HANDBOOKS OF TISSUE DOSES IN DIAGNOSTIC RADIOLOGY

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Two additional Handbooks for determining tissue doses from diagnostic radiology procedures are now available. One permits estimates of glandular tissue doses in mammography (1), the other is an update of an earlier Handbook which permits estimates of several tissue doses for common projections in diagnostic radiology (2). Both Handbooks have been derived from calculations using a Monte Carlo computer code and associated anthropomorphic phantoms.

Experience with previous Handbooks of this type has demonstrated the practical value and versatility of such a format for medical and radiation protection personnel.

HANDBOOK OF GLANDULAR TISSUE DOSES IN MAMMOGRAPHY

The Handbook of Glandular Tissue Doses in Mammography contains data applicable to a wide range of techniques in present day mammography. In mammography the glandular tissue is the tissue considered vulnerable to radiation-induced breast cancer. The Handbook presents the absorbed dose to glandular tissue in the breast per unit entrance exposure (free-in-air) as a function of breast size, breast composition, breast thickness, breast compression and x-ray beam quality. These data permit absorbed dose to glandular tissue to be computed readily for the array of current mammography techniques.

From the absorbed dose computed in the whole breast tissue (excluding the skin layer), the glandular tissue dose (D_G) is determined by multiplying the dose to the whole breast (D_B) by the ratio of the mass energy absorption coefficient of glandular tissue $(\mu_{en}/\rho)_G$ to that of the whole breast $(\mu_{en}/\rho)_B$. The mass energy absorption coefficient for the whole breast is derived from the weight percents of glandular (G) and adipose (A) tissues and the mass energy absorption coefficients of the two tissues $(\mu_{en}/\rho)_G$ and $(\mu_{en}/\rho)_A$. Therefore:

$$D_G = D_B \frac{(\mu_{en}/\rho)_G}{(\mu_{en}/\rho)_B},$$

where $$(\mu_{en}/\rho)_B = G(\mu_{en}/\rho)_G + A(\mu_{en}/\rho)_A.$$

A sample of the Handbook data is given in Table 1 for the craniocaudal view and a uniform firm compression of 6 cm.

Table 1. Glandular Tissue Doses in Mammography

Craniocaudal view, 6-cm thickness, glandular tissue content between 5 and 100 percent (by weight)

HVL (mm Al)	Glandular tissue dose (mGy) for 1 mC/kg entrance exposure (free-in-air)[a] — Glandular tissue content: 5%	25%	50%	75%	100%
0.2	2.6	2.4	2.1	1.8	1.6
0.4	7.1	6.4	5.8	5.2	4.9
0.6	10.8	9.9	9.0	8.4	7.8
0.8	14.0	13.0	12.0	11.3	10.7
1.2	18.5	17.5	16.5	15.7	15.1
1.6	21.5	20.5	19.4	18.7	18.0
2.0	23.9	22.8	21.8	21.0	20.4
2.4	25.7	24.6	23.6	22.8	22.3

[a] Multiply table entries (mGy per mC/kg) by 25.8 to obtain previous units in mrad per R.

To compute glandular tissue doses from specific mammography applications, the user applies measured or estimated values of entrance exposure (free-in-air) and x-ray beam quality (half-value-layer) relevant to the actual clinical conditions of interest.

UPDATE OF HANDBOOK OF TISSUE DOSES FOR COMMON PROJECTIONS IN DIAGNOSTIC RADIOLOGY

The update of the Handbook of Tissue Doses for Common Projections in Diagnostic Radiology contains an expanded collection of data applicable to a reference adult patient. The range of x-ray beam qualities (half-value-layers) covers from 1.0 to 6.5 mm Al, as appropriate. Additional tissues, notably the female breast, have been included, and distinction is made between tissue doses to males and females when appropriate.

The Handbook table for each projection includes an indicator of cancer detriment from the aggregate of these tissue doses, based on current risk coefficients for various cancers induced by radiation and the severity of those cancers.

A Cancer Detriment Index (I_c) has been formulated as follows:

$$I_c = \sum_{i=1}^{n} \left[r_i(f) + s_i \; r_i(c) \right] D_i$$

where $r_i(f)$ is the lifetime risk coefficient for fatal cancer i (per mGy),
$r_i(c)$ is the lifetime risk coefficient for "curable" cancer i (per mGy),
s_i is the relative severity associated with successful treatment of cancer i, and
D_i is the average absorbed dose in the appropriate tissue for cancer i (mGy).

The risk coefficients and relative severities for treatment used in the Cancer Detriment Index are given in Table 2.

Table 2. Lifetime Risk Coefficients[a] for Induction of Fatal and "Curable" Cancers and the Relative Severities for Treatment of "Curable" Cancers

	$r_i(f)$[a]		$r_i(c)$[a]		
Cancer (i)	Male	Female	Male	Female	s_i
Lung	2.0	2.0	0.1	0.1	0.95
Leukemia	2.4	1.6	0.12	0.08	0.95
Thyroid	0.33	0.67	6.3	12.7	0.05
Breast	---	5.0	---	3.0	0.60
Other	5.0	5.0	1.5	1.5	0.75

[a] Multiply table entries for $r_i(f)$ and $r_i(c)$ by 10^{-6} to obtain risk coefficients per mGy.

The entries in Table 2 and the formulation of the Cancer Detriment Index take advantage of the rationale and discussion by Pochin in ICRP 45 (3), with modifications to distinguish between risks to males and females. The breast cancer risk coefficient is asssigned entirely to females, therefore, the value found in ICRP 45 that is for a mixed occupational population is doubled. The risk coefficients for leukemia and thyroid cancer have been adjusted to reflect the observed differences in risk to males and females (4).

The Cancer Detriment Index therefore reflects both the detriment from fatal cancers, and the detriment from cancers that can be treated sucessfully, the latter being given a weight equal to the ratio of fatal to fatal plus "curable" cancers (3). The result is an indication of the overall detriment from all potential cancer risks.

A typical Handbook tabulation, presenting the tissue doses and the resulting Cancer Detriment Index for a sample x-ray projection, is given in Table 3. All values are presented per unit entrance exposure (free-in-air).

Table 3. Tissue Doses (mGy) for 1 mC/kg Entrance Exposure (free-in-air)[a] and Cancer Detriment Index (I_c) (per mC/kg)[b] - AP Thoracic Spine, SID = 102 cm, 17.8 x 43.2 cm field size, 80 kVp

HVL(mm Al) ⟶	2.5		3.5		4.5	
Tissue	Male	Female	Male	Female	Male	Female
Lungs	5.5	4.1	7.0	5.2	8.4	6.3
Active Bone Marrow	0.7	0.7	1.0	0.9	1.2	1.0
Thyroid	3.7	3.7	4.6	4.6	5.4	5.4
Breasts	---	14.0	---	16.0	---	17.5
Other Tissue	1.9	1.5	2.3	1.9	2.7	2.2
I_c (multiply values by 10^{-4})	0.28	1.19	0.34	1.39	0.41	1.54

[a] Multiply table entries (mGy per mC/kg) by 25.8 to obtain previous units in mrad per R.

[b] Multiply table entries for I_c (per mC/kg) by 0.258 to obtain I_c for previous units (per R).

To compute tissue doses and the Cancer Detriment Index for a reference adult patient from specific diagnostic projections, the user applies measured or estimated values of entrance exposure (free-in-air) and x-ray beam quality (half-value-layer) relevant to the actual clinical conditions of interest. For example, an examination consisting of 3 AP thoracic spine films at HVL = 2.5 mm Al and 0.1 mC/kg (0.39 R) each would yield Cancer Detriment Indexes of 8.4×10^{-6} (male) and 3.6×10^{-5} (female).

Consideration is being given to formulating corresponding detriment indexes for hereditary effects and effects to children irradiated *in utero*.

REFERENCES

(1) Handbook of Glandular Tissue Doses in Mammography. HHS Publication FDA 85-8239, Center for Devices and Radiological Health, Rockville, Maryland (1985).

(2) Handbook of Tissue Doses for Common Projections in Diagnostic Radiology. In preparation, Center for Devices and Radiological Health, Rockville, Maryland (1988).

(3) Quantitative Bases for Developing a Unified Index of Harm. ICRP Publicaton 45. Pergamon Press, Oxford (1985).

(4) Ionizing Radiation: Levels and Effects, Volume II: Effects. United Nations Scientific Committee on the Effects of Atomic Radiation, New York (1972).