mird / DOSE ESTIMATE REPORT NO. 5

SUMMARY OF CURRENT RADIATION DOSE ESTIMATES TO HUMANS FROM ^{123}I, ^{124}I, ^{125}I, ^{126}I, ^{130}I, ^{131}I, and ^{132}I AS SODIUM IODIDE

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SUMMARY OF ESTIMATED ABSORBED DOSES FROM RADIOIODINE AFTER A SINGLE ORAL ADMINISTRATION OF SODIUM IODIDE TO A EUTHYROID ADULT

Target organ	Maximum thyroid uptake (%)	Absorbed dose (rads/mCi of radioiodine administered)						
		^{123}I	^{124}I	^{125}I	^{126}I	^{130}I	^{131}I	^{132}I
Liver	5	0.029	0.36	0.087	0.25	0.32	0.20	0.14
	15	0.028	0.45	0.22	0.45	0.30	0.35	0.13
	25	0.027	0.55	0.36	0.65	0.29	0.48	0.13
Ovaries	5	0.036	0.33	0.029	0.14	0.34	0.14	0.14
	15	0.034	0.31	0.033	0.15	0.31	0.14	0.14
	25	0.031	0.30	0.039	0.15	0.29	0.14	0.13
Red marrow	5	0.030	0.27	0.044	0.16	0.23	0.14	0.094
	15	0.030	0.36	0.077	0.26	0.23	0.20	0.092
	25	0.030	0.46	0.12	0.37	0.23	0.26	0.091
Stomach wall	5	0.25	2.4	0.27	1.5	2.4	1.7	1.2
	15	0.23	2.2	0.26	1.4	2.2	1.6	1.2
	25	0.21	2.0	0.26	1.3	2.0	1.4	1.1
Testes	5	0.013	0.18	0.015	0.088	0.18	0.084	0.078
	15	0.012	0.18	0.018	0.094	0.17	0.085	0.076
	25	0.012	0.17	0.024	0.10	0.16	0.088	0.074
Thyroid	5	2.4	180.0	140.0	320.0	22.0	260.0	2.3
	15	7.5	530.0	450.0	960.0	68.0	800.0	7.4
	25	13.0	890.0	790.0	1,600.0	120.0	1,300.0	13.0
Total body*	5	0.025	0.36	0.11	0.28	0.25	0.24	0.10
	15	0.027	0.59	0.29	0.61	0.27	0.47	0.10
	25	0.029	0.83	0.49	0.95	0.29	0.71	0.11

* Includes dose from source organs plus dose from radioiodine assumed to be distributed uniformly in the total body.

RADIOPHARMACEUTICAL

Sodium iodide as a radiopharmaceutical is supplied in a basic solution to prevent volatilization of the iodine and contains a reducing agent to minimize the conversion to iodate. Liquid and solid forms are available for oral administration as well as sterile solutions for intraveonus use; however, most radioiodide is administered orally. The biologic availability of iodide from some solid dose forms may be less than 100%. All production methods for radioisotopes of iodine yield carrier-free products except for ^{131}I. In the case of ^{131}I, the very small quantity of stable iodine does not affect the biologic distribution. For purposes of these dose calculations, the radionuclidic and radiochemical purity of the pharmaceutical have been assumed to be 100%.

NUCLEAR DATA

Nuclear data for the radioisotopes of iodine considered in this report are given in Table 1.

BIOLOGIC DATA

The human tissue distribution data for radioiodine administered as iodide on which this report is based were obtained from the literature and from studies by Henry N. Wellman and his associates at the Nuclear Medicine Laboratory, University of Cincinnati School of Medicine. These data were evaluated by Mones Berman and his associates at the National Institutes of Health and were used as the input data for Berman's model of iodide kinetics (*2*). The thyroid iodide uptake rate constant was then adjusted

TABLE 1. NUCLEAR DATA*

Radionuclide	^{123}I		^{124}I		^{125}I		^{126}I		^{130}I		^{131}I		^{132}I	
Physical half-life	13.0 hr		4.2 days		60.2 days		13.0 days		12.5 hr		8.06 days		2.38 hr	
Decay constant	0.0533 hr^{-1}		0.1650 days^{-1}		0.0115 days^{-1}		0.0533 days^{-1}		0.0555 hr^{-1}		0.0860 days^{-1}		0.2912 hr^{-1}	
Mode of decay	Electron capture		Electron capture and beta plus		Electron capture		Beta minus, electron capture and beta plus		Beta minus		Beta minus		Beta minus	
Equilibrium dose constant for nonpenetrating radiation (g-rad/μCi-hr)	0.0610		0.4660		0.0434		0.3116		0.6355		0.4085		1.0651	
	E_i	n_i†	E_i	n_i‡	E_i	n_i†	E_i	n_i†	E_i	n_i†	E_i	n_i†	E_i	n_i‡
Principal photons:	0.028§	0.867	0.028§	0.562	0.028§	1.400	0.028§	0.420	0.030§	0.013	0.030§	0.046	0.506	0.051
E_i, energy (MeV)	0.159	0.836	0.511	0.512	0.035	0.067	0.389	0.333	0.418	0.320	0.080	0.026	0.523	0.159
n_i, mean number per dis.	0.529	0.011	0.603	0.617			0.491	0.022	0.536	0.991	0.284	0.058	0.630	0.138
			0.723	0.102			0.666	0.328	0.586	0.016	0.364	0.820	0.668	0.986
			1.691	0.100			0.754	0.042	0.668	0.971	0.637	0.065	0.672	0.053
									0.739	0.852	0.723	0.017	0.727	0.065
									1.157	0.114			0.773	0.770
													0.812	0.057
													0.955	0.180
													1.399	0.070

* For complete compilation of nuclear data, reader is referred to Ref. 1. Values computed by L. T. Dillman, et al using method described in Ref. 1.
† Photons whose mean number per disintegration is 0.01 or greater.
‡ Photons whose mean number per disintegration is 0.05 or greater.
§ Weighted mean energy of K x-rays.

to generate three selected levels for maximum thyroid uptakes of 5%, 15%, and 25% corresponding to 24-hr uptakes of 4.5%, 13.8%, and 23.6%, respectively. These values were considered to encompass the range of the current adult euthyroid population in the United States. The model used here does not apply to hypo- or hyperthyroid patients, to iodine-deficient patients, or to patients receiving therapeutic amounts of radioiodine or medications that directly or indirectly affect iodine metabolism.

The biologic parameters given in Table 2 were computed using Berman's model (*2*) and a fractional turnover constant of 0.0140 day^{-1} for thyroid secretions. The values for $\alpha_h(t)$ calculated from data given in Table 2 describe the kinetics of iodine administered as iodide, and do not take into account physical decay of the nuclide. To obtain the quantity of radioactivity, $A_h(t)$, at any time, $q_h(t)$ must be multiplied by $e^{-\lambda t}$, where λ is the physical decay constant of the radioisotope of iodine. The computed biologic half-time of iodine in the thyroid was 52.1 days for a maximum uptake of 5%, 57.0 days for a maximum uptake of 15%, and 65.1 days for a maximum uptake of 25%. Maximum uptake of administered iodide by the thyroid occurs at approximately 2 days in the euthyroid subject. The maximum level of radioactivity in the thyroid will vary as well as the time at which this maximum is reached depending on the physical half-life of the radioisotope of iodine administered.

The biologic parameters given in Table 2 are for a single intravenous injection. Oral administration will delay the appearance of radioiodine in the blood by 10–15 min, but it will have a minimal effect on the actual levels of activity in the blood, and relatively little effect on the final thyroid uptake.

The histogram shown in Fig. 1 was computed based on the values given in Table 2 and summarizes the biologic distribution of radioiodine after a single oral administration of radioiodide in a euthyroid adult with a maximum thyroid uptake of 15%. The values given for the stomach, intestine, blood, extracellular-extravascular space (ECEV), thyroid, liver, quantity excreted, and activity unaccounted for (other) are for 1 hr, 6 hr, 24 hr, 20 days, and 80 days after the radionuclide was administered.

ABSORBED-DOSE ESTIMATES

The cumulated activities for the radioisotopes of iodine in the five source organs for the three values of maximum thyroid uptake were computed using the distribution parameters in Table 2, and the physical half-lives of the isotopes of iodine in Table 1. It was assumed that the radioactivity in each source organ was uniformly distributed.

The masses used for computing the dose to the target organs were as follows: liver, 1,809 gm; ovaries, 8.3 gm; red marrow, 1,500 gm; stomach wall, 150 gm; testes, 37 gm; thyroid, 19.6 gm; and total body, 69,880 gm (*3*).

The absorbed fractions used for the dose estimate calculations in this report were obtained from special

TABLE 2. BIOLOGIC PARAMETERS OF THE FRACTIONAL DISTRIBUTION FUNCTIONS, $\alpha_h(t)$, OF IODINE IN A EUTHYROID ADULT FROM A SINGLE INTRAVENOUS ADMINISTRATION OF SODIUM IODIDE*

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

Source organs r_h	α_{h1}	λ_1 (hr^{-1})	α_{h2}	λ_2 (hr^{-1})	α_{h3}	λ_3 (hr^{-1})	α_{h4}	λ_4 (hr^{-1})
Maximum thyroid uptake of 5% yields a 24-hr uptake of 4.5%								
Intestine	0.169	0.0879	0.000502	0.0488	−0.0000262	0.00492	0.0000579	0.000554
Liver	0.0156	0.0879	−0.000390	0.0488	−0.00109	0.00492	0.00139	0.000554
Stomach	0.149	0.0879	0.000459	0.0488	−0.0000245	0.00492	0.0000529	0.000554
Thyroid	−0.0517	0.0879	—	—	—	—	0.0519	0.000554
Total body†	0.944	0.0879	—	—	—	—	0.056	0.000554
Maximum thyroid uptake of 15% yields a 24-hr uptake of 13.8%								
Intestine	0.169	0.0994	0.000982	0.0488	−0.0000669	0.00492	0.000152	0.000498
Liver	0.0159	0.0994	−0.00130	0.0488	−0.00313	0.00492	0.00408	0.000498
Stomach	0.149	0.0994	0.000882	0.0488	−0.0000629	0.00492	0.000140	0.000498
Thyroid	−0.154	0.0994	—	—	—	—	0.154	0.000498
Total body†	0.836	0.0994	—	—	—	—	0.164	0.000498
Maximum thyroid uptake of 25% yields a 24-hr uptake of 23.6%								
Intestine	0.169	0.114	0.00115	0.0488	−0.0000962	0.00496	0.000221	0.000444
Liver	0.0159	0.114	−0.00206	0.0488	−0.00506	0.00496	0.00667	0.000444
Stomach	0.149	0.114	0.00103	0.0488	−0.0000913	0.00496	0.000204	0.000444
Thyroid	−0.255	0.114	—	—	—	—	0.255	0.000444
Total body†	0.729	0.114	—	—	—	—	0.271	0.000444

* The activity in the source region r_h at time t after administration of the radionuclide of activity A_0 is given by $A_h(t) = q_h(t)e^{-\lambda t}$, where $q_h(t) = A_0 \sum_j \alpha_{hj} e^{-\lambda_j t}$, and α_{hj} is the initial value of the j^{th} exponential component of the fraction of the iodine administered as iodide that appears in the 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 the source region r_h over an infinite period is given by $\tilde{A}_h(\infty) = A_0 \sum_j \alpha_{hj}/(\lambda_j + \lambda)$.

† Values for total body include all tissues.

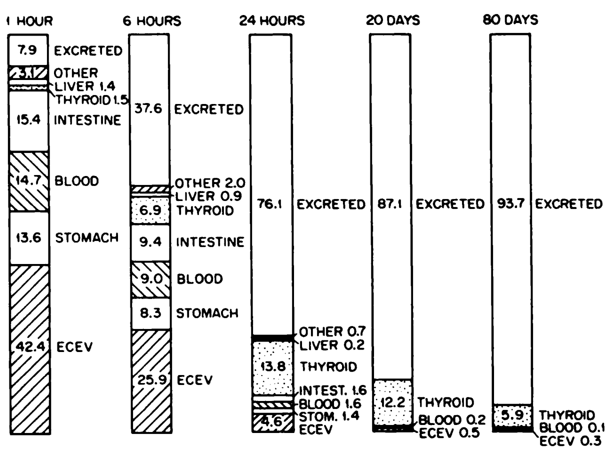

FIG. 1. Estimated percent of administered radioiodine in tissues of body at various times after single oral administration of radioiodide corrected for radioactive decay. Maximum thyroid uptake is assumed to be 15%.

Monte Carlo computer calculations using the complete energy spectrum of penetrating and nonpenetrating radiations emitted by the radioisotopes of iodine instead of from the interpolated values of absorbed fractions published in MIRD Pamphlet No. 5 (*4*). The heterogeneous phantom used previously (*4*) has been modified (*3*) so that it is no longer necessary to consider the wall and the contents of an organ, such as the stomach, as a single unit. Instead they may be handled separately, usually with the contents as the source organ and the wall as the target organ. Red marrow is considered as a separate source organ in the revised heterogeneous phantom.

Radioiodine in the intestine is localized predominately in the small intestine and, for the purposes of dose estimation, is assumed to be entirely located in this section. The contribution of fecal radioactivity to the dose received by the walls of the large intestine is neglected.

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