

ESTIMATES OF DOSE RATE TO GONADS OF INFANTS AND CHILDREN FROM A PHOTON EMITTER IN VARIOUS ORGANS OF THE BODY*

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Abstract

Estimates of genetic dose are needed for infants and children for realistic appraisal of environmental exposure of the population and also for medical use of radionuclide. Estimates of the dose rate due to a photon emitter from a source in ovaries or in testes are given in this paper for photons of 12 energies between 10 keV and 4 MeV in five phantoms corresponding to the newborn and children of ages 1, 5, 10, and 15 years. These estimates are obtained by use of the Monte Carlo technique applied to a phantom which is a transformation by similitude of a modification of the adult phantom reported in MIRD Pamphlet No. 5. Thus these estimates reflect the relative size, shapes, densities, and compositions of the various organs. By use of the reciprocity theorem, it should be possible to infer gonad dose from a radionuclide deposited in any source organ where the estimate is statistically reliable. It would be expected that this use of the reciprocity theorem would give estimates of gonad dose which are high but not by a large factor, perhaps by a factor of two or three at most.

This paper provides some estimates of dose rates to gonads from sources of a photon emitter distributed uniformly in various organs of the body. The results are obtained by application of the reciprocity theorem to the Monte Carlo estimates of dose rate from gonads to large organs. Although only results for photon energies of 0.02, 0.05, 0.1, 0.5, 1, and 2 MeV are reported here, it is planned to complete the series so the 12 monoenergetic sources used in MIRD Pamphlet No. 5¹ will be available for interpolation of other photon energies.

The basic phantoms used are essentially modifications of that reported in reference 1. The modifications include specification of regions where active bone marrow is deposited in the adult, addition of clavicles and scapulae to the skeleton, rounding of the top of the head, separate legs for the phantom, and relocation of the testes. These modifications will be presented in detail in a separate publication.²

For these calculations, the head, trunk, and leg sections of the adult phantom were transformed by similitudes to form the new phantoms. Although all organs and regions in each of these sections were shrunk by the same factors, these factors were not identical for

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the three sections which were given over-all dimensions typical for a given age. These factors are given in reference 3. The phantoms produced by use of these transformations are referred to below as being those of ages 0 (newborn), 1, 5, 10, 15, and 20 (adult) years. The corresponding masses for the total body are approximately 3.4, 10, 19.5, 31.8, 54, and 70 kg.

Since the dose rates given below are based entirely on use of the reciprocity theorem, it is appropriate to consider the validity of this theorem in phantoms corresponding to the various ages. The validity in the adult phantom has been studied extensively and is reported in reference 4. The theorem has been tested by programming sources of 60,000 photons at three widely separated regions of these phantoms and at several energies. The three regions used were the central volumes (approximately elliptical cylinders of semi-axes 16 cm and 8 cm and height 14 cm) of the top, middle, and bottom fifths of the trunk of the phantom. The regions contain rather different amounts of bone and lung tissue so that the inhomogeneity of the phantom is well represented. Three source energies were chosen--0.03, 0.1, and 0.5 MeV--and in all cases reciprocity held within 12%, generally being within a few percent in the corresponding cases. While far from the ideal solution of the problem, it is believed the values obtained for genetic dose by this means are sufficiently accurate for practical use since the actual distances of the gonads from the various source organs will vary with the individual and will only be approximately specified.

In Table 1 are displayed the estimates of dose rate from various source organs to the ovaries and testes of the newborn and the 1-year-old phantoms. As explained above, these values were obtained by Monte Carlo calculation and represent the dose rate to these organs from sources placed in the ovaries or testes, and thus the estimates given here are based on the use of reciprocity. It is expected that more complete results will be published when the results for the 12 monoenergetic sources of photons become available. When the indicated value is 0, the estimate is not considered to be reliable.

References

1. W. S. Snyder et al., "Estimates of Absorbed Fractions for Monoenergetic Photon Sources Uniformly Distributed in Various Organs of a Heterogeneous Phantom," J. Nucl. Med. Suppl. No. 3, 5 (1969).
2. W. S. Snyder and M. R. Ford, ORNL report (to be published).
3. M. J. Hilyer, G. S. Hill, and G. G. Warner, "Dose from Photon Emitters Distributed Uniformly in the Total Body as a Function of Age," These proceedings.
4. Walter S. Snyder, "Estimation of Absorbed Fraction of Energy from Photon Sources in Body Organs," Medical Radionuclides: Radiation Dose and Effects (USAEC/DTI, Oak Ridge, Tennessee, 1970), p. 33.

DOSES (RADS/PHOTON) AND COEFFICIENTS OF VARIATION (PER CENT)

SOURCE IN OVARIES OF NEWBORN PHANTOM

ENERGY (MEV)

	0.020		0.050		0.100		0.500		1.000		2.000	
	DOSE	C.V.	DOSE	C.V.	DOSE	C.V.	DOSE	C.V.	DOSE	C.V.	DOSE	C.V.
ADRENALS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BLADDER WALL	2.1E-13	8.1E 00	2.9E-13	6.2E 00	3.8E-13	7.7E 00	1.8E-12	1.2E 01	3.5E-12	1.4E 01	4.6E-12	1.8E 01
STOMACH WALL	7.9E-15	2.1E C1	6.1E-14	7.4E 00	7.3E-14	9.3E 00	3.3E-13	1.5E 01	5.7E-13	1.9E 01	9.5E-13	2.2E 01
SMALL INTESTINE	7.2E-13	1.0E 00	5.2E-13	1.2E 00	6.0E-13	1.4E 00	3.1E-12	2.1E 00	5.6E-12	2.4E 00	9.2E-12	2.8E 00
U.I.-I. WALL	7.2E-13	2.2E C0	4.5E-13	2.5E 00	5.0E-13	3.3E 00	2.8E-12	4.7E 00	5.0E-12	5.6E 00	7.9E-12	6.7E 00
L.I.-I. WALL	1.2E-12	2.0E C0	6.3E-13	2.4E 00	7.3E-13	3.1E 00	3.9E-12	4.6E 00	7.4E-12	5.3E 00	1.2E-11	6.4E 00
HEART	0.0	0.0	1.4E-14	8.7E 00	2.7E-14	8.6E 00	1.4E-13	1.2E 01	3.7E-13	1.2E 01	4.9E-13	1.5E 01
KIDNEYS	5.2E-15	2.1E 01	6.0E-14	6.1E 00	7.6E-14	7.3E 00	4.0E-13	1.1E 01	6.2E-13	1.3E 01	1.0E-12	1.5E 01
LIVER	4.2E-15	9.9E 00	4.4E-14	3.1E 00	6.2E-14	3.5E 00	2.8E-13	5.0E 00	5.4E-13	5.7E 00	8.5E-13	6.8E 00
LUNGS	0.0	0.0	1.2E-14	6.7E 00	2.0E-14	7.0E 00	1.2E-13	9.9E 00	2.5E-13	1.1E 01	4.8E-13	1.2E 01
RED MARROW	1.9E-13	1.1E 00	2.8E-13	1.1E 00	1.0E-13	1.5E 00	4.8E-13	2.6E 00	9.3E-13	3.0E 00	1.6E-12	3.5E 00
YELLOW MARROW	9.3E-14	1.1E 00	1.9E-13	1.0E 00	1.2E-13	1.4E 00	3.4E-13	2.4E 00	6.7E-13	2.8E 00	1.1E-12	3.3E 00
OVARIES	9.4E-11	9.8E-01	2.2E-11	1.8E 00	2.6E-11	2.3E 00	1.7E-10	3.1E 00	3.2E-10	3.6E 00	5.2E-10	4.2E 00
PANCREAS	0.0	0.0	3.8E-14	1.5E 01	7.0E-14	1.6E 01	3.4E-13	2.5E 01	8.3E-13	2.5E 01	0.0	0.0
SKELETON	5.4E-14	1.1E 00	1.1E-13	9.3E-01	7.8E-14	1.3E 00	2.1E-13	2.1E 00	4.1E-13	2.4E 00	6.9E-13	2.9E 00
TOTAL SKIN	2.4E-15	8.6E 00	2.1E-14	2.6E 00	2.6E-14	3.3E 00	1.5E-13	5.1E 00	2.9E-13	5.8E 00	5.1E-13	6.8E 00
SPLEEN	0.0	0.0	5.0E-14	8.4E 00	5.0E-14	1.1E 01	2.2E-13	1.7E 01	5.1E-13	1.8E 01	1.1E-12	2.0E 01
THYRUS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
UTERUS	1.5E-12	2.7E 00	1.0E-12	3.1E 00	1.1E-12	4.0E 00	5.9E-12	5.8E 00	1.1E-11	6.9E 00	1.8E-11	8.0E 00
TOTAL BODY	9.1E-14	7.0E-02	9.2E-14	3.6E-01	1.0E-13	4.6E-01	5.0E-13	5.5E-01	9.2E-13	6.3E-01	1.5E-12	7.6E-01

DOSES (RADS/PHOTON) AND COEFFICIENTS OF VARIATION (PER CENT)

SOURCE IN TESTES OF NEWBORN PHANTOM

ENERGY (MEV)

	0.020		0.050		0.100		0.500		1.000		2.000	
	DOSE	C.V.	DOSE	C.V.	DOSE	C.V.	DOSE	C.V.	DOSE	C.V.	DOSE	C.V.
ADRENALS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BLADDER WALL	1.9E-13	8.4E 00	2.3E-13	7.2E 00	3.4E-13	8.5E 00	1.7E-12	1.3E 01	2.9E-12	1.5E 01	5.0E-12	1.8E 01
STOMACH WALL	0.0	0.0	9.3E-15	2.0E 01	1.7E-14	2.1E 01	1.4E-13	2.5E 01	0.0	0.0	0.0	0.0
SMALL INTESTINE	1.3E-15	2.1E 01	3.3E-14	4.8E 00	4.2E-14	5.3E 00	2.2E-13	7.2E 00	5.0E-13	7.9E 00	6.4E-13	1.0E 01
U.L.I. WALL	0.0	0.0	3.2E-14	8.8E 00	4.1E-14	1.0E 01	2.3E-13	1.5E 01	4.9E-13	1.7E 01	7.8E-13	2.0E 01
L.L.I. WALL	2.1E-14	1.3E 01	9.9E-14	6.1E 00	1.3E-13	7.4E 00	6.1E-13	1.1E 01	1.0E-12	1.4E 01	1.9E-12	1.6E 01
HEART	0.0	0.0	3.0E-15	2.1E 01	5.2E-15	2.1E 01	4.0E-14	2.0E 01	1.0E-13	2.2E 01	2.4E-13	2.3E 01
KIDNEYS	0.0	0.0	5.5E-15	1.8E 01	1.0E-14	1.9E 01	6.7E-14	2.4E 01	1.7E-13	2.5E 01	2.8E-13	2.9E 01
LIVER	0.0	0.0	6.7E-15	8.4E 00	1.0E-14	8.4E 00	6.9E-14	9.5E 00	1.4E-13	1.1E 01	2.1E-13	1.3E 01
LUNGS	0.0	0.0	1.9E-15	1.7E 01	3.3E-15	1.7E 01	2.7E-14	1.9E 01	9.2E-14	1.7E 01	1.3E-13	2.0E 01
RED MARROW	4.5E-15	6.2E 00	4.4E-14	2.6E 00	3.5E-14	3.3E 00	1.1E-13	5.1E 00	1.7E-13	6.2E 00	3.1E-13	7.1E 00
YELLOW MARROW	3.8E-15	5.2E 00	4.7E-14	2.1E 00	3.6E-14	2.6E 00	1.2E-13	3.9E 00	2.3E-13	4.7E 00	4.2E-13	5.5E 00
PANCREAS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SKELETON	6.7E-15	3.0E 00	5.6E-14	1.4E 00	4.2E-14	1.9E 00	1.3E-13	2.7E 00	2.5E-13	3.1E 00	4.2E-13	3.7E 00
TOTAL SKIN	6.7E-14	1.9E 00	3.8E-14	2.2E 00	4.7E-14	2.8E 00	2.7E-13	3.9E 00	5.2E-13	4.5E 00	8.0E-13	5.5E 00
SPLEEN	0.0	0.0	8.5E-15	2.3E 01	1.4E-14	2.1E 01	0.0	0.0	0.0	0.0	0.0	0.0
TESTES	5.8E-11	7.2E-01	1.4E-11	1.4E 00	1.7E-11	1.8E 00	1.1E-10	2.4E 00	2.0E-10	2.6E 00	3.3E-10	3.2E 00
THYROID	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
UTERUS	1.1E-14	2.8E 01	7.3E-14	1.1E 01	1.1E-13	1.2E 01	4.8E-13	2.0E 01	7.7E-13	2.5E 01	1.8E-12	2.6E 01
TOTAL BODY	6.7E-14	2.3E-01	5.4E-14	5.3E-01	6.2E-14	6.2E-01	3.3E-13	7.1E-01	6.3E-13	8.0E-01	1.0E-12	9.4E-01

DOSES (RADS/PHOTON) AND COEFFICIENTS OF VARIATION (PER CENT)

SOURCE IN OVARIES OF ONE YEAR OLD PHANTOM

E N E R G Y (MEV)

	0.020		0.050		0.100		0.500		1.000		2.000	
	DOSE	C.V.	DOSE	C.V.	DOSE	C.V.	DOSE	C.V.	DOSE	C.V.	DOSE	C.V.
ADRENALS	0.0	0.0	1.2E-14	2.9E 01	1.9E-14	2.9E 01	0.0	0.0	0.0	0.0	0.0	0.0
BLADDER WALL	5.0E-14	9.6E 00	1.6E-13	5.0E 00	1.7E-13	6.5E 00	8.3E-13	1.0E 01	1.4E-12	1.3E 01	2.3E-12	1.5E 01
STOMACH WALL	0.0	0.0	2.5E-14	7.1E 00	3.2E-14	7.9E 00	1.6E-13	1.3E 01	3.2E-13	1.4E 01	6.7E-13	1.6E 01
SMALL INTESTINE	2.4E-13	1.0E 00	2.7E-13	1.0E 00	3.1E-13	1.2E 00	1.5E-12	1.7E 00	2.6E-12	2.0E 00	4.3E-12	2.4E 00
U.L.I. WALL	2.7E-13	2.1E 00	2.4E-13	2.1E 00	2.7E-13	2.6E 00	1.3E-12	4.0E 00	2.4E-12	4.6E 00	3.6E-12	5.8E 00
L.L.I. WALL	4.6E-13	1.9E 00	3.3E-13	2.0E 00	3.5E-13	2.6E 00	1.9E-12	3.8E 00	3.5E-12	4.4E 00	5.2E-12	5.5E 00
HEART	0.0	0.0	4.0E-15	1.0E 01	9.5E-15	8.6E 00	5.0E-14	1.1E 01	1.0E-13	1.3E 01	2.2E-13	1.3E 01
KIDNEYS	0.0	0.0	2.4E-14	5.5E 00	3.9E-14	5.6E 00	1.7E-13	8.9E 00	3.4E-13	1.0E 01	5.0E-13	1.3E 01
LIVER	3.3E-16	2.1E 01	1.8E-14	3.0E 00	2.7E-14	3.0E 00	1.2E-13	4.4E 00	2.2E-13	5.1E 00	4.2E-13	5.6E 00
LUNGS	0.0	0.0	3.3E-15	7.1E 00	6.6E-15	7.0E 00	4.3E-14	9.2E 00	1.0E-13	9.9E 00	1.8E-13	1.1E 01
RED MARROW	4.7E-14	1.3E 00	1.5E-13	9.1E-01	1.1E-13	1.2E 00	2.6E-13	2.1E 00	4.4E-13	2.6E 00	7.4E-13	3.0E 00
YELLOW MARROW	2.1E-14	1.3E 00	4.3E-14	8.8E-01	6.4E-14	1.2E 00	1.7E-13	2.0E 00	2.9E-13	2.4E 00	4.7E-13	2.9E 00
OVARIES	4.6E-11	7.9E-01	1.1E-11	1.5E 00	1.3E-11	1.9E 00	8.4E-11	2.6E 00	1.6E-10	3.0E 00	2.4E-10	3.6E 00
PANCREAS	0.0	0.0	2.0E-14	1.2E 01	3.6E-14	1.2E 01	1.0E-13	2.4E 01	3.7E-13	2.3E 01	0.0	0.0
SKELTON	1.3E-14	1.3E 00	5.1E-14	7.9E-01	4.1E-14	1.0E 00	1.1E-13	1.7E 00	1.8E-13	2.1E 00	3.1E-13	2.5E 00
TOTAL SKIN	3.9E-16	1.3E 01	7.9E-15	2.6E 00	1.2E-14	2.8E 00	7.2E-14	4.1E 00	1.4E-13	4.7E 00	2.5E-13	5.6E 00
SPLEEN	0.0	0.0	4.7E-14	8.3E 00	2.5E-14	9.2E 00	1.3E-13	1.3E 01	2.1E-13	1.7E 01	4.1E-13	1.9E 01
THYROID	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
UTERUS	5.0E-13	2.8E 00	5.0E-13	2.6E 00	5.5E-13	3.3E 00	2.7E-12	5.0E 00	4.9E-12	5.9E 00	7.8E-12	7.2E 00
TOTAL BODY	3.1E-14	5.4E-02	4.3E-14	2.8E-01	5.1E-14	3.9E-01	2.3E-13	4.5E-01	4.3E-13	5.1E-01	7.1E-13	6.2E-01

DOSIS (PADS/PHOTON) AND COEFFICIENTS OF VARIATION (PER CENT)

SOURCE IN TESTES OF ONE YEAR OLD PHANTOM

ENERGY (MEV)

	0.020		0.050		0.100		0.500		1.000		2.000	
	DOSE	C.V.	DOSE	C.V.	DOSE	C.V.	DOSE	C.V.	DOSE	C.V.	DOSE	C.V.
ADRENALS	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BLADDER WALL	4.2E-14	1.1E 01	1.3E-13	5.7E 00	1.4E-13	7.4E 00	6.2E-13	1.2E 01	1.4E-12	1.3E 01	2.5E-12	1.5E 01
STOMACH WALL	0.0	0.0	2.1E-15	2.2E 01	8.3E-15	1.7E 01	3.7E-14	2.8E 01	0.0	0.0	0.0	0.0
SMALL INTESTINE	0.0	0.0	1.3E-14	4.4E 00	2.0E-14	4.6E 00	9.0E-14	6.6E 00	1.9E-13	7.3E 00	3.0E-13	8.7E 00
U.L.I. WALL	0.0	0.0	1.2E-14	8.9E 00	2.1E-14	8.4E 00	8.8E-14	1.4E 01	1.9E-13	1.7E 01	3.5E-13	1.8E 01
L.L.I. WALL	3.7E-15	1.8E 01	4.3E-14	5.1E 00	6.0E-14	6.0E 00	2.7E-13	9.6E 00	5.1E-13	1.1E 01	8.2E-13	1.3E 01
HEART	0.0	0.0	3.0	0.0	1.1E-15	2.3E 01	1.3E-14	2.2E 01	3.7E-14	2.0E 01	7.3E-14	2.2E 01
KIDNEYS	0.0	0.0	1.2E-15	2.4E 01	3.9E-15	1.6E 01	3.0E-14	2.1E 01	7.8E-14	2.2E 01	1.7E-13	2.3E 01
LIVER	0.0	0.0	1.7E-15	9.9E 00	4.0E-15	7.9E 00	2.3E-14	1.0E 01	5.9E-14	9.6E 00	1.1E-13	1.1E 01
LUNGS	0.0	0.0	2.8E-16	2.5E 01	1.8E-15	1.5E 01	1.2E-14	1.8E 01	3.0E-14	1.8E 01	7.5E-14	1.8E 01
BED MARROW	4.7E-16	1.0E 01	1.9E-14	2.4E 00	1.8E-14	2.7E 00	4.4E-14	4.5E 00	1.1E-13	4.9E 00	1.6E-13	5.9E 00
YELLOW MARROW	2.7E-16	9.5E 00	1.6E-14	2.1E 00	1.7E-14	2.3E 00	4.9E-14	3.6E 00	1.0E-13	4.0E 00	1.7E-13	4.7E 00
PANCREAS	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SKELETON	8.6E-16	4.8E 00	2.8E-14	1.3E 00	2.4E-14	1.5E 00	6.4E-14	2.3E 00	1.2E-13	2.6E 00	2.1E-13	3.0E 00
TOTAL SKIN	2.1E-14	1.9E 00	1.7E-14	1.9E 00	2.3E-14	2.2E 00	1.3E-13	3.2E 00	2.5E-13	3.7E 00	4.5E-13	4.2E 00
SPLEEN	0.0	0.0	1.2E-15	2.8E 01	2.6E-15	2.6E 01	0.0	0.0	0.0	0.0	0.0	0.0
TESTES	2.3E-11	5.7E-01	6.2E-12	1.1E 00	7.6E-12	1.4E 00	4.6E-11	1.9E 00	8.1E-11	2.2E 00	1.4E-10	2.6E 00
THYROID	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
UTERUS	0.0	0.0	3.6E-14	8.9E 00	4.9E-14	1.1E 01	2.4E-13	1.7E 01	4.0E-13	1.9E 01	6.3E-13	2.4E 01
TOTAL BODY	2.5E-14	1.9E-01	2.6E-14	4.5E-01	3.2E-14	5.3E-01	1.6E-13	5.9E-01	3.0E-13	6.6E-01	5.1E-13	7.7E-01