MIRD DOSE ESTIMATE REPORT NO. 10

Radiation Absorbed Dose from Albumin Microspheres Labeled with Technetium-99m

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RADIOPHARMACEUTICAL

Human albumin microspheres,* pretreated with Sn^{2+}, are labeled by the addition of [Tc-99m]pertechnetate. Over 95% of the particles are in the size range of 15–45 micrometers. The free pertechnetate in this preparation is less than 3%.

The kinetic behavior of the radioactivity from other lung-imaging agents (macroaggregated albumin, etc.), and from microspheres labeled with other nuclides or by other chemical techniques, may be quite different from that of the radiopharmaceutical described above. This report of dose estimates does not include information on these materials, or provide estimates for the dose from microspheres administered by other than the intravenous route.

NUCLEAR DATA

Technetium-99m decays to Tc-99 by isomeric transition, with a half-life of 6.02 hr. Technetium-99 decays by beta minus decay, with a half-life of 2.1×10^5 yr. The very small contribution of Tc-99 decay to the radiation dose has been ignored in these estimates. Decay data and radiation dose constants are listed in Table 1.

BIOLOGICAL DATA

The dose estimates in this report are based on distribution and excretion measurements on over 30 patients (*1*). Volunteers for this study came from the group of patients referred to the Nuclear Medicine Clinic of the Buffalo Veterans Administration Medical Center for lung perfusion studies. All had normal lung scans. A detailed description of the technique used is given in Ref. 1. Measurements made at the University of Chicago and the University of Cincinnati support these data (personal communication, K. A. Lathrop and S. R. Thomas).

The initial uptake, as expected, is almost entirely in the lungs. The radioactivity apparently leaves the lungs in the form of TcO_4^-, principally by leaching off the microspheres rather than by their breakup. This conclusion is based on the kinetic behavior of the Tc-99m activity after it leaves the lungs. The distribution of TcO_4^- following a single intravenous injection has been determined (*2*). However, radioactivity leaching from

TABLE 1. NUCLEAR DATA

Radionuclide			Tc-99m
Physical half-life			6.02 h
Mode of decay			I.T. to Tc-99
$\Sigma\Delta_i$ for non-penetrating radiation			0.0332
Principal photons	E_i	n_i	Δ_i
	18–21	0.074	0.0029
	140.5	0.89	0.266

E_i = energy (keV)

Δ_i = mean energy emitted per unit cumulated activity (g-rad/μCi-h)

n_i - mean number per transformation

Nonpenetrating radiation includes conversion and Auger electrons.

Data from NCRP Report #58 (*5*).

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TABLE 2. PARAMETERS OF THE FRACTIONAL DISTRIBUTION FUNCTION, $\alpha_h(t)$, FOR Tc-99m FROM A SINGLE I.V. INJECTION OF LABELED MICROSPHERES

$$\alpha_h(t) = \alpha_{h_1}e^{-\lambda_{j1}t} + \alpha_{h_2}e^{-\lambda_{j2}t}$$

Source organ	α_{h_1}	α_{h_2}	$\lambda_{j_1}(h^{-1})$	$\lambda_{j_2}(h^{-1})$	$\tau(h)^\dagger$
Lung	0.600	0.413	0.383	0.0192	4.28
Stomach	−1.799	1.802	0.0886	0.0795	0.429
Kidney	−0.127	0.135	0.148	0.00204	0.672
Blood	−0.096	0.095	1.752	0.0363	0.580
Urine	−1.730	1.727	0.0331	0.0231	0.830
Bladder					0.209
Thyroid					0.020*
Salivary gland					0.041*
Large intestine					0.321*
Extra-vascular space					1.823*

* Calculated from lung disappearance curve and TcO_4^- kinetics. See text.

† Residence time, τ, includes physical decay ($\lambda = 0.115h^{-1}$) and is calculated as $\tau_h(\lambda) = \sum_j \alpha_{hj}/(\lambda + \lambda_j)$ (Eq. 32 of ref. 6); λ_j's are biological rate constants only. Small discrepancies between tabulated τ's and those calculated from the corresponding α's and λ's are due to rounding off of table entries.

the microspheres in the lungs enters the vascular space as the equivalent of a slow intravenous injection. The disappearance rate from the lungs as the input function was convolved with the equations in Ref. 2, which describe the kinetic behavior of TcO_4^-, to calculate the expected distribution of Tc-99m (*3*). When the TcO_4^- kinetic parameters given in Ref. 2 for "resting" subjects are used, the predicted blood and urine curves match those measured in the lung-study patients quite closely. In these patients the curve for radioactivity in the stomach was between those predicted from the kinetic parameters given in Ref. 2 for the "resting" group and for the "nonresting" group. Details are given in Ref. 1.

Table 2 lists the biologic parameters and residence times for the measured organs: lung, stomach, kidney, blood, and urine. In addition, derived residence times are given for thyroid, salivary gland, large intestine, and extravascular space, based on convolution integrals, calculated as described above, and using the biologic parameters given in Ref. 2 for "resting" subjects. The residence time for the bladder was calculated with a 4.8-hr emptying time, assuming an initially empty bladder. There was no measurable activity in the liver at any time.

The biologic parameters in Table 2 were derived from data obtained by conjugate counting using self-absorption corrections based on transmission images (*1*). The results have not been adjusted to 100% of the injected activity at each time period. Instead, the parameters listed are calculated from the directly measured values. The sum of the activities in the listed organs varied from 100–110% of the injected dose over the course of the study. Consequently, the sum of the calculated residence times for the organs listed (excluding bladder, which is included in τ for urine) is 9.0 hr, although the theoretical maximum residence time for Tc-99m is 8.7 hr. Thus, the radiation absorbed doses calculated from these data are slight overestimates.

ABSORBED DOSE ESTIMATES

From the distribution data in Table 2 and the S values in MIRD pamphlet #11 (*4*), absorbed dose estimates were made for the organs listed as well as for red marrow, ovaries, and testes as target organs. In the absence of S values, the dose to salivary gland was not estimated. The doses to other organs from photons originating in the salivary gland was approximated by using the S values for thyroid as the source organ.

SUMMARY OF ESTIMATED ABSORBED DOSES AFTER I.V. ADMINISTRATION OF Tc-99m-LABELED MICROSPHERES

Organ	Dose per unit administered activity rads/mCi	μGy/MBq
Lung	0.23	62.
Kidney	0.14	38.
Stomach	0.072	19.
Thyroid	0.072	19.
Bladder wall	0.040	11.
Large-intestine wall	0.035	9.4
Red marrow	0.020	5.4
Ovaries	0.013	3.5
Testes	0.005	1.4

FOOTNOTE

* 3M Corp.

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