RADIATION DOSE TO THE HUMAN BODY FROM INTRAVENOUSLY ADMINISTERED ^{75}SE-SODIUM SELENITE

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The dose of radiation to the human body and some of its organs after intravenous administration of ^{75}Se-sodium selenite for diagnostic purposes has been calculated on the basis of followup of 26 patients for as long as 517 days with measurements of:

1. ***The retention of ^{75}Se in the whole body.***
2. ***The retention of ^{75}Se in the blood, liver, kidneys, ovaries, testicles, and hair.***
3. ***The excretion of ^{75}Se in urine and feces.***

Whole-body counting and profile scanning were done on the patients and samples of blood from different organs, urine, and feces were measured for radioactivity. The dose of radiation received was calculated for an average patient of 70 kg. These doses were found to be slightly higher than previously reported on a smaller number of patients and with a shorter followup. They were slightly lower than those from ^{75}Se-methionine to the whole body but higher to the liver and kidneys. The margin of error in this investigation was estimated to be about 20% for the whole-body dose and probably higher for different organs, mostly due to the poorly known rate of retention of selenite in different organs.

Both the usefulness and the limitations of ^{75}Se-sodium selenite for demonstration of malignant tumors have been previously demonstrated (*1–5*). Radioactive selenium is a relatively cheap material, emits gamma rays suitable for detection, and has a relatively good tumor specificity; 28:25:7:5:1 relative concentration was experimentally obtained in kidney:liver:tumor:heart:muscle of hamsters (*6*). There are two main limitations for its use in tumor detection: (A) lesions less than 2 cm in diameter are usually not visualized due to the limited resolving power of the equipment and (B) a relatively high dose of radiation to the body due to selenium's long physical and biologic half-life.

Selenium is a normal metabolite in human nutrition. Both selenium toxicity and deficiency are known in animals. No deficiency is known in humans and toxicity in humans occurs at much higher doses than those used in nuclear medicine. The mechanism of uptake in tissues is not known. It is excreted in urine and feces. Previous estimates of the radiation dose to the body and its vital organs are uncertain due mainly to the small number of observations and short time of followup. Cavalieri (*7*) estimated the radiation dose to the whole body after intravenous administration of ^{75}Se to be 4 mrads/μCi injected. The radiation dose after their standard diagnostic administration of 400 μCi of ^{75}Se was 1.1 rads to the whole body, 4.8 rads to the liver, and 6.1 rads to the kidney. Nordman (*8*) estimated slightly higher doses. Apparently no attempt has been made to estimate the dose of radiation to the gonads.

The aim of this study has been to estimate the dose of radiation to the whole human body and some of the more important organs from the diagnostically administered radioactive selenite on the basis of dose measurements on a relatively large number of patients with long followup.

MATERIALS AND METHODS

Twenty-six patients who had received radioactive sodium selenite (^{75}Se) for diagnostic purpose were studied. The youngest patient was 21, the oldest 81 years, the mean age being 52.8 years.

The dose injected was 400 μCi of ^{75}Se in all patients. They were followed for up to 517 days with measurements of retention and distribution of sodium selenite. All patients voluntarily agreed to the

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procedures involved. The following factors were measured: (A) retention of ^{75}Se in the whole body and in the blood; (B) distribution of ^{75}Se, by way of dose measurements on tissue specimens obtained at surgery or autopsy, scintigrams of the whole body, and profile studies of the whole body; and (C) excretion of ^{75}Se measured in urine and feces.

The dose of radiation to the whole body was calculated on the basis of data obtained by the measurement of the retention of ^{75}Se in the whole body. The radiation dose to the liver, the kidneys, the gonads, and the bone marrow was estimated on the basis of the retention of the ^{75}Se in the body and its distribution within these organs. Reliable retention curves for each of these organs could not be obtained due to the small number of patients available for these studies. They were assumed for the purpose of dose estimation to be roughly parallel to the whole-body retention curve.

Whole-body retention measurements. Whole-body retention measurements were performed in 26 patients on two of the Institute's whole-body counters (*9*); an ionization chamber was used when the total amount of ^{75}Se was more than about 5 μCi; a whole-body scanner was used with lower activities. Furthermore, measurements of profile were done on the Radiumhemmet's LKB-scanner in 16 patients.

The measurements of the blood. The ^{75}Se contents in 54 blood samples from 15 patients were measured on a 5 in. $\times$ 4 in. NaI crystal. The smallest detected quantity was 0.0015% of the given dose per liter of blood (3% over the background) in a 10-ml sample and 10 min counting time.

The measurements of tissue (organ) specimens. These measurements were done in the same manner as those of the blood. ICRP II (*10*) data were used for calculation of the ^{75}Se retention in organs. Whole-body scintigraphy was done on only two patients 27 days after the administration of ^{75}Se in both.

The measurements of ^{75}Se in urine and feces. Measurements of ^{75}Se in urine and feces were done on six patients on the adjusted whole-body scanner. The total quantity excreted within 24 hr was measured with the counting time chosen so that the statistical margin of error was less than 1%.

The calculation of the radiation dose to the whole body and some vital organs. This calculation was done following the principle described by Loevinger and Berman (*11*). The radiation dose to the liver has been calculated as the sum of the doses from the accumulated activities in the liver, the kidneys, and the rest of the body (the latter under the assumption of equal distribution). The dose to the whole body has been calculated both (A) under the assumption of equal distribution of radioactivity throughout the body and (B) taking into account the higher accumulation of radioactivity in the liver and the kidneys and assuming its equal distribution throughout the rest of the body. The radiation dose to the blood and to the bone marrow has been estimated by adding the dose from the nonpenetrating radiation from blood and bone marrow to the average dose throughout the body from penetrating radiation.

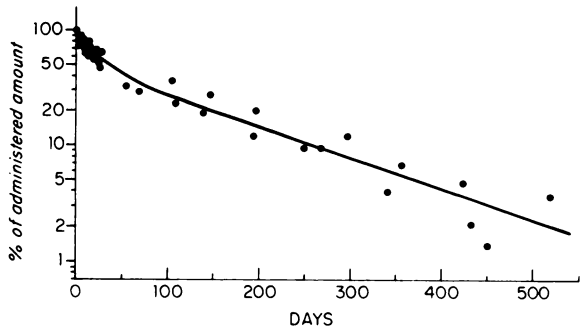

FIG. 1. Retention of intravenously administered ^{75}Se-sodium selenite in whole body. Corrected for physical decay.

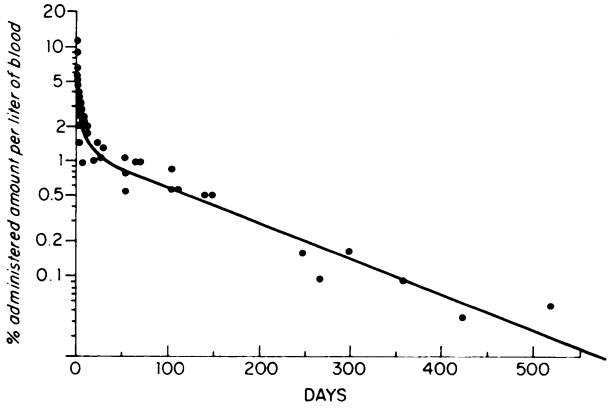

FIG. 2. Retention of intravenously administered ^{75}Se-sodium selenite in blood. Corrected for physical decay.

RESULTS

Accumulation and retention of ^{75}Se in the human body and some of its organs. Figure 1 shows the measured retention in the whole body corrected for physical decay.

The retention rate of ^{75}Se in the whole body has been approximated by two exponential terms. About 12% of the administered amount is excreted within the first 24 hr. Thereafter, about 40% is excreted with a biologic half-life of about 20 days and about 48% with a biologic half-life of approximately 115 days.

Figure 2 shows the measured retention of ^{75}Se in the blood in percent of administered dose per liter of blood after correction for physical decay.

TABLE 1. RETENTION OF ^{75}Se IN DIFFERENT ORGANS*

Organ	Percentage of administered ^{75}Se: Per gram	Percentage of administered ^{75}Se: Whole organ	Percentage dose retained in whole body
Bone marrow	0.0033	9.90	11.4
Blood (calculated values)	0.0033	17.9	20.6
Liver	0.014	23.8	27.3
Lungs	0.0056	5.6	6.4
Kidneys	0.034	10.2	11.7
Testicles	0.0013	0.052	0.060

* Twenty-four hours after intravenous administration (whole-body retention = 87%).

TABLE 2. RETENTION OF ^{75}Se IN DIFFERENT ORGANS*

Organ	Percentage of administered ^{75}Se: Per gram	Percentage of administered ^{75}Se: Whole organ	Percentage dose retained in whole body
Bone marrow	0.000046	0.137	3.4
Blood (calculated values)	0.000067	0.362	9.0
Hair	0.00068	0.068	1.7
Liver	0.000308	0.524	13.1
Abdominal lymph nodes	0.000118	0.047	1.2
Kidneys	0.000453	0.136	3.4
Ovaries	0.000134	0.00107	0.027

* Four hundred sixteen days after intravenous administration (whole-body retention = 4%).

The retention of the ^{75}Se in the blood can also be described by a two-phase exponential course with the biologic half-lives of 5 and 97 days, respectively, about 80% being excreted with a 5-day biologic half-life.

Tables 1 and 2 show the retention of ^{75}Se in different organs in two different patients at 1 day and at 416 days after administration, the retention in the whole body at that time being 87% and 4%, respectively, of the administered dose.

Only two whole-body scintigrams were done, both 27 days after the administration of ^{75}Se. Both show the accumulation of radioactivity in the liver and kidneys but in no other areas of the body. The bulk of the tumor was removed in both patients after administration of ^{75}Se and before the scintigrams were done.

Profile measurements showed the activity in the region of the liver to diminish faster than in other areas. This was corroborated to some degree by the organ measurements.

Both profile and organ measurements showed the highest concentration of ^{75}Se in the liver and the kidneys. Table 3 shows the excretion of ^{75}Se in urine and feces.

The rate of excretion has also been calculated with the assumption that the whole-body retention follows the retention equation. The table shows relatively good correlation of the measured and calculated data.

Dose measurements. The fraction of the administered amount of radioactivity in the different organs was calculated on the basis of the profile measurements and measurements of tissue specimens. Table 4 shows the doses from 1 μCi ^{75}Se intravenously administered as sodium selenite.

The accumulation of radioactivity in the gonads was no higher than in the body as a whole. There was relatively little accumulation in the bone marrow. Most of the ^{75}Se accumulated in the liver and kidneys with the amount in the liver diminishing faster than that in the rest of the body. A relatively high accumulation was found in the hair a long time after administration. The excretion was mostly in the urine and feces, the former dominating during the first month.

DISCUSSION

The margin of error. The margin of error was estimated on the basis of the calibration procedures to be below 10% in the retention measurements of ^{75}Se in the whole body and in the blood. It was estimated to be below 3% during the first month whenever measurements could be performed within 24 hr of the administration of the ^{75}Se.

Some circumstances contributing to the error in estimating the radiation dose from ^{75}Se were: (A) the calculations were performed assuming a homogeneous distribution of the ^{75}Se throughout an organ; (B) a mathematical human model, 70 kg in weight with "standard size" organs, was used for the calculations of the radiation dose to the whole body; (C) unknown retention curves in the different organs had to be estimated from tissue specimens from sick patients with possibly altered metabolism of selenium; and (D) the magnitude of the fraction excreted with the long half-life of 115 days is a biologic parameter with apparently rather wide individual variation.

The excretion through the lungs of ^{75}Se has been investigated before (*8*) and found to be practically negligible. It was therefore not investigated here.

The retention of ^{75}Se in the tumor tissue is not relevant to the consideration of the radiation dose to the human body and different organs, since in the

TABLE 3. EXCRETION OF ^{75}Se THROUGH URINE AND FECES AFTER INTRAVENOUS ADMINISTRATION

Patient No.	Days after administration	Daily excretion in percent of administered dose—corrected for physical decay			Calculated excretion
		Urine	Feces	Total	Total
12	11	0.52	1.40	1.92	1.23
28	30	0.33			
1	31	0.26	0.07	0.33	0.71
2	62	0.19	0.14	0.33	0.36
29	84	0.16	0.13	0.29	0.25
6	88	0.10	0.04	0.10	0.24

TABLE 4. DOSE OF RADIATION (MILLIRADS)*

Radiation dose from organ	Radiation dose in millirads per microcurie ^{75}Se						
	Bone marrow	Blood	Liver	Kidneys	Testicle	Ovaries	Whole body
Bone marrow	0.84†						
Blood		0.83†					
Liver			26.9	2.8	0.006	0.24	1.3
Kidneys			1.1	31	0.010	0.14	0.48
Testicles					1.5		
Ovaries						2.4	
Rest of body			5.3	4.6	5.1	4.2	4.6
Whole body (homogeneous distribution)	5.7‡	5.7‡					6.3
Summary	6.5	6.5	33	38	6.6	7.0	6.4

* From 1 μCi ^{75}Se intravenously administered as sodium selenite.
† Nonpenetrating radiation.
‡ Penetrating radiation.

long-term survivors most or all of the tumor has been removed. In addition, the mass of the tumor being a relatively unknown and changeable quantity, its dosimetry would be expected to be extremely unreliable. Enough data exist (*7,8*) to the effect that the accumulation of ^{75}Se in most kinds of malignant tumors is high and increases relatively fast (with respect to other organs) during a short period of time after administration of ^{75}Se.

The radiation doses calculated in this study are somewhat higher than those from some previous studies. However, our calculations for the dose to the liver and the kidneys are also based only on data from two patients and are not reliable.

Compared with the radioactive selenomethionine (with ^{75}Se), also used for detection of malignant tumors, the sodium selenite is being excreted somewhat faster (*12*) resulting in a lower dose of radiation to the whole body. Due to the difference in the metabolism, however, the dose to the liver and kidneys is slightly higher from ^{75}Se-sodium selenite than from ^{75}Se-selenomethionine.

Technetium-99m-pertechnetate, probably the most widely used diagnostic radioactive isotope at the present, gives a radiation dose to the whole body of only 10–20 mrads/mCi, i.e., at least 30 times less than that from ^{75}Se.

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GREATER NEW YORK AREA CHAPTER
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FIRST ANNUAL SCIENTIFIC MEETING

The Greater New York Area Chapter of the Society of Nuclear Medicine will hold its first annual meeting on November 21–23, 1975, in the Empire Room of the Waldorf Astoria. The program will include scientific sessions, teaching sessions, and commercial exhibits.

A unique approach to be utilized at this meeting will be the format of panel discussions on major subject areas in nuclear medicine. Each panel will be conducted by a group of experts in that specific area, including members of the Chapter and outside speakers. The subjects chosen for this meeting include: Radionuclide Procedures in the Detection of Neoplasms; Radioimmunoassay; Cardiovascular Nuclear Medicine; The Role of Nuclear Medicine in Benign Bone Disease; Trauma; and New Concepts and Developments in the Field of Nuclear Medicine Instrumentation. Members of the New York Chapter are invited to submit original papers for inclusion in any of these panels. Papers are to be submitted by September 15, 1975, to John S. Laughlin, Ph.D., Memorial Sloan-Kettering Cancer Center, 410 East 68th Street, New York, N.Y. 10021.

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Registration fees for the meeting will be $15.00 for technicians who are members of the New York Chapter, medical students and house officers with supporting letters; $25.00 for full members of the New York Chapter and for technicians who are not members of the New York Chapter; $50.00 for all other individuals.

Members of the New York Chapter will be admitted to the business meeting without charge.

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