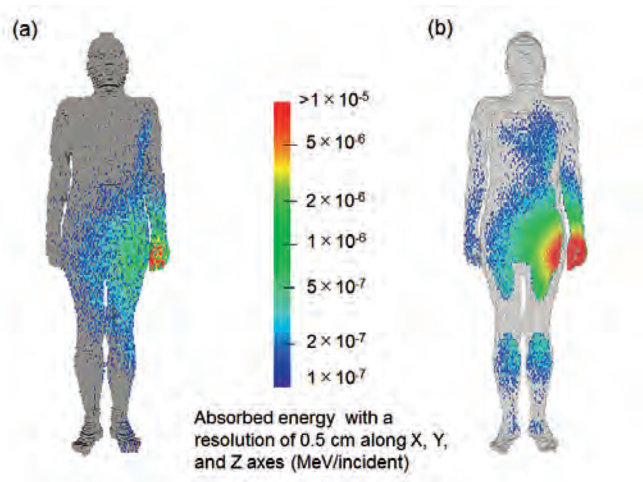

Fig. 1. Absorbed energy in human body (a: body surface; b: vertical slice of source position).

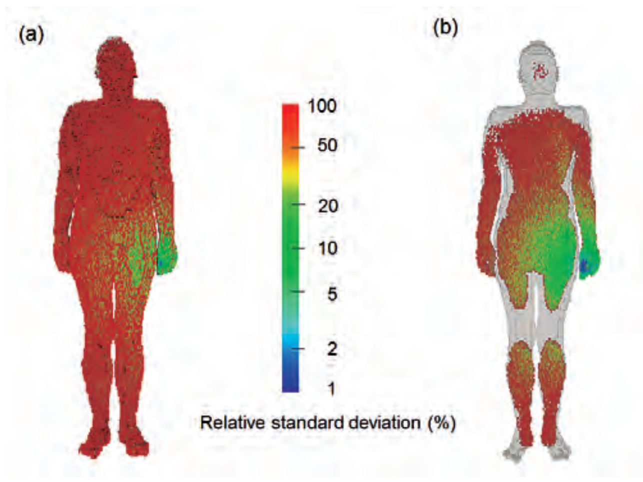

Fig. 2. Relative standard deviation of absorbed energy in the body (a: body surface; b: vertical slice of source position).

Figures 1 and 2 were shown with a mesh of X, Y, and Z, it is also possible to calculate absorbed energy for regions of organs/tissue. For example, the absorbed energy of the urinary bladder using the above-mentioned expediency condition (Table 1) was calculated as 8.0×10^{-5} MeV/incident (2.1 % as a relative standard deviation among batches). When it is necessary to consider the influence on a specific organ or tissue, these results provide useful information.

4. Future work

The particle transport simulation code can be used in future radiation emergency situations to estimate radiation exposure levels. At Hirosaki University, the particle transport simulation code will continue to be utilized for the dose estimation during emergency situations while it is updated to its latest version.

On the other hand, dose estimation by using the particle transport simulation code might not be orderly conducted on an individual with potential radiation symptoms in an emergency situation because the emergency situation might cause turmoil in the hospital (e.g. A large number of people could potentially be brought to hospital). Therefore, it is also important to provide practical training for personnel using virtual emergency situations[4]. Such training is currently provided at Hirosaki University[14] and is expected to continue.

Acknowledgments

The authors would like to thank the secretariats of PHITS for its provision in Monte Carlo particle transport simulation code. This work was partially supported by JSPS KAKENHI Grant Numbers JP16K16234 and JP16H02667.

Conflict of Interest Disclosure

The authors declare that they have no conflicts of interest.

References

1. UNSCEAR. Sources and effects of ionizing radiation, UNSCEAR 2008 report. New York: UNSCEAR; 2008.
2. NRA. The 25th Nuclear Regulation Authority commission meeting. [cited 2016 Dec 6]. Available from: https://www.nsr.go.jp/data/000119505.pdf. Japanese.
3. IAEA. Diagnosis and Treatment of Radiation Injuries, IAEA Safety report series 2. Vienna: IAEA; 1998.
4. IAEA. Preparedness and Response for a Nuclear or Radiological Emergency, GS-R-2. Vienna: IAEA; 2002.
5. IAEA. Generic procedures for assessment and response during a radiological emergency, IAEA-TECDOC-1162. Vienna: IAEA; 2000.
6. IAEA. Cytogenetic Analysis for Radiation Dose Assessment: A Manual, Technical Report Series 405. Vienna: IAEA; 2001.
7. Sato T, Niita K, Matsuda N, Hashimoto S, Iwamoto Y, Noda S, Ogawa T, Iwase H, Nakashima H, Fukahori T, Okumura K, Kai T, Chiba S, Furuta T and Sihver L. Particle and Heavy Ion Transport Code System PHITS, Version 2.52. J Nucl Sci Technol. 2013;50:913–23.
8. PHITS development team. PHITS Ver. 2.88 User's Manual. [cited 2017 March 8]. Available from: http://phits.jaea.go.jp/manual/manualE-phits.pdf.
9. Niita K, Sato T, Iwase H, Nose H, Nakashima H, Sihver L. PHITS—a particle and heavy ion transport code system. Radiation Measurements. 2006;41:1080–90.
10. Iwase H, Niita K, Nakamura T. Development of general-purpose particle and heavy ion transport Monte Carlo code. J Nucl Sci Technol. 2002;39:1142–51.
11. Niita K. ANGEL Ver. 4.31 User's Manual. [cited 2017 May 23].

Available from: https://phits.jaea.go.jp/manual/manualJ-angel4.pdf Japanese.

12. Ahrens J, Geveci B, Law C. ParaView: An End-User Tool for Large Data Visualization. In: Hansen C and Johnson C, editors. The Visualization Handbook., Academic Press; 2005. p. 717–731.

13. ICRP. Adult Reference Computational Phantoms, ICRP Publication 110. Oxford: Pergamon press; 2009.

14. Hirosaki University. Hirosaki University Center for radiation Support and Safety. [cited 2017 March 8]. Available from: http://crss.hirosaki-u.ac.jp/.