Handbook of Glandular Tissue Doses in Mammography

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Handbook of Glandular Tissue Doses in Mammography

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INTRODUCTION

This Handbook contains data from which absorbed dose to glandular tissue in the breast (glandular tissue dose) can be estimated for mammographic procedures. The breast (excluding the skin) is a composite of adipose (i.e., fatty) and glandular (i.e., other soft) tissues. The glandular tissue is the tissue considered at risk for breast cancer.

The intent of the Handbook is to permit the user to compute glandular tissue dose for various techniques in mammography as a function of breast compression, breast size, breast composition, and the quality of the x-ray beam.

Glandular tissue dose for individual patients can also be estimated by selecting data from the tables that have been produced for the same physical characteristics of the breast, and the same technical parameters used in the actual mammographic examination.

The method used to compute most of the basic data was a radiation transport calculation using a specialized version of a computer code developed at the Oak Ridge National Laboratory (Warner, 1973). The results of the calculations were then converted into the Handbook entries, using the specific characteristics of current mammographic techniques (Andersen and Rosenstein, 1984). Additional data are reproduced from previous work of others (Stanton, et al., 1984 and Stanton, 1985).

The data are primarily for the craniocaudal view, with one exception for the mediolateral view:

Craniocaudal (CC) view - the radiation is incident on the upper surface of the compressed breast and directed downward.

Mediolateral (ML) view - the radiation is incident on the lateral surface of the compressed breast and directed from the middle of the body toward one side.

The breast configurations for which data are tabulated are given below. Glandular tissue content is given in percent, by weight. The remainder of the tissue content is adipose tissue.

Sketches of the various reference breast configurations for firm and moderate compression are given in the Appendix. In all cases the x-ray field size is larger than the dimensions of the breast.

The doses tabulated are the average dose (mrad) to glandular tissue in the breast, excluding the skin layer. The values tabulated are normalized to a 1 roentgen entrance exposure, free-in-air. Therefore, the user must apply the actual entrance exposures at a given facility to estimate the dose for a particular procedure.

The average glandular tissue dose can be converted to integral glandular tissue dose per roentgen (g-rad per R) by multiplying the value of mrad per R by the product of the appropriate glandular tissue content (weight fraction) and the assumed or determined total breast weight for the case of interest.

The beam qualities (HVL, mm Al) listed cover the range expected from the target materials used in mammographic equipment (i.e., tungsten, tungsten-molybdenum alloys, and molybdenum). The data in Table 1 are from Stanton, et al., 1984, and Stanton, 1985, and include a value for tungsten targets and a separate value for molybdenum or tungsten-molybdenum targets. The data in Tables 2 through 6 were computed by the method of Rosenstein, 1984, and give only a single value for each HVL.

A total of 51 experimentally measured mammographic spectra (Fewell and Shuping, 1978) were used to generate the data in Tables 2 through 6 (19 for tungsten, 14 for tungsten-molybdenum alloys, and 18 for molybdenum). For these spectra, there was some scatter among the results for the same target type and beam quality, but different peak kilovoltages. The individual values were within 10 percent of the average over the range of peak kilovoltages (Rosenstein, 1984). For these spectra, there was also some scatter among the results for similar HVL's using different target materials. The individual values are within a few percent of the average for the three target types (Rosenstein, 1984). The data in Tables 2 through 6 result from smooth curves fit to the results from the individual x-ray spectra.

The data in Tables 2 through 6 are given for a source-to-image receptor distance (SID) of 30 inches (76.2 cm). SID's within 10 inches (25.4 cm) of this reference SID would not result in variations in dose larger than 5 percent.

More details on the breast models for mammography, the selection of mammographic x-ray spectra, and the methodology used to

obtain the data tabulated in the Handbook can be found in the following references:

Andersen, L.W. and M. Rosenstein. Computer Program for Breast Doses in Mammography. Available from the Authors, Center for Devices and Radiological Health, Rockville, MD (1984).

Fewell, T.R. and R.E. Shuping. Handbook of Mammographic X-Ray Spectra. Bureau of Radiological Health. HHS Publication FDA 79-8071, Rockville, MD (1978).

Hammerstein, G.R., D.W.Miller, D.R.White, M.E. Masterson, H.Q. Woodward, and J.S. Laughlin. Absorbed Radiation Dose in Mammography. Radiology 130:485 (1979).

Rosenstein, M. Mathematical Model for Breast Doses in Mammography. In: Symposium on Biological Effects, Imaging Techniques, and Dosimetry of Ionizing Radiations. Bureau of Radiological Health, HHS Publication FDA 80-8126, Rockville, MD (1980).

Rosenstein, M. Handbook of Glandular Tissue Doses in Mammography. Presentation at the Twenty-ninth Meeting of the Health Physics Society, New Orleans, Louisiana. Available from the Author, Center for Devices and Radiological Health, Rockville, MD (1984).

Stanton, L., J.L. Day, S.D. Brattelli, D.A.Lightfoot, M.A.Vince, and R.E. Stanton. Comparison of Ion Chamber and TLD Dosimetry in Mammography. Med Phys 8:792 (1981).

Stanton, L., T. Villafana, J.L. Day, and D.A. Lightfoot. Dosage Evaluation in Mammography. Radiology 150:577 (1984).

Stanton, L. Personal Communication (February 11, 1985).

Warner, G.G. BRHGAM: A Medical X-Ray Dose Estimation Program. Oak Ridge National Laboratory Technical Memo 4393 (1973).

The data in Table 1 are from experimental phantom measurements and have an associated uncertainty (1 standard deviation) of a few percent or less (Stanton, et al., 1981 and 1984). The data in Tables 2 through 6 are derived from radiation transport calculations. The radiation transport calculations have an associated coefficient of variation of between 1 and 5 percent, depending on breast size and composition. The coefficient of variation is a measure of the reproducibility (1 standard deviation) of the radiation transport calculations.

INSTRUCTIONS FOR USE OF HANDBOOK

1. Select the degree of compression (i.e., firm or moderate), specific view, breast size, and breast composition. For example: firm compression, CC view, 6-cm thickness, 25% glandular tissue content.

2. Determine the actual beam quality (HVL, mm Al) and entrance exposure (R),free-in-air, for the equipment used, or for the specific mammogram.

3. Look up the glandular tissue dose (mrad) for 1 R entrance exposure in Tables 1 to 6 for the degree of breast compression, specific view, breast size, breast composition, and beam quality (HVL, mm Al).

For firm compression and uniform breast thicknesses other than 6 cm, a procedure for computing glandular tissue dose when the glandular tissue content is other than 50% is described in Table 1, pages 7 and 8. For other conditions data are tabulated in Tables 2 through 6.

For all Tables, linear interpolation between adjacent HVL's is recommended.

For Table 1, linear interpolation between adjacent uniform breast thicknesses is recommended.

For Tables 2 through 6, selection of the value for glandular tissue content nearest to the case of interest is recommended. The value of mrad per R does not usually change by more than a few percent between adjacent glandular tissue contents, and the actual glandular tissue content cannot usually be determined precisely.

4. Multiply the glandular tissue dose (mrad per 1 R) obtained in instruction 3 by the actual entrance exposure (R), free-in-air, to obtain the glandular tissue dose (mrad) for the view.

5. To obtain the glandular tissue dose for multiple views or examinations, repeat instructions 1 through 4 for each set of conditions and sum the resultant doses.

Table 1. **Firm Compression - Uniform Breast Thickness**

Craniocaudal view, uniform breast thicknesses between 3 and 8 cm, 50 percent (by weight) glandular tissue content

HVL (mm Al)	Glandular tissue dose (mrad) for 1 R entrance exposure (free-in-air) — Compressed breast thickness					
	3 cm	4 cm	5 cm	6 cm	7 cm	8 cm
0.3	220(220)*	185(175)*	150(140)*	125(115)*	100(95)*	--
0.4	--	235(220)*	190(175)*	160(145)*	--	--
0.6	--	325	275	235	205	180
0.8	470	395	335	295	260	230
1.0	535	455	395	350	310	275
1.2	595	515	450	400	360	325
1.4	645	570	510	460	415	375
1.6	710	630	565	515	470	425

*Values in parentheses are for molybdenum and molybdenum-tungsten alloy targets; all other values are for tungsten targets.

--No specific values given in references.

Table 1 Notes:

(1) The data given in Table 1 are from Working Curve #2 in Stanton, et al., 1984, supplemented by additional data from Stanton, 1985. A comparison of these data for the 6-cm breast thickness with corresponding data in Table 2 computed by the method of Rosenstein, 1984 is given in the Appendix, page 14.

(2) An estimate of the mrad per 1 R for firm compression for glandular tissue content other than 50 percent can be obtained as follows:

(A) For 6-cm thickness, use data in Table 2.

Example: 25 percent glandular tissue, 6-cm thickness, 1.4 mm Al HVL

From Table 2: 493 mrad per 1 R

(B) For other uniform thicknesses, multiply the entry in Table 1 for firm compression by the ratio of the value for the desired content to the value for 50 percent content found in Tables 3 to 5 for moderate compression, as follows:

For uniform thickness of	Use ratio from
3 or 4 cm	Table 3 (small breast)
5 cm	Table 4 (medium breast)
7 or 8 cm	Table 5 (large breast)

Example: 75 percent glandular tissue,
4-cm uniform thickness,
0.6 mm Al HVL

From Table 1 (4-cm uniform thickness):
50 percent - 325 mrad per 1 R

From Table 3 (small breast, moderate compression):
75 percent - 316 mrad per 1 R
50 percent - 327 mrad per 1 R;
Ratio = 0.966

Therefore the estimate for 4-cm thickness (firm compression) is:
325 x 0.966 = 314 mrad per 1 R

Table 2. Firm Compression - Uniform Breast Thickness

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

HVL (mm Al)	Glandular tissue dose (mrad) for 1 R entrance exposure (free-in-air)				
	Glandular tissue content				
	5%	25%	50%	75%	100%
0.2	68	61	53	47	42
0.3	133	120	106	96	87
0.4	184	166	149	135	125
0.5	232	212	191	176	163
0.6	279	256	233	216	202
0.8	361	336	310	291	276
1.0	427	401	374	354	338
1.2	478	451	425	404	388
1.4	520	493	466	445	430
1.6	555	528	501	481	465
1.8	587	559	533	512	497
2.0	615	587	561	540	526
2.2	640	612	587	566	551
2.4	662	633	609	587	574

Table 3. **Moderate Compression - Non-Uniform Breast Thickness**

Craniocaudal view,small breast*, glandular tissue content between 5 and 100 percent (by weight)

HVL (mm Al)	Glandular tissue dose (mrad) for 1 R entrance exposure (free-in-air)				
	Glandular tissue content				
	5%	25%	50%	75%	100%
0.2	101	93	86	79	75
0.3	186	175	164	155	149
0.4	248	236	223	213	205
0.5	304	291	277	266	258
0.6	355	341	327	316	307
0.8	440	426	410	399	390
1.0	504	488	472	461	452
1.2	551	535	519	507	498
1.4	590	573	556	544	535
1.6	623	605	588	575	566
1.8	652	633	616	602	593
2.0	677	658	640	625	616
2.2	698	677	659	644	635
2.4	714	691	673	657	648

*Small breast simulated by ¼ ellipsoid (see Appendix): Thickness at chest wall is 4 cm; thickness at ½ the distance between chest wall and nipple is 3.5 cm.

Table 4. **Moderate Compression - Non-Uniform Breast Thickness**

Craniocaudal view, medium breast*, glandular tissue content between 5 and 100 percent (by weight)

HVL (mm Al)	Glandular tissue dose (mrad) for 1 R entrance exposure (free-in-air)				
	Glandular tissue content				
	5%	25%	50%	75%	100%
0.2	76	67	59	52	47
0.3	150	136	122	111	103
0.4	206	189	171	158	147
0.5	259	239	219	204	191
0.6	308	287	266	249	236
0.8	393	371	349	332	319
1.0	458	437	415	399	386
1.2	506	486	466	451	439
1.4	545	526	507	493	482
1.6	578	560	543	529	520
1.8	608	590	574	561	553
2.0	633	617	601	589	582
2.2	655	639	625	614	607
2.4	673	657	644	633	626

*Medium breast simulated by ¼ ellipsoid (see Appendix): Thickness at chest wall is 6 cm; thickness at ½ the distance between chest wall and nipple is 5.2 cm.

Table 5. **Moderate Compression - Non-Uniform Breast Thickness**

Craniocaudal view, large breast*, glandular tissue content between 5 and 100 percent (by weight)

HVL (mm Al)	Glandular tissue dose (mrad) for 1 R entrance exposure (free-in-air)				
	Glandular tissue content				
	5%	25%	50%	75%	100%
0.2	54	47	41	37	33
0.3	111	100	89	80	73
0.4	157	142	127	115	106
0.5	201	183	165	151	141
0.6	244	224	204	189	176
0.8	321	299	276	258	244
1.0	383	359	335	316	302
1.2	431	406	381	362	348
1.4	470	444	420	400	386
1.6	503	477	452	433	418
1.8	532	507	482	462	447
2.0	559	533	508	489	474
2.2	582	556	532	512	498
2.4	603	574	552	531	519

*Large breast simulated by ½ ellipsoid (see Appendix): Thickness at chest wall is 8 cm; thickness at ½ the distance between chest wall and nipple is 6.9 cm.

Table 6. **Moderate Compression - Non-Uniform Breast Thickness**

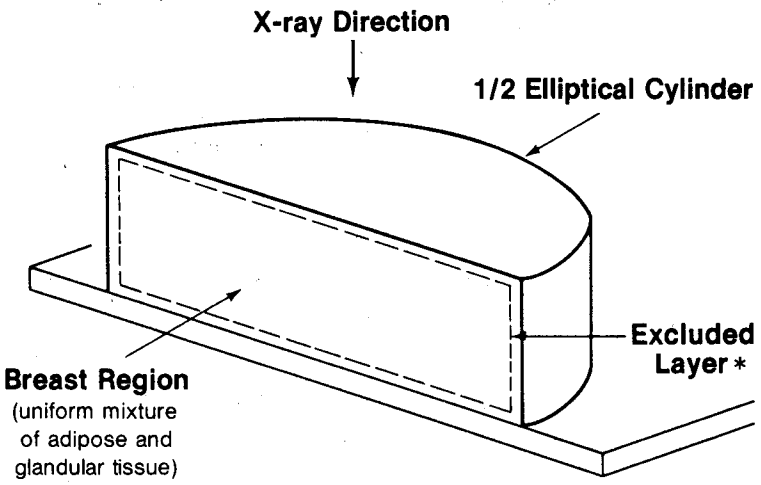
Mediolateral view, medium breast*, glandular tissue content between 5 and 100 percent (by weight)

HVL (mm Al)	Glandular tissue dose (mrad) for 1 R entrance exposure (free-in-air)				
	Glandular tissue content				
	5%	25%	50%	75%	100%
0.2	95	83	73	65	60
0.3	176	160	143	129	119
0.4	238	217	195	179	166
0.5	294	270	246	227	213
0.6	346	321	294	275	259
0.8	435	408	380	359	343
1.0	503	476	448	428	412
1.2	554	528	501	481	466
1.4	596	570	545	525	510
1.6	632	606	582	563	548
1.8	663	639	614	596	582
2.0	691	667	643	625	612
2.2	715	691	668	650	638
2.4	734	708	689	671	661

*Medium breast simulated by ½ ellipsoid (see Appendix): Thickness at chest wall is 6 cm; thickness at ½ the distance between chest wall and nipple is 5.2 cm.

Appendix. Breast Configurations Representing Compression in Mammography

Firm Compression - Uniform 6-cm Breast Thickness Craniocaudal View



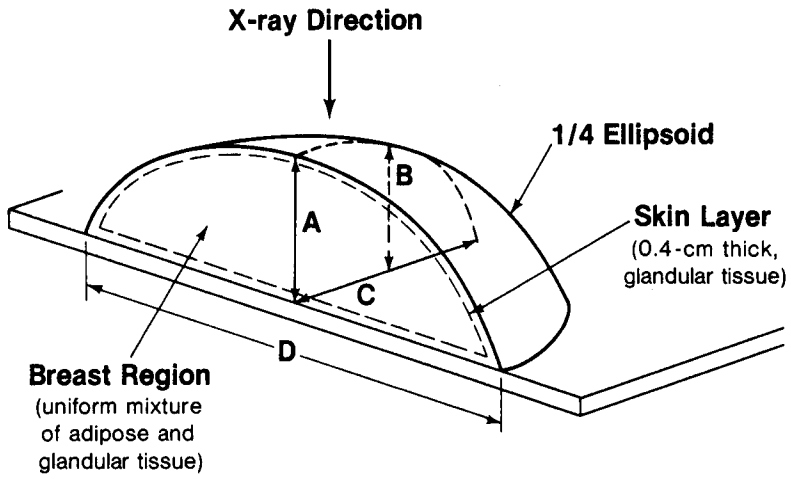
*Stanton, et al., 1984: 0.5-cm thick, adipose tissue
Rosenstein, 1984: 0.4-cm thick, glandular tissue

Comparative data for 6-cm thickness, 50 percent (by weight) glandular tissue content, mrad per 1 R

HVL (mm Al) →	0.3	0.4	0.6	0.8	1.0	1.2	1.4	1.6
Table 1 [Stanton]	125(115)	160(145)	235	295	350	400	460	515
Table 2 [Rosenstein]	106	149	233	310	374	425	466	501
Table 2/Table 1 ratio	0.84(0.92)	0.93(1.03)	0.99	1.05	1.07	1.06	1.01	0.97

Appendix. (Continued)

Moderate Compression - Non-Uniform Breast Thickness Craniocaudal View



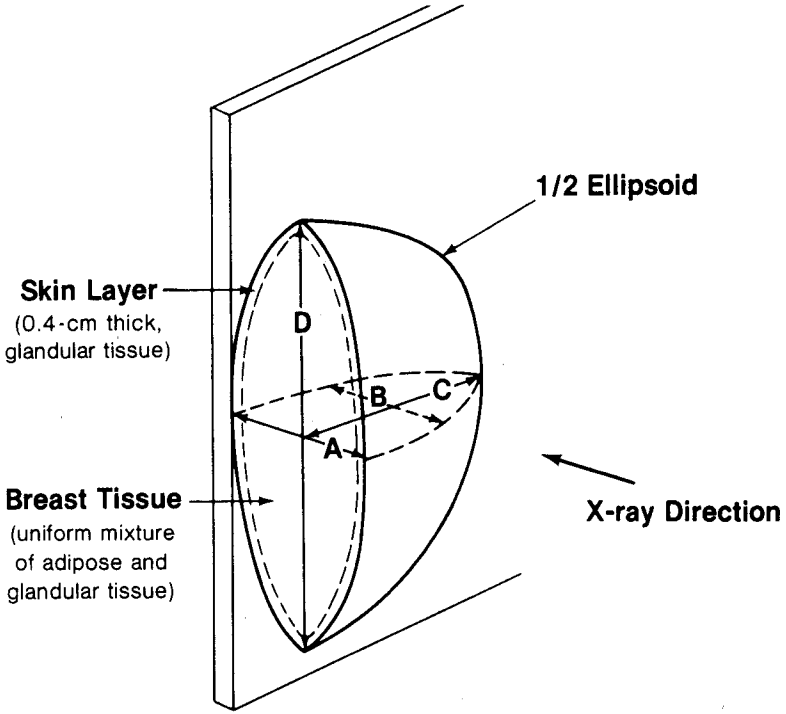
*Breast configuration dimensions, cm

Nominal size	Chest wall to nipple (C)	Thickness* (A)	(B)	Width (D)
Small	4	4	3.5	12
Medium	8	6	5.2	18
Large	10	8	6.9	20

*(A) Thickness at chest wall
(B) Thickness at ½ the distance between chest wall and nipple

Appendix. (Continued)

Moderate Compression - Non-Uniform Breast Thickness
Mediolateral View



Breast configuration dimensions, cm

A Thickness at chest wall - 6 cm
B Thickness at ½ the distance between chest wall and nipple - 5.2 cm
C Chest wall to nipple - 9 cm
D Height - 18 cm