TECHNICAL REPORT
RERF TR 9-86
業 績 報 告 書

DENTAL RADIOGRAPHY EXPOSURE OF THE HIROSHIMA AND NAGASAKI POPULATIONS
広島及び長崎の対象集団の歯科X線被曝

SHIGETOSHI ANTOKU, Ph.D. 安徳重敏
MASAHARU HOSHI, Ph.D. 星 正治
WALTER J. RUSSELL, M.D., D.M.Sc.

放影研
RERF

RADIATION EFFECTS RESEARCH FOUNDATION
財団法人 放射線影響研究所
A Cooperative Japan - United States Research Organization
日米共同研究機関

ACKNOWLEDGMENT
謝　辞

The authors are grateful to the J. Morita Dental Manufacturing Company for donating a dental radiogrpahic unit for use in our series of dosimetry studies. The technical assistance of Messrs. Masayoshi Mizuno and Shoji Nishio throughout this study is greatly appreciated. Mrs. Grace Masumoto and Mrs. Merry Uemoto's assistance in preparing this manuscript are deeply appreciated.

一連の線量測定調査で使用した歯科X線装置を寄付してくださったモリタ製作所に感謝する．本調査の実施中，技術的御援助をいただいた水野正義，西尾正二の両氏に深く感謝する．本報告書の作成に御協力いただいた舛本幸江，上本靖子の両氏に感謝の意を表する．

RERF TECHNICAL REPORT SERIES
放影研業績報告書集

The RERF Technical Reports provide the official bilingual statements required to meet the needs of Japanese and American staff members, consultants, and advisory groups. The Technical Report Series is not intended to supplant regular journal publication.

放影研業績報告書は，日米専門職員，顧問，諮問機関の要求に応えるための日英両語による公式報告記録である．業績報告書は通例の誌上発表論文に代わるものではない．

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.

放射線影響研究所（元ABCC）は，昭和50年4月1日に公益法人として発足したもので，その経費は日米両政府の平等分担により，日本は厚生省の補助金，米国はエネルギー省との契約に基づく米国学士院の補助金とをもって運営されている．

放影研 RERF RADIATION EFFECTS RESEARCH FOUNDATION
財団法人 放射線影響研究所

Research Project 研究課題 1-74

DENTAL RADIOGRAPHY EXPOSURE OF THE HIROSHIMA AND NAGASAKI POPULATIONS
広島及び長崎の対象集団の歯科X線被曝

SHIGETOSHI ANTOKU, Ph.D. (安徳重敏)*; MASAHARU HOSHI, Ph.D. (星 正治)**; WALTER J. RUSSELL, M.D., D.M.Sc.

Division of Radiology, Department of Clinical Studies
臨床研究部放射線科

SUMMARY
Dental radiography doses in Hiroshima and Nagasaki were estimated using doses measured by a thermoluminescent dosimeter and a phantom, and survey data from dental hospitals and clinics in Hiroshima and Nagasaki. Doses to organs, including the lens, pituitary fossa, thyroid gland, and skin were calculated. Average doses per examination to these body sites were calculated using data obtained during a two-week survey in both cities. The mean caput doses were calculated from the data indicating frequency per year, and were tabulated by organ, age, teeth examined, type of examination, pupulation, sex, and city. No significant difference was observed by age, population, sex, or city. Currently, the doses incurred during dental radiography may not be sufficiently high to cause bias in the assessments for late radiation effects among atomic bomb survivors. However, the mean caput thyroid doses of 62 mrad and 67 mrad in Hiroshima and Nagasaki, respectively, cannot be ignored from the standpoint of their potential in contributing to radiation-induced carcinogenesis.

INTRODUCTION
Diagnostic radiological procedures are an important source of ionizing radiation exposure for populations worldwide. This source could be acting as a contaminant, to cause bias in the ongoing assessments of A-bomb survivors for late effects of the ionizing radiation from the Hiroshima and Nagasaki A-bombs. As part of

要 約
広島・長崎における歯科X線線量を推定した．熱ルミネッセンス測定装置及びファントムを用いて測定した線量，並びに広島・長崎における歯科病院・医院における調査データを用いて，水晶体，下垂体窩，甲状腺及び皮膚に対する臓器線量を算出した．両市で2週間にわたって行われた調査で得られたデータを用いて，これらの部位に対する1検査当たりの平均線量を算出した．1人当たりの年間平均線量を，年別検査頻度を示すデータから算出し，臓器，年齢，検査対象歯，検査の種類，対象集団，性及び都市別に集計した．年齢，対象集団，性又は都市別に見て有意差は認められなかった．現在のところ，歯科X線検査による線量は，原爆被爆者における放射線後影響の評価に偏りをもたらすほど高いものではないと考えられる．しかし，1人当たりの年間平均甲状腺線量が，広島・長崎でそれぞれ62mradと67mradであるということは，放射線誘発性発癌に対する寄与の可能性という点から看過できない問題である．

緒 言
診断用X線照射は，世界中の人々にとって主な電離放射線被曝源となっている．この線源が，広島・長崎の原爆被爆者に対して現在行われている電離放射線の後影響についての評価に偏りをもたらす汚染被曝源となる可能性がある．放影研は追跡調査の一環と

*RERF Consultant and Department of Experimental Radiology, Faculty of Medicine, Kyushu University
放影研顧問及び九州大学医学部放射線基礎医学教室
**Department of Radiation Biology, Research Institute for Nuclear Medicine and Biology, Hiroshima University
広島大学原爆放射能医学研究所障害基礎研究部門

Approved 承認 15 July 1986

Printed 印刷 April 1987

these follow-up studies, RERF has periodically surveyed Hiroshima and Nagasaki institutions for the medical and dental X-ray exposures they incurred to RERF Adult Health Study (AHS) and Life Span Study (LSS) subjects, comprising the fixed population samples under surveillance, originally numbering 20,000 and 90,000, respectively.

Annual changes in the frequency of dental radiological examinations depend on whether such examinations are covered by health insurance, and the radiation exposure dose fluctuates according to X-ray unit used, radiographic conditions, and X-ray film speed. Therefore, continuing studies are needed. For example, it was only in recent years that full-mouth examination and orthopantomography have been covered by health insurance in Japan. Rapid increases in these examinations are continuing.

Doses received by the AHS subjects from dental radiography have already been reported.[1] In the present study, the magnitude of dental radiography's contribution to the overall exposure of LSS subjects, and to the Hiroshima and Nagasaki populations to ionizing radiation was assessed. The present study was prompted by the report of increased thyroid cancer among survivors with A-bomb exposure doses of 50 rad or more.[2]

MATERIALS AND METHODS

Frequency of Dental Radiography Exposures and Technical Exposure Factors. Dental radiography exposure factors of relatively large hospitals and of a 40% random sample of all dental clinics in Hiroshima and Nagasaki were determined by survey for a period of two weeks in 1975. This information included types of radiography, body sites examined, numbers of exposures, and exposure factors such as tube voltage and tube current, necessary to estimate doses. Detailed information obtained in the survey has been published elsewhere.[3]

Phantom Dosimetry. The phantom dosimetry, performed in a previous study[1] according to type of examination, teeth examined, and field size, is described here briefly.

A conventional dental radiographic unit (Type Max-II, J. Morita Dental Manufacturing Co.), rated at 60 kVp and 10 mA was used to expose the

して，本来各々20,000人と90,000人の固定観察集団である放影研成人健康調査（AHS）集団と寿命調査（LSS）集団の対象者が，広島，長崎の医療機関で受けた医療用及び歯科X線被曝を定期的に調査している．

歯科X線検査の頻度は，その検査が健康保険の対象になるか否かにより年々変化し，また放射線被曝線量は，使用したX線装置，X線撮影条件，X線フィルム感度によって変わる．したがって，継続的な調査が必要である．例えば，日本で全顎X線検査及びorthopantomographyが健康保険の対象になったのは最近のことである．これらの検査は急激に増加しつつある．

成人健康調査対象者が歯科X線検査で受けた線量については既に報告されている．[1] 本研究では，寿命調査対象者の総被曝線量及び広島・長崎の集団が受けた電離放射線量に対する歯科X線撮影の寄与の大きさを評価した．原爆被曝線量が50rad以上の被爆者に甲状腺癌が増加しているという報告[2]が，本研究の実施を促進した．

材料及び方法

歯科X線被曝頻度と照射条件．1975年に2週間にわたり実施した調査によって，広島・長崎の比較的大きな病院，及び全歯科医院から無作為に抽出した40%の医院における歯科X線撮影条件が明らかになった．この情報には，X線検査の種類，検査した身体部位，照射回数，及び管電圧や管電流等の照射条件等，線量推定に必要な項目が含まれていた．その調査により入手した詳細な情報については，別報[3]に記載されている．

ファントムによる線量測定．以前の調査[1]で，検査の種類，検査対象歯，及び照射野別に行ったファントムによる線量測定について以下に簡単に記す．

人体ファントムの照射には，通常の歯科X線装置（Max-Ⅱ型，モリタ製作所製，60kVp，10mA）を

phantom human. Orthopantomographic units[1] (Panex, J. Morita Dental Manufacturing Co. and a Siemens Type OP-2, Siemens Manufacturing Company) and a cephalometric unit (Tokyo Engine Kogyo) were also used in the dosimetry for some of the examinations.

A thermoluminescent dosimeter (TLD) system (Model 2000 TL Analyzer, Harshaw) and LiF powder in gelatin capsules 0.5 cm in diameter × 1 cm in length were used. To correlate the TLD readings with exposures in mR, Memorial diagnostic X-ray ionization chambers were used with a Farmer-Baldwin electrometer (Type RB, Baldwin Instrument Co., Ltd.).[4,5] Exposures in mR were converted to doses in mrad, using a conversion factor of 0.89 R/rad. The head and neck portions of a Rando phantom (Alderson Research Laboratories) were altered, with holes accommodating LiF capsules at six sites as follows: right and left lens, right and left lobes of the thyroid gland, pituitary gland, and skin at the centers of the exposure fields.

Bone marrow and gonad doses were measured during the previous study.[1] Bone marrow doses were less than 2 mrad during the exposures of 14 films for a full-mouth examination. Male and female gonad doses were not detectable for maximum exposures of 400 mAs, except for those to the male gonads incurred during upper incisor and upper cuspid examinations. Dosimetry for these organs was therefore not performed in the present study. The t-test was used to determine the statistical significance of the differences between results.

RESULTS

Phantom Dosimetry

Among a total of 189 apparatuses, 169 were operated at fixed tube voltages of 60 kVp; 1 at 50 and 55 kVp; 7 at 65 kVp; and 12 at 70 kVp. The phantom was exposed using a fixed tube voltage of 60 kVp.

Table 1 shows the doses incurred to various body sites according to teeth examined.[1] The dose data in Table 1 were applied to each exposure in the community institutions. Whenever the beam sizes of the examination differed from those in Table 1, the one best approximating that for the exposure was used for dose calculation. Beam sizes exceeding 10 cm in diameter were rarely encountered in this investigation (less

用いた．特殊なX線検査の線量推定には，orthopantomograph 装置[1]（Panex，モリタ製作所製及び Siemens OP-2 型，Siemens 社製）と頭部X線規格撮影装置（東京エンジン工業製）を用いた．

熱ルミネッセンス線量計（TLD）システム（2000型 TL 分析器，Harshaw 社製）と直径0.5cm×長さ1cm のゼラチン・カプセル入り LiF 粉末とを用いた．熱ルミネッセンス線量計の測定値と mR 単位の線量との関係は，Memorial 診断X線用電離箱と Farmer-Baldwin 電位計（RB 型，Baldwin Instrument 社製）とによって求めた．[4,5] 変換係数 0.89R/rad を用いて，mR 単位の線量を mrad 単位の線量に変換した．Rando ファントム（Alderson Research Laboratories 製）の頭部と頚部に変更を加えて，次の6部位に LiF カプセルを入れる穴を設けた：左右の水晶体，甲状腺の左右葉，下垂体，及び照射野の中心部の皮膚．

骨髄線量及び生殖腺線量は，以前の調査[1]で測定されている．骨髄線量は，14枚のフィルムによる全顎撮影検査で2mrad 未満であった．上顎切歯及び上顎犬歯の検査で男性生殖腺に照射した線量を除き，最高曝射 400mAs でも男性及び女性生殖腺線量は検出できなかった．したがって，本研究ではこれらの臓器の線量測定は行わなかった．結果の差異が統計的に有意か否かを判定するために，t テストを行った．

結　果

ファントムによる線量測定

計189台の装置のうち，169台は 60kVp の一定管電圧で，1台は50及び 55kVp，7台は65kVp，12台は 70kVp であった．ファントムの照射は 60kVp の一定管電圧を用いた．

表1は，各部位の線量を検査した歯別に示している．[1] 表1の線量データを地元機関の各照射例に適用した．検査の照射野が表1とは異なる場合，最も近い値を用いて線量を算出した．本調査では直径が10cm

TABLE 1 DOSES TO BODY SITES IN A PHANTOM ACCORDING TO TEETH EXAMINED
60 kVp, 10 mAs, FSD 15.5 cm, 0.5 mm Al FILTRATION (Unit: mrad)
表1 検査した歯別のファントム中の部位における線量，60kVp，10mAs，
FSD 15.5cm，0.5mm Al フィルター（単位：mrad）

Site	Incisors		Cuspids		Premolars		Molars	
	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
			Beam Size: 6.5 cm ϕ					
Lens	20	10	113	8	56	1	10	0
Pituitary Fossa	0	10	3	8	0	0	0	0
Thyroid Gland	8	27	15	18	25	36	19	106
Skin	1320	1260	1310	1240	1330	1310	1310	1300
			Beam Size: 8.0 cm ϕ					
Lens	35	17	475	8	371	4	22	1
Pituitary Fossa	0	10	5	10	0	1	4	1
Thyroid Gland	8	60	18	54	39	103	101	429
Skin	1350	1250	1420	1300	1310	1310	1340	1340
			Beam Size: 10.0 cm ϕ					
Lens	155	43	613	124	446	14	47	6
Pituitary Fossa	0	40	7	30	4	4	6	3
Thyroid Gland	8	103	23	46	68	286	179	520
Skin	1240	1430	1230	1210	1310	1300	1290	1310

FSD = Distance from focal spot to skin. FSD＝焦点から皮膚までの距離

than 0.5%). For the lens and thyroid gland, averages of doses to the right and left sides have been used throughout this report. Upper cuspid and upper premolar examinations incurred relatively high doses to the lens; lower premolar and lower molar examinations did so to the thyroid gland. Doses to the pituitary fossa were relatively low for all types of examinations where beam sizes were less than 8 cm in diameter.

を超える照射野はまれであった（0.5%未満）．水晶体及び甲状腺については，本報告を通して左右の平均線量を用いた．上顎犬歯及び上顎小臼歯の検査では，水晶体線量が比較的大きく，下顎小臼歯及び下顎大臼歯の検査では甲状腺線量が比較的大きかった．下垂体窩線量は，照射野の直径が8 cm未満の場合，全種類の検査で比較的小さかった．

Application of Dose Tables to the Populations of RERF, and to Hiroshima and Nagasaki

In Table 2, the numbers of exposures and examinations during two-week periods are shown by examination type and by city.[3] These data, including the technical factors used and the dose tables compiled, are stored on computer tapes. The organ doses per exposure and per examination were calculated according to the AHS, LSS (Non-AHS), and Hiroshima and Nagasaki populations, by type of examination, teeth examined, age, and city. In the calculations, doses were considered directly proportional to mAs, and according to the inverse square law of the distance between the focal spot and the skin (FSD).

放影研調査集団及び広島・長崎の集団への線量表の適用

表2は，2週間における照射及び検査の回数を検査の種類及び都市別に示している．[3] 使用した照射条件及び作成した線量表を含め，これらの情報はコンピューター・テープに保存されている．1照射当たり及び1検査当たりの臓器線量は，成人健康調査対象者及び寿命調査対象者（成人健康調査対象者以外）ごとに，また広島及び長崎の集団ごとに，検査の種類，検査した歯，年齢，及び都市別に算出した．線量はmAsに正比例し，焦点から皮膚までの距離（FSD）の逆2乗法則に従うものとして計算を行った．

An example of the average dose per exposure is shown in Table 3. All of the A-bomb survivors

1照射当たりの平均線量の1例を表3に示す．1975年

TABLE 2 EXPOSURES AND EXAMINATIONS (NUMBERS) BY TYPE OF RADIOGRAPHY DURING A TWO-WEEK PERIOD IN 1975 SURVEY OF HIROSHIMA AND NAGASAKI DENTAL INSTITUTIONS

表2 1975年に2週間の期間について広島・長崎の歯科医院で実施した調査におけるX線検査の種類別照射及び検査回数

	Intraoral	Full-mouth	Orthopantomography	Bitewing	Occlusal
			Hiroshima		
Exposures	7596	1462	185	10	38
Examinations	4380	168	180	3	23
Expo./Exam.	1.73	8.70	1.03	3.3	1.65
			Nagasaki		
Exposures	2940	496	79	0	9
Examinations	1823	50	79	0	3
Expo./Exam.	1.61	9.92	1.00	-	3.00
			Total		
Exposures	10536	1958	264	10	47
Examinations	6203	218	259	3	26
Expo./Exam.	1.70	8.98	1.02	3.3	1.81

were more than 30 years of age in 1975, and the doses for this group were calculated and are shown separately. There were no significant differences between the doses per exposure and per examination of the A-bomb survivors and those of the general populations by age and by city.[3] The average doses per exposure to various body sites by intraoral radiography, by city, are shown in Table 4. In this table and in subsequent ones, for ages 30 or more, city, and population were combined. Since nearly half of the intraoral examinations were of molars, doses incurred by molar examinations contributed much more than did examinations of the other teeth.

The average doses per examination to body sites by type of examination and city appear in Table 5. The averages of skin doses from intraoral and full-mouth examinations shown were summed at the centers of the exposure fields during several exposures. Skin doses from orthopantomography varied from 6 to 100 mrad according to sites on the skin. Although the doses per intraoral examination were 15% to 30% of those per full-mouth examination, their contributions to mean caput doses were 4-8 times greater than were those by full-mouth examinations because of the high frequency of intraoral examinations. Doses from bitewing and occlusal radiography were estimated, but those data are not shown here because of the very low frequency of those examinations.

には原爆被爆者はすべて30歳以上であり，この群の線量の算出結果は別に示す．年齢及び都市別の1照射当たり及び1検査当たりの線量には，原爆被爆者と一般集団の間で有意差はなかった．[3] 口内X線検査による各部位への1照射当たりの平均線量を，都市別に表4に示す．この表及びこれ以降の表では，30歳以上の年齢について，都市及び集団を合わせて検討した．口内検査の半数近くが大臼歯の検査であったので，大臼歯の検査による線量の寄与は他の歯の検査よりかなり大きかった．

各部位への1検査当たりの平均線量を，検査の種類及び都市別に表5に示す．口内検査及び全顎検査での皮膚線量の平均は，数回の照射において照射野の中心で合算したものである．Orthopantomography での皮膚線量は，皮膚上の位置により6mradから100mradまで変化した．1口内検査当たりの線量は1全顎検査当たりの線量の15%～30%であったが，口内検査は頻度が高いため，1人当たりの平均線量への寄与は全顎検査の4～8倍であった．咬翼及び咬合X線検査での線量も推定したが，これらの検査の頻度は極めて低いため，そのデータはここでは示さない．

TABLE 3 EXAMPLES OF AVERAGE DOSE PER EXPOSURE TO BODY SITES BY AGE AND CITY DURING RADIOGRAPHY OF UPPER INCISORS (Unit: mrad/Exposure)

表3 上顎切歯X線検査における各部位への1照射当たりの年齢及び都市別平均線量例(単位: mrad/照射)

Site	Age in years							
	13-29	30-39	40-49	50-59	60-69	70+	13+ Total	30+
				Hiroshima				
Lens	16±11	16±11	17±11	17±12	19±12	15±10	15±11	17±11
Pituitary Fossa	0	0	0	0	0	0	0	0
Thyroid Gland	4.6±2.9	4.5±3.1	4.9±3.0	4.5±2.6	5.3±3.1	4.0±3.4	4.7±2.9	4.7±3.0
Skin	820±520	800±550	870±540	800±470	940±570	710±610	830±530	840±530
				Nagasaki				
Lens	21±24	22±25	16±15	14±10	22±16	17±8	19±20	18±18
Pituitary Fossa	0	0	0	0	0	0	0	0
Thyroid Gland	4.1±3.0	4.9±5.3	4.0±2.2	3.3±1.5	4.6±2.7	3.9±1.6	4.1±3.0	4.2±3.4
Skin	720±390	860±920	710±400	600±270	830±480	710±290	740±540	740±590
				Total				
Lens	17±15	18±16	17±13	16±11	20±13	16±10	17±14	17±14
Pituitary Fossa	0	0	0	0	0	0	0	0
Thyroid Gland	4.5±2.8	4.6±3.8	4.6±2.8	4.2±2.4	5.1±3.0	4.0±3.0	4.5±3.0	4.5±3.1
Skin	790±490	820±670	820±500	750±440	910±550	710±530	800±530	810±550

TABLE 4 AVERAGE DOSES PER EXPOSURE TO BODY SITES DURING INTRAORAL RADIOGRAPHY IN HIROSHIMA AND NAGASAKI (Unit: mrad/Exposure)

表4 広島・長崎の口内X線検査における各部位への1照射当たりの平均線量(単位: mrad/照射)

Site	Incisors		Cuspids		Premolars		Molars	
	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
				Hiroshima				
Lens	17±11	7.7±5.2	160±140	6.3±6.5	120±110	2.0±1.4	12.8±6.5	0.43±0.69
Pituitary Fossa	-	7.5±6.3	2.8±1.9	6.7±4.3	0.05±0.27	0.46±0.69	1.3±1.9	0.40±0.61
Thyroid Gland	4.7±3.0	23±16	10.2±5.5	21±14	22±11	47±31	42±34	180±130
Skin	840±530	800±590	850±480	850±490	990±520	1000±520	1200±560	1120±570
				Nagasaki				
Lens	18±18	8.1±5.2	200±160	11±19	160±140	2.5±2.6	14.8±9.6	0.8±1.3
Pituitary Fossa	-	7.1±4.9	2.9±2.0	6.5±4.8	0.22±0.74	0.75±0.95	2.1±2.6	0.63±0.80
Thyroid Gland	4.2±3.4	24±15	10.0±5.7	19±15	24±18	56±53	54±44	210±170
Skin	740±590	770±500	790±470	670±360	950±820	780±380	1140±770	1030±590
				Total				
Lens	17±14	7.8±5.2	170±150	8±12	130±130	2.1±1.8	13.4±7.6	0.52±0.89
Pituitary Fossa	-	7.4±6.0	2.8±1.9	6.7±4.5	0.11±0.49	0.55±0.79	1.5±2.2	0.46±0.67
Thyroid Gland	4.5±3.1	23±16	10.1±5.6	20±14	23±14	49±39	45±38	190±140
Skin	810±550	800±570	830±470	800±470	980±640	940±490	1180±630	1090±570

TABLE 5 AVERAGE DOSES PER EXAMINATION TO BODY SITES DURING INTRAORAL, FULL-MOUTH RADIOGRAPHY, AND ORTHOPANTOMOGRAPHY IN HIROSHIMA AND NAGASAKI

(Unit: mrad/Examination)

表5 広島・長崎の口内X線検査，全顎X線検査，及びorthopantomographyにおける各部位への1検査当たりの平均線量（単位：mrad/検査）

Site	Intraoral*	Full-mouth	Orthopantomography
		Hiroshima	
Lens	59±150	460±440	13.6±6.4
Pituitary Fossa	2.6±6.6	17±13	37±10
Thyroid Gland	110±180	470±380	140±110
Skin	1800±2200	8600±4500	17±14**
Expo./Exam.	1.75	8.59	1.01
		Nagasaki	
Lens	77±175	440±480	16.4±4.0
Pituitary Fossa	2.6±6.4	17±20	38.4±9.6
Thyroid Gland	110±180	470±490	52±13
Skin	1500±1800	7800±4900	6.6±15**
Expo./Exam.	1.59	9.76	1.00
		Total	
Lens	65±158	460±440	14.8±5.7
Pituitary Fossa	2.6±6.6	17±15	38±10
Thyroid Gland	110±180	470±410	102±95
Skin	1700±2100	8500±4600	13±12**
Expo./Exam.	1.70	8.83	1.01

*Includes full-mouth examination. 全顎検査を含む.

**Skin dose at molars. 大臼歯の皮膚線量

Mean doses to the thyroid gland per caput per year during intraoral examinations and orthopantomography were calculated based on the data in Table 5, and those for examination frequency appearing in a previous report[3] are shown in Tables 6 and 7, respectively. Per caput doses for AHS subjects are shown in Table 8. No significant difference was observed by population, city, and sex, except for doses during orthopantomography in Nagasaki (Tables 7 and 8). The doses during orthopantomography were estimated using apparatus of two manufacturers,[1] namely the Morita Panex and Siemens Type OP-2. These two types of X-ray apparatus were used for 60%-70% of orthopantomography dosimetry in both cities. In Hiroshima the Siemens Type OP-2 units comprised 60% of the two types of apparatus being used. The dose rate of the Siemens apparatus was relatively high compared to that of Morita. Therefore, some Hiroshima doses may be higher than those of Nagasaki. However, the dose rates of 30%-40% of the other types of apparatus were not available; thus,

口内検査及びorthopantomographyでの1年当たり及び1人当たりの甲状腺平均線量は，表5のデータと以前の報告[3]にあった検査頻度を基に算出し，各々表6及び7に示した．成人健康調査対象者1人当たりの線量を表8に示す．長崎のorthopantomographyでの線量を除き，集団，都市，性による有意差は認められなかった（表7及び8）．Orthopantomographyの線量は二つの製作所で作られた装置，すなわちモリタ製作所製Panexと Siemens 社製OP-2型[1]を使用して推定した．この二つの型式のX線装置が両市のorthopantomographyの60%～70%に用いられていた．広島では，この2型式の装置のうちSiemens社製OP-2型が60%を占めていた．Siemens社製装置の線量率は，モリタ製作所製装置に比べ高かった．それゆえ広島の実際の線量は長崎のそれらより高いことが考えられる．しかし，その他の装置のうち30%～40%については線量率が得られなかったので，それ

those dose estimates include larger variations. Since orthopantomography was conducted less frequently than intraoral or full-mouth examinations, it was not a major factor in estimating dental exposure dose. Other technical factors, such as mA, time, FSD, and field size were similar in both cities, as was the case in a previous dental radiographic survey[6] and a survey for medical radiographic exposures.[7]

らの線量推定値の変動はより大きい．Orthopantomography の頻度は口内又は全顎検査より低いので，歯科X線照射線量の推定にとってそれは重要な因子ではない．以前の歯科X線調査[6]及び医療用X線調査[7]の場合と同様に，mA，時間，FSD，照射野等その他の照射条件は両市とも類似していた．

TABLE 6 MEAN DOSES PER CAPUT PER YEAR TO THE THYROID GLAND DURING INTRAORAL RADIOGRAPHY INCLUDING FULL-MOUTH RADIOGRAPHY BY POPULATION AND CITY
(Unit: mrad/caput/year)

表6 口内X線検査(全顎検査を含む)における1年当たり及び1人当たりの甲状腺平均線量，集団及び都市別
(単位：mrad/人/年)

Population	Total	Male	Female
	Hiroshima		
AHS	58±95	71±116	52±84
Non-AHS	49±80	44±72	53±86
General population	54±88	47±76	61±100
Handbook holder	39±64	28±46	47±76
Nonholder	60±98	53±86	67±109
	Nagasaki		
AHS	63±103	51±83	71±117
Non-AHS	72±118	44±71	93±152
General population	44±72	36±59	52±85
Handbook holder	31±51	22±36	37±60
Nonholder	56±92	44±72	68±112

TABLE 7 MEAN DOSES PER CAPUT PER YEAR TO THE THYROID GLAND DURING ORTHOPANTOMOGRAPHY BY POPULATION AND CITY
(Unit: mrad/caput/year)

表7 Orthopantomography における1年当たり及び1人当たりの甲状腺平均線量，集団及び都市別(単位：mrad/人/年)

Population	Total	Male	Female
	Hiroshima		
AHS	3.7±2.9	6.9±5.4	2.1±1.6
Non-AHS	2.8±2.2	2.5±2.0	2.9±2.3
General population	3.3±2.6	3.6±2.8	3.0±2.4
Handbook holder	1.4±1.1	1.0±0.8	1.7±1.3
Nonholder	4.0±3.2	4.3±3.4	3.7±2.9
	Nagasaki		
AHS	3.5±0.9	3.0±0.7	3.8±1.0
Non-AHS	0.2±0.1	-	0.7±0.2
General population	1.2±0.3	1.0±0.3	1.4±0.4
Handbook holder	0.9±0.2	0.5±0.2	1.1±0.3
Nonholder	1.4±0.4	1.2±0.3	1.6±0.4

TABLE 8 MEAN DOSES PER CAPUT PER YEAR TO BODY SITES DURING DENTAL RADIOGRAPHY FOR AHS SUBJECTS IN HIROSHIMA AND NAGASAKI, 1975
(Unit: mrad/caput/year)

表8 広島・長崎の成人健康調査対象者の歯科X線検査における各部位への1年当たり及び1人当たりの平均線量，1975年（単位：mrad/人/年）

	Body Site			
	Lens	Pituitary Fossa	Thyroid Gland	Skin
		Hiroshima		
Intraoral	31±79	1.4±3.5	58±95	950±1160
Orthopantomography	3.6±1.7	1.0±0.3	3.7±2.9	0.5±0.4
Total	35±79	2.4±3.5	62±95	950±1160
		Nagasaki		
Intraoral	44±100	1.5±3.7	63±103	860±1030
Orthopantomography	1.1±0.3	2.6±0.7	3.5±0.9	0.4±0.1
Total	45±100	4.1±3.8	67±103	860±1030
		Cities Combined		
Intraoral	35±85	1.4±3.6	59±97	920±1130
Orthopantomography	0.6±0.3	1.6±0.5	4.4±4.1	0.6±0.5
Total	36±85	3.0±3.6	63±97	920±1130

DISCUSSION

The scale of the present study was about 20 times that of a previous AHS survey.[6] Statistical analysis showed no significant differences between the mean doses of the previous and present studies. Results of the present study were compared with dose data reported by Maruyama et al,[8] and the dose to the thyroid gland was higher in the present study. Compared to some A-bomb radiation doses, a 60-70 mrad thyroid dose may be relatively small, and may by some be considered negligible in the study of late effects of A-bomb radiation exposure, but it will pose a problem in examinations of large numbers of people exposed to this much radiation. According to an UNSCEAR Report, the rate of thyroid cancer induced by radiation is 15×10^{-5}/rem. If the dose levels of Hiroshima and Nagasaki are applied on a national scale, it would be 1.5×10^{-5}/rem × 0.065 rem/y × 1.1×10^{8} persons = 107, suggesting theoretically that approximately 100 cases of thyroid cancer would be attributable to dental radiography. This is why every effort is made to reduce radiation exposure as much as possible during radiography.

Reported doses for full-mouth radiography have ranged from 5 to 60 rad to the skin, 80 to 1,500 mrad to the lens, and 50 to 900 mrad to

考　察

本調査の規模は，以前の成人健康調査集団に関する調査[6]の約20倍であった．統計的解析を行ったところ，前回と今回の調査の平均線量に有意差は認められなかった．本調査の結果を丸山らが報告している線量データ[8]と比較したところ，本調査の甲状腺線量の方が大きかった．原爆放射線量と比較すると，60～70mrad の甲状腺線量は比較的小さく，原爆放射線被曝の後影響の調査では無視できると考える人もいるかもしれない．しかし，これだけの量の放射線を多数の人が検査によって被曝することは問題になると思われる．国連原子放射線影響科学委員会（UNSCEAR）報告によると，放射線による甲状腺癌の誘発率は 15×10^{-5}/rem である．広島・長崎の線量レベルを全国的な規模に適用すれば，1.5×10^{-5}/rem × 0.065rem/y × 1.1×10^{8} 人＝107となり，計算上は約100例の甲状腺癌が歯科X線検査に起因することが示唆される．したがって，X線検査中の放射線被曝を可能な限り少なくすることに努力が払われている．

報告によると，全顎X線検査での皮膚線量は5～60rad，水晶体線量は80～1,500mrad，甲状腺線量は

the thyroid gland.[9-13] In the present study, the values for these sites were 8.5 rad, 460 mrad, and 470 mrad, respectively. In the United States, a 1,140 mrad skin dose per exposure in 1964 was reduced to 910 mrad in 1970.[14] The skin dose in the present study was 1,000 mrad, nearly equal to that for the United States. According to Bushong et al,[15] the average thyroid dose for 55 patients during full-mouth examinations, using intermediate-speed film and 65 kVp, was 0.37 rad. With ultraspeed film and higher kVp, this dose was reduced by a factor of five to eight. The corresponding value was 0.47 rad, reflecting the use of intermediate-speed film and 60 kVp in the majority of Hiroshima and Nagasaki dental clinics.

The contribution of dental X-ray examinations to the annual genetically significant dose was 0.01 to 0.15 mrem, while that of medical X-ray examinations was about 30 mrem.[16] The gonad dose from dental exposure can be considered negligible when compared to medical and other sources of exposures.

Currently, the doses from dental X-ray examinations may not be sufficiently high to cause bias in the studies for late effects among A-bomb survivors; however, the mean caput thyroid dose of 62 mrad in Hiroshima and 67 mrad in Nagasaki (Table 8) cannot be ignored from the standpoint of potential radiation-induced carcinogenesis in the thyroid gland. Furthermore, the frequency of full-mouth examinations and mean caput doses in the present study were greater than those of a previous study. Also, regulations are being revised with increasing frequency, authorizing the use of and reimbursement for ever greater numbers of radiographic examinations and films during dental care. Therefore, efforts should be made to reduce doses by means of higher speed films, higher kVp, and improved beam collimation. All these observations further underscore the necessity for continued monitoring of diagnostic radiological procedures.

50～900mrad である．[9-13] 本調査では，これらの部位の線量は各々 8.5rad, 460mrad, 470mrad であった．米国では，1964年には1照射当たりの皮膚線量は1,140mrad であったが，1970年には 910mrad に減少した．[14] 本調査の皮膚線量は 1,000mrad で，米国の値にほぼ等しい．Bushong ら[15] によると，中感度のフィルム並びに 65kVp を用いた全顎検査では，患者55名の平均甲状腺線量は 0.37rad であった．高感度のフィルムを用いて kVp を高くすると，線量は 1/5～1/8 に減少した．本研究での平均甲状腺線量 0.47rad は，広島・長崎の歯科医院のほとんどが中感度のフィルム，60kVp を用いていたことを反映している．

歯科X線検査が年間遺伝有意線量に寄与する量は 0.01～0.15mrem であるが，医療用X線検査の場合は約 30mrem である．[16] 歯科X線照射による生殖腺線量は，医療用及び他の照射源に比べて無視することができる．

現在，歯科X線検査による線量は，原爆被爆者における後影響の調査に偏りをもたらすほど高くないかもしれない．しかし，1人当たりの年間平均甲状腺線量が広島で 62mrad，長崎で 67mrad（表8）であることは，甲状腺の放射線誘発癌を考える上で，無視できない．更に，本調査での全顎X線検査の頻度，及び1人当たりの平均線量は以前の調査に比べて高い．歯科診療において，より多くのX線検査の実施及びフィルムの使用に対して健康保険支払いが認められることによって，検査頻度が増加する方向に規則の改正が行われている．したがって，より高感度なフィルム及び高い kVp を用い，ビームの絞りを改良することによって，線量減少への努力を行うべきである．以上の結果は，診断用X線検査方法の監視の継続が必要であることを示している．

REFERENCES
参考文献

1. ANTOKU S, KIHARA T, RUSSELL WJ, BEACH DR: Doses to critical organs from dental radiography. Oral Surg 41:251-60, 1976 (ABCC TR 40-72)

2. SAMPSON RJ, KEY CR, BUNCHER CR, IIJIMA S: Thyroid carcinoma in Hiroshima and Nagasaki. 1. Prevalence of thyroid carcinoma at autopsy. JAMA 209:65-70, 1969 (ABCC TR 25-68)

3. KIHARA T, SAWADA S, ANTOKU S, TAKESHITA K, RUSSELL WJ, OTAKE M, YOSHINAGA H, BEACH DR: Survey of dental radiology among RERF, Hiroshima and Nagasaki populations. RERF TR 26-81

4. GARRETT R, LAUGHLIN JS: A diagnostic X-ray exposure dose chamber. Health Phys 2:189-95, 1959

5. ANTOKU S, RUSSELL WJ, MIZUNO M, SUGA Y: Memorial ionization chambers. Construction and response. Health Phys 23:559-63, 1972 (ABCC TR 30-70)

6. KIHARA T, ANTOKU S, FUJITA S, BEACH DR, RUSSELL WJ, MIZUNO M, NISHIO S: Technical factors in dental radiography in Hiroshima and Nagasaki. J Am Dent Assoc 88:367-77, 1974 (ABCC TRs 5-72, 6-72, 24-72)

7. SAWADA S, WAKABAYASHI T, TAKESHITA K, RUSSELL WJ, YOSHINAGA H, IHNO Y: ABCC-JNIH Adult Health Study: Exposure to medical X-ray in community hospitals and clinics, survey of subjects, February 1964-January 1965, Hiroshima and Nagasaki. ABCC TR 24-67

8. MARUYAMA T, HASHIZUME T, NISHIZAWA K, ANDO S, SHINOHARA K, AIZAWA H: Estimation of population doses from dental radiography in Japan, 1974. Jpn Soc Dental Radiol 17:52-63, 1977

9. RICHARD AG: Roentgen-ray doses in dental roentgenography. J Am Dent Assoc 56:351-68, 1958

10. BJARNGARD B, HOLLENDER L, LINDAHL B, SONESSON A: Radiation doses in oral radiography. I. Measurement of doses to gonads and certain parts of head and neck during full mouth roentgenography. Odontol Revy 10:355-66, 1959

11. BJARNGARD B, HOLLENDER L, LINDAHL B, SONESSON A: Radiation doses in oral radiography. II. The influence of technical factors on the doses to the patient in full mouth roentgenography. Odontol Revy 11:100-12, 1960

12. BAILY NA: Patient exposure to ionizing radiation in dental radiography. Radiology 69:42-55, 1957

13. RICHARD AG, WEBBER RL: Dental X-ray exposure of sites within the head and neck. Oral Surg 13: 752-6, 1964

14. UNITED NATIONS: Report of the United Nations Scientific Committee on the Effects of Atomic Radiation. General Assembly, 1977

15. BUSHONG SC, GALBREATH JC, GARRIS R, MERRITT E: Reduction of patient exposure during dental radiography. Health Phys 21:281-4, 1971

16. UNITED NATIONS: Report of the United Nations Scientific Committee on the Effects of Atomic Radiation. General Assembly. Official Records, Seventeenth Session, Supplement No. 16 (A/5216), New York, 1962