

# A discussion on the number of age-specific phantoms practically needed for external photon dosimetry

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**ABSTRACT** - Three age-specific phantoms (infant, child and adult) are used in the current Dosimetry System 2002 (DS02) in organ dose calculations for atomic bomb survivors. The need of additional age-specific phantoms was identified at the RERF workshop in 2011. The purpose of this study is to quantify dosimetric differences of the three age groups in DS02 for external exposure to gamma rays, and identify the number of age-specific phantoms practically needed for the dosimetry. The analysis showed that on average, the current three age-specific phantoms used in DS02 can fulfil the dosimetric accuracy requirement if one would consider a separate model for every 5% increase in organ doses for external exposure to gamma rays. If higher accuracy is required, especially for certain organs of particular interest, an additional phantom corresponding to a child of age ten years could be included in DS02.

## DOSIMETRIC DIFFERENCES AMONG THREE AGE GROUPS IN DS02

Organ doses in mGy for infants, children and adults in Hiroshima at 1500 m ground distance to the hypocenter in the category of In-Open and Facing. Differences in percentage relative to adult doses given in bracket:

	infant	child	adult
marrow	484 (12.6%)	491 (14.2%)	430
bladder	467 (11.9%)	431 (3.3%)	417
skeleton	450 (7.5%)	458 (9.5%)	418
brain	473 (8.2%)	436 (-0.2%)	437
breast	529 (9.8%)	495 (2.8%)	482
eye	512 (-0.7%)	518 (0.5%)	515
uterus	446 (2.9%)	458 (5.7%)	434
colon	455 (10.3%)	451 (9.2%)	413
liver	491 (9.7%)	467 (4.2%)	448
lung	474 (5.4%)	461 (2.6%)	450
ovary	440 (20.1%)	429 (16.9%)	367
pancreas	443 (14.4%)	403 (4.1%)	388
stomach	487 (11.9%)	469 (7.7%)	435
testes	494 (-2.5%)	506 (-0.2%)	507
thyroid	506 (1.9%)	493 (-0.7%)	496
average	8.2%	5.3%	

Generally speaking, organ doses increase to some extent with decreasing age. On average, infant and child organ doses are 8% and 5% higher than adult doses, respectively. The age-dependency of organ doses is rather small compared with uncertainties inherent in dose assessment of this nature. Such small differences in organ doses, in the wide age range from infant to adult, indicate that there is practically no need to have more age-specific phantoms in DS02.

## DOSIMETRIC DIFFERENCES AMONG FIVE AGE GROUPS

To verify the above findings, organ doses were calculated with newer fluence-to-dose conversion coefficients derived from more sophisticated voxel phantoms for 5 age groups by Lee and Bolch (Phys. Med. Biol. 51, 4663-4688, 2006). With those fluence-to-dose conversion coefficients and the DS02 total gamma-ray free-in-air fluences at 1 m above ground, organ doses are calculated for 5 different age groups and for the irradiation category of "unknown" and In Open at 500m, and 1500m from the hypocenter in Hiroshima.

Percentage changes in organ doses relative to the doses to ICRP 110 adults (Chen et al. Radiat. Prot. Dosim. 2012) for "unknown" and In Open irradiation geometry at 500m, and 1500m from the hypocenter in Hiroshima:

	500m					1500m				
	9m	4y	8y	11y	14y	9m	4y	8y	11y	14y
Bladder	15.5%	12.7%	11.4%	10.6%	9.9%	12.6%	10.9%	10.8%	8.9%	9.0%
Bone surface	13.7%	16.5%	12.8%	8.8%	7.6%	9.7%	12.1%	8.9%	5.6%	4.6%
Colon	13.6%	13.4%	8.8%	6.7%	3.0%	11.7%	12.7%	8.1%	5.7%	2.5%
Gonads	15.7%	18.2%	11.7%	11.8%	2.0%	14.0%	17.3%	9.1%	11.7%	2.3%
Liver	14.2%	5.1%	3.6%	6.9%	2.9%	12.9%	4.6%	2.8%	6.1%	2.5%
Lung	13.2%	5.5%	4.5%	10.3%	8.6%	11.1%	4.5%	3.8%	7.2%	7.1%
RBM	20.5%	14.5%	10.2%	11.0%	8.1%	18.9%	13.6%	9.8%	10.3%	7.8%
Oesophagus	9.7%	12.5%	0.3%	6.3%	6.7%	8.4%	12.3%	-1.3%	5.1%	5.4%
Skin	8.0%	9.4%	8.3%	6.5%	6.4%	6.9%	9.3%	8.7%	6.1%	6.6%
Stomach	15.5%	3.6%	9.9%	7.7%	6.0%	14.3%	3.1%	9.7%	7.3%	5.7%
Thyroid	19.8%	16.9%	10.9%	7.9%	-0.8%	18.8%	16.8%	8.1%	8.2%	-2.4%
average	14.5%	11.7%	8.4%	8.6%	5.5%	12.7%	10.6%	7.1%	7.5%	4.7%

On average, there are no significant differences in organ doses for children of 8 and 11 years, which can be grouped into a group of 10 years subsequently. Considering dose comparisons at three difference distances to the hypocenter, the summary results suggest that organ doses increase with decreasing age, and the increases, generally speaking, are 13% for infants, 11% for children of 4-years, 7.5% for 10-year olds, and 4.9% for 14-year olds. If one would consider a separate model for every 5% increase in organ doses in external exposure to photons, four age-specific phantoms may be needed: infant, 5-year, 12-year, and adult.

When studying the age-dependency of organ doses, phantoms representing the Japanese population at the time of the bombing should be considered. As treated in DS86, the sex-averaged body weight of Japanese adults in 1945 is about 55 kg, corresponding to the current ICRP reference child of 15 years.

Percentage changes in organ doses relative to the doses to ICRP 14-year olds (representing Japanese adults in 1945) for "unknown" irradiation geometry at 500m, and 1500m from the hypocenter in Hiroshima:

	500m				1500m			
	9m	4y	8y	11y	9m	4y	8y	11y
Bladder	5.1%	4.1%	2.9%	0.6%	3.3%	2.3%	2.2%	-0.1%
Bone surface	5.6%	5.8%	2.4%	1.1%	4.9%	5.1%	2.1%	0.9%
Colon	10.3%	12.1%	7.5%	3.6%	9.0%	11.2%	6.7%	3.1%
Testes	13.5%			9.6%	11.4%			9.1%
Liver	10.9%	8.9%	7.3%	3.9%	10.1%	8.3%	6.4%	3.5%
Lung	4.3%	2.5%	1.6%	1.6%	3.7%	2.3%	1.7%	0.0%
RBM	11.5%	9.1%	5.0%	2.7%	10.3%	8.2%	4.5%	2.3%
Oesophagus	2.8%	10.7%	-1.3%	-0.3%	2.8%	11.2%	-2.2%	-0.3%
Skin	1.5%	2.7%	1.6%	0.1%	0.3%	1.9%	1.3%	-0.5%
Stomach	9.0%	4.3%	10.6%	1.7%	8.1%	3.0%	9.6%	1.5%
Thyroid	20.7%	19.1%	13.0%	8.7%	21.7%	21.0%	12.0%	10.9%
average	8.7%	7.9%	5.1%	3.0%	7.8%	7.4%	4.4%	2.8%

Again, if one would consider a separate model for every 5% increase in organ doses in external exposure to gamma rays, three age-specific phantoms could fulfil the dosimetric requirement. The choice of age-specific phantoms could be the three currently used in current DS02: infant of 1 year, child of 5 years and adult. This means, for the majority of organs, the DS02 has provided reasonably accurate dosimetry for the A-bomb survivors of various ages. The systematic errors resulting from the limited number of phantoms were estimated to be less than 5%, on average. If higher accuracy is required, especially for certain organs of particular interest, a phantom representing a child of ten years age could be added to the DS02.