Specific Absorbed Fractions for Photon Sources Uniformly Distributed in the Heart Chambers and Heart Wall of a Heterogeneous Phantom

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J Nucl Med 22: 65–71, 1981

FOREWORD

The Medical Internal Radiation Dose (MIRD) Committee of the Society of Nuclear Medicine is charged with the responsibility of providing the nuclear medicine community with guidance on how to calculate the radiation dose delivered by radionuclides. To accomplish this goal, the Committee has published pamphlets that describe the techniques of dose calculation and provide tables of dosimetric data.

The MIRD Heart Task Group was organized by Dr. Walter S. Snyder shortly before his death in 1977, with the goal of developing an improved anatomic model of the heart for dosimetry. This was also a goal of the preceding Cardiovascular Task Group headed by Dr. John McAfee. Data compiled by the original group were helpful in the development of the new heart model for the heterogeneous phantom.

This new heart model, and a modification of the lung models, have been incorporated into the phantom. This pamphlet provides estimates of specific absorbed fractions to 21 target organs from photon sources in the heart chambers and heart walls. The pamphlet has been reviewed by the MIRD Committee but, as always, the Committee welcomes comments. We would especially appreciate suggestions regarding how to make the information more useful to the nuclear medicine community.

The work of the MIRD Committee is made possible by the continued encouragement and support of the Society of Nuclear Medicine and the Bureau of Radiological Health, Food and Drug Administration, Department of Health and Human Services.

Katherine Austin Lathrop, Chairman
Medical Internal Radiation Dose Committee

Received Aug. 4, 1980; revision accepted Aug. 12, 1980.

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INTRODUCTION

Dose estimates based on the generalized heart model of MIRD Pamphlet No. 5, Revised (*1*), are only a first approximation because there is no separation of heart walls from heart chambers, and it is unlikely that any radionuclide would be uniformly distributed throughout both walls and chambers. Coffey (*2*) has developed a more detailed model of the heart and has redesigned the lung model. We have incorporated these changes into the heterogeneous phantom (*1*) and have used the Monte Carlo technique to calculate specific absorbed fractions. A discussion of the Monte Carlo technique and a description of the remainder of the heterogeneous phantom are given in MIRD Pamphlet No. 5, Revised (*1*).

ANATOMIC DESCRIPTION OF THE HUMAN HEART

Anatomic data (*3–18*) used in developing the new model for the heart and its chambers are summarized in Table 1. The shape of the heart was determined from anatomic drawings (*5,18,19*), which suggest an ellipsoidal configuration. The four chambers of the heart are represented by sections of ellipsoids. Although the atria are more irregular in shape than the ventricles, ellipsoidal sections are assumed to describe both for dosimetry purposes. Dimensions of the ellipsoidal chambers were chosen to: (a) resemble the shape of the actual chamber, and (b) give volumes approximately equal to those reported in the literature.

According to *Morris' Human Anatomy* (*5*), the longitudinal axis of the heart forms a 40° angle with the horizontal plane of the body and a 40° angle with the midsagittal plane. The heart model was placed in the heterogeneous phantom so that the major axis of the heart formed a 40° angle with the horizontal plane of the phantom. The angle of the major axis, relative to the sagittal plane, was increased to 55° because the smaller angle did not allow the heart model to fit into the phantom. Further details of fitting the heart model into the phantom are included in Ref. *2*.

MATHEMATICAL DESCRIPTION OF THE HEART MODEL

In the heterogeneous phantom, the origin is located

TABLE 1. SUMMARY OF CARDIAC DATA OBTAINED FROM THE LITERATURE

Heart section	Value	Reference	Comments
Total heart wall	300 g	(*3*)	normal adult subjects
	301 g	(*4*)	0.43% of adult body weight
	312 g	(*5*)	adult male
	326 g	(*6*)	357 normal adult males
	302 g	(*6*)	adult males
Left-ventricular wall	188 ± 33 g	(*7*)	15 normal adult males, 71 kg body weight
	121 ± 14 g	(*7*)	7 normal adult females, 57 kg body weight
	164.3 ± 14.2 g	(*8*)	6 normal adult subjects
Right-ventricular wall	70 g	(*9*)	normal adults
	47 ± 11 g	(*10*)	13 male clinical normals, mean age = 55 yr
	46 g	(*11*)	14 normal adult males
Total atrial wall	49 g	(*11*)	15 normal adult males
	60 g	(*12*)	0.25% of ventricle weight in adult subjects
Left-ventricular volume (average)	94 ml	(*3*)	normal adult subjects
	90 ml	(*7*)	11 normal adult males
	95 ml	(*8*)	6 normal adult subjects
	100 ml	(*13*)	normal adults
Right-ventricular volume (average)	106 ml	(*14*)	6 normal adult males
	90 ml	(*15*)	10 normal adult patients
	109 ml	(*16*)	9 adult patients with normal right-ventricular function
Left-atrial volume (average)	100–130 ml	(*17*)	adult subjects
	140 ml	(*13*)	adult subject
Right-atrial volume (average)	100–185 ml	(*17*)	adult subjects
	163 ml	(*13*)	adult subject
Left-ventricular wall thickness (average)	1.1–1.4 cm	(*17*)	adult subjects
	1.19 cm	(*7*)	11 normal adult males
	1.26 cm	(*8*)	6 normal subjects
Right-ventricular wall thickness (average)	0.5–0.7 cm	(*17*)	adult subjects
	0.2–0.6 cm	(*9*)	normal adults
Atrial wall thickness (average)	0.05–0.35 cm	(*17*)	adult subjects
	0.2–0.3 cm	(*18*)	adult

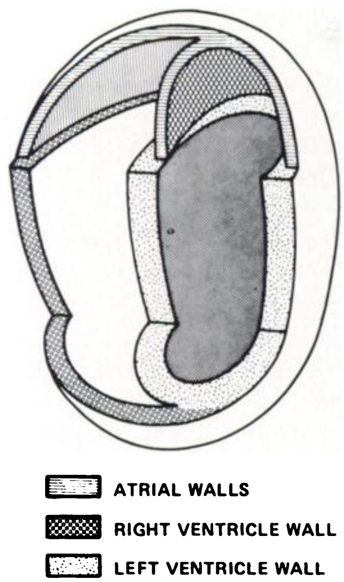

Fig. 1. Cutaway drawing of new heart model.

at the center of the base of the trunk section (*1*). The z axis is directed toward the head, the x axis to the phantom's left, and y axis toward the posterior side of the phantom. All dimensions are in centimeters. The density used is 0.9869 g/cm^3—i.e., the soft-tissue density of the heterogeneous phantom.

The four chambers of the heart are represented by sections of ellipsoids (Fig. 1). Because of the orientation of the heart, its axes are not parallel to axes of the phantom, and transformation equations are required. These are:

$$x_1 = 0.6751(x - 1.0) - 0.4727(y + 1.8) - 0.5664(z - 50),$$

$$y_1 = -0.4640(x - 1.0) - 0.3249(y + 1.8) - 0.8241(z - 50),$$

$$\text{and } z_1 = 0.5736(x - 1.0) - 0.8191(y + 1.8),$$

where x, y, and z are as defined in Ref. *1*.

Left ventricle. The chamber of the left ventricle is described by half an ellipsoid,

$$\left(\frac{x_1}{7.3}\right)^2 + \left(\frac{y_1}{3.7}\right)^2 + \left(\frac{z_1}{1.8}\right)^2 \leq 1 \text{ when } x_1 \geq 0.$$

The volume of the chamber is 101.83 cm^3 and the mass is 100.49 g.

The wall of the left ventricle is described by the volume between two concentric half-ellipsoids. The outer ellipsoid is given by

$$\left(\frac{x_1}{8.6}\right)^2 + \left(\frac{y_1}{5.0}\right)^2 + \left(\frac{z_1}{3.1}\right)^2 \leq 1 \text{ when } x_1 \geq 0. \qquad (1)$$

The inner is given by

$$\left(\frac{x_1}{7.3}\right)^2 + \left(\frac{y_1}{3.7}\right)^2 + \left(\frac{z_1}{1.8}\right)^2 \leq 1 \text{ when } x_1 \geq 0.$$

The volume of the wall is 177.36 cm^3 and the mass is 175.04 g.

Right ventricle. The chamber of the right ventricle is defined as the portion of a quarter-ellipsoid that remains after overlapping portions of the ellipsoid described by Eq. 1 are removed. The quarter-ellipsoid is defined as

$$\left(\frac{x_1}{8.0}\right)^2 + \left(\frac{y_1}{4.4}\right)^2 + \left(\frac{z_1}{6.4}\right)^2 \leq 1 \text{ when } x_1 \geq 0 \text{ and } z_1 \leq 0. \qquad (2)$$

The volume of the right-ventricular chamber is 108.45 cm^3 and the mass is 107.03 g.

The wall of the right ventricle is described by the volume between two concentric quarter-ellipsoids that remain after overlapping portions of the ellipsoid defined by Eq. 1 are removed. The inner ellipsoid is given by

$$\left(\frac{x_1}{8.0}\right)^2 + \left(\frac{y_1}{4.4}\right)^2 + \left(\frac{z_1}{6.4}\right)^2 \leq 1 \text{ when } x_1 \geq 0 \text{ and } z_1 \leq 0.$$

The outer is given by

$$\left(\frac{x_1}{8.6}\right)^2 + \left(\frac{y_1}{5.0}\right)^2 + \left(\frac{z_1}{7.0}\right)^2 \leq 1 \text{ when } x_1 \geq 0 \text{ and } z_1 \leq 0.$$

The volume of the right-ventricular wall is 67.17 cm^3 and the mass is 66.29 g.

Left atrium. The chamber of the left atrium is described by two quarter-ellipsoids. The left section of the chamber is defined by the equation

$$\left(\frac{x_1}{5.1}\right)^2 + \left(\frac{y_1}{4.7}\right)^2 + \left(\frac{z_1}{2.8}\right)^2 \leq 1 \text{ when } x_1 \leq 0 \text{ and } z_1 \geq 0.$$

The right section of the chamber is defined by the equation

$$\left(\frac{x_1}{5.1}\right)^2 + \left(\frac{y_1}{4.7}\right)^2 + \left(\frac{z_1}{1.8}\right)^2 \leq 1 \text{ when } x_1 \leq 0 \text{ and } z_1 \leq 0.$$

The total volume for the left-atrial chamber is 115.46 cm^3, the mass is 113.95 g.

The wall of the left atrium is defined by the volume between two sets of two concentric quarter-ellipsoids. The left section of the wall is the volume between

TABLE 2. MASSES USED FOR HEART MODEL

Heart chamber	Mass(g) Contents	Wall
Left ventricle	100	175
Right ventricle	107	66
Left atrium	114	31
Right atrium	110	27
Total	431	299

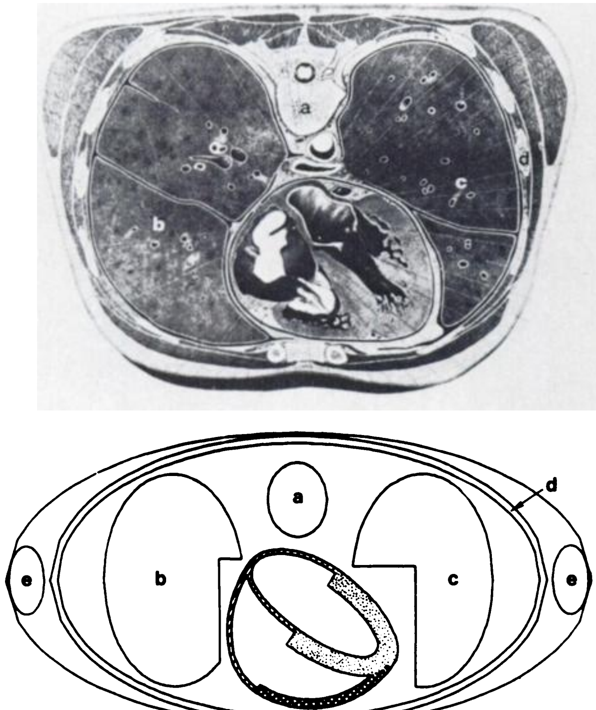

Fig. 2. Comparison of phantom transverse section at z = 50 with drawing of cadaver transverse section at level of eighth thoracic vertebra. a = spine, b = right lung, c = left lung, d = rib, e = arm bones.

$$\left(\frac{x_1}{5.4}\right)^2 + \left(\frac{y_1}{5.0}\right)^2 + \left(\frac{z_1}{3.1}\right)^2 \le 1 \text{ when } x_1 \le 0 \text{ and } z_1 \ge 0,$$

and

$$\left(\frac{x_1}{5.1}\right)^2 + \left(\frac{y_1}{4.7}\right)^2 + \left(\frac{z_1}{2.8}\right)^2 \le 1 \text{ when } x_1 \le 0 \text{ and } z_1 \ge 0.$$

The right section of the left-atrial wall is the volume between

$$\left(\frac{x_1}{5.4}\right)^2 + \left(\frac{y_1}{5.0}\right)^2 + \left(\frac{z_1}{2.1}\right)^2 \le 1 \quad \text{when } x_1 \le 0 \text{ and } z_1 \le 0, \quad (3)$$

and

$$\left(\frac{x_1}{5.1}\right)^2 + \left(\frac{y_1}{4.7}\right)^2 + \left(\frac{z_1}{1.8}\right)^2 \le 1 \text{ when } x_1 \le 0 \text{ and } z_1 \le 0.$$

The volume of the wall is 31.57 cm^3 and the mass is 31.16 g.

Right atrium. The chamber of the right atrium is defined by a quarter-ellipsoid with the volume described by Eq. 3 removed. The quarter-ellipsoid is described by

$$\left(\frac{x_1}{5.1}\right)^2 + \left(\frac{y_1}{4.7}\right)^2 + \left(\frac{z_1}{6.7}\right)^2 \le 1 \quad \text{when } x_1 \le 0 \text{ and } z_1 \le 0. \quad (4)$$

The volume of the right-atrial chamber is 111.14 cm^3 and the mass is 109.68 g.

The wall of the right atrium is the volume between two concentric quarter-ellipsoids that remain after those portions described by Eq. 3 are removed. The outer ellipsoid is defined by

$$\left(\frac{x_1}{5.4}\right)^2 + \left(\frac{y_1}{5.0}\right)^2 + \left(\frac{z_1}{7.0}\right)^2 \le 1 \text{ when } x_1 \le 0 \text{ and } z_1 \le 0,$$

and the inner by

$$\left(\frac{x_1}{5.1}\right)^2 + \left(\frac{y_1}{4.7}\right)^2 + \left(\frac{z_1}{6.7}\right)^2 \le 1 \text{ when } x_1 \le 0 \text{ and } z_1 \le 0.$$

The volume of the wall is 27.40 cm^3 and the mass is 27.04 g.

Table 2 lists the masses of the walls and the contents of the heart chambers.

MATHEMATICAL DESCRIPTION OF REVISED LUNG MODEL

Because the position the new heart model occupies within the phantom would result in some overlap with the existing lungs (*1*), it was necessary to redesign the lung model. The lungs described in MIRD Pamphlet No. 5, Revised, are equal in volume; however, the Reference Man Report (*17*) states that the right lung is 16% larger than the left lung. The redesigned model takes into account the difference in left and right lung volumes while retaining the same total volume and mass.

The left lung is defined by

$$\left(\frac{x - 8.5}{5}\right)^2 + \left(\frac{y}{7.5}\right)^2 + \left(\frac{z - 43.5}{24}\right)^2 \le 1 \qquad \text{where } z \ge 43.5,$$

and whenever $43.5 \le z \le 55$ and $y < 1$, then $x \ge 8$.

The right lung is defined by

$$\left(\frac{x + 8.5}{5}\right)^2 + \left(\frac{y}{7.5}\right)^2 + \left(\frac{z - 43.5}{24}\right)^2 \le 1 \qquad \text{where } z \ge 43.5,$$

and whenever $46.0 \le z \le 54.0$ and $y < 1.5$, then $x < 5.4$.

The volume of the revised lungs is 3378 cm^3 and the mass is 999.2 g. Figure 2, a transverse section through the chest region of the phantom where z = 50, shows positions of the heart and lungs. For comparison, Fig. 2 also includes a drawing of a cadaver cross section at approximately the same level (*19*).

SPECIFIC ABSORBED FRACTIONS

The revised phantom was used to calculate specific absorbed fractions (a) when the source is located in the heart contents and (b) when the source is in the heart wall. Specific absorbed fractions for the revised lungs as

TABLE 3. SPECIFIC ABSORBED FRACTIONS (g^{-1}) AND COEFFICIENTS OF VARIATION (%) SOURCE IN HEART CHAMBERS

Targets	Photon Energy (MeV) 0.010		0.015		0.020		0.030		0.050		0.100	
Adrenals	1.67E-11	b	2.51E-11	a	5.25E-08	a	5.81E-06	22	1.70E-05	12	1.23E-05	11
Bladder wall	*		*		7.99E-17	a	1.20E-10	a	2.33E-08	a	1.52E-07	a
Bone (total)	8.00E-07	b	1.20E-07	10	1.02E-06	3	5.43E-06	1	9.47E-06	1	6.26E-06	1
GI (stomach wall)	5.45E-09	b	8.18E-09	a	4.71E-07	30	4.96E-06	8	9.59E-06	5	8.94E-06	5
GI (SI & contents)	6.03E-19	b	9.04E-19	a	5.58E-12	a	2.44E-08	a	3.73E-07	10	9.90E-07	6
GI (ULI wall)	1.04E-18	b	1.56E-18	a	8.93E-12	a	9.05E-09	43	5.26E-07	15	1.22E-06	9
GI (LLI wall)	*		*		1.41E-13	a	2.44E-09	a	5.41E-08	47	2.56E-07	24
Heart wall	1.99E-04	3	4.38E-04	2	5.54E-04	1	4.68E-04	1	2.39E-04	1	1.39E-04	1
Kidneys	2.32E-14	b	3.48E-14	a	1.09E-09	a	4.58E-07	19	2.01E-06	8	3.70E-06	5
Liver	6.34E-08	b	9.51E-08	28	1.52E-06	6	9.54E-06	2	1.45E-05	2	1.19E-05	2
Lungs	1.05E-06	b	1.58E-06	9	1.42E-05	3	3.93E-05	1	4.19E-05	1	2.51E-05	1
Marrow (red)	1.01E-06	b	1.52E-07	11	1.32E-06	3	7.21E-06	1	1.29E-05	1	8.91E-06	1
Other tiss. (musc.)	1.10E-07	1	1.61E-06	1	4.75E-06	1	9.48E-06	1	9.77E-06	1	7.40E-06	1
Ovaries	*		*		4.84E-15	a	1.02E-09	a	9.02E-08	a	4.08E-07	a
Pancreas	3.00E-10	b	4.50E-10	a	2.05E-07	a	7.03E-06	10	1.51E-05	5	1.42E-05	5
Skin	2.79E-08	b	4.19E-08	33	2.24E-07	12	1.18E-06	4	1.80E-06	2	1.69E-06	2
Spleen	2.63E-12	b	3.95E-12	a	1.36E-08	a	2.33E-06	12	6.34E-06	6	6.87E-06	5
Testes	*		*		1.86E-20	a	2.53E-12	a	2.21E-09	a	2.79E-08	a
Thyroid	7.13E-17	b	1.07E-16	a	9.88E-11	a	1.32E-07	a	1.66E-06	34	2.08E-06	22
Uterus (nongravid)	*		*		3.20E-15	a	8.52E-10	a	8.16E-08	a	1.90E-07	36
Total body	1.41E-05	1	1.41E-05	1	1.40E-05	1	1.32E-05	1	1.00E-05	1	6.93E-06	1

Targets	Photon Energy (MeV) 0.200		0.500		1.000		1.500		2.000		4.000	
Adrenals	1.08E-05	13	8.09E-06	21	1.14E-05	21	7.08E-06	26	8.13E-06	26	7.46E-06	29
Bladder wall	2.56E-07	a	3.44E-07	a	4.02E-07	a	4.25E-07	a	4.38E-07	a	4.27E-07	a
Bone (total)	3.83E-06	1	2.98E-06	1	2.79E-06	2	2.56E-06	2	2.45E-06	2	2.08E-06	2
GI (stomach wall)	8.67E-06	5	7.17E-06	7	8.26E-06	8	6.76E-06	9	6.32E-06	10	6.50E-06	11
GI (SI & contents)	1.05E-06	6	1.08E-06	7	1.25E-06	8	1.18E-06	8	1.38E-06	8	1.04E-06	10
GI (ULI wall)	1.19E-06	10	1.72E-06	12	1.42E-06	15	1.48E-06	16	1.33E-06	18	9.24E-07	22
GI (LLI wall)	3.89E-07	21	3.44E-07	25	4.52E-07	31	4.11E-07	36	8.30E-07	27	3.62E-07	41
Heart wall	1.32E-04	1	1.31E-04	2	1.24E-04	2	1.10E-04	2	1.01E-04	2	7.88E-05	3
Kidneys	3.26E-06	6	3.70E-06	7	3.25E-06	9	3.89E-06	9	3.27E-06	10	2.69E-06	12
Liver	1.02E-05	2	9.35E-06	2	8.69E-06	2	7.80E-06	3	7.18E-06	3	6.63E-06	3
Lungs	2.09E-05	1	2.01E-05	2	1.86E-05	2	1.65E-05	2	1.49E-05	3	1.30E-05	3
Marrow (red)	5.43E-06	1	4.16E-06	2	3.94E-06	2	3.62E-06	2	3.46E-06	2	2.92E-06	3
Other tiss. (Musc.)	6.79E-06	1	6.59E-06	1	6.23E-06	1	5.76E-06	1	5.44E-06	1	4.52E-06	1
Ovaries	5.86E-07	a	1.34E-07	45	7.29E-07	a	7.40E-07	a	7.37E-07	a	6.83E-07	a
Pancreas	1.25E-05	6	1.33E-05	7	9.81E-06	9	8.34E-06	11	8.21E-06	12	9.11E-06	11
Skin	1.75E-06	3	2.00E-06	3	1.96E-06	4	1.90E-06	4	1.90E-06	4	1.79E-06	5
Spleen	6.21E-06	6	5.31E-06	8	5.03E-06	9	4.61E-06	10	4.43E-06	11	4.27E-06	12
Testes	6.45E-08	a	1.13E-07	a	1.57E-07	a	1.82E-07	a	1.97E-07	a	2.13E-07	a
Thyroid	2.44E-06	28	2.57E-06	29	1.24E-06	40	3.52E-06	37	3.40E-06	35	2.17E-06	a
Uterus (nongravid)	2.84E-07	33	2.68E-07	26	4.40E-07	38	5.68E-07	41	7.08E-07	a	6.59E-07	a
Total body	6.14E-06	1	5.94E-06	1	5.62E-06	1	5.16E-06	1	4.83E-06	1	4.00E-06	1

a Buildup factor method.
b Extrapolated from higher energy.
* < 1.0 E − 20.

a source organ were not computed, but these are not expected to differ significantly from those in MIRD Pamphlet No. 5, Revised (*1*).

The Monte Carlo technique described by Snyder et al. (*1*) was used to calculate the specific absorbed fractions. When the coefficient of variation exceeded 50%,

TABLE 4. SPECIFIC ABSORBED FRACTIONS (g^{-1}) AND COEFFICIENTS OF VARIATION (%) SOURCE IN HEART WALL

Targets	Photon Energy (MeV) 0.010		0.015		0.020		0.030		0.050		0.100	
Adrenals	6.73E-11	b	1.01E-10	a	1.10E-07	a	1.09E-05	19	1.83E-05	10	1.18E-05	11
Bladder wall	*		*		2.55E-16	a	2.01E-10	a	3.14E-08	a	1.84E-07	a
Bone (total)	5.67E-09	49	3.68E-07	6	1.65E-06	3	5.86E-06	1	9.18E-06	1	5.92E-06	1
GI (stomach wall)	7.80E-08	b	1.17E-07	a	3.03E-06	14	1.39E-05	5	1.67E-05	4	1.46E-05	4
GI (SI & contents)	6.07E-18	b	9.11E-18	a	1.77E-11	a	2.48E-08	32	6.13E-07	9	1.05E-06	6
GI (ULI wall)	1.07E-17	b	1.60E-17	a	2.97E-11	a	5.55E-08	a	7.62E-07	12	1.68E-06	8
GI (LLI wall)	1.51E-20	b	2.27E-20	a	5.83E-13	a	4.69E-09	a	1.57E-07	31	2.62E-07	20
Heart wall	2.86E-03	1	2.08E-03	1	1.47E-03	1	7.82E-04	1	3.36E-04	1	1.99E-04	1
Kidneys	1.49E-13	b	2.24E-13	a	2.98E-09	a	8.05E-07	17	3.19E-06	7	4.17E-06	5
Liver	5.04E-07	b	7.56E-07	10	3.74E-06	4	1.23E-05	2	1.52E-05	2	1.23E-05	2
Lungs	3.08E-06	b	4.62E-06	5	1.93E-05	2	4.04E-05	1	3.60E-05	1	2.37E-05	1
Marrow (red)	5.91E-09	49	4.02E-07	6	1.94E-06	3	7.31E-06	1	1.22E-05	1	8.27E-06	1
Other tiss. (musc.)	2.45E-06	1	5.96E-06	1	9.13E-06	1	1.19E-05	1	1.03E-05	1	7.67E-06	1
Ovaries	*		*		1.53E-14	a	1.73E-09	a	1.21E-07	a	4.97E-07	a
Pancreas	4.99E-09	b	7.48E-09	a	1.18E-06	30	1.46E-05	7	2.24E-05	4	1.92E-05	4
Skin	6.12E-08	b	9.18E-08	22	4.79E-07	8	1.41E-06	4	1.85E-06	2	1.75E-06	2
Spleen	3.55E-11	b	5.32E-11	a	2.98E-07	43	4.19E-06	10	9.33E-06	5	8.77E-06	5
Testes	*		*		5.51E-20	a	3.95E-12	a	2.99E-09	a	3.44E-08	a
Thyroid	1.02E-16	b	1.53E-16	a	8.92E-11	a	1.04E-07	a	1.38E-06	a	1.62E-06	23
Uterus (nongravid)	*		*		9.98E-15	a	1.44E-09	a	1.71E-07	45	1.14E-07	35
Total body	1.41E-05	1	1.41E-05	1	1.40E-05	1	1.30E-05	1	9.74E-06	1	6.72E-06	1

Targets	Photon Energy (MeV) 0.200		0.500		1.000		1.500		2.000		4.000	
Adrenals	1.29E-05	13	1.31E-05	18	9.18E-06	23	9.80E-06	22	1.21E-05	22	9.01E-06	28
Bladder wall	1.39E-07	44	3.90E-07	a	7.91E-07	43	4.71E-07	a	4.81E-07	a	4.63E-07	a
Bone (total)	3.70E-06	1	2.98E-06	1	2.70E-06	2	2.54E-06	2	2.45E-06	2	2.00E-06	2
GI (stomach wall)	1.21E-05	5	1.09E-05	6	1.03E-05	7	9.23E-06	8	8.85E-06	9	7.76E-06	10
GI (SI & contents)	1.14E-06	6	1.36E-06	6	1.37E-06	7	1.71E-06	7	1.40E-06	8	1.36E-06	9
GI (ULI wall)	1.19E-06	10	1.78E-06	12	1.29E-06	16	1.77E-06	15	1.35E-06	17	1.08E-06	20
GI (LLI wall)	3.20E-07	25	4.12E-07	25	8.43E-07	22	4.53E-07	30	6.93E-07	28	2.41E-07	45
Heart wall	1.97E-04	1	2.05E-04	1	1.89E-04	2	1.71E-04	2	1.61E-04	2	1.26E-04	2
Kidneys	4.04E-06	6	3.99E-06	7	4.54E-06	8	3.39E-06	9	3.55E-06	10	2.79E-06	12
Liver	1.03E-05	2	9.77E-06	2	9.58E-06	2	9.18E-06	2	8.06E-06	3	7.03E-06	3
Lungs	2.03E-05	1	1.89E-05	2	1.70E-05	2	1.54E-05	2	1.40E-05	3	1.20E-05	3
Marrow (red)	5.17E-06	1	4.17E-06	2	3.70E-06	2	3.51E-06	2	3.38E-06	2	2.76E-06	3
Other tiss. (musc.)	7.16E-06	1	7.01E-06	1	6.59E-06	1	6.16E-06	1	5.79E-06	1	4.84E-06	1
Ovaries	6.86E-07	a	7.81E-07	a	8.18E-07	a	8.18E-07	a	7.82E-07	a	7.45E-07	a
Pancreas	1.70E-05	5	1.56E-05	7	1.43E-05	8	1.42E-05	8	1.40E-05	9	1.09E-05	10
Skin	1.77E-06	3	2.13E-06	3	2.01E-06	4	1.99E-06	4	2.04E-06	4	1.71E-06	5
Spleen	7.69E-06	5	7.83E-06	7	6.09E-06	9	6.36E-06	9	6.21E-06	9	4.29E-06	12
Testes	7.62E-08	a	1.30E-07	a	1.75E-07	a	2.00E-07	a	2.16E-07	a	2.30E-07	a
Thyroid	1.40E-06	40	2.59E-06	30	1.98E-06	45	2.03E-06	48	2.42E-06	44	3.00E-06	44
Uterus (nongravid)	4.28E-07	28	4.48E-07	39	1.19E-06	35	6.86E-07	37	1.62E-07	41	8.90E-07	33
Total body	5.98E-06	1	5.87E-06	1	5.48E-06	1	5.11E-06	1	4.79E-06	1	3.98E-06	1

a Buildup factor method.
b Extrapolated from higher energy.
* <1.0 E-20.

the specific absorbed fractions were recalculated by the buildup factor method (*20*). Tables 3 and 4 are listings of specific absorbed fractions for 21 target organs. In the tables, a numeral or letter appears after each specific absorbed fraction. The numerals indicate the coefficient of variation (%) for that specific absorbed fraction. For example, with a 0.05-MeV photon source in the heart chambers, the specific absorbed fraction in the adrenals is 1.70E-5 (i.e., 1.70×10^{-5}) with a coefficient of variation of 12%. This estimate was obtained by the Monte Carlo technique. A letter appearing in this column means that the estimate of the specific absorbed fraction was obtained by a method other than the Monte Carlo method. The meanings of the letters can be found in the tables' footnotes, and a detailed discussion of the method used is in MIRD Pamphlet No. 5, Revised (*1*).

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