Calculation of Dose Coefficient for Estimating Organ Doses in Korean Radiation Workers

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Keywords : health impact, organ dose, dose coefficient, exposure scenario

1. Introduction

In Korea, the exposure management of radiation workers is performed based on the personal dose equivalent ($H_p(10)$), which can be measured by personal dosimeter. However, the Nuclear Safety Act requires not only the exposure management of radiation workers but also the evaluation of their health impact from radiation exposure [1]. In order to assess these health impact, organ doses rather than $H_p(10)$ are required.

Organ doses cannot be directly measured using dosimeters. In previous studies, starting with the International Nuclear Workers Study (INWORKS), various research efforts have estimated organ doses from $H_p(10)$ by applying dose conversion coefficients [2]. However, in Korea, no studies have been conducted to estimate organ doses using $H_p(10)$.

Therefore, this study established a methodology for estimating organ doses applicable to Korean radiation workers. To achieve this, exposure scenarios were developed for each representative facility, and organ dose conversion coefficients applicable to $H_p(10)$ were derived.

2. Material and Methods

2.1 Establishment of a methodology

In order to convert $H_p(10)$ values into organ doses (D_T), $H_p(10)$ must first be converted to air kerma (K_a). Subsequently, the air kerma is converted to organ doses using the appropriate dose conversion coefficients. Mathematically, this organ dose reconstruction procedure can be expressed by the following equation:

$$(1)\quad \boldsymbol{D_T = H_p(10) \times \frac{1}{H_p(10)/K_a} \times \frac{D_T}{K_a}}$$

where D_T is the organ dose (Gy), $H_p(10)$ is the personal dose equivalent (Sv), and $H_p(10)/K_a$ and D_T/K_a are the dose conversion coefficients for air kerma-to-$H_p(10)$ (Sv/Gy) and air kerma-to-organ dose (Gy/Gy), respectively. Both dose conversion coefficients are dependent on the exposure environment (radiation energy, exposure geometry). Therefore, to accurately estimate the organ dose for radiation workers, it is important to properly use the dose conversion coefficients considering the exposure environments that workers can encounter when working with radioactive substances.

2.2 Exposure scenario

The exposure scenarios include information on the radiation energy and exposure geometries in the workers' environments. The exposure geometries considered were Anteroposterior (AP), Posteroanterior (PA), Left Lateral (LLAT), Right Lateral (RLAT), Rotational (ROT), and Isotropic (ISO).

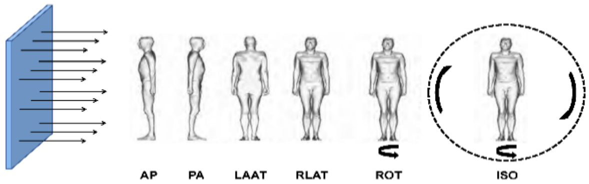

Fig. 1. Types of exposure geometry for radiation worker

The exposure scenarios were selected as representative scenarios for each facility type, rather than individual scenarios for each worker. The facilities were classified as four types: nuclear power plant (NPP), nondestructive testing (NDT), medical, and other facilities (e.g., industrial, research, education, and military facilities). The representative exposure scenarios were determined based on foreign studies and consultations with domestic experts. The foreign studies referenced included INWORKS and the U.S. Million Worker Study (MWS) [3].

2.3 Organ dose coefficient

To convert $H_p(10)$ to organ doses, conversion coefficients for $H_p(10)/K_a$ and D_T/K_a were required. $H_p(10)/K_a$ coefficients were calculated using the Monte Carlo simulation code, MCNP 6. The personal dosimeter and phantom were modeled in the simulation to derive $H_p(10)/K_a$ according to radiation energy and exposure geometry. The TLD-UD-802 model was applied as the personal dosimeter, and the KTMAN-2, a CT image-based Korean voxel phantom, was used as the phantom.

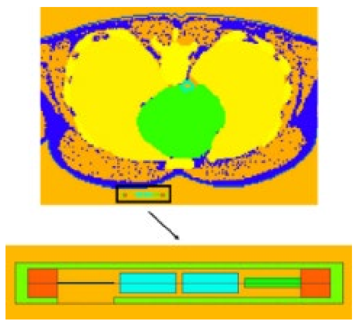

Fig. 2. Phantom and personal dosimeter Simulation Using MCNP6

The D_T/K_a coefficients were obtained from data provided in ICRP Publication 116 [4]. In this publication, organ dose conversion coefficients were derived by applying Monte Carlo methods to voxel-type computational phantoms, based on advanced imaging techniques such as CT and MRI. ICRP Publication 116 provides organ dose conversion coefficients according to radiation energy, exposure geometry, organ, and gender, based on air kerma.

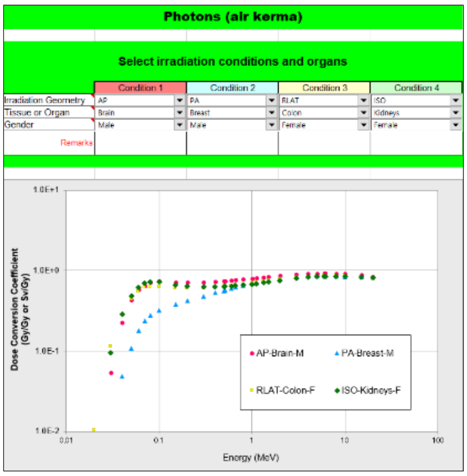

Fig. 3. D_T/K_a data sheet provided in ICRP Publication 116

3. Results and Discussion

3.1 Exposure scenario

Facilities were classified into four categories (NPP, NDT, medical, other facilities) to efficiently develop exposure scenarios. Representative values for radiation energy and exposure geometry were applied for each facility type.

Table I: Representative exposure scenarios by facility type

Facility	Exposure scenario	
	Radiation energy	Exposure geometry
NPP	662 keV	AP 50%, ISO 50%
NDT	397 keV	AP 75 %, RLAT 25 %
Medical	218 keV	AP 100 %
Other	662 keV	AP 50%, ROT 50%

3.2 Organ dose coefficient

In this study, coefficients for $H_p(10)/K_a$ and D_T/K_a were derived to estimate organ doses from $H_p(10)$. The $H_p(10)/K_a$ coefficients were calculated through Monte Carlo simulations, while the D_T/K_a coefficients were adopted from the values presented in ICRP Publication 116. The final organ dose coefficients were determined according to the representative exposure scenarios established for each facility type, considering a total of 28 organs. Table I presents the organ doses for each exposure scenario.

Table II: Organ dose coefficients by exposure scenario

Organ	Organ dose coefficient ($D_T/H_p(10)$)			
	NPP	NDT	Medical	Other
RBM	0.720	0.706	0.661	0.775
Colon	0.778	0.827	0.783	0.840
Lungs	0.789	0.774	0.739	0.834
Stomach	0.770	0.781	0.796	0.821
Breasts	0.936	0.998	0.953	0.966
Gonads	0.875	0.909	0.943	0.916
Urinary bladder	0.778	0.838	0.856	0.843
Oesophagus	0.750	0.746	0.709	0.809
Liver	0.729	0.809	0.702	0.781
Thyroid	0.906	1.011	1.003	0.981
Endosteum	0.786	0.770	0.696	0.832
Brain	0.724	0.678	0.489	0.753
Salivary glands	0.840	0.854	0.689	0.902
Skin	0.802	0.805	0.713	0.826
Adrenals	0.591	0.491	0.411	0.650
Extra-thoracic	0.844	0.900	0.746	0.899
Gall bladder	0.712	0.820	0.697	0.777
Heart	0.779	0.803	0.790	0.830
Kidneys	0.607	0.554	0.460	0.676
Lymph nodes	0.791	0.813	0.779	0.846
Muscle	0.791	0.765	0.692	0.841
Oral mucosa	0.779	0.827	0.674	0.831
Pancreas	0.707	0.768	0.709	0.773
Prostate	0.729	0.741	0.736	0.795
Small intestine	0.771	0.828	0.803	0.840
Spleen	0.638	0.495	0.479	0.692
Thymus	0.890	0.933	0.974	0.937
Lens of the eye	0.957	1.025	0.895	0.990

4. Conclusions

This study derived dose coefficients to convert $H_p(10)$ into organ doses(D_T). To achieve this, representative exposure scenarios were selected for each facility type, and corresponding $H_p(10)/K_a$ and D_T/K_a coefficients were calculated. Based on these, the $H_p(10)$-to-D_T coefficients for each facility type were determined. The results of this study can be utilized as data for evaluating the health impact of radiation workers in Korea.

REFERENCES

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