THE CHOISE OF A BIOLOGICAL MODEL IN ASSESSING INTERNAL DOSE EQUIVALENT

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Assessing the dose equivalent resulting from a known uptake of radioactive material is probably the most difficult feature of the whole radiation dosimetry. Besides duing direct bioassays, as whole body or organ counting, it is usually necessary to analyse excreta. This is because one can calculate the internal exposure from the amount of radioactive material in excreta and the excretion rate, by means of an appropriate biological model.

The kinetic behaviour of radionuclides within the organism or in an organ can be described by various models. This is true particularly for the metabolic kinetics of bone-seekers radionuclides, for which different retention functions derived from different models have been proposed.

One finds retention expressed either by an exponential equation, or by a power equation, or by an exponential and power equation. Retention function expressed as linear combination of exponential terms are obtained by coherent compartmental analysis and allow a mathematical formalism fairly well definite and easily adaptable to computer. Moreover, it is possible to use extant graphs and nomograms (1) which facilitate the calculations of internal exposure. Because of the complexity of the metabolic processes of the bone tissue, five or six exponential terms may be required to fit experimental data. However, it is possible to use less parameters by expressing retention as power function or by a more complicated function with exponential and power terms. Even so, the calculations of internal exposure become more complicated and time consuming.

In the model developed by the Task Group of the Committee 2 of the ICRP (2) to explain the metabolism of alkaline earth radionuclides, retention is expressed by an exponential and power equation. This model is very realistic and takes into account the essential features of the biological processes which take place in the tissues. Nevertheless, estimates of internal dose equivalent in the organism or in an organ are

difficult and time consuming.

Other authors have used multicompartmental models to explain the metabolism of these nuclides: exponential retention are reported, e.g., for calcium (3) and radium (4), injected intravenously in man. We ourselves (5) have developed a four compartment model for radium metabolism, using virtually all of the existing data as reanalysed by the Task Group of Committee 2 of the ICRP. The whole body retention is plotted in fig. 1, while fig. 2 shows the plasma retention per gram calcium. The values of parameters of the retention equations

$$R = \sum k_n \exp(-b_n t)$$

are reported in table 1. The model is very simple and fits well the experimental data; calculation of internal exposure is easy and rapid in any case, and it becomes immediate when one makes use of the graphs or nomograms of ref. 1.

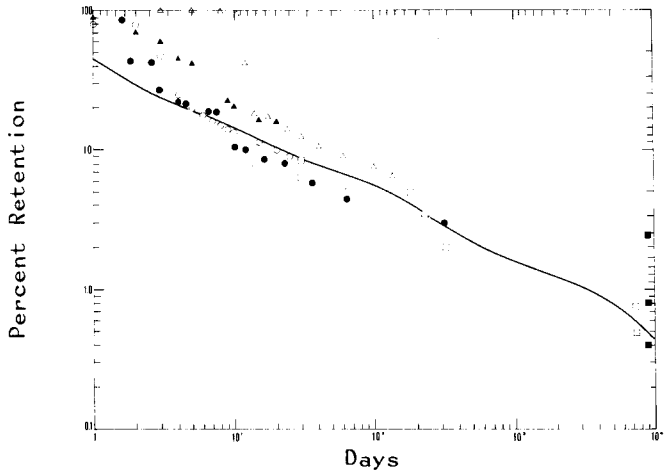

Fig. 1. Radium retention in whole body. Data: ○ Harrison (6); □ Schlundt (7); □ Norris (8); ■ Miller (9); △ Mays (10); ● Mays (2); ▲ Maletskos (11). Pratically all data available for adult man, as reanalysed by the Task Group of the ICRP (2), are reported.

Internal exposure values for 1, 50 and infinite years after injection are reported in table 2, which compares the values obtained with three most recent models. It shows that our results are within 8% of those obtained by the Task Group of the Committee 2 of ICRP, while the others obtained following the

use of the five compartment model, reported in the ICRP Publication 10A (4), are substancially different.

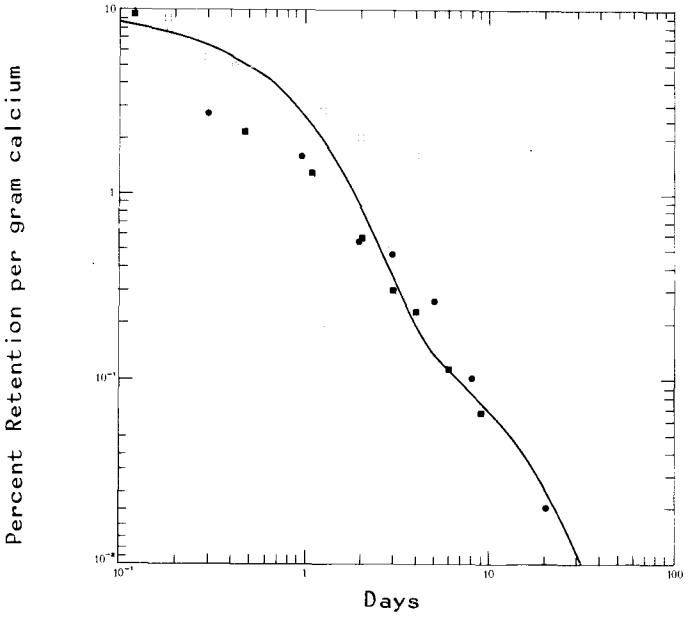

Fig. 2. Radium retention per gram calcium in blood plasma. Data: ■ Harrison (6); ○ Mays (10); ● Mays (2); □ Maletskos (11). Data are reported following reanalysis of the Task Group of the Committee 2 of the ICRP.

n	b_n	k_n				
		Whole body	Blood	Exchangeable bone	Deep bone	Soft tissue
1	1.300	0.730	$2.8\ 10^{-2}$	-0.133	-0.0133	0.847
2	0.112	0.177	$5.9\ 10^{-4}$	0.136	-0.0058	0.046
3	0.0062	0.075	$1.4\ 10^{-5}$	$5.7\ 10^{-4}$	0.0044	0.070
4	0.00015	0.018	$0.8\ 10^{-7}$	$3.2\ 10^{-6}$	0.0163	0.0017

Table I. Parameters of the retention functions of the four compartments model. Of course, only 8 of them are indipendent. Whole body and plasma retention are plotted in figures 1 and 2.

The choise of the model appears therefore less important than the determination of the appropriate value of the parameters. However, the most interesting deduction derived from the comparison is that results obtained with a simple multicompartmental model are pratically the same obtained with the model proposed by the Task Group of the ICRP, which is, formally at least, much more complex. On the other hand, the role of the biological model in internal dosimetry must be referred to the reliability of the quantitative informations on the kinetic behaviour of the radionuclides in an organism only in relation to the accuracy of the doses calculated. After all, from the point of view of the internal dosimetry, each biophysical model is good when allows to obtain good estimates of dose with simple calculations.

Time (Ys)	Whole body	Blood	Surface bone	Deep bone	Soft tissue	Model
1	30.8	(0.0284)	--	--	--	1971 (4)
	18.8	0.0288	1.16	7.15	10.8	1973 (2)
	19.4	0.0290	1.19	6.37	11.7	1977 (5)
50	183.3	(0.0298)	--	--	--	1971 (4)
	119.0	0.0296	1.19	97.5	21.2	1973 (2)
	126.5	0.0298	1.22	102.5	22.7	1977 (5)
∞	194.4	(0.0299)	--	--	--	1971 (4)
	147.7	0.0297	1.19	125.1	21.5	1973 (2)
	134.2	0.0298	1.23	109.5	23.4	1977 (5)

Table 2. Internal exposure due to a single uptake of 1 μCi of ^{226}Ra in μCi·days for 1, 50 and infinite years after injection. The values written between brackets are not reported in Ref. 4; they have been calculated by means of eq.:

$$R_{Blood} = - 0.0299 \, (dR_{Whole\text{-}body}/dt)$$

based on the postulate that number of radioactive atoms excreted from the body per unit time is proportional to the number in the plasma at that time.

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