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ABSORBED DOSE IN PHANTOMS WHICH REPRESENT VARIOUS AGED MALE HUMANS FROM EXTERNAL SOURCES OF PHOTONS AS A FUNCTION OF AGE*

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Abstract

It has long been suggested that there might be a large variation in absorbed dose among various aged humans. One expects this to be the result of the effect of the inverse square law in cases where the sources of radiation are internal. Now, studies have been made with the use of a computer to assess the photon dose received by various phantoms representing different aged male humans due to external sources. The studies included 12 monoenergetic infinite external sources, ranging in energy from 10 keV to 4 MeV, and 6 phantoms, representing a newborn, a 1 year old, a 5 year old, a 10 year old, a 15 year old, and an adult. The data indicate that dose to the genitalia of a newborn might be 3 times higher than dose to the genitalia of an adult at higher emitter energies or 30 times as high at the lowest emitter energy. In general, from the 1 year old upward in age, dose decreases with age.

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Various computer studies have been made at the Oak Ridge National Laboratory which have indicated that variations of dose exist among various aged humans when the sources of radiation were within the body (ORNL-4720, 1971; ORNL-4811, 1972; and ORNL-4903, 1973). Hilyer has reported on estimates of dose to infants and children from a photon emitter in the lungs (ORNL-4811, 1972) and on estimates of dose to infants and children from medical uses of Xenon-133 (San Juan, 1972). It has been found that dose from internal sources to internal organs has been greater for younger individuals, that the specific absorbed fraction of source energy decreases as age increases, and that the specific absorbed fraction decreases as energy increases.

Now, we have investigated the effect of age on absorbed dose and on specific absorbed fraction when six phantoms have been immersed in infinite external sources of photons. An IBM 360/91 computer was used for these studies. At each of 12 energies, 60,000 monoenergetic photons were initiated externally and allowed to impinge on the surface of each of the phantoms which represented a newborn, a 1 year old, a 5 year old, a 10 year old, a 15 year old, and an adult. The adult phantom is one that has been much publicized and is familiar to many (Warner, 1973). The phantoms of younger males were created by reducing the adult in similitude. That is to say, a coordinate point in the adult was transformed to a coordinate point in a younger phantom by factors separate for each coordinate axis. Loci which were non-intersecting in the adult were also non-intersecting in a younger phantom. Figure 1 shows the relative sizes of the various phantoms.

Data were taken in many internal organs, but interest in the gonads has prompted us to report on the genitalia regions here. Figure 2 shows part of the legs and the male genitalia of the adult phantom. Genitalia in the younger phantoms are similar. Data were taken on the testes separately, but generally the statistics were poor enough here to cause suspicion of their reliability; so data for the genitalia regions which include the testes were chosen. Figure 3 shows a comparison of teste data with genitalia data indicating errant teste data. Table 1 shows that the coefficients of variation for data in the testes are higher than coefficients of variation for data in the genitalia region.

Figure 4 shows the specific absorbed fraction of initial energy in the genitalia as a function of initial energy. The absorbed fractions decrease with increase in energy for all phantoms. The absorbed dose (rads/photon) however, increases with energy at initial energies above .100 MeV for all phantoms (Figure 5). Table 2 shows the absorbed dose for genitalia regions of 5 younger phantoms normalized to the absorbed dose for the genitalia region of the adult. These data indicate how much more dose is obtained in the younger phantom than is obtained in an adult at each energy. For instance, depending on the energy, the dose to the newborn genitalia might be from 3½ times to 31 times the dose to the adult genitalia. These factors decrease as age increases. Indications are that for initial energies above .030 MeV, for instance, the 1 year old received 5.7 times as much dose as the adult, the 5 year old received 3.2 times as much dose, the 10 year old 1.8 times as much, and the 15 year old 1.1 times as much. Figure 6 shows the amount of energy absorbed in the genitalia compared with the amount of energy absorbed in the whole phantom. Again, because the

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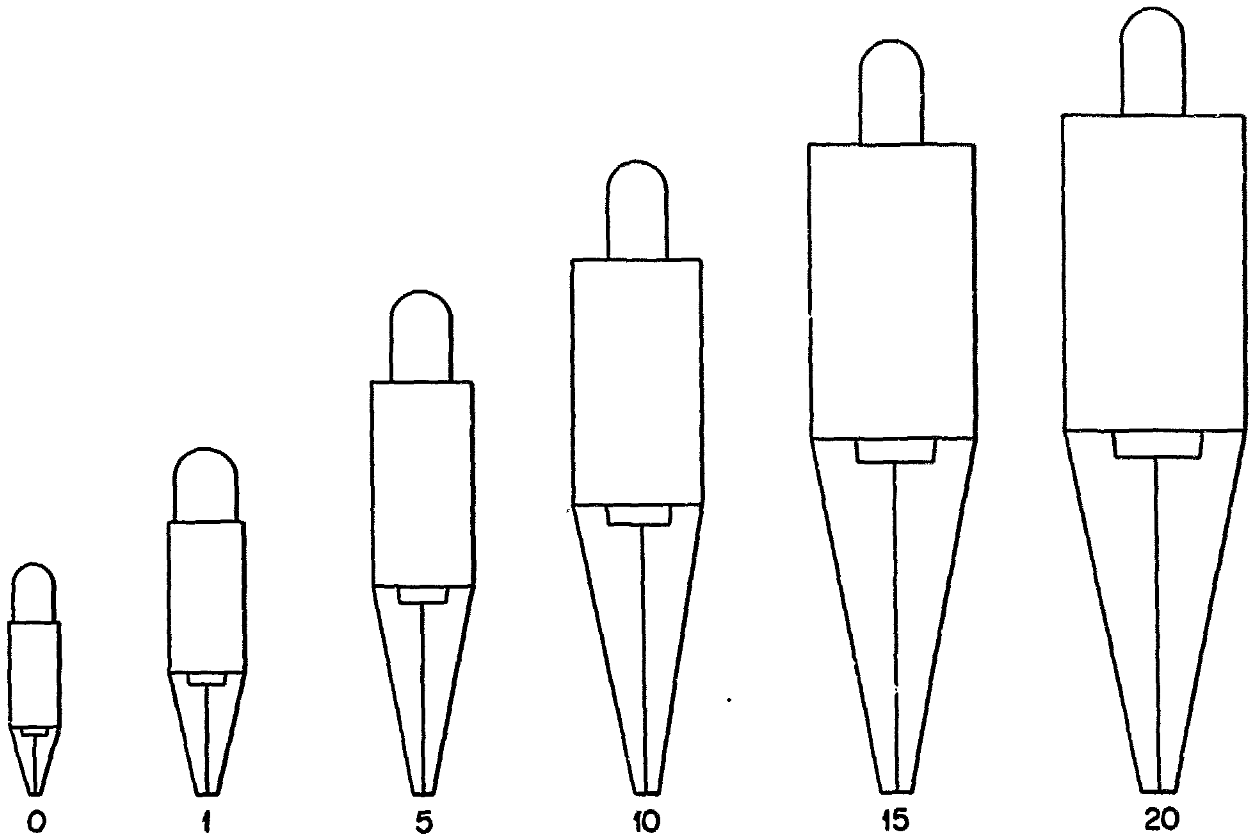

Relative Size of Phantoms for 0, 1, 5, 10, 15, and 20 Years.

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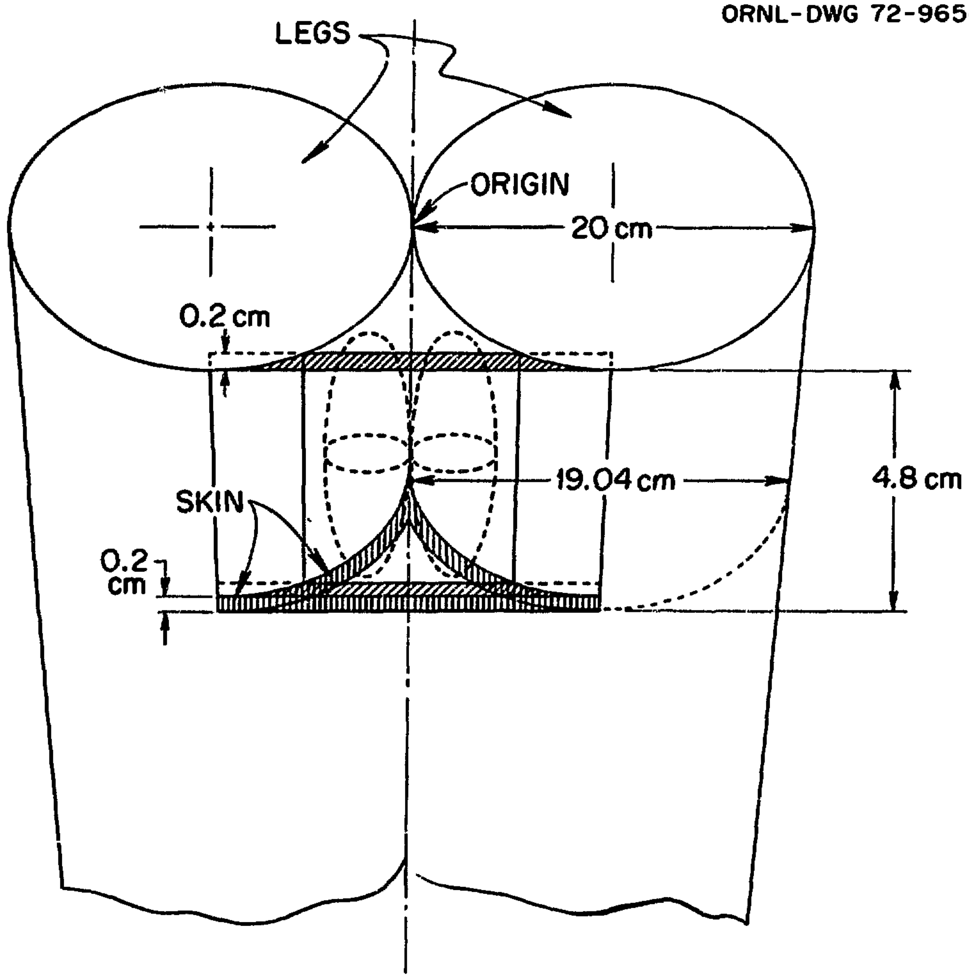
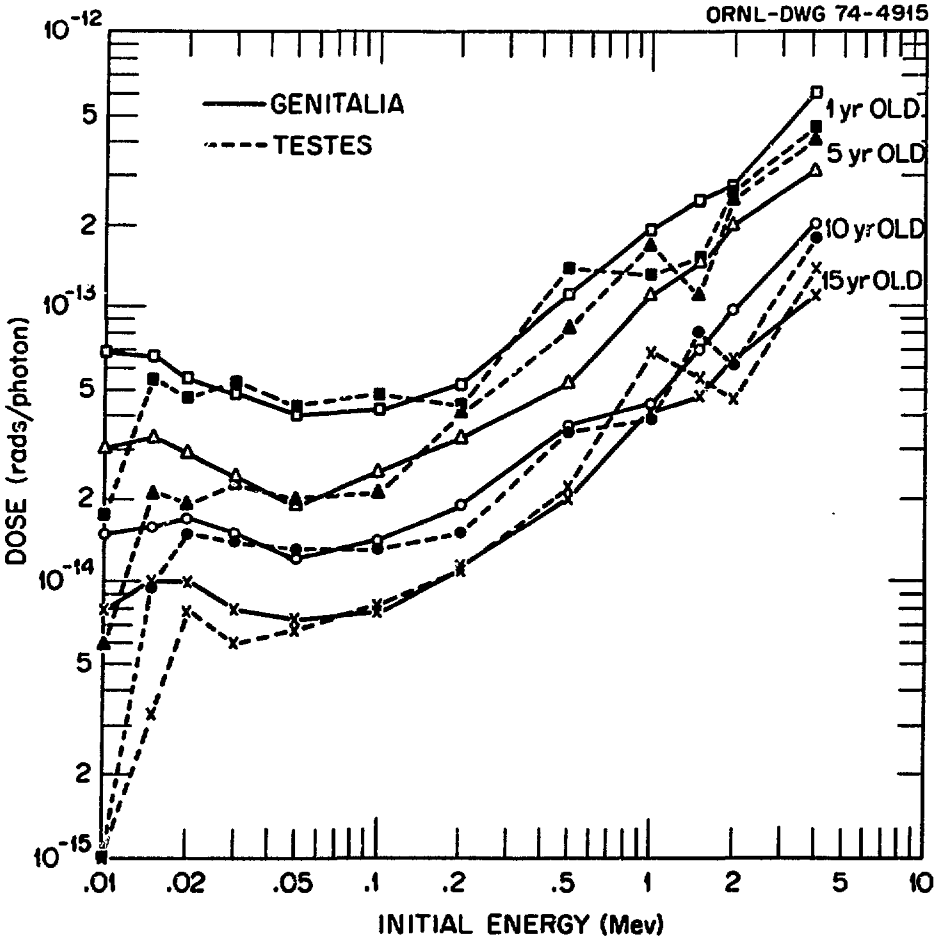


Legs and Male Genitalia of Phantom.



Dose vs Initial Energy of 12 Monoenergetic Infinite External Sources of Photons.

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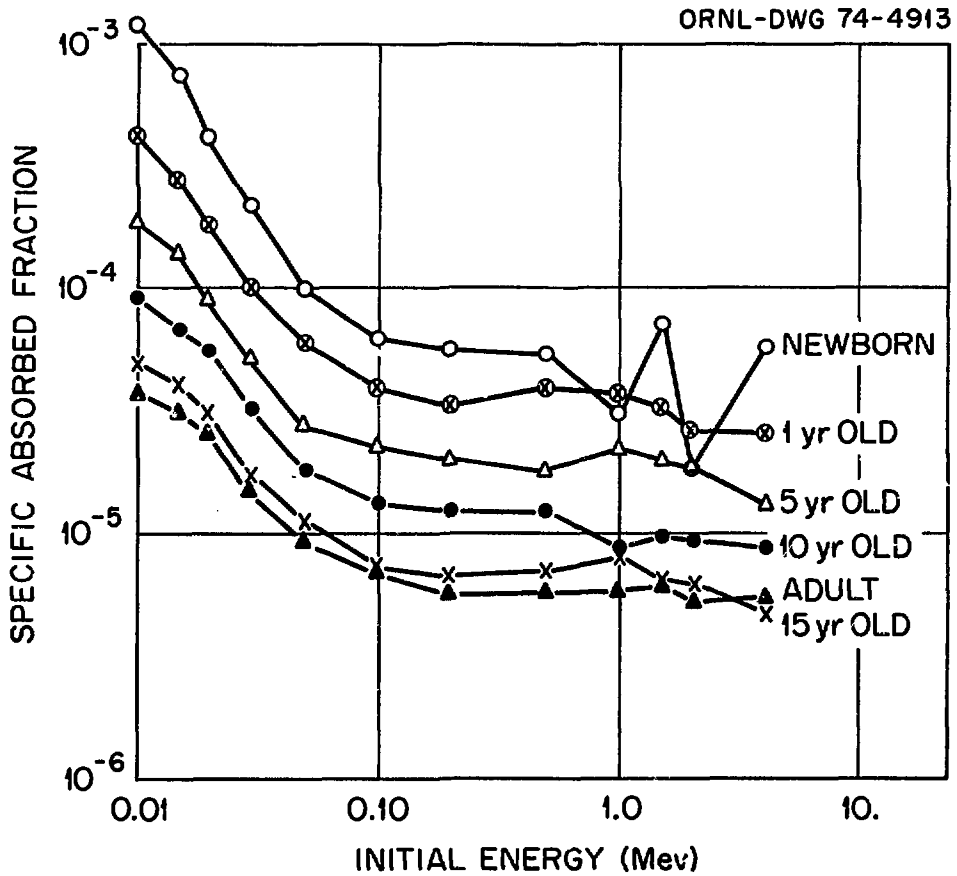
Table 1

Ranges of Coefficients of Variation of Dose From All Ages According to Initial Energy of Source

Initial Energy (MeV)	Target Regions	
	Testes	Genitalia
.010	26% to 42%	5% to 7%
.100	25% to 45%	8% to 18%
1.00	25% to 43%	13% to 40%



Specific Absorbed Fraction of Energy Absorbed in Genitalia as a Function of Initial Energy for 12 Monoenergetic Infinite External Sources of Photons.

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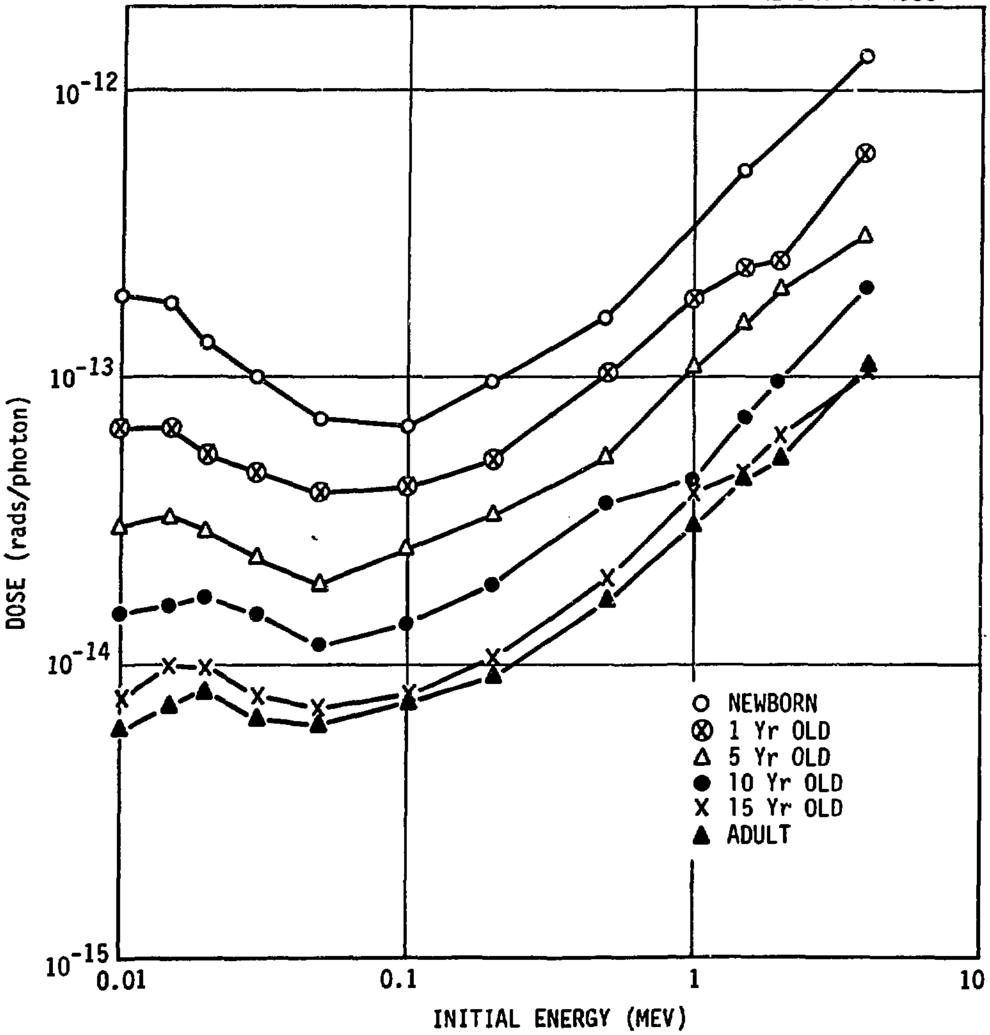

DOSE (rads/photon) IN GENITALIA REGION AS A FUNCTION OF INITIAL ENERGY OF 12 MONOENERGETIC INFINITE EXTERNAL SOURCES OF PHOTONS.

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Table 2

Doses for Genitalia of All Ages Normalized to Doses for Adult Genitalia at All Initial Energies

Initial Energy (MeV)	Phantoms				
	Newborn	1 yr old	5 yr old	10 yr old	15 yr old
.010	31.0	11.0	4.9	2.5	1.3
.015	24.0	9.1	4.5	2.2	1.3
.020	16.0	6.8	3.6	2.1	1.2
.030	15.0	7.2	3.6	2.2	1.2
.050	11.0	6.2	2.9	1.8	1.1
.10	8.9	5.6	3.3	1.9	1.0
.20	9.8	5.6	3.5	2.0	1.2
.50	9.4	6.5	3.1	2.1	1.2
1.0	5.0	6.3	3.7	1.5	1.4
1.5	12.0	5.3	3.3	1.6	1.0
2.0	3.5	5.0	3.8	1.8	1.2
4.0	11.0	5.0	2.6	1.7	.92

data are fairly constant above .030 MeV, of the energy absorbed in the whole body of each phantom, .13% was absorbed in the genitalia of the 1 year old, .20% in the 5 year old, .22% in the 10 year old, and .26% in the 15 year old. These data are tabulated in Table 3.

Finally, Figures 7 and 8 show that indeed both the specific absorbed fraction of initial energy in the genitalia and the absorbed dose in rads per photon in the genitalia vary inversely with age. Whereas Figure 8 does not show every energy, the lines for energies now shown follow the pattern.

Data tables follow.

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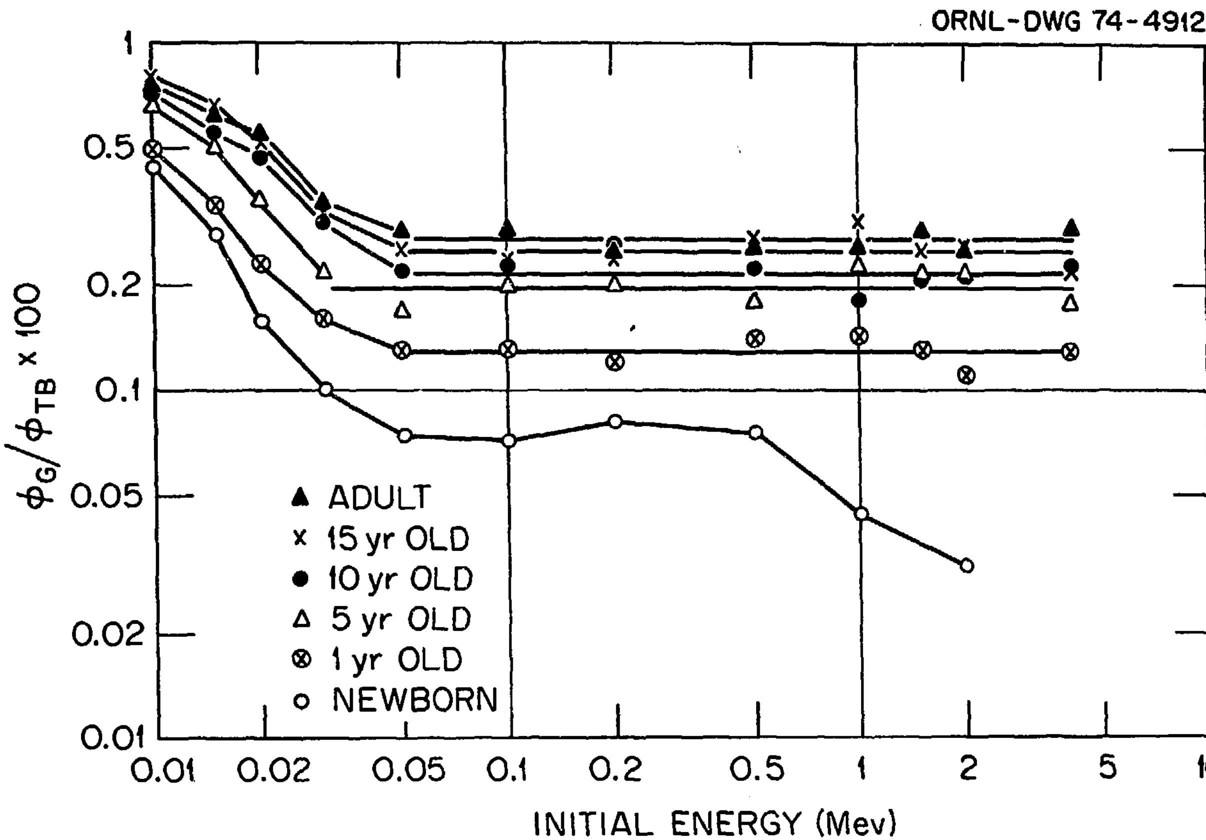

Amount of Energy Absorbed in Genitalia Compared with Amount of Energy Absorbed in Total Body from 12 Monoenergetic Infinite External Sources of Photons.

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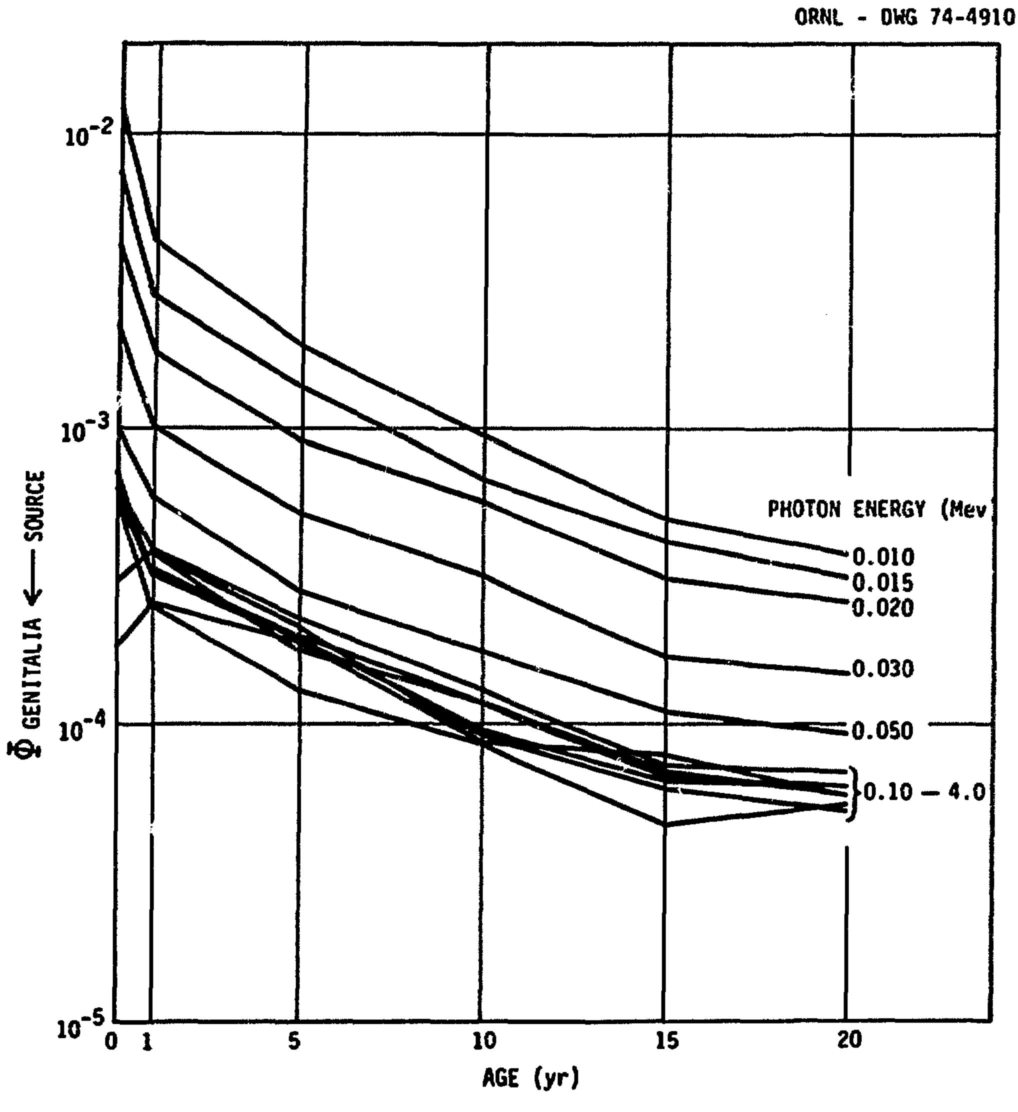
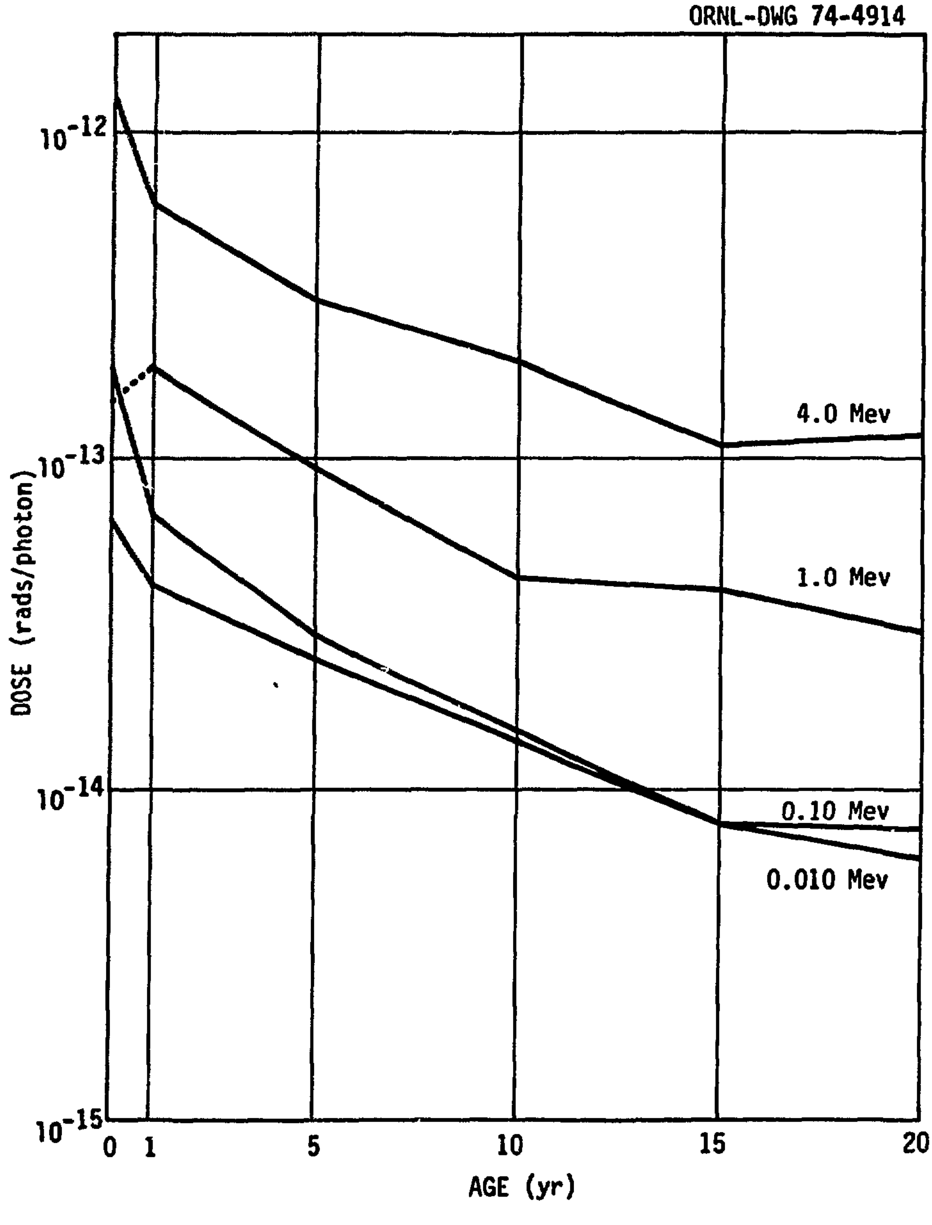
Table 3

Amount of Energy Absorbed in Genitalia as Percent of Amount of Energy Absorbed in ~~Testal~~ Total Body for All Phantoms at Every Initial Energy

Initial Energy (MeV)	Phantoms					
	Newborn	1 yr old	5 yr old	10 yr old	15 yr old	Adult
.010	.43	.49	.66	.72	.78	.76
.015	.28	.34	.50	.55	.66	.63
.020	.16	.23	.35	.47	.53	.55
.030	.10	.16	.22	.31	.33	.35
.050	.075	.13	.17	.22	.26	.29
.10	.072	.13	.20	.23	.24	.29
.20	.081	.12	.20	.24	.24	.25
.50	.076	.14	.18	.26	.27	.26
1.0	.044	.14	.23	.18	.30	.26
1.5	.11	.13	.22	.21	.25	.29
2.0	.031	.11	.22	.22	.26	.25
4.0	.11	.13	.18	.23	.22	.29



SPECIFIC ABSORBED FRACTION OF INITIAL ENERGY ABSORBED IN GENITALIA REGION AS A FUNCTION OF AGE. (MONOENERGETIC INFINITE EXTERNAL SOURCES OF PHOTONS)



DOSE (rads/photon) IN GENITALIA REGION AS A FUNCTION OF AGE. (MONO-ENERGETIC INFINITE EXTERNAL SOURCES OF PHOTONS)

Absorbed Doses, Specific Absorbed Fractions, and Coefficients of Variation for Energy Deposited in the Testes of Various Aged Phantoms from 12 Monoenergetic Infinite External Sources of Photons

Initial Energy (MeV)	Rads/ Photon	Φ	C.V. (%)	Rads/ Photon	Φ	C.V. (%)	Rads/ Photon	Φ	C.V. (%)
	Newborn (.5608 grams)			1 Year Old (2.136 grams)			5 Year Old (6.450 grams)		
.010	5.3-14*	.34-3	29.	1.6-14	.10-3	27.	5.9-15	.37-4	26.
.015	1.9-13	.78-3	18.	5.5-14	.23-3	18.	2.1-14	.89-4	16.
.020	1.6-13	.50-3	21.	4.7-14	.15-3	19.	1.9-14	.60-4	17.
.030	1.1-13	.24-3	23.	5.3-14	.11-3	19.	2.3-14	.51-4	17.
.050	7.6-14	.11-3	24.	4.4-14	.64-3	20.	2.0-14	.30-4	16.
.10	3.1-14	.29-4	45.	4.8-14	.45-4	21.	2.1-14	.20-4	16.
.20	9.8-14	.62-4	45.	4.3-14	.27-4	26.	4.1-14	.26-4	19.
.50	1.2-13	.42-4	36.	1.4-13	.47-4	42.	8.4-14	.29-4	24.
1.0	1.7-13	.33-4	42.	1.3-13	.25-4	43.	1.7-13	.34-4	37.
1.5	9.4-13	.13-3	69.	1.5-13	.20-4	42.	1.1-13	.15-4	48.
2.0	1.8-13	.17-4	86.	2.7-13	.26-4	44.	2.5-13	.24-4	37.
4.0	4.2-14	.18-5	48.	4.5-13	.19-4	65.	4.1-13	.17-4	48.
	10 Year Old (14.54 grams)			15 Year Old (29.28 grams)			Adult (37.08 grams)		
.010	9.8-16	.62-5	42.	1.0-15	.65-5	29.	1.5-16	.93-6	68.
.015	9.5-15	.40-4	16.	3.3-15	.14-4	19.	2.7-15	.12-4	19.
.020	1.5-14	.47-4	14.	7.8-15	.25-4	14.	6.0-15	.19-4	14.
.030	1.4-14	.31-4	14.	6.0-15	.13-4	15.	6.9-15	.15-4	13.
.050	1.3-14	.19-4	13.	6.7-15	.97-5	13.	6.2-15	.91-5	12.
.10	1.3-14	.12-4	14.	8.0-15	.75-5	14.	9.4-15	.88-5	12.
.20	1.5-14	.95-5	16.	1.1-14	.67-5	17.	1.0-14	.64-5	16.
.50	3.5-14	.12-4	19.	2.2-14	.74-5	23.	2.0-14	.67-5	25.
1.0	3.9-14	.76-5	39.	6.8-14	.13-4	25.	4.1-14	.80-5	25.
1.5	8.0-14	.11-4	39.	5.5-14	.75-5	28.	4.5-14	.61-5	24.
2.0	6.2-14	.60-5	46.	4.6-14	.45-5	48.	5.2-14	.50-5	37.
4.0	1.8-13	.76-5	47.	1.4-13	.60-5	41.	1.7-13	.73-5	35.

*5.3-14 read as 5.3 x 10^{-14}.

Absorbed Doses, Specific Absorbed Fractions, and Coefficients of Variation for Energy Deposited in the Genitalia Regions of Various Aged Phantoms from 12 Monoenergetic Infinite External Sources of Photons

Initial Energy (MeV)	Rads/ Photon	Φ	C.V. (%)	Rads/ Photon	Φ	C.V. (%)	Rads/ Photon	Φ	C.V. (%)
	Newborn (2.930 grams)			1 Year Old (11.16 grams)			5 Year Old (33.69 grams)		
.010	1.9-13*	.12-2	6.8	6.8-14	.43-3	5.9	3.0-14	.19-3	5.1
.015	1.8-13	.75-3	8.3	6.7-14	.28-3	7.0	3.3-14	.14-3	5.7
.020	1.3-13	.42-3	10.	5.5-14	.18-3	8.2	2.9-14	.91-4	6.7
.030	1.0-13	.22-3	12.	4.8-14	.10-3	8.8	2.4-14	.52-4	7.2
.050	7.1-14	.10-3	12.	4.0-14	.59-4	9.1	1.9-14	.28-4	7.6
.10	6.7-14	.63-4	15.	4.2-14	.39-4	9.4	2.5-14	.23-4	7.3
.20	9.1-14	.57-4	18.	5.2-14	.33-4	12.	3.3-14	.20-4	8.9
.50	1.6-13	.54-4	27.	1.1-13	.38-4	19.	5.3-14	.18-4	13.
1.0	1.5-13	.30-4	40.	1.9-13	.37-4	20.	1.1-13	.22-4	17.
1.5	5.2-13	.71-4	34.	2.4-13	.32-4	24.	1.5-13	.20-4	19.
2.0	1.8-13	.18-4	37.	2.6-13	.26-4	26.	2.0-13	.19-4	20.
4.0	1.3-12	.56-4	43.	6.0-13	.25-4	31.	3.1-13	.13-4	23.
	10 Year Old (75.93 grams)			15 Year Old (153.0 grams)			Adult (193.7 grams)		
.010	1.5-14	.93-4	4.8	7.9-15	.50-4	4.6	6.1-15	.38-4	4.7
.015	1.6-14	.68-4	5.5	9.9-15	.41-4	4.9	7.4-15	.31-4	5.1
.020	1.7-14	.56-4	5.8	9.9-15	.31-4	5.4	8.1-15	.26-4	5.4
.030	1.5-14	.32-4	6.4	7.9-15	.17-4	6.1	6.7-15	.15-4	6.1
.050	1.2-14	.18-4	6.5	7.3-15	.11-4	6.4	6.5-15	.94-5	5.9
.10	1.4-14	.13-4	6.8	7.8-15	.74-5	6.5	7.5-15	.70-5	6.2
.20	1.9-14	.12-4	8.0	1.1-14	.67-5	7.6	9.3-15	.58-5	7.2
.50	3.6-14	.12-4	11.	2.0-14	.70-5	10.	1.7-14	.58-5	10.
1.0	4.4-14	.86-5	14.	4.1-14	.80-5	13.	3.0-14	.58-5	12.
1.5	7.0-14	.95-5	16.	4.7-14	.64-5	14.	4.5-14	.62-5	14.
2.0	9.6-14	.93-5	18.	6.3-14	.61-5	16.	5.2-14	.51-5	16.
4.0	2.0-13	.86-5	19.	1.1-13	.46-5	18.	1.2-13	.53-5	16.

*1.9-13 read as 1.9×10^{-13}