Interpretation program for internal contamination measurement*

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Abstract An internal dose calculation program is introduced. It adopts the ICRP new respiratory tract model. It is capable of calculating the initial intakes and the committed effective dose from the measured radioactivities of nuclides in body in acute and constant continuous intake conditions. It may also give the detailed committed equivalent dose of lung region and other organs.

Keywords Internal exposure, Lung model, Computer code

1 Introduction

To evaluate the internal contamination, the measured results of nuclides in vivo must be translated into initial intakes, or committed effective dose (CED).[1] Because ICRP has recently renewed the lung model[2] used in internal exposure calculation, it is necessary to compile internal dose code according to this ICRP new lung model.

2 Computerizing program

2.1 Mathematical model

We incorporate the ICRP-30[3] gastrointestinal tract model (GI model), the skin direct intake model and the ICRP-66 respiratory tract model to describe the intakes of nuclides from in vitro to in vivo; and use the compartment model to describe the retention and transport of nuclides in different tissues or organs after the uptake to blood. These compartment models are shown in Fig.1.

In Fig.1, the compartments ET, BB, bb, AI, LNET, LNTH represent the extrathoracic region, bronchi, bronchioles, alveolar interstitial, lymphatic tissue in extrathoracic and the thoracic regions, respectively; ST, SI, ULI, LLI, are stomach , small intestines, upper large intestines, lower large intestines, respectively; U stands for the uptake to blood; IS represents a tissue or an organ; E does excretion; the arrow indicates the transport direction of the nuclides in body.

For these compartment models, we use the method given by Birchall[4] to calculate the nuclide retention function $q(t)$ in body at time t.

The initial intakes A_0(Bq) and the CED $E(50)$ (Sv) are calculated by

$$A_0 = A(t)/q(t) \tag{1}$$

$$E(50) = A_0F \tag{2}$$

where $A(t)$ is measured nuclide content (Bq) in body at time t , F is CED per Bq intake, Sv/Bq, its value may refer to ICRP-68.[5]

For the constant continuous intake condition, the nuclide retention function $Q(t)$ is obtained by the convolution of retention function $q(t)$ in an acute intake condition.

Except the CED calculation by using dose coefficient in Eq.(2), the program may also calculate the organ committed equivalent dose (OCED) $HT(50)$ in each lung tissue and other organs of the body as the following equation:

$$HT(50) = \Sigma U_S(50) \cdot SEE(T \leftarrow S) \tag{3}$$

where $U_S(50)$ is the number of radioactive disintegration (ND) during the period of 50 years following the intake in source organ (S), SEE ($T \leftarrow S$) is specific effective energy in target organ T induced by a ND occurring in source organ S, Sv(Bqs)$^{-1}$.

The $U_S(50)$ is calculated by

$$U_S = \int^{50} q(t)\mathrm{d}t \tag{4}$$

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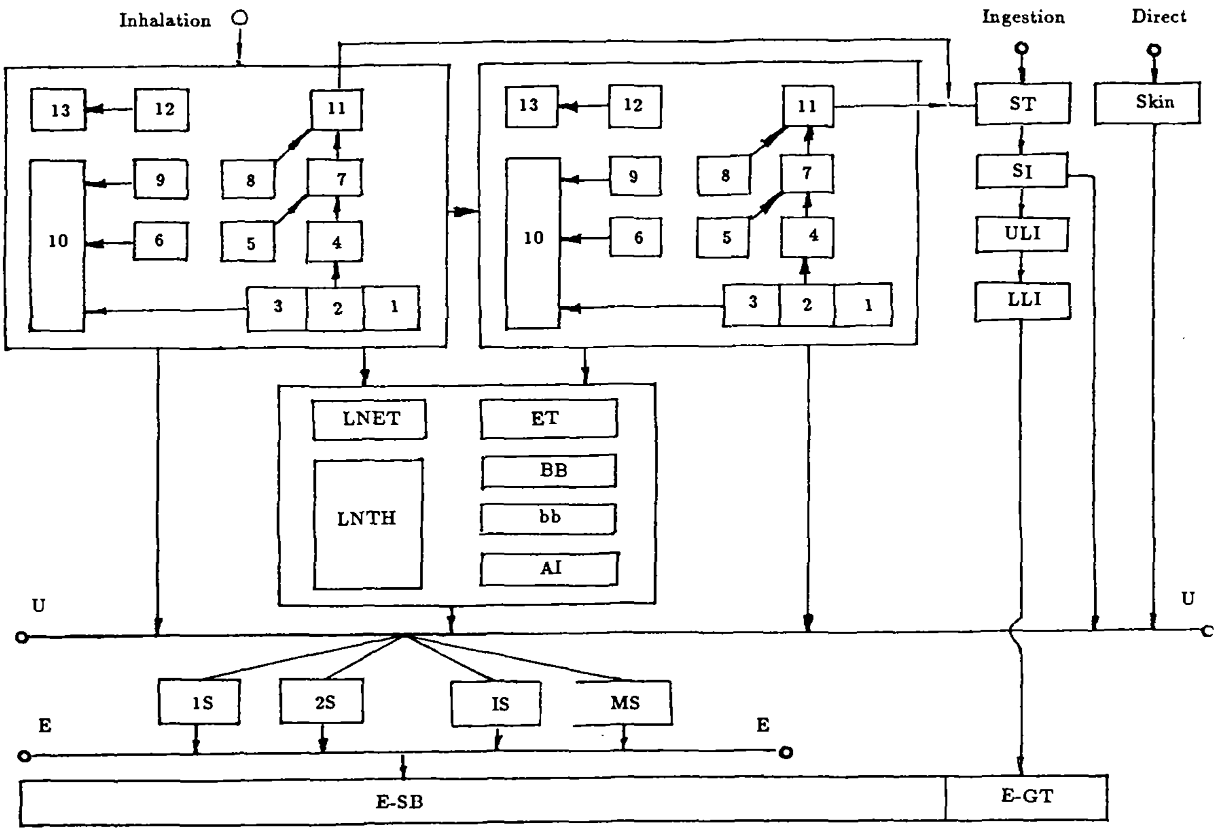

Fig.1 Overall compartment model for nuclide transport in body

1,2,3 are compartment numbers in AI region; 4,5,6, in bb region; 7,8,9, in BB region; 10 LNTH compartment; 11,12 compartment numbers in ET region; 13 LNET compartment

2.2 Program structure and operation

According to this model, the program INT-PRT is compiled. It is built up in modular forms, including calculation module and management module. The former implements the calculations of initial intakes, CED and OCED of different tissues or organs. The later is used to manage and renew the dosimetry parameters, such as the CED coefficients, the SEE values, the organ masses, the metabolism parameters of nuclides in body and the deposition fraction of aerosol particle with different diameters in lung regions.

The program is menu-driven. By which, the users can enter or select above parameters and input other parameters such as the intake model and the time after intake.

2.3 Example calculation

Assuming an acute inhalation of 1 Bq long life type S aerosol by a reference worker, we calculate ND for each retention region in lung over 50 a. The results are shown in Table 1, which also lists the estimated values by ICRP-66[2] at the same intake condition.

Table 2 lists the calculated and ICRP-30[3] values of ND in some organs over 50 a after ingestion of 1 Bq ^{32}P, ^{60}Co, ^{131}I and ^{134}Cs, respectively. Table 3 gives the calculated CED by acute inhalation/ingestion of 1 Bq nuclides, this table also lists the ICRP-68[5] values for comparison.

Table 1 ND in lung region over 50 a after 1 Bq acute inhalation

	AI	bb	BB	LNTH	ET2	ET1	LNET
ICRP-66	4.65×10^{6}	1.56×10^{4}	1.86×10^{4}	4.88×10^{5}	1.61×10^{4}	2.94×10^{4}	1.32×10^{5}
INTPRT	4.61×10^{6}	1.56×10^{4}	1.86×10^{4}	4.44×10^{5}	1.61×10^{4}	2.94×10^{4}	1.29×10^{5}

Table 2 ND in some organs over 50 a after 1 Bq acute ingestion

	^{32}P ($f1$=0.8)		^{60}Co ($f1$=0.3)		^{131}I ($f1$=1.0)		^{134}Cs($f1$=1.0)	
	ICRP-30	INTPRT	ICRP-30	INTPRT	ICRP-30	INTPRT	ICRP-30	INTPRT
Thyroid	–	–	–	–	2.9×10^{5}	2.9×10^{5}	–	–
ULI	9.1×10^{3}	9.1×10^{3}	3.3×10^{4}	3.3×10^{4}	–	–	–	–
LLI	1.6×10^{4}	1.6×10^{4}	8.2×10^{4}	8.2×10^{4}	–	–	–	–
Liver	–	–	4.0×10^{4}	4.0×10^{4}	–	–	–	–
Cort bone	2.1×10^{5}	2.1×10^{5}	–	–	–	–	–	–
Trab bone	2.1×10^{5}	2.1×10^{5}	–	–	–	–	–	–
Other tissues	3.8×10^{5}	3.8×10^{5}	3.6×10^{5}	3.6×10^{5}	–	–	1.1×10^{7}	1.1×10^{7}

Table 3 CED for 1 Bq acute intake of some nuclides

Nuclides	Type	$f1$	AMAD	Inhalation		Ingestion	
				ICRP-68	INTPRT	ICRP-68	INTPRT
^{32}P	F	0.8	5 μm	1.1×10^{-9}	1.1×10^{-9}	2.4×10^{-9}	2.2×10^{-9}
			1 μm	8.0×10^{-10}	7.7×10^{-10}	–	–
^{60}Co	S	0.05	5μm	1.7×10^{-8}	1.8×10^{-8}	2.5×10^{-9}	2.6×10^{-9}
			1 μm	2.9×10^{-8}	3.2×10^{-8}	–	–
	M	0.1	5 μm	7.1×10^{-9}	5.7×10^{-9}	3.4×10^{-9}	3.4×10^{-9}
			1 μm	9.6×10^{-9}	8.5×10^{-9}	–	–
^{131}I	F	1.0	5μm	1.1×10^{-8}	1.2×10^{-8}	2.2×10^{-8}	2.4×10^{-8}
			1 μm	7.6×10^{-9}	8.3×10^{-9}	–	–
^{134}Cs	F	1.0	5 μm	9.6×10^{-9}	9.0×10^{-9}	1.9×10^{-8}	1.9×10^{-8}
			1 μm	6.8×10^{-9}	6.5×10^{-9}	–	–

It can be seen from Table 1 that the calculated ND in lung region for inhalation is in agreement with the estimated values in ICRP-66, which indicates that the nuclide retention calculation for inhalation intake model is correct. Similarly, it can be seen from Table 2 that the calculation for ingestion intake model is also correct.

The CED results by INTPRT and ICRP-68 in Table 3 are also in accordance. However, the differences of applied nuclear decay data and the models between INTPRT and ICRP-68 make the above results a little different from each other.

3 Conclusion

The INTPRT program in this article adopts the new respiratory tract model. It reflects the new progress in internal dosimetry. The example calculation shows that it may be used to calculate initial intakes and CED from the measured body contents of nuclides in different intake conditions.

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