SUMMARY OF CURRENT RADIATION DOSE ESTIMATES TO NORMAL HUMANS FROM ^{99m}Tc AS SODIUM PERTECHNETATE

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SUMMARY OF ESTIMATED ABSORBED DOSES TO NORMAL HUMANS FROM ^{99m}Tc AFTER A SINGLE INTRAVENOUS ADMINISTRATION OF LABELED SODIUM PERTECHNETATE*

Target organ	Absorbed dose (rads/mCi of ^{99m}Tc administered)	
	Resting population	Nonresting population
Bladder wall	0.053	0.085
Gastrointestinal tract:		
stomach (wall)	0.25	0.051
upper large intestine (wall)	0.068	0.12
lower large intestine (wall)	0.061	0.11
Ovaries	0.022	0.030
Red marrow	0.019	0.017
Testes	0.009	0.009
Thyroid	0.13	0.13
Total body†	0.014	0.011

* These dose estimates are for subjects not pretreated with blocking agents such as $NaClO_4$, $KClO_4$, or iodide.

† Technetium-99m is assumed to be distributed uniformly in the total body.

RADIOPHARMACEUTICAL

Technetium-99m-sodium pertechnetate as a radiopharmaceutical may be obtained as a sterile solution in isotonic sodium chloride or by elution from a sterile radionuclide generator. The *U.S. Pharmacopeia XIX* (*1*) specifies that the ^{99m}Tc present must be between 90 and 110% of the labeled quantity, of which 95% of the ^{99m}Tc must be present as pertechnetate. The allowable radionuclidic impurities, which will vary with the method of production, are also specified by the *Pharmacopeia* (*1*). For purposes of these dose calculations, the radionuclidic and radiochemical purity of the pharmaceutical are assumed to be 100%.

NUCLEAR DATA

Nuclear data for ^{99m}Tc are given in Table 1 (*2*). The decay of 1 mCi of ^{99m}Tc results in the production of approximately 3×10^{-9} mCi of ^{99}Tc (half-life 2.1×10^{5} year).

BIOLOGIC DATA

The human distribution and excretion functions for ^{99m}Tc-pertechnetate administered as sodium pertechnetate used in this report are based on a model developed by Hays and Berman (*3*). This model was constructed on the basis of data obtained by the authors, supplemented by published data (*4–8*), and subsequently modified by additional unpublished data provided by K. Lathrop. In developing the model, data on ^{99m}Tc activity in plasma, erythrocytes, saliva, stomach plus contents, intestine plus contents, urine, feces, and total body, derived from one or more of the above sources, were used. These data were obtained from subjects who had not been pretreated with blocking agents such as $NaClO_4$, $KClO_4$, or iodide. In analyzing the data in terms of the model it became apparent that they fell into two distinct groups possibly related to inactivity (resting) and to normal physical activity (nonresting) of the subjects. Hence, two sets of biologic parameters are derived, forming the bases for computing lower and upper radiation dose estimates.

A histogram of the distribution of ^{99m}Tc activity in the body as a function of time is presented in Fig. 1, and the biologic parameters are given in Table 2.

TABLE 1. NUCLEAR DATA*

Radionuclide	^{99m}Tc	
Physical half-life	6.03 hr	
Decay constant	0.1149 hr^{-1}	
Mode of decay	Isomeric transition	
Equilibrium dose constant for nonpenetrating radiation (gm-rad/μCi-hr)	0.0369	
Principal photons	E_i (MeV)	n_i
	0.0186†	0.077
	0.1405	0.879

* For complete compilation of nuclear data reader is referred to Ref. 2. Table lists only photons with mean yield per disintegration > 0.01; E_i is photon energy; n_i is mean number of photons per disintegration.

† Weighted mean energy of K x-rays.

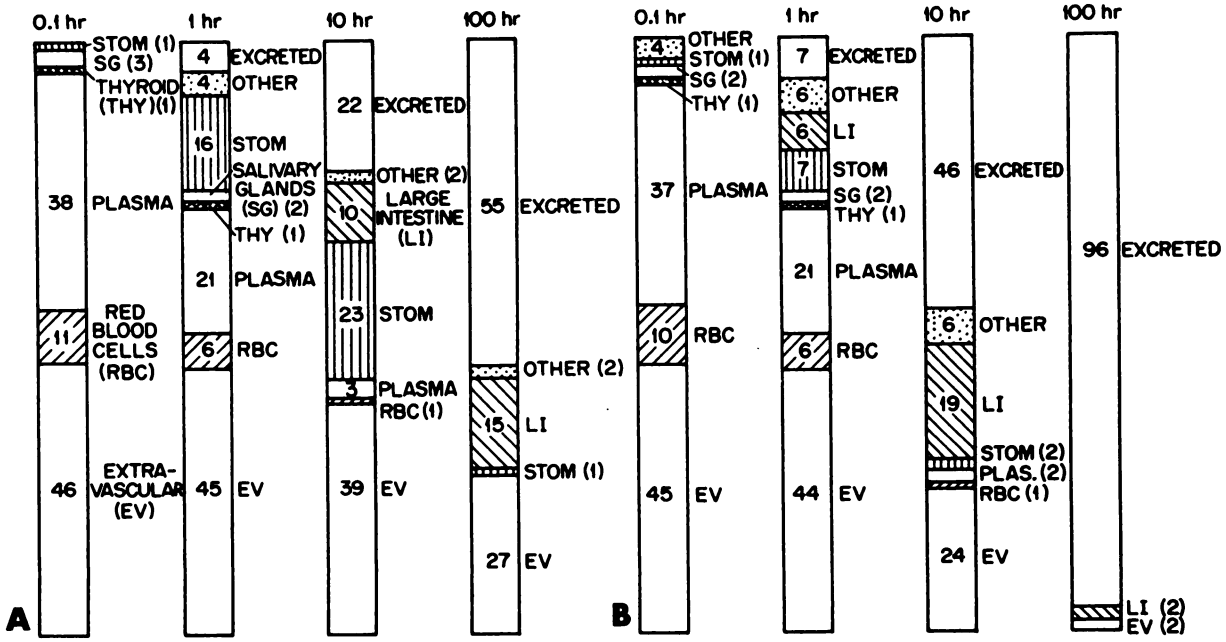

FIG. 1. Estimated percent of administered ^{99m}Tc in tissues at various times after intravenous administration of ^{99m}Tc-sodium pertechnetate. Corrected for radioactive decay. (A) Resting population; (B) nonresting population.

TABLE 2. BIOLOGIC PARAMETERS OF THE FRACTIONAL DISTRIBUTION FUNCTIONS $\alpha_h(t)$ OF PERTECHNETATE FROM A SINGLE INTRAVENOUS ADMINISTRATION OF SODIUM PERTECHNETATE*

$$\alpha_h(t) = \sum_j \alpha_{hj} e^{-\lambda_j t} = \alpha_{h1} e^{-\lambda_1 t} + \alpha_{h2} e^{-\lambda_2 t} + \alpha_{h3} e^{-\lambda_3 t} + \alpha_{h4} e^{-\lambda_4 t} + \alpha_{h5} e^{-\lambda_5 t}$$

Source organs	α_{h1}	α_{h2}	α_{h3}	α_{h4}	α_{h5}
Resting population	$\lambda_1 = 7.92\ hr^{-1}$	$\lambda_2 = 0.630\ hr^{-1}$	$\lambda_3 = 0.0702\ hr^{-1}$	$\lambda_4 = 0.00396\ hr^{-1}$	
Extravascular	−0.0739	0.0962	—	0.402	—
Large intestine	—	0.0107	−0.231	0.220	—
Plasma	0.093	0.301	0.0497	0.00582	—
Red blood cells	0.026	0.0860	0.0142	0.00132	—
Salivary glands	—	0.0300	0.00632	0.000546	—
Stomach	0.0345	−0.477	0.424	0.0191	—
Thyroid	−0.0199	0.0165	0.00307	0.000268	—
Total body†	—	0.0661	0.259	0.675	—
Nonresting population	$\lambda_1 = 7.98\ hr^{-1}$	$\lambda_2 = 4.82\ hr^{-1}$	$\lambda_3 = 0.553\ hr^{-1}$	$\lambda_4 = 0.115\ hr^{-1}$	$\lambda_5 = 0.0246\ hr^{-1}$
Extravascular	−0.058	—	0.0199	0.268	0.194
Large intestine	−0.049	0.103	−0.266	−0.051	0.263
Plasma	0.124	—	0.259	0.060	0.0049
Red blood cells	0.036	—	0.074	0.017	0.0014
Salivary glands	−0.035	—	0.0270	0.0077	0.00057
Stomach	0.132	−0.214	0.0128	0.0656	0.0037
Thyroid	−0.0189	—	0.0149	0.0037	0.000285
Total body†	—	—	—	0.518	0.482

* The activity in the source region r_h at time t after administration of the radionuclide of activity A_o is given by $A_h(t) = q_h(t)e^{-\lambda t}$, where $q_h(t) = A_o \sum_j \alpha_{hj} e^{-\lambda_j t}$, α_{hj} is the initial value of the j^{th} exponential component of that fraction of the pertechnetate administered as sodium pertechnetate that appears in source region r_h, λ_j is the biologic disappearance constant of the j^{th} exponential component, and λ is the physical decay constant of the radionuclide. The cumulated activity in source region r_h over an infinite period is given by $\tilde{A}_h(0,\infty) = A_o \sum_j \alpha_{hj}/(\lambda_j + \lambda)$.

† Values for total body include all tissues.

ABSORBED-DOSE ESTIMATES

The values of cumulated activity for the labeled pertechnetate located extravascularly, in plasma and in the red cells, were computed using the data in Table 2. The absorbed fractions for these source regions were assumed to be equal to those for sources uniformly distributed in the total body.

The activity contained in the large intestine was assumed to be uniformly distributed with respect to weight between the contents of the upper and lower large intestines. The above was an approximation since the fraction of the administered activity and its residence time in the intestinal wall were unknown. The dose to the intestinal wall was calculated on the assumption that the contents of the intestine were irradiating the wall.

The activity contained in the stomach was distributed between the contents of the stomach and the lumen of the gastric glands. The exact distribution between the two regions was unknown. For the purpose of these dose calculations, all of the activity was assumed to be located in the contents of the stomach.

To calculate the cumulated activity for the bladder contents, $\tilde{A}_{BLADC}$, the bladder was assumed to fill at a rate of 62.5 ml/hr and to empty completely five times daily at regular intervals of 4.8 hr (*9*). A maximum value of $\tilde{A}_{BLADC}$ was calculated by assuming that the bladder was empty at the time sodium pertechnetate was administered. The rate constant for plasma-to-urine transport of pertechnetate is 0.228 hr^{-1} for the resting population and 0.402 hr^{-1} for the nonresting population. The details for computing $\tilde{A}_{BLADC}$ are available from the MIRD Committee. The average dose to the bladder wall was computed using the method described by Snyder et al (*10,11*).

The salivary glands were used as source organs because of their high uptake of ^{99m}Tc. To obtain the necessary absorbed fractions for the salivary glands as a source organ, which are not yet available in the heterogeneous phantom (*12*), the absorbed fractions for the thyroid were used since the locations and sizes of these organs are similar. To calculate the dose to the thyroid from the activity in the salivary glands, only the absorbed fractions for penetrating radiations were used. It was assumed that the activity in the salivary glands was located in the thyroid. This approximation will result in an overestimate of the dose.

The masses of the target organs are given in Table 3.

The absorbed fractions used for the dose estimate calculations in this report were obtained from special Monte Carlo computer calculations, using the complete energy spectrum of penetrating and nonpenetrating radiation emitted by ^{99m}Tc, instead of from the interpolated values of absorbed fractions published in *MIRD Pamphlet No. 5* (*12*). The heterogeneous phantom (*13*) used for these calculations is a modification of that described in *MIRD Pamphlet No. 5* and more nearly simulates man.

TABLE 3. MASS OF TARGET ORGANS (13)

Target organ	Mass (gm)
Bladder wall	45
Gastrointestinal tract:	
stomach—wall	150
upper large intestine	
wall	209
contents	220
lower large intestine	
wall	160
contents	137
Ovaries	8.3
Red marrow	1,500
Testes	37
Thyroid	19.6
Total body	69,880

The dose from the ^{99}Tc associated with ^{99m}Tc has been neglected since these doses are five orders of magnitude less than the dose from ^{99m}Tc.

REFERENCES

1. Sodium pertechnetate Tc-99m solution. In *U.S. Pharmacopeia XIX*, Rockville, Md, 1975, pp 463–464

2. Dillman LT, Von der Lage FC: *Radionuclide Decay Schemes and Nuclear Parameters for Use in Radiation Dose Estimates*, MIRD Pamphlet No 10, New York, Society of Nuclear Medicine, 1975

3. Hays MT, Berman M: Pertechnetate distribution in man: A compartmental model: Submitted for publication

4. Beasley TM, Palmer HE, Nelp WB: Distribution and excretion of technetium in humans. *Health Phys* 12: 1425–1435, 1966

5. Lathrop KA, Harper PV: Biologic behavior of ^{99m}Tc from ^{99m}Tc-pertechnetate ion. *Prog Nucl Med* 1: 145–162, 1972

6. Harden RMcG, Alexander WD: The relation between the clearance of iodide and pertechnetate in human parotid saliva and salivary flow rate. *Clin Sci* 33: 425–431, 1967

7. Welch MJ, Adatepe M, Potchen EJ: An analysis of technetium ($^{99m}TcO_4^-$) kinetics: The effect of perchlorate and iodide pretreatment. *Int J Appl Radiat Isot* 20: 437–445, 1969

8. Hays MT: ^{99m}Tc-pertechnetate transport in man: Absorption after subcutaneous and oral administration; secretion into saliva and gastric juice. *J Nucl Med* 14: 331–335, 1973

9. Snyder WS, Ford MR: A dosimetric study for the administration of Neohydrin labeled with ^{203}Hg and ^{197}Hg. In *Health Physics Division Annual Progress Report*, Oak Ridge, Tenn, ORNL 4168, July 31, 1967, pp 267–273

10. Snyder WS, Ford MR, Warner GG: Estimation of dose and dose commitment to bladder wall from a radionuclide present in urine. In *Health Physics Division Annual*

Progress Report, Oak Ridge, Tenn, ORNL 4585, July 31, 1970, pp 206–208

11. Snyder WS, Poston JW, Warner GG, et al: Dose to a dynamic bladder for administered radionuclides. In *Health Physics Division Annual Progress Report*, Oak Ridge, Tenn, ORNL 4979, July 31, 1974, pp 13–16

12. Snyder WS, Ford MR, Warner GG, et al: Estimate of absorbed fractions for monoenergetic photon sources uniformly distributed in various organs of a heterogeneous phantom. MIRD Pamphlet No 5, *J Nucl Med* 10 (Suppl 3): 8, 1969

13. Snyder WS, Ford MR, Warner GG: *Estimates of Specific Absorbed Fractions for Radiation Sources Uniformly Distributed in Various Organs of a Heterogeneous Phantom*, MIRD Pamphlet: to be published

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