MIRD DOSE ESTIMATE REPORT NO. 12

Radiation Absorbed Dose from Tc-99m Diethylenetriaminepentaacetic Acid (DTPA)

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RADIOPHARMACEUTICAL

Technetium-99m diethylenetriaminepentaacetic acid (Tc-99m DTPA) is formed by the addition of Tc-99m as pertechnetate to a lyophilized mixture of $CaNa_3DTPA$ and $SnCl_2$. A Tc-99m DTPA tin chelate is formed. This dose estimate report is only for Tc-99m DTPA formed by the above method and not for other formulations that may also contain DTPA. The biological distributions used in this report were obtained with preparations having a radiochemical purity of ≥95% as measured chromatographically.

NUCLEAR DATA

Technetium-99m decays to Tc-99 by isomeric transition with a half-life of 6.02 h. Technetium-99 undergoes beta-minus decay with a half-life of 2.13×10^5 yr. The very small contribution of Tc-99 to the radiation absorbed dose has been ignored in these estimates. The nuclear data for Tc-99m are given in Table 1.

BIOLOGICAL DATA

The dose estimates in this report are based on three sources of data: (a) from whole-body retention determined in 11 patients (H. L. Atkins, unpublished data); (b) from quantitative renal uptake studies made over 24 h by conjugate counting on three patients with normal renal function (S. R. Thomas, unpublished data); and (c) from three normal volunteers in whom kidney uptake was determined quantitatively by comparison with a renal phantom (*1*).

After intravenous administration, Tc-99m DTPA is rapidly distributed throughout the extracellular fluid space (*1*,*2*). Plasma clearance is by glomerular filtration (*2*). Only kidneys and bladder contents specifically accumulate the Tc-99m DTPA.

Table 2 lists the biological parameters and residence times. Bladder residence time was calculated for both 2.4-h and 4.8-h voiding intervals (*3*).

ABSORBED DOSE ESTIMATES

The distribution data listed in Table 2 along with S values given in MIRD Pamphlet No. 11 (*4*) were used to make absorbed dose estimates for various organs. The source organs included kidney, bladder contents, and the remaining body activity distributed uniformly throughout the remainder of the total body. This remaining body activity was obtained by subtracting kidney activity from total-body activity, with the latter measured immediately after voiding the urine. The dose to each specific organ was then calculated according to the procedures outlined in MIRD Pamphlet No. 1, revised (*5*). The dose per unit administered activity for an organ is the sum of the products obtained from multiplying the residence time in each organ by the appropriate S value. Calculation of S values for each target organ from the remainder of the body was done according to the S value correction method of Coffey and Watson (*6*). The remainder of the body is the body apart from all source organs. In this report, all of the body except kidneys and bladder contents is included in the remainder. The S values are provided in Table 3.

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TABLE 1. NUCLEAR DATA (7)

Radionuclide			Tc-99m		Tc-99	
Physical half-life			6.02 h		2.13×10^5 y	
Decay constant			$0.1151\ h^{-1}$		$3.25 \times 10^{-6}\ y^{-1}$	
Mode of decay			I.T. to Tc-99		β^-, γ	
Principal radiations:	E_i* (keV)	n_i†	Δ_i‡ rad-g/μCi-h	Δ_i Gy-kg/MBq-s	Δ_i rad-g/μCi-h	Δ_i Gy-kg/MBq-s
Photon	18–21	0.074	0.0029	2.18×10^{-10}		
	140.5	0.89	0.266	2.00×10^{-8}		
Nonpenetrating			0.0332	2.49×10^{-9}	0.180	1.35×10^{-8}

* E_i is energy per photon.

† n_i is mean number per nuclear transition.

‡ Δ_i is mean energy emitted per unit cumulated activity.

Nonpenetrating radiation from Tc-99m includes conversion and Auger electrons ranging in energy from 1.6 keV to 140 keV.

Nonpenetrating radiation from Tc-99 includes beta-minus emissions with a maximum energy of 294 keV and an average energy of 84.6 keV.

Only photons whose mean number per disintegration is 0.01 or greater are included.

NOTE: Complete decay of 1 unit of activity of Tc-99m produces 3.2×10^{-9} units Tc-99.

TABLE 2. PARAMETERS OF THE FRACTIONAL DISTRIBUTION FUNCTION $\alpha_h(t)$ FOR A SINGLE INTRAVENOUS ADMINISTRATION OF Tc-99m(Sn)DTPA CHELATE

$$\alpha_h(t) = \alpha_{h1}e^{-\lambda_{h1}t} + \alpha_{h2}e^{-\lambda_{h2}t}$$

	α_{h1}	λ_{h1}	α_{h2}	λ_{h2}	τ_h
Total body	0.579	0.690	0.421	0.0750	3.20
Remainder of the body	0.541	0.618	0.399	0.0746	2.84
Kidneys	0.0479	2.908	0.0122	0.0434	0.092
Bladder contents					
2.4 h void interval					0.842
4.8 h void interval					1.720

Notes:
1. λ_{hj}'s are biological rate constants in h^{-1} for source organ, h.
2. The residence time, τ_h, in hours, includes physical decay and is calculated using relationship $\tau_h = \Sigma\alpha_{hj}/(\lambda + \lambda_{hj})$ (5), where λ is physical decay constant given in reciprocal hours (for Tc-99m, $\lambda = 0.1151\ h^{-1}$). τ_h values given for the total body and kidneys represent average of individual τ_h values obtained through individual curve-fitting analysis. These values differ slightly from values that would be derived from average α's and λ's given in table.
3. τ for bladder contents represents average of τ calculations for each individual patient.

ESTIMATED ABSORBED DOSES FROM AN I.V. ADMINISTRATION OF Tc-99m DTPA

	Absorbed dose per unit administered activity			
	2.4 h voiding schedule		4.8 h voiding schedule	
Organ	rad/mCi	μGy/MBq	rad/mCi	μGy/MBq
Bladder wall*	0.14	38.0	0.28	76.0
Kidneys	0.022	5.9	0.022	6.0
Ovaries	0.013	3.5	0.019	5.3
Red marrow	0.010	2.8	0.012	3.3
Testes	0.0088	2.4	0.013	3.5
Total body	0.0075	2.0	0.0091	2.5
Thyroid	0.0043	1.2	0.0043	1.2

Minor discrepencies in conversion from traditional to S.I. units are due to rounding off of the values.

* Bladder-wall dose is calculated for an assumed constant bladder content of 200 ml (4).

TABLE 3. S VALUES USED FOR "REMAINDER OF THE BODY"*

Target organ (k)	S values for "remainder of the body" to the target organ (rad/μCi·h)	S values for the total body to the target organ (rad/μCi·h)
Bladder wall	1.9×10^{-6}	2.3×10^{-6}
Kidneys	1.4×10^{-6}	2.2×10^{-6}
Ovaries	2.4×10^{-6}	2.4×10^{-6}
Red marrow	2.9×10^{-6}	2.9×10^{-6}
Testes	1.7×10^{-6}	1.7×10^{-6}
Total body	2.0×10^{-6}	2.0×10^{-6}
Thyroid	1.5×10^{-6}	1.5×10^{-6}

* In this report "remainder of the body" refers to total body minus kidneys and bladder contents. $S(k \leftarrow RB) = S(k \leftarrow TB)(m_{TB}/m_{RB}) - S(k \leftarrow kid)(m_{kid}/m_{RB}) - S(k \leftarrow Bldc)(m_{Bldc}/m_{RB})$.

TB: total body.

RB: "remainder of the body."

Bldc: bladder contents.

kid: kidneys.

k: target organ.

m: mass.

See Ref. *6* for details.

REFERENCES

1. MCAFEE JG, GAGNE G, ATKINS HL, et al: Biological distribution and excretion of DTPA labeled with Tc-99m and In-111. *J Nucl Med* 20:1273-1278, 1979
2. KLOPPER JF, HAUSER W, ATKINS HL, et al: Evaluation of ^{99m}Tc-DTPA for the measurement of glomerular filtration rate. *J Nucl Med* 13:107-110, 1972
3. CLOUTIER RJ, SMITH SA, WATSON EE, et al: Dose to the fetus from radionuclides in the bladder. *Health Phys* 25: 147-161, 1973
4. SNYDER WS, FORD MR, WARNER GG, WATSON SB: *"S" Absorbed Dose per Unit Cumulated Activity for Selected Radionuclides and Organs Pamphlet No. 11.* New York, Society of Nuclear Medicine, 1975
5. LOEVINGER R, BERMAN M: *A Revised Schema for Calculating the Absorbed Dose from Biologically Distributed Radionuclides, MIRD Pamphlet No. 1, Revised.* New York, Society of Nuclear Medicine, 1976
6. COFFEY JL, WATSON EE: Calculating dose from remaining body activity: A comparison of two methods. *Med Phys* 6: 307-308, 1979
7. NCRP Report No. 58, A Handbook of Radioactivity Measurements Procedures, National Council on Radiation Protection and Measurements, Washington, DC, 1978