mird / DOSE ESTIMATE REPORT NO. 7

SUMMARY OF CURRENT RADIATION DOSE ESTIMATES TO HUMANS FROM ^{123}I, ^{124}I, ^{126}I, ^{130}I, AND ^{131}I AS SODIUM ROSE BENGAL

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SUMMARY OF ESTIMATED ABSORBED DOSES FROM RADIOIODINE AFTER A SINGLE INTRAVENOUS ADMINISTRATION AS SODIUM ROSE BENGAL

Target organ	Absorbed dose (rads/mCi of radioiodine administered)				
	^{123}I	^{124}I	^{126}I	^{130}I	^{131}I
Gallbladder (wall)*	0.25	1.6	0.91	2.3	1.1
Gastrointestinal tract					
Small intestine	0.60	5.9	3.3	5.8	3.5
Upper large intestine (wall)	1.4	17	12	13	14
Lower large intestine (wall)	1.5	38	32	14	35
Liver	0.19	1.4	0.75	1.9	0.80
Ovaries	0.28	3.6	1.7	2.4	1.6
Red marrow	0.080	0.74	0.37	0.52	0.32
Testes	0.014	0.33	0.15	0.19	0.14

* Portion of wall in contact with the surface of the liver.

RADIOPHARMACEUTICAL

Rose bengal is a halogenated fluorescent dye, Na-4, 5, 6, 7-tetrachloro-2′, 4′, 5′, 7′-tetraiodofluorescein, used for many years for testing liver function. The radiopharmaceutical, sodium rose bengal labeled with ^{131}I, is commercially available as a sterile, nonpyrogenic, isotonic aqueous solution for intravenous injection containing 0.9% benzyl alcohol as a preservative. The *U.S. Pharmacopeia XIX* (*1*) specifies that 90–100% of the radionuclide must be present as rose bengal and other radionuclides are absent. For purposes of these dose calculations, the radionuclidic and radiochemical purity of the pharmaceutical are assumed to be 100%. If free radioactive iodine is present, MIRD Dose Estimate Report No. 5 (*2*) can be used to estimate the radiation dose.

NUCLEAR DATA

Nuclear data for the radioisotopes of iodine considered in this report are given in Table 1 (*3*).

BIOLOGIC DATA

This report uses human distribution and excretion data for ^{131}I-labeled sodium rose bengal from published reports (*4–7*).

These dose estimates are for an adult without hepatic, biliary, or gastrointestinal pathology who has been pretreated and maintained on Lugol's solution so that no radioactive iodide released as a result of the metabolism of labeled rose bengal is taken up by the thyroid.

In the normal individual, the half-time for disappearance from the blood of radioiodine injected as rose bengal is between 6 and 9 min, which is equal to the half-time for uptake by the liver. Radioiodine reaches a maximum in the liver approximately 30 min after administration as rose bengal.

Due to the lack of quantitative data, the temporal distributions of the administered radioactivity in the biliary tract, gallbladder, and small intestine were estimated by members of the Task Group from clinical records of sequential scintiphotos. An estimated 90% of the administered radioiodine clears from the liver into the small intestine with a half-time of 1.5 hr. The remaining 10% appears in the contents of the gallbladder with a biologic half-time of 1.5 hr. Seventy-five percent of the radioiodine in the gallbladder was assumed to pass into the small intestine 3 hr after administration as rose bengal, and the remaining 25% 9 hr after administration. This sequence of excretion from the gallbladder corresponds to eating the noon and evening meals.

The biologic model used for these dose calculations is an irreversible catenary compartment model with one bypass, the gallbladder. The biologic parameters are given in Table 2, and the details for the movement of material through the gastrointestinal tract are given by Bernard (*8*). When the rose bengal enters the small intestine, it remains within the gastrointestinal tract and moves sequentially from the small intestine to the upper large intestine, to the lower large intestine, and is excreted in the feces.

TABLE 1. NUCLEAR DATA*

	Radionuclide				
	^{123}I	^{124}I	^{129}I	^{130}I	^{131}I
Physical half-life	13.0 hr	4.2 day	13.0 day	12.5 hr	8.06 day
Decay constant	0.0533 hr^{-1}	0.1650 day^{-1}	0.0533 day^{-1}	0.0555 hr^{-1}	0.0860 day^{-1}
Mode of decay	Electron capture	Electron capture and beta plus	Beta minus, electron capture and beta plus	Beta minus	Beta minus
Equilibrium dose constant for non-penetrating radiation (g-rad/μCi-hr)	0.0610	0.4660	0.3116	0.6355	0.4085
	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|| 0.420	0.030|| 0.013	0.030|| 0.046
E_i, energy (MeV)	0.159 0.836	0.511 0.512	0.389 0.333	0.418 0.320	0.080 0.026
n_i, mean number	0.529 0.011	0.603 0.617	0.491 0.022	0.536 0.991	0.284 0.058
per disintegration		0.723 0.102	0.666 0.328	0.586 0.016	0.364 0.820
		1.691 0.100	0.754 0.042	0.668 0.971	0.637 0.065
				0.739 0.852	0.723 0.017
				1.157 0.114	

* For complete compilation of nuclear data, reader is referred to Ref. 3. Values computed by L. T. Dillman, et al using method described in Ref. 3.
† 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.

The mean time of rose bengal in the small intestine is 4 hr; in the upper large intestine, 13 hr; and the lower large intestine, 24 hr (*9*). It is assumed that 100% of the administered radioiodine is excreted in the feces and none in the urine.

This model predicts that more than 95% of the radioiodine will be excreted within 90 hr of its administration. This agrees with the results reported by Lushbaugh, et al (*4*) who studied rose bengal retention in 18 patients. The total-body retention curve consisted of two components: the first with an 18-hr half-time accounting for 97% of the ^{131}I label on rose bengal and the second with a 50-day half-time accounting for the remaining 3%. Because no thyroid blocking agent was used in this study, the second component represents metabolism of thyroid hormones produced in the unblocked thyroid gland.

TABLE 2. BIOLOGIC PARAMETERS OF ROSE BENGAL FROM A SINGLE INTRAVENOUS ADMINISTRATION OF SODIUM ROSE BENGAL

Source organ	Biologic disappearance constant, λ_h (hr^{-1})
Liver and biliary tract	0.462
Contents of gallbladder	—*
Small intestine and contents	0.250†
Contents of upper large intestine	0.0769†
Contents of lower large intestine	0.0417†

* See text.
† $\lambda_h = 0.693/T_h = 1/\bar{T}_h$, where T_h is the biologic half-time and $\bar{T}_h$ is the mean time.

TABLE 3. MASS OF TARGET ORGANS*

Target organ	Mass (gm)
Liver	1,809
Gallbladder (wall)	10
Gastrointestinal tract	
Small intestine and contents	1,044
Upper large intestine (wall)	209
Lower large intestine (wall)	160
Ovaries	8.3
Red marrow	1,500
Testes	37

* These masses were obtained from Ref. 11 with the exception of the gallbladder wall (*10*).

ABSORBED-DOSE ESTIMATES

The cumulated activity in the liver, $\tilde{A}_L$, was computed by assuming instantaneous uptake of the radioiodine by the liver and a biologic half-time of 1.5 hr. The catenary compartment model (*8*) was used to calculate the cumulated activities for the other source organs (Table 2). Instantaneous and uniform mixing was assumed as the radioiodine entered each source organ. There was no elimination of radioactivity from a source organ except by physical decay or by excretion into the next compartment of the model. In computing the dose to all target organs except

the gallbladder and liver, the cumulated activities for the liver, $\tilde{A}_{L}$, and the gallbladder contents, $\tilde{A}_{GBC}$, were combined and the absorbed fraction for each target organ was obtained by assuming that the liver was the source organ.

The wall of the gallbladder weighs 10 gm (*10*). The gallbladder fills at a constant rate and it empties when it contains 70 gm (*10*). The gallbladder is located on the undersurface of the right lobe of the liver above the transverse colon. Because the gallbladder is not a source or target organ in the heterogeneous phantom (*11*), the dose to the liver from radioiodine contained in the gallbladder was calculated by using $\phi(L \leftarrow L)$ for penetrating radiation. This technique overestimates the dose to the liver somewhat.

The nonpenetrating radiation dose to the gallbladder wall from activity contained in its contents will be approximately one-half of the nonpenetrating dose to the contents. Because nonpenetrating radiation emitted from the liver can strike the wall of the gallbladder in contact with the liver, the total nonpenetrating radiation dose to this portion of the gallbladder wall will be:

$$\bar{D}(GBW)_{np} = 0.5\bar{D}(GBC)_{np} + 0.5\bar{D}(L)_{np}$$

$$= 0.5\,\frac{\tilde{A}_{GBC}}{m_{GBC}}\,(\Sigma\Delta_{np}\phi_{np}) + 0.5\,\frac{\tilde{A}_{L}}{m_{L}}\,(\Sigma\Delta_{np}\phi_{np}),$$

where ϕ_{np} is taken as unity.

The dose to the gallbladder wall from penetrating radiation is approximately equal to the dose to the liver plus the dose to the gallbladder contents from penetrating radiation:

$$\bar{D}(GBW \leftarrow GBC + L)_{p} = \bar{D}(L \leftarrow L) + \bar{D}(GBC \leftarrow GBC)$$

$$= \frac{\tilde{A}_{L}}{m_{L}}\Sigma\Delta\phi(L \leftarrow L) + \frac{\tilde{A}_{GBC}}{m_{GBC}}\Sigma\Delta\phi(GBC \leftarrow GBC)$$

The absorbed fraction for the gallbladder contents can be obtained by assuming the gallbladder is an ellipsoid of 70 gm and interpolating the values in *MIRD Pamphlet No. 8* (*12*). This approach is possible because the gallbladder is semiengulfed within the liver. To compute the dose to the wall of the gallbladder from source organs other than itself and the liver, the specific absorbed fraction for the liver as the target organ was used.

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 radiations emitted by the radioisotopes of iodine instead of from the interpolated values of absorbed fractions published in *MIRD Pamphlet No. 5* (*11*). The heterogeneous phantom used previously (*11*) has been modified (*13*) so that the wall and the contents of an organ such as the upper large intestine may be considered separately, usually with the contents as the source organ and the wall as the target organ.

DISCUSSION

The greatest uncertainty in these dose estimates is due to the variability in time for the movement of radioiodine through the biliary tract, gallbladder, and gastrointestinal tract.

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