TIME OF ENTRY OF STRONTIUM-90 AND ITS ELIMINATION FROM BONE

Yu. M. Moskalev

Presented by Active Member AMN SSSR A. V. Lebedinskii
Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 53, No. 1, pp. 59 - 62, January, 1962
Original article received March 7, 1961

The object of the present investigation has been to study the rate of elimination of Sr^{90} from rat bone in relation to the times of uptake, because despite the considerable number of experiments with Sr^{90}, these points have not yet been sufficiently investigated [1 - 4].

METHOD

Experiments were carried out on 348 rats of both sexes having a mean initial weight of 180 g. Each animal received intraperitoneally 1 - 1000 μCuries of Sr^{90}, given either as a single dose or repeatedly either daily for 100 days, or as five injections given once per month, or as ten fortnightly injections. At various times after the injections had been completed, and, in the case of repeated injections, also during the injection period, the Sr^{90} content of the upper leg was determined. The upper leg was incinerated in a muffle furnace at 600°, the mineral residue was dissolved in concentrated hydrochloric acid, and the solution diluted in a measuring flask with distilled water to the required volume, and 0.2 ml was placed on a target. Measurement of the samples by Geiger counters was made after equilibrium had been established between Sr^{90} and its daughter radioactive product V^{90}, not earlier than two weeks after placing the sample on the target. In calculating the amount of Sr^{90} in the whole skeleton, the skeletal weight was taken as 20 times that of the weight of femur.

RESULTS

The results are shown in Figs. 1 and 2, from which it can be seen that the amounts of Sr^{90} deposited and eliminated from the bone depend on the way it is introduced. Repeated as opposed to single injections have the effect that the rate of deposition is reduced and the elimination slowed.

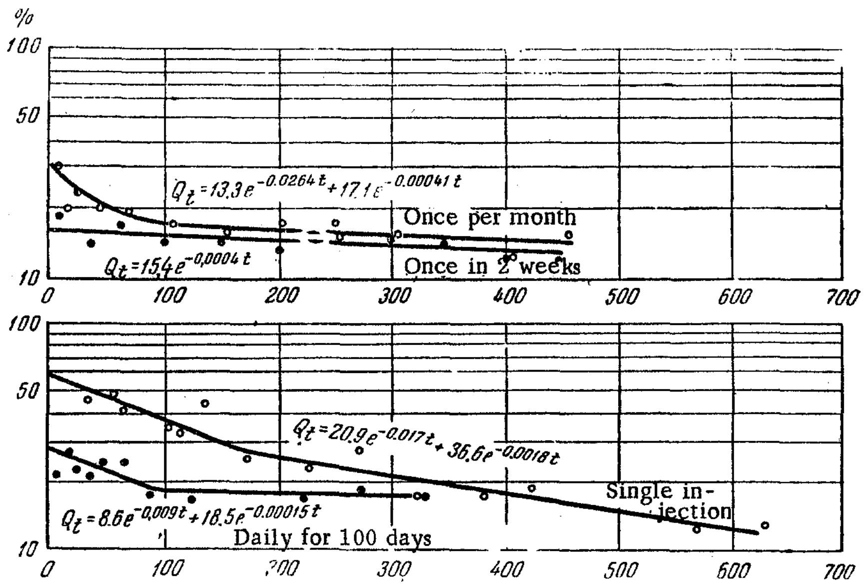

Fig. 1. Elimination of Sr^{90} from rat bone after a single injection and after injections given repeatedly over a period of time.

Change in the Sr^{90} content of the bones after a single injection is well expressed by the equation

$$Q_t = 21.0\ e^{-0.017\ t} + 36.6\ e^{-0.0018\ t} \quad (1)$$

Here, of the activity initially present in the skeleton about 36% has been eliminated with a biological half-life Tb of 41 days, while 64% elimination corresponds to Tb of 392 days.

When a daily injection of Sr^{90} is given for 100 days, after the injections have ceased, the elimination of the isotope is given by the equation

$$Q_t = 8.6\ e^{-0.009\ t} + 18.5\ e^{-0.00015\ t} \quad (2)$$

It follows from this equation that immediately after the injections, the bones contain less Sr^{90} (27.1%) than after a single injection, when the content is 57.6%. About 32% of the activity found in the rat skeleton at the end of the Sr^{90} injections i.e. 100 days after the beginning of the experiments) is excreted with a Tb of 77 days, while for the remaining 68% the Tb is 4620 days. The latter value is probably too high, because observations on the changes in Sr content made after the cessation of the injections were continued for only 340 days.

When the injections were given over 120 days at 30-day intervals, the elimination of Sr^{90} after the end of the injections is given by the equation

$$Q_t = 13.3\ e^{-0.0264\ t} + 17.1\ e^{-0.00041\ t}. \quad (3)$$

Immediately after the injections had finished, the Sr^{90} bone content was 31%, half the value found after a single injection. About 46% of the activity was eliminated with a Tb of 26 days, and 54% with a Tb of 1690 days.

After Sr^{90} had been given repeatedly over a period of 126 days at fortnightly intervals, its elimination was described by the equation

$$Q_t = 15.4\ e^{-0.0004\ t}. \quad (4)$$

With this experimental arrangement, the amount of Sr^{90} found was almost four times less (15.4%), than when the single injection was given. The biological period for elimination of half the Sr^{90} from the skeleton was 1730 days.

Elimination of Sr^{90} from bone is best described as a logarithmic function (see Fig. 2): then the Sr^{90} content of bone changes linearly with time, indicating that the reduction of the rate of elimination from the skeleton is reduced as the content falls.

When the isotope is given over a long period, both the rates of deposition and of elimination are reduced; we attribute this effect to the influence of age on the rate of mineral metabolism in bone.

A knowledge of the deposition and elimination constants is important practically for calculating the permissible rates of entry of radioactive substance into the body. These calculations show that the rates of deposition in and elimination from the critical organ do not change with time, but that the accumulation of the isotope and its elimination are governed by the exponential law where Q_t is the amount of radioisotope present in the organ at time $\underline{t}$; λ_1, λ_2 are the elimination constants; f_1, f_2 are the amounts deposited in the body; $\underline{q}$ is the amount of isotope entering the body per unit time

$$Q_t = \frac{f_1 q}{\lambda_1}(1 - e^{-\lambda_1 t}) + \frac{f_2 q}{\lambda_2}(1 - e^{-\lambda_2 t}). \quad (5)$$

Actually, the relationships are more complex, as is shown, incidentally, by the results reported here, which indicate the "variability" of the constants of deposition and elimination for the different times of entry.

In some of the animals we measured the Sr^{90} content of the skeleton at various times during the introduction of the isotope. When 1μ Curie of Sr^{90} was injected daily, the contents of the whole skeleton on the 55th, 70th, and 90th day were 10.4, 13.4 and 15μ Curies. These quantities were 10 - 15 times above the daily dose, but less than the values calculated from equation (5). If the deposition of Sr^{90} in the skeleton was completely governed by the exponential law, then, for the daily injection, calculated from the coefficients given above (f_1= 0.086, f_2= 0.185;

$\lambda_1 = 0.009$, $\lambda_2 = 0.00015$), over a period of 100 days, the expected activities would have been 15.7, 17, and 21.4 μ Curies. The absence of correspondence between the experimental and calculated values shows that further investigations must be done to determine the law governing the deposition of radioactive substances in the critical organ under conditions when its entry into the body is prolonged. Estimates of the factor describing the amount of isotope deposited or eliminated from an organ may lead to erroneous conclusions.

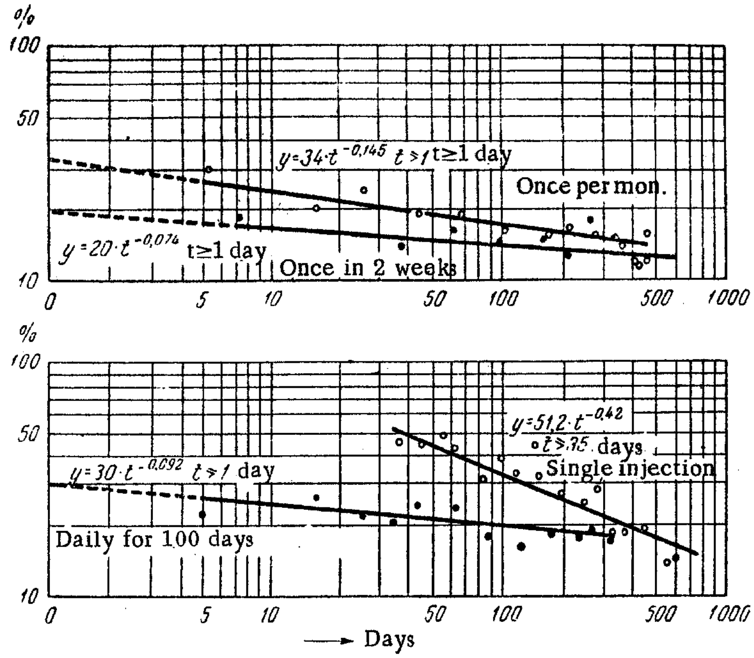

Fig. 2. Changes in the bone content of Sr^{90} after the end of the injections, and the effect of the timing of the injections.

SUMMARY

Sr^{90} was administered to rats either as a single injection, or in repeated injections given daily over 100 days, five monthly injections, or ten injections once every two weeks. Sr^{90} was eliminated more slowly after the multiple injections. Further investigations will be required to study radioisotope accumulation in the critical organ under conditions of prolonged administration.

LITERATURE CITED

1. D. I. Zakutinskii, Problems of the Toxicology of Radioactive Substances. Moscow (1959).
2. D. I. Il'in and Yu. I. Moskalev, In book: Collection of Abstracts on Radiation Medicine for 1958. Moscow (1959), p. 61.
3. É. B. Kurlyandskaya, In book: Data on the Toxicology of Radioactive Substances. Moscow (1957), p. 3.
4. Yu. I. Moskalev, In book: Medical Radiology. Moscow (1960), p. 314.