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Influence of the Monitoring Interval and Intake Pattern for the Evaluation of Intake

내부피폭 감시주기 및 섭취형태가 방사성핵종 섭취량 평가에 미치는 영향

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Abstract

A variety of factors such as the pattern of intake (acute or chronic), monitoring interval and the characteristics of the radionuclides could have a significant influence on the estimates for the intake and internal dose. The relative differences of the assessed intakes based on the assumption of an acute intake to that of a chronic intake were evaluated by using the predicted bioassay quantity in the whole body or organs for an acute and chronic intake through the inhalation of ^{125}I, ^{137}C, ^{235}U with the AMAD of 1 ㎛ and 5 ㎛ for the monitoring intervals of 7, 14, 30, 60, 90, 120, 180, 360 days, respectively. The relative difference of the assessed intakes based on the intake pattern is affected by the monitoring interval, radionuclide and absorption type, but the particle size has little influence on the difference of the assessed intakes based on the intake pattern. The maximum monitoring interval, which is defined as the monitoring interval that the relative difference of the assessed intakes based on the assumption of an acute intake to that of a chronic intake is less than 10%, is 60 d for ^{125}I with Type F, 180 d for ^{137}C with Type F, 90 d for ^{235}U with Type M, and 360 d for ^{235}U with Type S. It was concluded that an intake pattern has little influence on the estimates of the assessed intake in the case where the monitoring interval is shorter than the maximum monitoring interval for each radionuclide.

Key words : Acute Intake, Chronic Intake, Monitoring Interval, and Relative Difference

요약

방사성핵종의 특성, 섭취형태 그리고 내부피폭 감시주기는 작업자의 방사성핵종 섭취량 및 내부피폭선량 평가 결과에 중요한 영향을 줄 수 있다. 따라서 방사성핵종이 흡입섭취될 경우 섭취형태(급성 또는 만성) 및 내부피폭 감시주기에 따른 섭취량 평가 오차를 계산하였다. 섭취 핵종으로는 ^{125}I(Type F), ^{137}Cs(Type F), ^{235}U(Type M, Type S)를 고려하였고, 방사능입자크기(AMAD)는 1 ㎛와 5 ㎛를 고려하였다. 섭취형태에 따라 평가된 섭취량의 상대오차는 방사성핵종, 흡수형태 그리고 내부피폭 감시주기에 따라 달랐으나, 입자크기에 의한 영향은 거의 없었다. 섭취형태 가정에 따른 섭취량 평가 오차를 10% 미만으로 줄일 수 있는 내부피폭 최대감시주기는 ^{125}I(Type F)에 대해 60일, ^{137}Cs(Type F)에 대해 180일, ^{235}U(Type M)에 대해 90일, 그리고 ^{235}U(Type S)에 대해 360일로 나타났다.

중심단어 : 급성섭취, 만성섭취, 감시주기, 섭취량 평가, 상대오차

I. Introduction

The radiation workers who deal with radioactive material could intake radionuclides through inhalation. As a consequence, the workers are exposed to radiation from the radionuclides deposited in the body until the radionuclides are eliminated from the body. Therefore the individual monitoring for the intakes of radioactive material should be performed routinely for the workers who are employed in a radioactive contamination area. One of the individual monitoring methods for the estimation of the intakes of radionuclides is the direct measurement of the radionuclides for the whole body or in specific regions of the body. The intakes of the radionuclides and the committed effective doses (CED) are assessed from the direct measurement results.

A variety of factors such as the pattern of the intake (acute or chronic), absorption type (F, M, S), particle size (AMAD; Activity Median Aerodynamic Diameter) and monitoring interval could have a significant influence on the assessment of the intake or CED[1].

Particle sizes (AMAD) are diverse, but the International Commission on Radiological Protection (ICRP) recommended that if a particle size is unknown, the default value for the AMAD is 5 ㎛ for a radiation worker[1].

Absorption means the movement of the material to the blood, and depends on the physical and chemical form of the deposited material. The absorption types are divided into fast (Type F), moderate (Type M), and slow (Type S)[1]. These absorption types and AMAD have an effect on the behavior or retention of the radioactive materials within the human body.

The patterns of the intake are classified into an acute intake and a chronic intake. If the intake pattern or intake time is not known, it is assumed that the intake took place in the middle of the monitoring interval by the recommendation of the ICRP[1]. But the

results of the assessment of the intake or the CED based on the respective assumptions of the acute intake and chronic intake are different, and the extent of the difference depends on the monitoring interval.

In this study, the relative differences of the assessed intakes were evaluated as a function of the intake pattern and monitoring interval. Finally this study is intended to investigate the influence of the monitoring interval and intake pattern for the evaluation of the intake.

Ⅱ. Materials and methods

The intake can be estimated from the measured quantity, M, in the whole body or body organs using the acute intake retention fraction $m_a(t)$ or the chronic intake retention fraction $m_c(t)$. The $m_a(t)$ is the predicted bioassay quantity in the whole body or organs at the time t days after an acute intake of 1 Bq, the $m_c(t)$ is the predicted bioassay quantity in the whole body or organs at the time t following a continuous chronic intake with an intake rate of 1 Bq/day during a period of chronic exposure.

For a routine monitoring, it is assumed that the intake took place in the middle of the monitoring interval of T days. For a given measured quantity, M, obtained at the end of the monitoring interval, the intake (I_{acute})[1] is

$$I_{acute} = \frac{M}{m_a(T/2)} \quad \cdots\cdots\cdots (1)$$

Assuming a chronic intake, it is assumed that the intake took place continuously with a constant intake rate during the monitoring interval T days. For a given measured quantity, M, obtained at the end of the monitoring interval, the intake ($I_{chronic}$)[2] is

$$I_{chronic} = \frac{M}{m_c(T)} \times T \quad \cdots\cdots\cdots (2)$$

The predicted values of $m_a(T/2)$ and $m_c(T)$ in the whole body or organs for the inhalation of the radionuclides in the case of each monitoring interval were calculated using the BiDAS (Bioassay Data Analysis Software) computer code[3] based on the respiratory tract model of ICRP-66[4], gastrointestinal tract model of ICRP-30[5] and the biokinetic model of ICRP-78[1].

The radionuclides and the monitoring intervals considered in this study are ^{125}I(Type F), ^{137}C(Type F), ^{235}U(Type M, Type S), and 7, 14, 30, 60, 90, 120, 180, 360 days, respectively.

The relative difference of the assessed intakes based on the assumption of an acute intake to that of a chronic intake with each monitoring interval is

Relative difference of the assessed intake

$$= \left(\frac{I_{acute} - I_{chronic}}{I_{chronic}} \right) \times 100\% \quad \cdots\cdots\cdots (3)$$

$$= \left(\frac{m_c(T)}{m_a(T/2) \cdot T} - 1 \right) \times 100\%$$

Thus relative differences of the assessed intakes based on the assumption of an acute intake to that of a chronic intake with each monitoring interval were evaluated. These evaluations were performed for the AMAD of 1 ㎛ and 5 ㎛ respectively to investigate the influence of the particle size on the relative difference of the assessed intakes. In the case of ^{235}U, Type M and Type S materials were considered for the assessment of an intake to investigate the influence of the absorption type on the relative difference of the assessed intakes.

Ⅲ. Results and Discussion

The predicted values of $m_a(T/2)$ and $m_c(T)$ in the whole body or organs for the inhalation of the radionuclides in the case of each monitoring interval were calculated using the BiDAS. Table 1 shows the predicted values of $m_a(T/2)$ in the body or organ for an acute intake and the predicted values of $m_c(T)$ in the whole body or organs for a chronic intake through the inhalation of ^{125}I(Type F), ^{137}C(Type F), ^{235}U(Type M, Type S) with the AMAD of 1 ㎛ and 5 ㎛ for each monitoring interval.

The relative differences of the assessed intakes based on the assumption of an acute intake to that of a chronic intake with every monitoring interval were evaluated by equation (3) for ^{125}I(Type F), ^{137}C(Type F), ^{235}U(Type M, Type S) with 1 ㎛ and 5 ㎛. Table 2 shows the relative differences.

As a result, the relative difference of the assessed intakes based on the intake pattern is affected by the monitoring interval, radionuclide and absorption type, but the particle size has little influence on the difference of the assessed intakes based on the intake pattern.

The monitoring interval having the smallest relative difference is 30 d for ^{125}I with Type F, 60 d for ^{137}C with Type F, 14 d for ^{235}U with Type M, and 14 d for ^{235}U with Type S.

The maximum monitoring interval, which is defined as the monitoring interval that the relative difference of the assessed intakes based on the assumption of an acute intake to that of a chronic intake is less than 10%, is 60 d for ^{125}I with Type F, 180 d for ^{137}C with Type F, 90 d for ^{235}U with Type M, and 360 d for ^{235}U with Type S. This means that an intake type has little influence on the result of the assessed intakes, if the interval is shorter than the maximum monitoring interval for each radionuclide. The maximum monitoring intervals appeared to be almost the same regardless of the particle size.

Ⅳ. Conclusion

The relative differences of the assessed intakes based on the assumption of an acute intake to that of a chronic intake were evaluated by using predicted values in the whole body or organs for an acute and a chronic intake through an inhalation of ^{125}I, ^{137}C, ^{235}U with the AMAD of 1 ㎛ and 5 ㎛ for the monitoring intervals of 7, 14, 30, 60, 90, 120, 180, 360 days, respectively.

Table 1. The Predicted Bioassay Values of $m_a(T/2)$ for Acute Intake of 1 Bq and $m_c(T)$ for Chronic Intake of 1 Bq/day through Inhalation of ^{125}I, ^{137}C, ^{235}U for each Monitoring Interval.

Nuclide (Subject)	Absorption Type	Monitoring Interval, T (days)	1 ㎛ (AMAD)		5 ㎛ (AMAD)	
			$m_a(T/2)$	$m_c(T)$	$m_a(T/2)$	$m_c(T)$
^{125}I (Thyroid)	Type F	7	9.70×10^{-2}	6.40×10^{-1}	1.34×10^{-1}	8.87×10^{-1}
		14	9.05×10^{-2}	1.23×10^{0}	1.25×10^{-1}	1.71×10^{0}
		30	7.76×10^{-2}	2.33×10^{0}	1.08×10^{-1}	3.22×10^{0}
		60	5.87×10^{-2}	3.68×10^{0}	8.14×10^{-2}	5.10×10^{0}
		90	4.47×10^{-2}	4.48×10^{0}	6.19×10^{-2}	6.20×10^{0}
		120	3.41×10^{-1}	4.94×10^{0}	4.73×10^{-2}	6.84×10^{0}
		180	1.99×10^{-2}	5.37×10^{0}	2.76×10^{-2}	7.44×10^{0}
		360	3.99×10^{-1}	5.58×10^{0}	5.54×10^{-1}	7.74×10^{0}
^{137}Cs (Whole Body)	Type F	7	3.25×10^{-1}	2.42×10^{0}	4.53×10^{-1}	3.46×10^{0}
		14	3.03×10^{-1}	4.48×10^{0}	4.21×10^{-1}	6.32×10^{0}
		30	2.84×10^{-1}	8.83×10^{0}	3.94×10^{-1}	1.23×10^{1}
		60	2.58×10^{-1}	1.59×10^{1}	3.58×10^{-1}	2.21×10^{1}
		90	2.35×10^{-1}	2.17×10^{1}	3.25×10^{-1}	3.02×10^{1}
		120	2.13×10^{-1}	2.65×10^{1}	2.96×10^{-1}	3.69×10^{1}
		180	1.76×10^{-1}	3.38×10^{1}	2.44×10^{-1}	4.69×10^{1}
		360	9.94×10^{-2}	4.44×10^{1}	1.38×10^{-1}	6.17×10^{1}
^{235}U (Lung)	Type M	7	1.04×10^{-1}	7.33×10^{-1}	5.46×10^{-2}	3.87×10^{-1}
		14	9.89×10^{-2}	1.39×10^{0}	5.18×10^{-2}	7.33×10^{-1}
		30	8.91×10^{-2}	2.71×10^{0}	4.64×10^{-2}	1.41×10^{0}
		60	7.47×10^{-2}	4.63×10^{0}	3.84×10^{-2}	2.39×10^{0}
		90	6.38×10^{-2}	6.10×10^{0}	3.25×10^{-2}	3.14×10^{0}
		120	5.54×10^{-2}	7.27×10^{0}	2.81×10^{-2}	3.72×10^{0}
		180	4.34×10^{-2}	9.01×10^{0}	2.18×10^{-2}	4.59×10^{0}
		360	2.38×10^{-2}	1.16×10^{1}	1.19×10^{-2}	5.91×10^{0}
	Type S	7	1.17×10^{-1}	8.26×10^{-1}	6.16×10^{-2}	4.37×10^{-1}
		14	1.14×10^{-1}	1.60×10^{0}	5.95×10^{-2}	8.40×10^{-1}
		30	1.07×10^{-1}	3.22×10^{0}	5.54×10^{-2}	1.68×10^{0}
		60	9.60×10^{-2}	5.88×10^{0}	4.94×10^{-2}	3.03×10^{0}
		90	8.83×10^{-2}	8.23×10^{0}	4.50×10^{-2}	4.22×10^{0}
		120	8.25×10^{-2}	1.04×10^{1}	4.18×10^{-2}	5.31×10^{0}
		180	7.48×10^{-2}	1.44×10^{1}	3.76×10^{-2}	7.31×10^{0}
		360	6.39×10^{-2}	2.49×10^{1}	3.20×10^{-2}	1.25×10^{1}

Table 2. The Relative Differences of the Assessed Intakes based on the Assumption of Acute Intake to that of Chronic Intake through Inhalation of ^{125}I, ^{137}C, ^{235}U for each Monitoring Interval.

Nuclide (Subject)	Absorption Type	Monitoring Interval, T(days)	Relative Difference (%)	
			1 ㎛ (AMAD)	5 ㎛ (AMAD)
^{125}I (Thyroid)	Type F	7	-5.73	-5.77
		14	-2.95	-2.76
		30	0.06	-0.12
		60	4.48	4.58
		90	11.4	11.3
		120	20.7	20.7
		180	49.7	49.6
		360	288	288
^{137}Cs (Whole Body)	Type F	7	6.49	9.18
		14	5.43	7.29
		30	3.48	4.41
		60	2.49	3.01
		90	2.75	3.13
		120	3.59	3.90
		180	6.48	6.73
		360	24.2	24.4
^{235}U (Lung)	Type M	7	0.82	1.37
		14	0.65	0.97
		30	1.22	1.51
		60	3.44	3.97
		90	6.28	7.12
		120	9.32	10.5
		180	15.4	17.0
		360	35.7	37.7
	Type S	7	0.70	1.22
		14	0.50	0.79
		30	0.80	1.04
		60	2.08	2.49
		90	3.57	4.19
		120	4.94	5.75
		180	6.90	7.92
		360	8.12	9.03

The relative difference of the assessed intakes based on the intakes pattern is affected by the monitoring interval, radionuclide and absorption type, but the particle size has little influence on the difference of the assessed intakes based on the intake pattern.

The monitoring interval having the smallest relative difference of the assessed intakes based on the intake pattern was different with each radionuclide.

The maximum monitoring interval, which is defined as the monitoring interval that the relative difference of the assessed intakes based on the assumption of an acute intake to that of a chronic intake is less than 10%, is 60 d for ^{125}I with Type F, 180 d for ^{137}C with Type F, 90 d for ^{235}U with Type M, and 360 d for ^{235}U with Type S.

It was concluded that an intake pattern has little influence on the estimates of the assessed intake in the case where the monitoring interval is shorter than the maximum monitoring interval for each radionuclide.

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