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II. Long-Term Cs^{137} Turnover in Man as Measured by a Whole-Body Counter[1]

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INTRODUCTION

In order to assess the radiation hazard of the fission product Cs^{137}, it is necessary to determine its long-term turnover rate in man. Part II of the report describes a long-term study of Cs^{137} made on five patients. Measurements of whole-body retention were made with the Brookhaven whole-body counter. It has been found that the technique of radiochemical analysis of excreta is of limited sensitivity for determining whole-body retention at very long periods of time after isotope administration.

In order to assay the radiation hazard, it is further necessary to estimate the retention over the normal life span of man on the basis of the data obtained. Thus a mathematical model must be developed from which long-term extrapolations can be made. In this study, data analysis was carried out with the use of a computer in order to determine the parameters of the mathematical functions that best describe these data.

METHODS

The Brookhaven whole-body counter used in this study has been previously described (*1*). The counter consists of an 8 × 4-inch NaI(Tl) crystal detector with three 3-inch photomultiplier tubes. The detector is suspended 19 inches over the adjustable cot holding the patient. A 400-channel transistorized RIDL (Model 34-12) pulse-height analyzer is employed.

$Cs^{137}Cl$ was administered intravenously as a single dose to two patients and orally to three patients. The descriptions of the patients and details of the isotope

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TABLE I

DESCRIPTION OF PATIENTS

Patient	*Dose of Cs^{137} Cl (μc)*	*Route of administration*	*Age (years)*	*Sex*	*Diagnosis*
	50	Oral	57	M	Pulmonary tuberculosis, inactive
	25	Oral	73	M	Hypopituitarism secondary to pituitary tumor
	10	Intravenous	45	F	Carcinoma of colon
	10	Intravenous	70	M	Malignant lymphoma
	10	Oral	60	F	Malignant lymphoma

administration are presented in Table I. All subjects were outpatients and were counted on the average of three times a month.

The variation in the counting rate for the photopeak of a point source of Cs^{137} is $\pm 0.24\%$. The precision of the counter for Cs^{137} in man is 0.36 mμc. The per cent standard deviation of the count rate in a patient for a 10-minute count one year after the oral administration of 50 μc of Cs^{137} is ± 0.27. The variability of the 10-minute background over a 30-day period is $\pm 1.10\%$. The variation in the count rate due to reproducing the patient's position on the cot is less than 2%. The Brookhaven-Merlin computer was programmed to determine the best least-squares fit for the curves and the standard errors.

RESULTS AND DISCUSSION

The whole-body retention data for intravenously-administered Cs^{137} for a representative patient (are shown in Fig. 1. The biological retention of Cs^{137} for all patients can be described by a sum of a number of exponential functions. However, only the final exponential component is considered in this report, as it represents 85 to 95% of the administered dose and thus accounts for practically all the radiation dose in all patients studied. The intercepts (A) and rate constants (λ) of this major exponential component for each patient, along with their standard errors, as determined by computer analysis, are presented in Table II.

In order to eliminate the effect on the geometry, and thus on the counting, of the initial variations in distribution of the administered isotope, Cs^{137} retention values were obtained from the excretion data for the first few weeks of the study. Thus, the curves were normalized to the retention values obtained by analysis of excretion in patients (and over the first 3 weeks.

The values for the biological half-life reported here range from 54 to 114 days, with a mean of 75 days. This value is in agreement with that obtained by Lidén (*2*), who reported a biological half-life of 74 days in one male injected intravenously. A similar spread in the values for biological half-life in a situation of

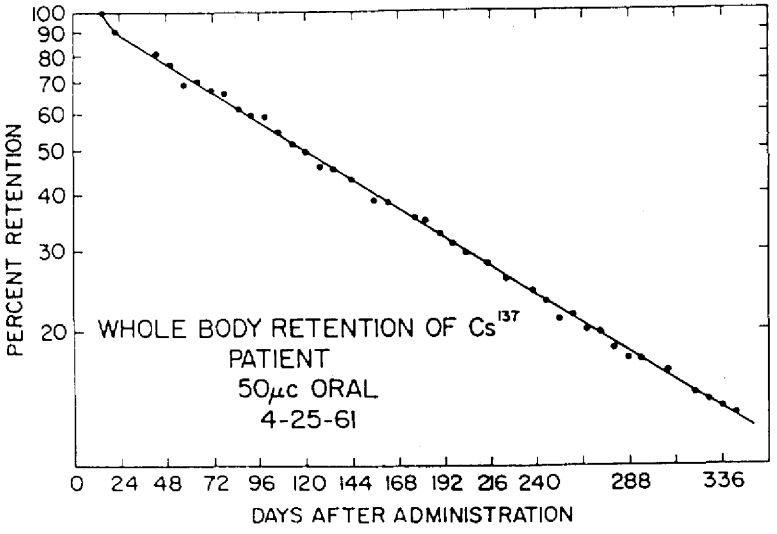

FIGURE 1

FIG. 1. Whole-body retention of Cs^{137}

TABLE II

LONG-TERM WHOLE-BODY RETENTION OF CESIUM-137

Per cent retention $(R) = Ae^{-\lambda t}$

Patient	*Period of study (days)*	*Number of counts*	A *(intercept)* (*% injected dose*)	λ *(slope)* (day^{-1}, × 10^4)	*Biological half-life (days)*
	22–343	41	94.47 ± 0.66[a]	60.72 ± 3.57[a]	113.99 + 0.67 − 0.66
	28–181	16	—	90.39 ± 1.08	76.65 + 0.90 − 0.84
	9–128	14	85.91 ± 0.90	120.53 ± 1.35	57.50 + 0.65 − 0.64
	23–239	17	86.67 ± 1.10	127.41 ± 0.90	54.39 + 0.39 − 0.38
	14–106	10	—	96.49 ± 1.97	71.82 + 2.49 − 1.44

[a] Standard error of the estimate of the coefficients of the line of regression: See Y. Beers, *Theory of Error*, Addison-Wesley Publishing Co., 1957.

chronic exposure was also noted by Rundo (*3*), who obtained values from 48 to 126 days and a mean of 87 days. These values can be compared to the mean value of 135 days as reported by Richmond *et al.* (*4*) and 115 days as reported by McNeil and Green (*5*). The wide variations in biological half-life reported may be due to the effects of age, or possibly metabolic variations or differences in diets of the subjects studied. In the present study the ages of the subjects were from 45 to 73 years, whereas in the other studies the subjects were generally young males. However, even in dogs of the same age and nutritional background, widespread differences in the Cs^{137} turnover rate still occur (*6*).

A single exponential term was sufficient to describe the data for the longest study in the present series, 343 days. Richmond *et al.* (*4*) in a study covering a period of 940 days also found that a single exponential term satisfactorily described the data. On the basis of these findings, it would appear that the data may be extrapolated over considerably longer periods of time. These findings also suggest that Cs^{137} is excreted primarily from one large compartment or, alternatively, is quite uniformly distributed throughout the body, as discussed in Part I.

It will be of interest to investigate, in future studies, the effects of such factors as age, diet, and metabolic disorders on the turnover rate, inasmuch as the present data suggest possible variations in the turnover on the basis of these factors.

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