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Organ Doses to Atomic Bomb Survivors from Radiological Examinations at the Radiation Effects Research Foundation

**Kazuo Kato, Ph.D.; Shigetoshi Antoku, Ph.D.;
Shozo Sawada, Ph.D.; Walter J. Russell, M.D., D.M.Sc.**

放影研 RERF **Radiation Effects Research Foundation**
A Cooperative Japan–United States Research Organization

RERF Technical Report Series

Technical reports are the basic medium for reporting of original research carried out at the Radiation Effects Research Foundation. Reports in this series receive both internal and external peer review and may serve as the basis for publication in the open scientific literature, in part or in toto. Although they may be quoted and cited, these reports are considered to be internal publications of the Foundation. Copies are available upon request from: Editorial Office, RERF, 5-2 Hijiyama Park, Minami-ku, Hiroshima, 732 Japan.

Beginning in 1989, the RERF Technical Report Series is no longer being published in the traditional Japanese-English bilingual format. However, major reports continue to be available in both languages as separate publications. Selected reports of a highly specialized nature, for which there is presumably less general interest, are produced only in English with an extended Japanese summary.

In this way, the Foundation will be able to more expeditiously report recent findings on the late biological effects of exposure of man to ionizing radiation resulting from the atomic bombings of Hiroshima and Nagasaki.

1989年から，放射線影響研究所の業績報告書は，従来の日英両文を併記した方式では発行しない．主要な報告書については，今後も日英両文で印刷するが，それぞれ別に発行する．内容が高度に専門的であり，一般の関心が少ないと思われる報告書については英文のみとし，日本文の要約を添付する．

これにより，広島・長崎の原爆電離放射線被曝の人体に及ぼす晩発性生物学的影響に関する最近の知見を今までよりも速やかにお知らせできることと思う．

The Radiation Effects Research Foundation (formerly ABCC) was established in April 1975 as a private nonprofit Japanese Foundation, supported equally by the Government of Japan through the Ministry of Health and Welfare, and the Government of the United States through the National Academy of Sciences under contract with the Department of Energy.

ERRATUM
正 誤

Title: Organ doses to atomic bomb survivors from radiological examinations at the Radiation Effects Research Foundation

Authors: Kazuo Kato, Shigetoshi Antoku, Shozo Sawada, Walter J. Russell

Page 5, Table 3:

The stomach dose from radiography of the abdomen (AP projection) should read 168, *not* 80.

標題　放射線影響研究所におけるX線検査による原爆被爆者の臓器線量

著者　加藤一生，安徳重敏，澤田昭三，Walter J. Russell

5ページ　表3の腹部撮影（腹背方向）における胃部の線量80を168に訂正します．

財団法人　放射線影響研究所
業　績　報　告　書

RERF TR 19-89
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放射線影響研究所におけるX線検査による原爆被爆者の臓器線量§

Organ Doses to Atomic Bomb Survivors from Radiological Examinations at the Radiation Effects Research Foundation

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要　約

原爆電離放射線による後影響についての臨床的評価の一環として，ABCC-放影研で行われたX線検査を受けた被爆者及び対照者における追加推定臓器線量についての情報を得ることを目的として本研究を行った．1970年に皮膚，赤色骨髄及び生殖腺のX線による被曝線量が推定され，以後今日に至るまでX線検査が行われるごとに通常業務として線量が追加されてきた．この線量情報はコンピューター・テープに記録保存されている．

原爆被爆者において唾液腺，甲状腺，乳腺，肺，胃，及び結腸の悪性及び良性疾患が増加していると認められることから，これらの部位についてもX線検査による電離放射線被曝線量を推定することが重要になっている．本研究では上記部位の被曝線量推定を行った．これにより，現行のコンピューター・プログラムに若干修正を加えて，成人健康調査対象者全員について各臓器の線量を遡及的に推定できる．

上記部位について電離放射線推定値が既に与えられているか，あるいは，推定値を今後与える予定の調査集団については別に詳細な報告がある．

§本報告にはこの要約以外に訳文はない．

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ABCC-放影研の放射線部で行われた全検査の記録並びに使用された放射線学的技法の記録に基づきX線条件を再現し，熱ルミネッセンス線量計をヒト・ファントムの唾液腺，甲状腺，肺，乳腺，胃，及び結腸の各部位に相当する箇所に設置してX線照射を行った．これらの臓器線量はX線検査の種類ごとに推定された．Aldersonヒト成人女性ファントムはKasei Optonix熱ルミネッセンス線量計を装着できるように改良した．線量の読み取りは，X線を1回照射するごとにHarshawモデル2000A熱ルミネッセンス読み取りシステムを用いて行われた．X線撮影及び透視検査に用いられている装置を使用して，上記線量計を装着したファントムのX線照射を行った．照射が完了すると，熱ルミネッセンス線量計をファントムからはずし，少なくとも1.5時間暗所に保存した後ルミネッセンスの測定を行った．各X線検査についてこのような測定を2〜4回繰り返した．

6臓器の各々における被曝線量を詳細に集計し，得られた結果については，他の研究の発表したもの並びに権威のある書物に掲載された情報をできる限り入手して比較検討した．しかし，比較の対象となる発表文献は比較的少なかった．

本調査で得られた臓器線量は，1948年から現在までにABCC-放影研で成人健康調査対象者が受けたすべてのX線検査での上記各部位の被曝線量を遡及的に割り当て，各対象者について既に推定・記録され，2年ごとに更新されている皮膚，赤色骨髄，及び生殖腺線量を補完するためのものである．線量を遡及的に割り当てる作業は，現行のコンピューター・プログラムを修正して行う．

結論として，臓器線量に関する今回の研究及びその他の研究が完了すれば，総合的な線量表ができると考える．線量の程度，線量率，及び放射線エネルギーの違い，短時間の繰り返し被曝からの回復における違いなど困難な面はあるが，以上のような線量データにより，成人健康調査対象者がX線検査及び原爆により受けた線量を評価するという重要な作業が促進されることが期待される．

Organ Doses to Atomic Bomb Survivors from Radiological Examinations at the Radiation Effects Research Foundation§

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Summary

When estimating the risks of oncogenesis and cancer mortality as a result of atomic bomb radiation exposure, medical X-ray doses received by the A-bomb survivors must also be estimated and considered. Using a phantom human, we estimated the X-ray doses received by A-bomb survivors during routine biennial medical examinations conducted at RERF as part of the long-term Adult Health Study (AHS), since these examinations may represent about 45% of the survivors' total medical irradiations. Doses to the salivary glands, thyroid gland, lung, breast, stomach, and colon were measured using thermoluminescent dosimeters. The results reported here will aid in estimating organ doses received by individual AHS participants.

Introduction

Among A-bomb survivors, excess mortality from leukemia and cancer of the lung, breast, stomach, and colon[1] and from radiation-induced tumors of the thyroid gland and salivary glands[2–4] prompted this investigation. When estimating the risk of oncogenesis and cancer mortality as a result of A-bomb radiation exposure, medical X-ray doses received by the survivors must also be estimated and considered.

During routine biennial visits to RERF, AHS participants receive radiological examinations, in addition to those received at other institutions. During a two-week survey,[5] 47% of the total X-ray examinations received by AHS participants

§**The complete text of this report will not be available in Japanese.**

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were those conducted at RERF in Hiroshima, whereas the corresponding rate in Nagasaki was 46%. Thus, accurate estimates of doses received at RERF are essential to estimating total medical X-ray doses.

In this study, we reproduced typical RERF radiological examinations using a phantom human with thermoluminescent dosimeters (TLD) positioned to estimate doses to the salivary glands, thyroid gland, lung, breast, stomach, and colon. These measurements supplement the cumulative active bone marrow, gonad, and surface doses per examination documented earlier[6] for AHS subjects.

Doses were estimated by type of examination and by organ, using TLDs,[7] which had been carefully assessed for their characteristics and had been accurately calibrated.

Experimental equipment

The following equipment was used in this study:

Phantom human: Alderson Rando adult (female) phantom human (Alderson Research Laboratories, Stamford, Conn, USA).

Thermoluminescent detectors: Kasei Optonix MSO-S TLD Mg_2SiO_4(Tb) (Kasei Optonix, Odawara).

Thermoluminescent readout system: Harshaw Model 2000A Thermoluminescent Measurement Apparatus and Model 2000B Automatically Integrating Picoammeter (Harshaw/Nuclear Systems, Cleveland, Ohio, USA).

X-ray apparatus: Toshiba X-ray apparatus with full-wave rectification of single-phase alternating current, which is inverted to high-frequency current (Model DRX2603HD X-ray tube, Model DC-15K controller, and Model DG-15F transformer) (Toshiba Medical Systems, Tokyo), and Hitachi fluoroscopy apparatus with full-wave rectification of three-phase alternating current (Model DR-125-22 TV) (Hitachi Medical Corporation, Tokyo).

Dosimetry methodology

Thermoluminescent (TL) detectors were annealed in an electric furnace of 400°C for seven hours, and then they were inserted at various sites in the phantom human as shown in Table 1. One dosimeter was employed at each measurement site. After exposing the phantom to X rays, the TLDs were removed, stored in the dark for a minimum of one and one-half hours, and then were assessed for thermoluminescence. The X-ray exposures and TLD measurements were repeated 2–4 times for each radiological examination. Details of these TLD measurements are being reported separately.[7] X-ray exposures were made according to the radiological techniques used at ABCC/RERF; Table 2 shows some of the representative technical factors used at RERF in Hiroshima. Doses for neck and rib examinations were measured using a 100 cm focus-to-film distance (FFD). Adjustments for differences in FFD were made by applying the "inverse square" law relationship. The measured thermoluminescence values were converted to exposures by using the sensitivity calibration data of the detectors, which had been individually calibrated.[7] The factor for converting exposures to absorbed doses was 0.87 (10^{-2} Gy/R), which is equivalent to the conversion factor for 30–50 keV photons in muscle.[8] The tube voltage was restricted to a range of 50–120 kVp. Thus, the above conversion factor was used, regardless of tube voltage and measurement site. Furthermore, except for the stomach, the volume of each organ was divided so that each resulting part contained one measured site. The average dose to each organ was calculated by obtaining the mean, weighted by the volume of each part. Using the output ratios, the doses obtained were corrected to those each machine actually induced during examinations.

Table 1. Dose measurement sites in the phantom

No.	Section number*	Measurement site**
1	6	Right parotid
2	6	Left parotid
3	8	Right submandibular gland
4	8	Left submandibular gland
5	8	Sublingual gland
6	9	Right thyroid gland
7	9	Left thyroid gland
8	17	Right breast (1)
9	17	Right breast (2)
10	17	Left breast (3)
11	17	Left breast (4)
12	13	Right lung (1)
13	13	Left lung (2)
14	15	Right lung (1)
15	15	Left lung (2)
16	18	Right lung (1)
17	18	Right lung (2)
18	18	Right lung (3)
19	18	Left lung (4)
20	18	Left lung (5)
21	18	Left lung (6)
22	20	Right lung (1)
23	20	Left lung (2)
24	23	Stomach
25	26	Large intestine (1)
26	26	Large intestine (2)
27	31	Large intestine
28	32	Right ovary
29	32	Left ovary
30		Surface (center of irradiation field)

*The phantom consists of numerous successive 2.5-cm-thick transverse sections. The sections are numbered beginning at the vertex.

**Measured sites belonging to a section and the same organ are numbered in order from right to left, as indicated in parentheses.

Table 2. Technical factors for radiography and fluoroscopy (upper gastrointestinal series); RERF, Hiroshima

Examination site	Projection	mAs	kVp	Added filtration (mm Al)	FFD* (cm)	Film size (inch)
Skull	PA	25	84	3.0	91	10 × 10
	Lateral	25	74	3.0	91	10 × 10
	AP	25	84	3.0	91	10 × 10
Sinuses	PA	20	78	3.0	91	8 × 10
	Lateral	20	66	3.0	91	8 × 10
Mastoid	PA-oblique	20	82	3.0	91	8 × 10
C-spine	AP	20	90	3.0	102	8 × 10
	Lateral	28	78	3.0	183	8 × 10
	AP-oblique	28	78	3.0	183	8 × 10
Neck	AP	10	90	3.0	183	8 × 10
	Lateral	10	90	3.0	183	8 × 10
T-spine	AP	20	100	3.0	102	11 × 14
	Lateral	30	110	3.0	102	11 × 14
L-spine	AP	20	100	3.0	102	14 × 17
	Lateral	40	120	3.0	102	14 × 17
	AP-oblique	40	100	3.0	102	14 × 17
Chest	PA	3	120	3.0	183	14 × 17
	Lateral	6	120	3.0	183	14 × 17
	PA-oblique	3	115	3.0	183	14 × 17
Rib	PA	12	80	3.0	183	10 × 12
	PA-oblique	16	98	3.0	91	10 × 12
Abdomen	AP	20	100	3.0	102	14 × 17
Pelvis	AP	20	100	3.0	102	14 × 17
Gallbladder	PA	30	100	3.0	102	14 × 17
	PA-oblique	30	100	3.0	102	14 × 17
Chest	Tomo, AP	40	80	2.5	102	8 × 10
Upper GI (Flx)**	—	0.5 mA	90	3.0	—	—
Upper GI (Spot)	—	PHT***	90	3.0	—	—

*FFD: focus-to-film distance

**Flx: fluoroscopy

***PHT: phototimer

Doses to the active bone marrow were not measured in the present study.

Results

Some of the resulting organ doses using the above methods are shown in Tables 3 and 4. The X-ray apparatus and technical factors used at ABCC/RERF in Nagasaki and in Hiroshima were identical until 1980 but have differed since

Table 3. Doses from radiography and fluoroscopy at RERF, Hiroshima
(Unit: 10^{-2} mGy/exposure)

Examination site	Projection	Surface	Salivary	Thyroid	Breast	Lung	Stomach	Colon
Skull	PA	176	46	25	0.36	1.0	0.11	0.08
	Lateral	125	64	64	0.65	0.64	0.011	0.053
	AP	183	67	117	1.4	1.2	0.091	0.11
Sinuses	PA	103	26	8.7	0.16	0.39	0.34	0.038
	Lateral	74	39	24	0.32	0.18	0.19	0.024
Mastoid	PA-oblique	115	11	5.9	0.14	0.52	0.058	0.049
C-spine	AP	194	89	171	3.1	22	0.25	0.13
	Lateral	59	27	32	0.31	1.9	0.020	0.020
	AP-oblique	68	35	50	0.67	4.3	0.040	0.028
Neck	AP	28	11	23	0.26	2.4	0.11	0.0070
	Lateral	33	16	17	0.57	0.69	0.0036	0.0049
T-spine	AP	316	9.1	17	203	71	63	8.7
	Lateral	800	5.8	7.5	25	185	5.5	1.2
L-spine	AP	300	0.99	1.3	5.4	5.3	171	135
	Lateral	1492	2.1	0.98	12	21	80	200
	AP-oblique	659	2.1	2.7	14	16	135	200
Chest	PA	14	0.94	1.2	2.0	6.6	2.3	0.25
	Lateral	33	6.1	8.0	11	12	2.1	0.35
	PA-oblique	11	0.48	1.8	0.85	5.0	2.2	0.17
Rib	PA	74	0.63	0.78	4.6	19	0.89	0.18
	PA-oblique	159	1.7	2.2	5.6	66	4.5	0.18
Abdomen	AP	294	0.88	1.3	5.5	5.6	168	96
Pelvis	AP	326	0.33	0.54	1.6	0.19	46	84
Gallbladder	PA	492	0.73	0.46	4.2	15	105	157
	PA-oblique	522	0.37	0.24	2.1	12	183	88
	(Erect)	456	0.24	0.14	1.2	4.2	139	74
Chest (Tomo)	AP	127	0.95	1.2	53	13	13	0.22
Upper GI (Flx)*		328**	0.83	1.2	34	18	234	77
Upper GI (Spot)		101**	0.25	0.36	11	5.6	72	24

Tomo: Tomography, Flx: Fluoroscopy, Spot: Spot filming

*Unit: 10^{-2} mGy/min, **Based on Antoku and Russell, reference 10

Table 4. Radiography doses; RERF, Nagasaki (Unit: 10^{-2} mGy/exposure)

Examination site	Projection	Surface	Salivary	Thyroid	Breast	Lung	Stomach	Colon
Skull	PA	132	34	19	0.27	0.79	0.079	0.062
	Lateral	96	49	49	0.50	0.49	0.0086	0.041
	AP	137	50	87	1.0	0.93	0.068	0.082
Sinuses	PA	49	13	4.1	0.74	0.18	0.16	0.018
	Lateral	38	20	12	0.16	0.092	0.096	0.012
Mastoid	PA-oblique	91	8.6	4.7	0.11	0.41	0.046	0.039
C-spine	AP	78	35	68	1.3	8.9	0.10	0.051
	Lateral	28	13	15	0.15	0.92	0.0097	0.0093
	AP-oblique	32	17	24	0.32	2.0	0.019	0.013
Neck	AP	8.6	3.4	7.1	0.081	0.78	0.034	0.0022
	Lateral	10	5.0	5.4	0.18	0.22	0.0011	0.0015
T-spine	AP	218	6.3	11	140	49	44	6.0
	Lateral	368	2.7	3.4	10	85	2.5	0.55
L-spine	AP	360	1.19	1.6	6.4	6.2	206	162
	Lateral	1805	2.5	1.2	14	25	97	242
	AP-oblique	527	1.7	2.2	11	13	108	147
Chest	PA	2.9	0.20	0.25	0.42	1.4	0.48	0.052
	Lateral	12	2.1	2.8	4.2	4.2	0.74	0.12
	PA-oblique	2.3	0.097	0.37	0.17	1.0	0.45	0.036
Abdomen	AP	209	0.59	0.93	3.9	3.8	119	68
Pelvis	AP	147	0.15	0.24	0.72	0.088	21	38
Gallbladder	PA	118	0.18	0.11	1.0	3.6	25	38
	PA-oblique	162	0.12	0.074	0.64	3.8	57	27
Chest (Tomo)	AP	191	1.4	1.7	79	19	19	0.33

Tomo: Tomography

then. The estimated organ doses from examinations now conducted at RERF in Nagasaki are shown in Table 4. Doses per milliampere-second during neck radiography are shown in Table 5 as examples. The doses within the irradiation fields were reproducible to within 3% of average values. Doses to the stomach and colon, located far from the neck regions, varied beyond 3%. However, the doses in these organs were very low. Only one measured site was used for stomach dose. Moreover the position was slightly changed, and the adjustments were done by using depth profiles of X-ray dose.[9] The uncertainties in stomach doses are estimated to be 20%–25%. The surface doses are important because they indicate both the maximum dose and the X-ray output. However, they are higher than the free-in-air dose (i.e., the dose in the absence of a human body) at the same measurement site, by the addition of backscattered X rays. Table 6 shows doses measured by placing an ionization chamber (Exradin A2 Shonka-Wyckoff Chamber, Warrenville, Ill, USA)[7] in the center of the exposure field with and without a Mix-DP block phantom behind it. The configuration of the surface of the human body differs by examination site, and variations in doses due to scattering were observed accordingly.

Table 5. Example of dosimetry (neck radiography, anteroposterior projection)

	Measured value (10^{-2} mGy/mAs)*					
Position**	No. 1	No. 2	No. 3	No. 4	Average	(SD)***
1	1.16	1.18	1.12	1.11	1.14	(0.03)
2	1.24	1.21	1.25	1.24	1.24	(0.02)
3	2.92	2.89	2.89	2.87	2.89	(0.02)
4	2.50	2.40	2.54	2.45	2.47	(0.06)
5	2.97	2.98	3.03	2.95	2.98	(0.03)
6	4.27	4.48	4.51	4.27	4.38	(0.13)
7	4.48	4.67	4.72	4.59	4.62	(0.10)
8	1.63	1.66	1.88	1.93	1.78	(0.15)
9	2.17	2.00	2.10	2.07	2.09	(0.07)
10	0.231	0.221	0.249	0.227	0.232	(0.01)
11	0.266	0.246	0.271	0.264	0.262	(0.01)
12	0.0352	0.0346	0.0369	0.0363	0.0358	(0.0010)
13	0.0539	0.0522	0.0525	0.0530	0.0529	(0.0007)
14	0.0521	0.050	0.051	0.0516	0.0510	(0.0009)
15	0.0393	0.0383	0.0394	0.0385	0.0389	(0.0006)
16	0.0418	0.0400	0.0430	0.0413	0.0415	(0.0012)
17	0.0540	0.0535	0.0547	0.0527	0.0537	(0.0008)
18	0.0479	0.0449	0.0493	0.0473	0.0474	(0.0018)
19	0.0524	0.0535	0.0576	0.0579	0.0554	(0.0028)
20	0.0491	0.0482	0.0476	0.0471	0.0480	(0.0009)
21	0.0382	0.0385	0.0389	0.0403	0.0390	(0.0009)
22	0.0199	0.0190	0.0210	0.0203	0.0201	(0.0008)
23	0.0210	0.0205	0.0218	0.0219	0.0213	(0.0007)
24	0.00214	0.00206	0.00223	0.00215	0.00215	(0.00007)
25	0.00162	0.00172	0.00188	0.00167	0.00172	(0.00011)
26	0.00184	0.00199	0.00196	0.00182	0.00190	(0.00009)
27	0.00045	0.00041	0.00058	0.00053	0.00049	(0.00008)
28	0.00023	0.00056	0.00063	0.00043	0.00046	(0.00018)
29	0.00023	0.00045	0.00051	0.00045	0.00041	(0.00012)
30	5.37	5.32	5.47	5.59	5.44	(0.12)

*Positions 1–7, 8–29, and 30 were irradiated using 200 mAs, 1,000 mAs, and 100 mAs, respectively. The focus-to-film distance was 100 cm. The other technical factors were the same as those shown in Table 2. The output of the X-ray equipment used for neck radiography was different from that for experimentation. Doses shown were not adjusted for differences in output and focus-to-film distance.

**See Table 1.

***Standard deviation

Table 6. Scattered X-ray contribution to surface doses

Tube voltage	Exposure (mR)	
	Direct X rays	Direct + scattered X rays
80	151	232
100	253	405
120	371	583

Note: X-ray exposure factors were as follows: a 17 cm × 17 cm irradiation field, a 100 cm focus-ionization chamber distance, 100 kVp tube voltage, and a 100 mAs of exposure time multiplied by current. Scattered X rays were caused by a 17 × 17 × 15 cm Mix-D block phantom placed behind the ionization chamber.

The X-ray output of the apparatus used in the experimental study and an example of measurement of the attenuation by aluminum filters are shown in Figure 1. At RERF, the output of the X-ray apparatus was periodically checked and recorded. Tables 3 and 4 show doses that were adjusted for differences in output for each of the machines recently in use and for the experimental apparatus. Table 5 shows doses without adjustment for the differences in output. Dosimetry for the upper gastrointestinal series was performed by simulating actual diagnostic examinations, each including 16 spot films. The dose rates shown in Table 3[10] were calculated from the results of dosimetry and the output rates of fluoroscopy and spot filming based on the assumption that the dose distribution from fluoroscopy was the same as that from spot filming. Exposures incurred in the past can be estimated from the ABCC/RERF records of technical factors used, the X-ray output at the time of exposure, and the doses measured in the present study. The doses obtained experimentally will be adjusted according to the physical stature of each AHS participant. For example, for posteroanterior (PA) chest radiography with a FFD of 183 cm and a tube voltage of 100 kVp, the dose per milliampere-second at the center of the body within the direct radiation beam for a person with a chest thickness of 30 cm is about half that for a person with a chest thickness of 20 cm.[9] However, even though the milliampere-second used for a person with a chest 30-cm-thick is greater than the milliampere-second shown in Table 2, the mean dose for each organ does not differ appreciably according to body thickness. Large differences due to various body thicknesses must be considered in reviewing the surface doses on the side nearest the X-ray tube.

Discussion

Hashizume and Maruyama[11] reported several organ doses while using average technical factors for diagnostic X-ray examinations in Japan. These are shown in Table 7 with ours for chest and abdominal radiography. All dose values were averaged by weighting the frequency of each exposure projection used at RERF and elsewhere in Japan. At RERF, abdominal radiography involved mainly the anteroposterior (AP) projection, and chest radiography involved PA and lateral projections.

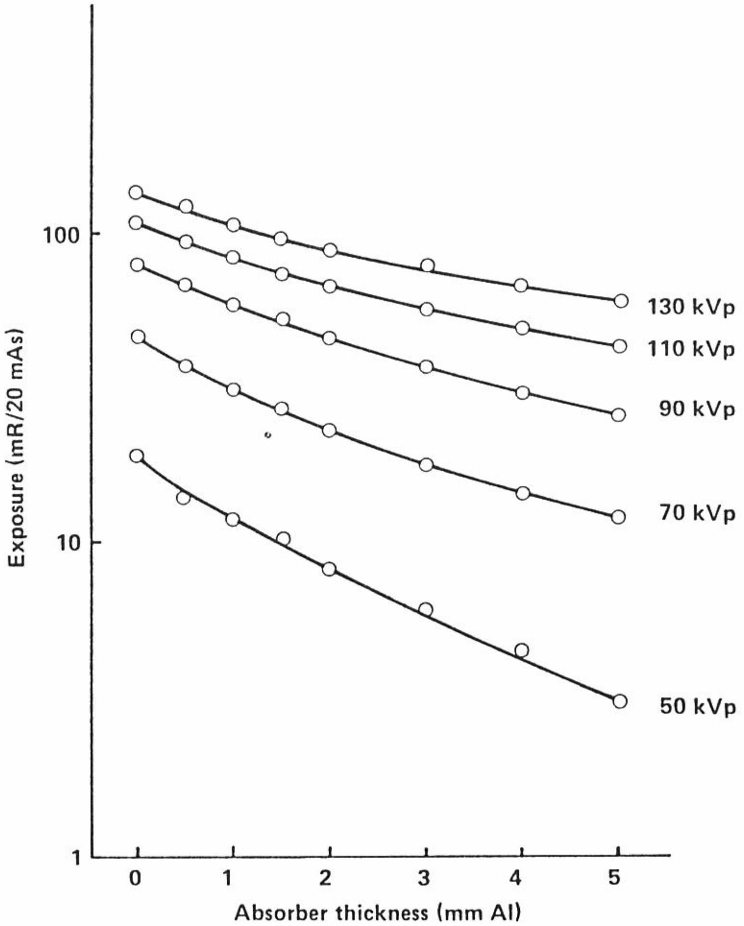

Figure 1. Output of X-ray apparatus used for experimental study, September 1987
Each exposure per 20 mAs was measured using the following technical factors: a focus-ionization chamber distance of 100 cm, a beam size of 20 × 20 cm, and a 0.5 mm Al inherent filter (excluding added filter).

Table 7. Doses from chest and abdominal radiography

Organ	Absorbed doses (10^{-2} mGy)	
	Present study	Hashizume and Maruyama[11]
Chest		
Thyroid gland	4.6	5
Lung	18.9	20
Breast	6.9	6.8
Abdomen		
Thyroid gland	1.3	0.3
Lung	5.6	5
Breast	5.5	15

Our thyroid gland, lung, and breast doses during chest radiography agree with those reported.[11] However, large discrepancies were observed among thyroid gland and breast doses during abdominal radiography. These organs are located far from the abdominal exposure field. Size and position of the field strongly influenced the scattered X-ray doses to these organs. Hashizume and Maruyama[11] also used an Alderson Rando phantom woman similar to ours, but their dosimeter was a cylindrical air chamber, 2 cm in diameter and 4 cm in length. The chamber was relatively large for the breast and thyroid gland, and therefore, we believe it was inferior to the TLDs used in the present study.

The National Council on Radiation Protection and Measurements (NCRP)[12] presented average exposure rates produced by diagnostic X-ray equipment. By using the average exposure rates and the present data on scattered X rays (Table 6), surface doses for chest and abdomen examinations were estimated to be approximately 0.18 and 3.2 mGy, respectively. These estimated values coincide well with the present values (Table 3). Therefore, the equipment used for these radiological examinations at RERF retained the average output shown by NCRP.[12]

Shown in Figure 2 are the cumulative organ doses received at RERF by a female AHS participant during radiological examinations. This subject's physical stature (chest thickness of 19 cm) was not considered. Data obtained by Antoku and Russell[10] were used for estimating doses to the active bone marrow and gonads. This AHS subject had received many abdominal examinations (upper GI series), therefore her stomach and colon doses were relatively high.

Doses received during radiological examinations at RERF can be similarly estimated for all AHS participants. Information concerning the body sites examined and the exposures received at other institutions has been obtained during interviews of AHS participants at ABCC/RERF, and that information has been documented and coded. Their exposures can thus be estimated from dosimetry results based on X-ray exposure factors used in Hiroshima and Nagasaki hospitals and clinics.[5]

Organ dose estimates for X-ray examinations of AHS subjects received outside RERF are being reported separately.[13]

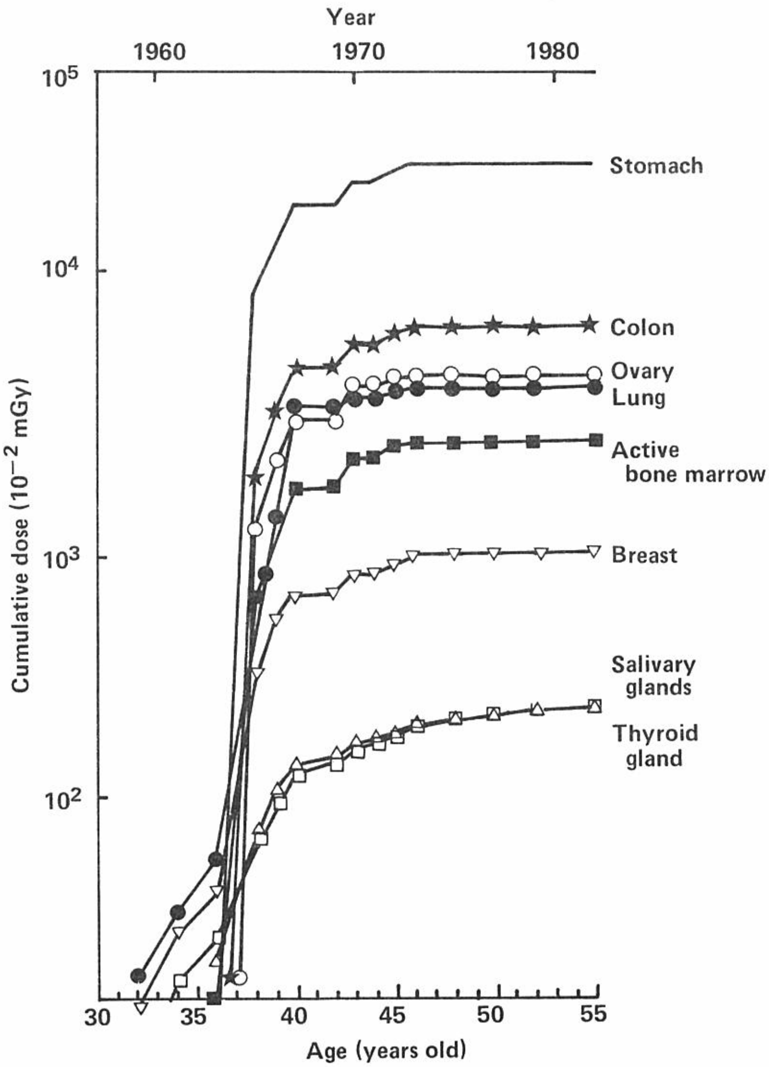

Figure 2. Cumulative organ doses from radiography at ABCC/RERF; a sample estimation

Cumulated organ doses received by an AHS participant (MF# 339524, female) since November 1959, and the date of her initial radiological examination, including ovary, active bone marrow, salivary gland, thyroid gland, breast, lung, stomach, and colon doses.

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