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EXCRETION AND RETENTION OF Ra^{226} IN HUMANS: A 2312-DAY FOLLOW-UP OF A SINGLE INHALATION CASE

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This summary brings to a close a 6.5-year period of observations on technician G who accidentally inhaled some $RaSO_4$ on June 13, 1952. Earlier data on body contents and excreta have been reported in the open literature(1) and later in some of the reports of our Division,(2,3) as well as elsewhere in this report. They are shown in Tables 16 and 17 in their

Table 16

Retention of Ra^{226} following single inhalation of $RaSO_4$

Days	Curies x 10^8		
	Gamma	Radon	Total
3	24.8	9.0	33.8
13	22.2	3.0	25.2
35	23.2	5.0	28.2
102	6.7	3.0	9.7
235	2.8	2.2	5.0
622	0.7	1.6	2.3
1012	0.58	1.12	1.7
2312	0.22	0.67	0.89

Table 17

Excretion of Ra^{226} following single inhalation of $RaSO_4$

Days	Curies	Days	Curies
3	2.06×10^{-8}	235	2.18×10^{-10}
7	5.6×10^{-9}	246	2.11×10^{-10}
13	4.4×10^{-9}	297	1.68×10^{-10}
34	3.2×10^{-9}	334	9.1×10^{-11}
57	1.7×10^{-9}	484	5.6×10^{-11}
61	1.6×10^{-9}	597	2.2×10^{-11}[a]
92	8.25×10^{-10}	622	1.8×10^{-11}[a]
102	7.8×10^{-10}	1012	1.1×10^{-11}[a]
122	5.1×10^{-10}	2300	5×10^{-12}[a]
185	3.56×10^{-10}		

[a]Corrected for 2×10^{-12} normal intake.

(These curves are plotted on log log paper in Fig. 16.)

*Biological and Medical Research Division entirety. The body contents, when plotted on log log paper, yield a good straight line between 100-2312 days, which is described analytically by

$$q \text{ (curies retained)} = 3.6 \times 10^{-6}\, t^{-.78} \qquad (1)$$

where t is in days.

The differential of this curve, namely the excretion curve

$$dq/dt \text{ (curies excreted)} = 2.8 \times 10^{-6}\, t^{-1.78} \qquad (2)$$

fits as well as any the measurements obtained from excreta in the same interval (Fig. 16). For either curve no fitting was attempted at less than 10^2 days for it was exhaustively shown by scanning[1] in vivo that, at early times, most of the radioelement was in the lung and was being released, therefore, with a half-life of the order of 30 days. This fact seems to have been overlooked in at least one paper dealing with the behavior of radium excretion from humans.[4] The consistency of both the gamma-ray and breath analysis on the one hand, and the excreta measurements on the other, do confirm the validity of our body measurements in absolute terms.

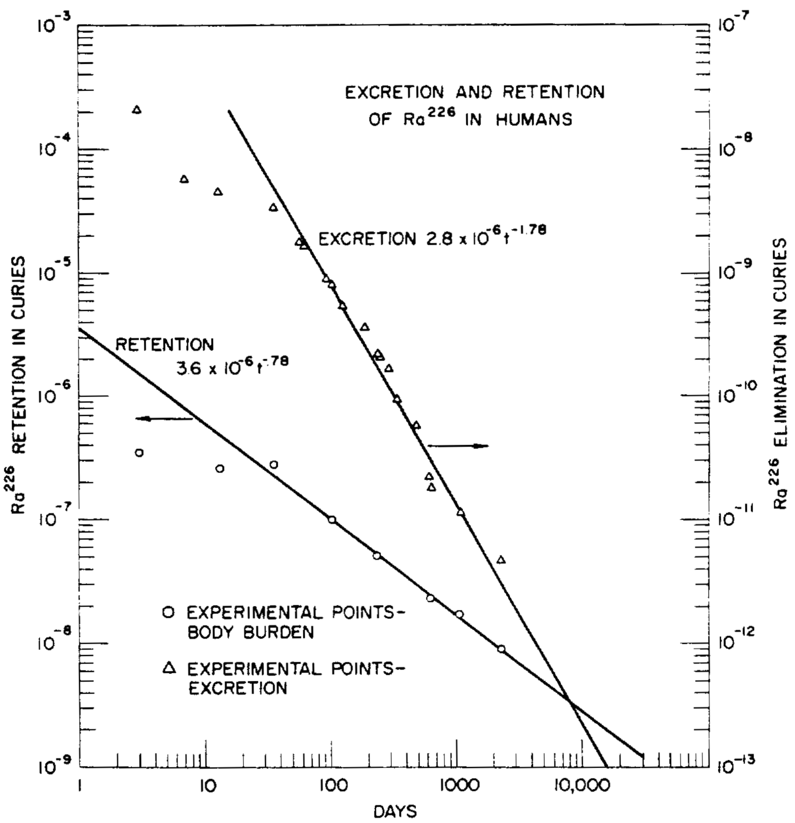

Fig. 16

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The above-mentioned equations are also consistent with the finding of Norris et al.[5] in patients observed more than 20 years after I.V. injec tion of radium; thus equations (1) and (2) predict daily coefficients of elim ination $\left(\text{computed as } \frac{dq/dt}{q} = bt^{-1}\right)$ of 9.6×10^{-5} and 9.05×10^{-5} at 8030 a 8620 days, respectively, in good agreement with Norris' values of 7.45 x and 8.05×10^{-5} for equivalent periods.[5] It would seem from these data t the power law correctly applies to radium metabolism in adult humans fo long periods of time.

As for the description of excretion in terms of a sum of exponenti terms, the data of Table 17 can be described adequately by the equation

$$dq/dt = 1.53 \times 10^{-8} e^{-3.01 \times 10^{-2} t} + 2.87 \times 10^{-11} e^{-5.13 \times 10^{-3} t} + 1.43 \times 10^{-12} e^{-5.06 \times 10^{-4} t} , \quad (3$$

but, in addition to its clumsiness, this expression suffers also of propheti blindness, inasmuch as it predicts at late times a coefficient of eliminatio of 5×10^{-4}.* This is close to what is experimentally found at 2312 days (Tables 16 and 17) but at variance with Norris' data at later times. The latter, it will be remembered, must be substantially correct for they were obtained from a total of 10 cases, and they were supported by independent remeasurements of the Elgin cases 760 days afterwards. In the second measurement the average contents of a large number of patients decrease by only 6.5%, consistent with a coefficient of elimination of 7.5×10^{-5} but not with its value of 5×10^{-4}. It will be very difficult to follow the excretion of this subject any further since corrections for normal radium intak in food and water have become necessary, and this would require hospitalization with metabolic ward facilities. Therefore, to settle any doubts[6,7, beyond dispute it is proposed to remeasure the whole-body burdens of the Elgin patients very soon in order to obtain an average coefficient of elimination utilizing observations covering a span of almost a decade. This seems to be much the most economic, direct, accurate and less punitive way of obtaining meaningful values of retention in long-lived mammals.

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*By plotting equation (2) on semilog paper it is possible to match the straight line with the following exponential expression:

$$dq/dt = 1.75 \times 10^{-10} e^{-3.3 \times 10^{-2} t} + 1.42 \times 10^{-11} e^{-7.7 \times 10^{-4} t} + 6.12 \times 10^{-13} e^{-8.75 \times 10^{-5} t} .$$

This equation will predict the correct excretion coefficient at later time ($\lambda = 8.75 \times 10^{-5}$); the trouble is that its form cannot be predicted from observations obtained at $t = 2 \times 10^3$ days if these are described as a series of exponential terms as in equation (3).

On the other hand, observations on excreta, beside their relatively higher cost and their inherent higher susceptibility to error, suffer also from considerable scatter due to their sensitivity to transient metabolic variables such as calcium content in diet, constipation, thyroid activity etc.(9) The experience of Van Dilla et al.(10) with measurements in a large number of beagles amply documents these facts; their long-term observations as well as M. P. Finkel's(11) with Sr^{90} in mice confirm the validity of the power law for alkaline earths in other mammals.

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