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Evaluation of personal dosimeter response for organ dose of Korean radiation workers

Byung Min Lee[1*], Jae Seok Kim[1], Min Seok Park[1], Ho Yeon Jeong[2]
[1]*Korea Institute of Radiological and Medical Sciences, 75 Nowon-ro, Nowon-gu, Seoul, Republic of Korea, 01812*
[2]*Yonsei Cancer Center, 50-1 Yonsei-ro, Seodaemun-gu, Seoul, Republic of Korea, 03722*
[*]*Corresponding author: byungmin95@kirams.re.kr*

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1. Introduction

In Korea, the exposure management of radiation workers is performed based on the personal equivalent dose (Hp(10)), which can be obtained by personal dosimeter. However, the Nuclear Safety Act requires not only the exposure management of radiation workers but also the evaluation of the health impact against radiation exposure [1]. In order to assess the health impact, organ doses of the radiation workers are needed instead of using Hp(10).
Organ doses cannot be directly measured using dosimeter. In the previous study, International Agency for Research on Cancer (IARC) and Japan estimated the organ doses from Hp(10) by using dose conversion coefficients. These studies evaluated the personal dosimeter response as fundamental research for organ dose assessment to reflect practical radiation exposure situations. In Korea, Korea Institute of Radiological and Medical Sciences (KIRAMS) is also conducting health impact survey for the radiation worker. This paper presents a study on personal dosimeter response, among health impact survey studies.

2. Material and Methods

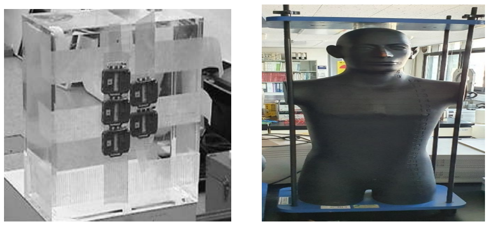
2.1 Personal dosimeter and phantom

The Korea Foundation of Nuclear Safety (KoFONS) provides basic data on radiation exposure doses for radiation workers in various industries [4]. According to the data, among the 50,000 domestic radiation workers surveyed, 69% used Thermoluminescence Dosimeters (TLD), 20% used Optically Stimulated Luminescence Dosimeters (OSLD), and 11% used Glass Dosimeters (GD). Therefore, for this study, TLD, OSLD, and GD were selected as personal dosimeter. Fig. 1 shows the types of personal dosimeters used in Korea.

TLD OSLD GD

Fig. 1. Types of personal dosimeter used in Korea

In the previous study, the slab phantom has been used for evaluate the personal dosimeter response against radiation exposure. However, the use of slab phantom causes the bias of dose response due to the geometrical difference between slab phantom and human body. Therefore, in this study, the personal dosimeter response was evaluated using the RANDO phantom (male), a physical phantom those has similar size and shape of the reference man presented in ICRP 89 [5]. Fig. 2 shows the slab and RANDO phantom used in radiation research.



Slab RANDO (male)

Fig. 2. Slab, RANDO phantom used for radiation irradiation

2.2 Exposure scenario

The term 'exposure scenario' refers to the specific conditions under which radiation workers are exposed to radiation, including factors such as radiation energy and exposure geometry. For this study, we selected exposure scenarios based on overseas cases and the working environments survey of domestic radiation workers. Based on the case analysis, radiation energy can be classified by type of beam. In this study, N-100, N-150, and Cs-137 beams were used. N-100 and N-150 are standard beams specified by ISO, with average energies of 83 keV and 118 keV, respectively [6]. The average energy of the Cs-137 beam corresponds to 662 keV. The exposure geometries include Anteroposterior (AP), Posteroanterior (PA), Left Lateral (LLAT), Right Lateral (RLAT), Rotational (ROT), and Isotropic (ISO).

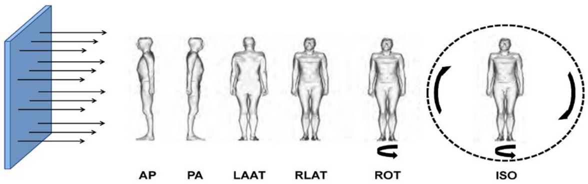


Fig. 3. Types of exposure geometry for radiation worker

2.3 Dosimeter response

The personal dosimeter reading result ($H_p(10)$) when irradiating unit air kerma (K_a) is defined as 'personal dosimeter response $(H_p(10)/K_a)'$ in this study. This can be used to calculate organ dose through the organ dose-air kerma conversion coefficient (D_t/K_a) presented by ICRP [7].

3. Results and Discussion

3.1 Personal dosimeter response

Table 1 presents the results of the personal dosimeter response analysis in this study. The personal dosimeter response was analyzed based on exposure geometry and energy. As a result of the analysis, no significant trend was observed in the personal dosimeter responses based on radiation energy. However, concerning exposure geometry, the personal dosimeter responses for Cs-137 beam (662 keV) showed relatively higher values for AP, LLAT, ROT, and ISO, ranging from 0.731 to 1.211. Conversely, RLAT and PA exhibited relatively lower values, ranging from 0.268 to 0.624. This is due to the calibration and reading of the personal dosimeter being conducted in the AP direction, resulting in lower response in directions other than AP. Additionally, the structure of the personal dosimeter may affect its response. In addition, in the case of PA and RLAT, there is a shielding effect due to the phantom.

Table I: Results of the personal dosimeter response

Dosimeter	Exposure geometry	Energy		
		N100 (83 keV)	N150 (118 keV)	Cs-137 (662 keV)
TLD	AP	1.149	1.205	1.211
	PA	0.239	0.262	0.402
	LLAT	1.077	0.992	1.088
	RLAT	0.38	0.514	0.563
	ROT	0.839	0.752	0.853
	ISO	0.663	0.693	0.721
GD	AP	0.605	1.211	1.149
	PA	0.189	0.218	0.268
	LLAT	1.01	1.112	1.198
	RLAT	0.849	0.361	0.565
	ROT	0.783	0.697	0.812
	ISO	0.716	0.686	0.831
OSLD	AP	1.736	1.129	1.196
	PA	0.177	0.204	0.356
	LLAT	1.247	1.036	0.84
	RLAT	1.065	0.592	0.624
	ROT	1.025	0.781	0.903
	ISO	0.883	0.781	0.756

3.2 Comparison of other cases and the results of this study

The study's results were compared with other cases, as shown in Fig. 4. The TLD response was compared with the IARC case, while GD and OSLD were compared with the Japan case. The comparison of response was based on the AP and ISO directions for Cs-137 beam (662 keV). The TLD response in this study was found to be 10% higher in the AP direction and 8% lower in the ISO direction compared to the IARC case. The relative error for GD, compared to Japan, was within 10%. For OSLD, the response was 1% higher in the AP direction compared to Japan, but 15% lower in the ISO direction. The errors in each direction are attributed to differences in attachment position of personal dosimeters, rotation speed, and rotation center position.

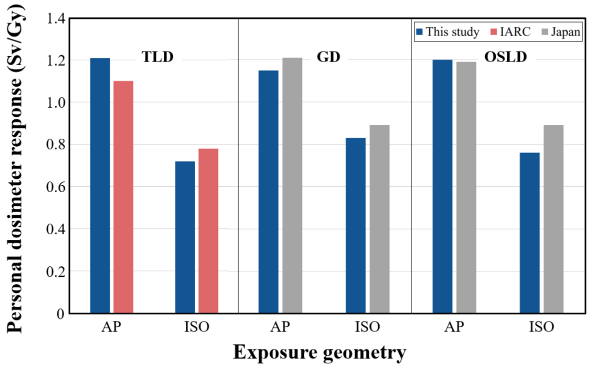


Fig. 4. Comparison of personal dosimeter response for domestic and foreign dosimeters based on exposure geometry

4. Conclusions

This study assessed the response of personal dosimeters commonly used in Korea to energy and exposure geometry. As a result of the analysis, it can be confirmed that the personal dosimeter response differs for each energy, although no significant trend in radiation exposure was noted. The personal dosimeter response was relatively low in the PA and RLAT directions. Therefore, it is important to consider personal dosimetry response research on energy and exposure geometry when evaluating organ doses to radiation workers. These results can be used to reconstruct organ dose evaluations that reflect actual radiation exposure situations.

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