

| | |
|--------------|---|
| Title | Medical and Dental Radiological Trends in Japan |
| Author(s) | 竹下, 健児; 木原, 卓司; 澤田, 昭三 |
| Citation | 日本医学放射線学会雑誌. 1978, 38(7), p. 682-696 |
| Version Type | VoR |
| URL | https://hdl.handle.net/11094/17715 |
| rights | |
| Note | |

Osaka University Knowledge Archive : OUKA

<https://ir.library.osaka-u.ac.jp/>

Osaka University

Medical and Dental Radiological Trends in Japan

Kenji Takeshita*, Takuji Kihara** and Shozo Sawada***

Department of Radiology, Atomic Bomb Casualty Commission

ATOMIC BOMB CASUALTY COMMISSION

Hiroshima and Nagasaki, Japan

A Cooperative Research Agency of

U.S.A. NATIONAL ACADEMY OF SCIENCES—NATIONAL

RESEARCH COUNCIL

and

JAPANESE NATIONAL INSTITUTE OF HEALTH OF THE MINISTRY

OF HEALTH AND WELFARE

with funds provided by

U.S.A. ATOMIC ENERGY COMMISSION

JAPANESE NATIONAL INSTITUTE OF HEALTH

U.S.A. PUBLIC HEALTH SERVICE

Present Address: *Consultant, Department of Radiology, Radiation Effects Research Foundation,⁺
Hiroshima
Professor, Department of Radiation Biology, Research Institute for Nuclear
Medicine and Biology, Hiroshima University
**Visiting Research Associate, Department of Radiology, Radiation Effects Research
Foundation,⁺Hiroshima
Assistant Professor, Department of Oral Radiology, Osaka Dental University
***Consultant, Department of Radiology, Radiation Effects Research Foundation,⁺
Hiroshima Professor, Department of Radiological Technology, College of
Biomedical Technology, Kumamoto University

⁺Formerly Atomic Bomb Casualty Commission

Research Code No.: 302

Key Words: X-ray examination frequency, Radiological hazards, Medical
exposure, Dental exposure

日本における医用および歯科用放射線の 使用頻度の年次的傾向

原爆傷害調査委員会放射線部

竹下 健児 木原 卓司 澤田 昭三

(昭和52年7月4日受付)

(昭和53年3月23日最終原稿受付)

日本全国における医用および歯科用放射線の年次の使用傾向の推定は、経年的な集団抽出調査に基づいた政府管掌健康保険による検査および治療の頻度を、(1) すべての保険による診療と、同保険による診療の頻度の比率、ならびに(2) 保険および自費負担による医療と保険のみによる医療の頻度の比率によつて修正して求めた。

一般撮影および透視の全件数、X線フィルム使用枚数、放射線治療、および歯科X線検査件数は、本調査に先だつ10年間に増加している。1970

年においては、国民1人当りの診療件数はそれぞれ一般撮影が1.2回、透視が0.1回、放射線治療が0.06回、歯科X線検査が0.3回であつた。歯科X線撮影の資料を広島・長崎両市のものに内挿し、1970年10月に両市の医療機関から提出された資料と比較した。この推定の主な資料は、社会医療調査報告、基金年報および国民健康保険事業年報から求められ、90%以上の必要な情報を得ることができた。

Abstract

Yearly trends in radiologic practice in Japan were estimated on the basis of annual sampling surveys of medical and dental examinations and treatments covered by Government-Managed Health Insurance, modified by (1) the ratio of all insurance-covered medical care to that covered by this insurance, and (2) the ratio of insured plus privately purchased medical care to insured medical care alone.

All radiographic and fluoroscopic examinations, X-ray films consumed, radiation treatments, and dental X-ray examinations, increased during the 10 years prior to this study. In 1970, numbers of examinations or treatments per capita were 1.2 for radiography, 0.1 for fluoroscopy, 0.06 for radiation treatments, and 0.3 for dental radiography, respectively. The dental radiography data were interpolated to Hiroshima and Nagasaki Cities and compared with those submitted by institutions in both cities in October 1970. The Reports of Annual Medical Care Survey, the Fund Office's Annual Reports, and the Annual Reports of the National Health Insurance were main sources for this estimate and provided more than 90% of the necessary information.

Introduction

Surveys by Sawada et al.^{1,2)} of radiologic practice since the atomic bombs (A-bombs) have defined well the trends in medical X-ray use in Hiroshima and Nagasaki. Whether those trends were peculiar to these two cities could not be determined without comparing them with those for Japan as a whole, or by similarly surveying other cities. One of the purposes of the present investigation, therefore, was to obtain nationwide trends in radiology, for comparison with those of Hiroshima and Nagasaki.

To estimate dental radiography doses, Kihara et al.³⁾ surveyed dental film use in Hiroshima and Nagasaki. They obtained insufficient data for this purpose because the majority of dental examinations occurred in clinics rather than dental departments of large hospitals. With the exception of a few clinics and hospitals with good record-keeping, it was practically impossible to document X-ray examination frequency or numbers of films used in clinics. A study of data for Japan as a whole according to all available references was therefore necessary to elucidate dental radiography.

Systematic comprehensive surveys to document X-ray examination frequency or numbers of films used in clinics will probably never be conducted, and publications of annual surveys are relatively few. One source consists of annual reports⁴⁾ of medical care by the Government-Managed Health Insurance

issued by the Health and Welfare Statistics Department, Minister's Secretariat. Using this source alone, however, estimates of trends in radiologic practice throughout Japan are still incomplete.

The present investigation established nationwide yearly trends in the use of medical and dental X-ray from reports of medical and dental care, particularly those of health insurance.

Materials and Estimation Method

I. Reports of Annual Medical Care Survey Under Government-Managed Health Insurance⁴⁾

The medical and dental care under Government-Managed Health Insurance is one of the Social Health Insurance Programs for employees and their dependents not subscribing to any Health Insurance Society. Annual medical care surveys have been conducted since 1955⁵⁾. Recently, 1/10 of the total hospitals and 1/100 of the total medical and dental clinics have been sampled. From statements for medical and dental care submitted by institutions to the Social Insurance Medical Fee Payment Fund Office, the numbers of examinations and treatments and their point scores, described in the next section, have been totaled by type of institution. The annual report of this survey was based on statements reviewed in June of each year for the examinations and treatments performed during the month of May.

In these annual reports, diagnostic X-rays and radiation treatments have been classified as follows:

1. Medical Radiology

Fluoroscopy examinations were categorized according to whether contrast media were used.

Radiographic examinations included plain radiography, spot filming, and "others" for special radiography, and radiography using contrast media. The latter consisted of (1) gastrointestinal (GI) series, (2) cardiography, angiography, cerebral angiography and myelography, and (3) examinations of other organs. Photofluorography in mass chest and upper GI series surveys were not entirely covered by these insurance programs.

Films were tabulated for radiography with and without contrast media, and for special radiography.

2. Radiation Therapy and Radioisotope Examinations

The numbers of treatments are described as X-ray therapy and radium or cobalt therapy. Since 1968, a column for diagnostic use of radioisotopes has been included under "function tests."

3. Dental Radiography

These consisted of periapical ("usual"), full-mouth—specified since 1968—and others including occlusals, panoramic or extraoral examinations.

II. References for Medical and Dental Care

As previously mentioned, annual medical care surveys⁴⁾ have been limited to Government-Managed Health Insurance (A.), which comprises about half of the Social Health Insurance (A). Its contribution to the whole insurance system consists of about 25% as shown in Appendix A. For this, the following sources were selected and analyzed.

1. Fund Office's Annual Reports⁶⁾

These are published by the Social Insurance Medical Fee Payment Fund, established in 1948 to ensure prompt payment of fees according to law, and contracts with insurance carriers. Each medical or dental service is reimbursable according to a point-unit-score system⁷⁾ after statements are confirmed at the Fund Office. The point score is based on the degree of disability and corresponding treatments,

one point corresponding to 10 yen. For example, posteroanterior chest radiography using 14×17 inch film was assigned a value of 103 points; one dental radiography with the periapical ("usual") dental film, 37 points; and a GI series including nine exposures using several film sizes, 700 points.

The numbers of cases and the confirmed annual point scores of the Social Health Insurance (A) and Public Fund (D) by type of insurance, type of public fund⁸⁾ and by prefecture were tabulated. Because payments are not made through the Fund Office, the Workmen's Accident Compensation Insurance (B), the National Health Insurance (C) and Mutual-Aid Association of the Japanese National Railway are excluded. However, from these annual reports, it is impossible to know the numbers of radiologic examinations and radiation treatments.

2. National Health Insurance Activity Annual Reports⁹⁾

These are reported by the Insurance Bureau of the Ministry of Health and Welfare. The medical and dental care benefits under the National Health Insurance (C), established within the cities, towns, or villages to insure those not eligible for Social Health Insurance Programs, are tabulated annually. The National Health Insurance covered about one third of the total health insurance program, as shown in Appendix A.

3. Others

Patients' expenditures (P) not covered by insurance or public funds were included in the Health and Welfare White Paper¹⁰⁾ as part of the total national expense for medical care. We obtained information concerning two insurance programs excluded from this estimate from the Statistics of Japan 1976¹¹⁾, published by the Prime Minister's Office Bureau of Statistics. We also compared our estimates of films consumed with those obtained from the Photosensitized Materials Manufacturer Association.

III. Analysis of Data of Reports of Annual Medical Care Survey Under Government-Managed Health Insurance

Table 1. Medical radiologic examinations and treatments and dental X-ray exposures by type and institution, May 1970 in Japan under the Government-Managed Insurance Program

| Medical exposures | Hospital (Table "Ko") | Clinic (Table "ko") | | Hospital (Table "Otsu") | Clinic (Table "Otsu") | |
|--|--------------------------|---------------------|-----------------|-------------------------------|-----------------------|-----------------|
| | | With beds | Without beds | | With beds | Without beds |
| Fluoroscopy | 45514 | 1084 | 4880 | 83625 | 66450 | 48410 |
| Radiography | 673742 | 17013 | 30497 | 917927 | 735300 | 297910 |
| Film | 796898 | 16055 | 36684 | 952412 | 686660 | 312140 |
| X-ray therapy | 450 | 337 | 106 | 7000 | 50860 | 50100 |
| Radium and cobalt therapy | 26192 | 880 | 106 | 9800 | 20 | 0 |
| Radioisotope examinations | 12558 | 56 | 88 | 1832 | 50 | 0 |
| | | | | Hospital department Annex | | Clinic |
| Dental exposures | | | | | | |
| Periapical and bitewing radiography | | | | 7112 | | 633500 |
| Full-mouth radiography | | | | 0 | | 48800 |
| Other radiography (occlusal, panoramic or extraoral) | | | | 402 | | 800 |

The point score in Table "Ko" was higher for the treatment of in-patients and medical examinations; that in Table "Otsu" was higher for the preparation of medications.

The data for medical and dental X-ray practice for one month by Government-Managed Health Insurance obtained in this survey⁴⁾ in 1970 are shown in Table 1 as an example. Data in the report were categorized for various items, but these are summarized in the table. Similar records also existed since 1967. Before 1967, the data from each randomly-sampled institution by class were merely totaled. Values for all of Japan were estimated by multiplying the reciprocal of each sampling rate by type of institution.

From the Fund Office's Annual Report⁶⁾ in year i , the confirmed point score was obtained as A for Social Insurance and D for Public Funds, and A_1 for Government-Managed Health Insurance. From the National Health Insurance Activity Annual Report⁹⁾ in year i , the confirmed point score was obtained as C for National Health Insurance.

The sum of these scores, $A+C+D$, for each year provided the total numbers of the confirmed point score for medical or dental examinations and treatments. The quotient of $A+C+D/A_1$ was the coef-

Table 2. Insurance point scores for medical and dental examinations and treatments per year in Japan

| Year i | Social Insurance | | National Health Insurance* C | Public Funds* D | $\frac{A+C+D}{A_1}$ |
|----------------|------------------|----------------------------------|------------------------------------|--------------------|---------------------|
| | Total* A | Government- Managed* A_1 | | | |
| Medical | | | | | |
| 1958 | 10.6 | 5.09 | 5.61 | 3.82 | 3.94 |
| 1959 | 13.8 | 5.67 | 7.67 | 4.77 | 4.63 |
| 1960 | 15.8 | 7.73 | 9.89 | 5.14 | 3.99 |
| 1961 | 20.2 | 9.85 | 13.3 | 6.57 | 4.06 |
| 1962 | 24.6 | 12.3 | 15.5 | 8.71 | 3.97 |
| 1963 | 31.3 | 15.7 | 18.8 | 10.6 | 3.87 |
| 1964 | 40.1 | 20.2 | 23.5 | 12.3 | 3.76 |
| 1965 | 49.8 | 25.3 | 28.1 | 15.4 | 3.69 |
| 1966 | 57.9 | 29.6 | 32.8 | 17.1 | 3.64 |
| 1967 | 67.0 | 34.2 | 39.4 | 19.2 | 3.67 |
| 1968 | 78.9 | 40.3 | 48.6 | 21.9 | 3.71 |
| 1969 | 91.4 | 46.2 | 56.5 | 29.3 | 3.84 |
| 1970 | 109 | 55.6 | 67.4 | 29.6 | 3.72 |
| Dental | | | | | |
| 1958 | 2.00 | 0.91 | 0.73 | 0.02 | 3.02 |
| 1959 | 2.64 | 1.21 | 1.18 | 0.03 | 3.18 |
| 1960 | 2.92 | 1.36 | 1.57 | 0.04 | 3.33 |
| 1961 | 3.63 | 1.68 | 2.14 | 0.05 | 3.46 |
| 1962 | 4.31 | 2.05 | 2.50 | 0.09 | 3.37 |
| 1963 | 4.90 | 2.30 | 2.86 | 0.10 | 3.42 |
| 1964 | 5.61 | 2.64 | 3.21 | 0.13 | 3.39 |
| 1965 | 6.87 | 3.23 | 3.70 | 0.15 | 3.32 |
| 1966 | 7.69 | 3.60 | 4.10 | 0.17 | 3.32 |
| 1967 | 8.79 | 4.10 | 4.74 | 0.21 | 3.35 |
| 1968 | 11.1 | 5.19 | 5.80 | 0.26 | 3.31 |
| 1969 | 12.3 | 5.68 | 6.48 | 0.28 | 3.36 |
| 1970 | 15.4 | 7.04 | 7.90 | 0.33 | 3.36 |

*Billions

ficient indicating the factor by which the total insurance point score exceeded that of the Government-Managed Program (Table 2).

The coverage provided by the Workmen's Accident Compensation Insurance (B) and the Japanese National Railway Mutual-Aid Association were excluded from this estimation because the necessary data were unobtainable. Since information on radiologic practice could not be obtained from the Fund Office's Annual Reports nor the National Health Insurance Activity Annual Reports, it was assumed in the present estimate that the examinations and treatments administered under other insurance programs and public funds were the same as those administered under the Government-Managed Health Insurance.

The monthly information for fluoroscopy, radiography, film numbers, radiation therapy, and dental X-ray examinations under Government-Managed Health Insurance were multiplied by the coefficient described above by year, then multiplied by 12 for making annual estimates. For instance, yearly total numbers of fluoroscopy T_f were estimated from the monthly information t_f as follows:

$$T_f = 12 \cdot \frac{A+C+D}{A_1} \cdot t_f \quad (1)$$

For dental radiography, one examination corresponds to one exposure.

The following additional correction factor was necessary: If N is the total national expense for medical and dental care, and P is the patients' total expenditures for care not covered by insurance in year i, the quotient of $N/(N-P)$ is the correction factor for the patients' expenditures for portions not covered by insurance. N and P were obtained from the Health and Welfare White Paper¹⁰⁾. This N value excluded drug purchases and massage treatments at home (Table 3).

Total X-ray films consumed were estimated on the basis of the Photosensitized Materials Manufacturer Association's data. If S is the total films shipped¹²⁾ in year i, E is the total exported and I is

Table 3. Yearly national medical expenses*

| Year i | Total for medical and dental care** N | Patients' expenditure** P | $\frac{N}{N-P}$ |
|-----------|---|---------------------------------|-----------------|
| 1955 | 239 | 50 | 1.26 |
| 1956 | 258 | 50 | 1.24 |
| 1957 | 290 | 52 | 1.22 |
| 1958 | 323 | 54 | 1.20 |
| 1959 | 353 | 32 | 1.10 |
| 1960 | 410 | 21 | 1.05 |
| 1961 | 513 | 19 | 1.04 |
| 1962 | 613 | 14 | 1.02 |
| 1963 | 754 | 10 | 1.01 |
| 1964 | 910 | 17 | 1.02 |
| 1965 | 1120 | 19 | 1.02 |
| 1966 | 1300 | 25 | 1.02 |
| 1967 | 1510 | 35 | 1.02 |
| 1968 | 1800 | 40 | 1.02 |
| 1969 | 1820 | 53 | 1.03 |
| 1970 | 2500 | 65 | 1.03 |

*Drug purchases and massage treatments at home were excluded.

**Billions of yen.

Table 4. Annual X-ray film deliveries in Japan

| Year | Number of films estimated* | Films delivered | |
|------|----------------------------|-----------------|----------------------------------|
| | | Total** | Numbers converted* to 10×12 inch |
| 1959 | 15.5 | | 29.3*** |
| 1960 | 13.0 | | 29.8*** |
| 1961 | 24.5 | | |
| 1962 | 28.2 | 2610 | 33.7 |
| 1963 | 31.0 | 3200 | 41.4 |
| 1964 | 46.5 | 3510 | 45.3 |
| 1965 | 46.5 | 4640 | 59.9 |
| 1966 | 52.1 | 5430 | 70.1 |
| 1967 | 68.2 | 6240 | 80.5 |
| 1968 | 91.3 | 8030 | 103 |
| 1969 | 119 | 8390 | 108 |
| 1970 | 129 | 10000 | 130 |

*Millions

**Thousands m²

***References 18, 19.

the total films imported per year¹³⁾, the total films delivered in Japan are obtained by $S-E+I$, where S , E , and I are in square meter units. The total numbers of films were estimated after converting film sizes to 10×12 inches (Table 4).

Results

The annual fluoroscopic and radiographic examinations, and numbers of X-ray, radium and cobalt treatments, and radioisotope examinations are shown in Table 5. The results for dental examinations are also shown in this table. Each periapical ("usual") examination involved one dental film; each full-mouth examination, four dental films.

As shown in Fig. 1, fluoroscopy, and medical and dental radiography showed a nearly linear increase when plotted on a semi-log scale. The regression lines when determined retrospectively from 1970 to 1959 were as follows:

$$\text{Fluoroscopy} \quad \log_{10}(T_f) = \log_{10}(1.41 \times 10^7) + 0.053(i-1970)$$

$$\text{Radiography} \quad \log_{10}(T_r) = \log_{10}(1.33 \times 10^8) + 0.091(i-1970)$$

$$\text{Dental Radiography} \quad \log_{10}(T_d) = \log_{10}(3.19 \times 10^7) + 0.12(i-1970)$$

These formulae show that the rate of increase was higher for dental than medical X-ray examinations, and higher for radiography than fluoroscopy among medical X-ray examinations.

Table 6 shows the radiologic examinations and treatments per capita resulting from dividing the respective annual totals by the total population for each year. That is, in 1970, the number of fluoroscopy examinations per capita was 0.1; radiography examinations, 1.2; and dental radiography, 0.3; while all radiation therapy was administered at a rate of 0.06 treatments per capita. An abrupt increase in dental radiography per capita occurred during the 10 years prior to 1970.

The numbers of films consumed during medical X-ray examinations throughout Japan were estimated by the above two methods. The results are shown in Table 4. The values obtained by these two

Table 5. Medical and dental X-ray examinations and treatments in Japan by year

| Year | Medical | | | | Dental | | |
|------|--------------|--------------|----------------|--------------------------|----------------------------|------------------|----------|
| | Fluoroscopy* | Radiography* | X-ray therapy* | Radium & cobalt therapy* | Radioisotope examinations* | Periapical type* | Others** |
| 1952 | 2.88 | 4.02 | 0.87 | 0.47 | | 0.024 | 4.3 |
| 1955 | 2.10 | 9.49 | 1.39 | 0.15 | | 0.37 | 7.6 |
| 1958 | — | — | — | — | | 0.83 | — |
| 1959 | 3.87 | 14.2 | 5.01 | 0.32 | | 2.12 | — |
| 1960 | 2.72 | 12.1 | 2.78 | 0.21 | | 1.41 | 4.2 |
| 1961 | 4.96 | 23.3 | 3.31 | 0.87 | | 2.56 | 4.3 |
| 1962 | 5.45 | 26.7 | 4.31 | 0.97 | | 2.49 | 3.7 |
| 1963 | 6.76 | 29.8 | 7.84 | 0.73 | | 3.95 | 18.0 |
| 1964 | 8.43 | 44.3 | 4.60 | 0.87 | | 6.04 | 27.0 |
| 1965 | 8.13 | 44.4 | 2.58 | 0.71 | | 7.09 | 27.0 |
| 1966 | 10.2 | 57.4 | 2.15 | 0.99 | | 12.0 | 43.0 |
| 1967 | 9.61 | 64.3 | 3.40 | 1.57 | | 13.0 | 47.0 |
| 1968 | 10.4 | 90.4 | 2.25 | 0.68 | 0.26 | 22.1 | 30.0 |
| 1969 | 12.4 | 111 | 4.28 | 1.23 | 0.33 | 24.0 | 272 |
| 1970 | 11.5 | 123 | 5.01 | 1.70 | 0.67 | 28.6 | 50.0 |

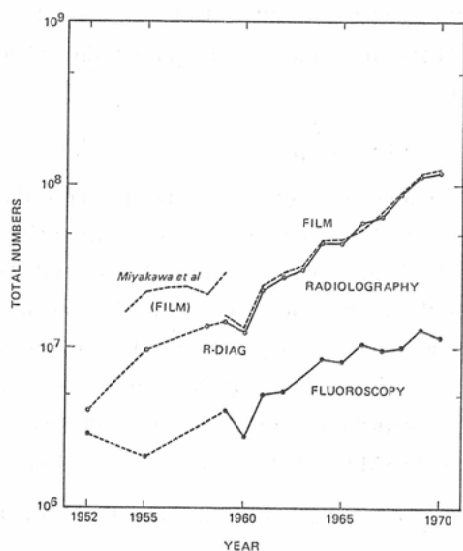
*Millions

**Thousands

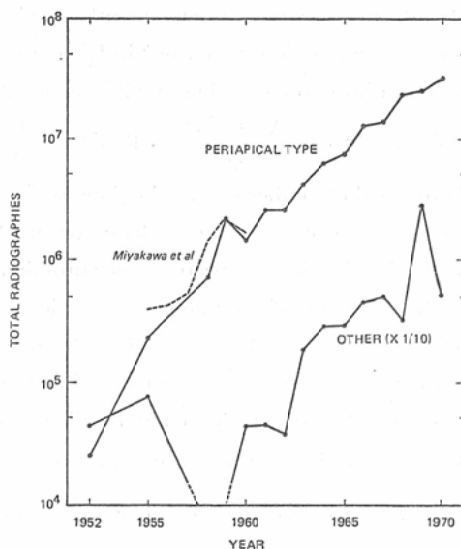
Sources: 1952, reference 17.

1955, reference 5.

1958 to 1970, reference 4.



(A). Fluoroscopic and radiographic examinations, and films used by year in Japan.



(B). Dental X-ray examinations by year.

Fig. 1.

Table 6. Medical and dental X-ray examinations and treatments per capita per year in Japan

| Year | Fluoroscopy | Radiography | Dental exposure (Periapical type) | X-ray therapy | Radium & cobalt therapy |
|------|-------------|-------------|--------------------------------------|------------------|----------------------------|
| 1952 | 0.034 | 0.047 | 0.0003 | 0.010 | 0.005 |
| 1955 | 0.024 | 0.12 | 0.001 | 0.015 | 0.017 |
| 1958 | — | — | 0.009 | — | — |
| 1959 | 0.042 | 0.15 | 0.023 | 0.054 | 0.003 |
| 1960 | 0.029 | 0.13 | 0.015 | 0.024 | 0.002 |
| 1961 | 0.053 | 0.25 | 0.027 | 0.035 | 0.005 |
| 1962 | 0.057 | 0.28 | 0.026 | 0.045 | 0.010 |
| 1963 | 0.070 | 0.31 | 0.042 | 0.082 | 0.007 |
| 1964 | 0.087 | 0.46 | 0.063 | 0.047 | 0.009 |
| 1965 | 0.083 | 0.45 | 0.073 | 0.026 | 0.007 |
| 1966 | 0.10 | 0.58 | 0.12 | 0.022 | 0.010 |
| 1967 | 0.096 | 0.65 | 0.13 | 0.034 | 0.016 |
| 1968 | 0.10 | 0.90 | 0.22 | 0.023 | 0.007 |
| 1969 | 0.12 | 1.1 | 0.24 | 0.043 | 0.012 |
| 1970 | 0.11 | 1.2 | 0.28 | 0.048 | 0.016 |

methods were in good agreement.

Application of Dental Data to Hiroshima and Nagasaki Cities

Hiroshima and Nagasaki Cities are peculiar because of their A-bomb experiences. A-bomb survivors have access to medical care under the auspices of the A-bomb Survivors Medical Treatment Law¹⁴⁾ (ABSMTL). As shown in Appendix A, although this fund (D_7) contributed only 0.3% to the total medical and dental care of all of Japan, about 90% of that fund was used in Hiroshima and Nagasaki Prefectures. A-bomb survivors were predominantly in Hiroshima and Nagasaki Cities. To calculate the numbers of X-ray examinations performed in Hiroshima or in Nagasaki City using the annual reports⁴⁾, this effect was taken into consideration by altering equation (1) as follows:

$$T = 12 \cdot \left(\frac{A+C+D'}{A_1} \cdot K_1 \cdot R_1 + \frac{D_7}{A_1} \cdot K_2 \cdot R_2 + \alpha \right) \cdot t \cdot \frac{N}{N-P} \quad (2)$$

where t is the number of examinations per month according to annual reports⁴⁾; D' is $D - D_7$; D_7 is the reported point scores per year⁶⁾ based on the ABSMTL¹⁴⁾. K_1 and K_2 are ratios of A_1 insurance points and D_7 Fund points, respectively of Hiroshima or Nagasaki Prefecture to those of all of Japan; and R_1 and R_2 are ratios of the numbers of physicians or dentists and the numbers of holders of ABSMTL handbooks in Hiroshima or Nagasaki City to corresponding prefecture, respectively. K_1 and K_2 are shown in Appendix A. They were 3.4% and 54% in Hiroshima and 1.4% and 35% in Nagasaki. Data for R_1 and R_2 are shown in Appendix B. The factor α is caused by expenditures for medical care and health welfare of survivors by both cities and prefectures before the ABSMTL of 1959 and has been additive to the latter since that time. The second and third terms $\left(\frac{D_7}{A_1} \cdot K_2 \cdot R_2 + \alpha \right)$ in this formula were not as effective for dental as medical X-ray because of the relatively low contribution of dental X-ray examinations to treatment under the ABSMTL. After checking the seasonal variations of dental radiography in 1970¹⁵⁾, an extrapolation of dental radiologic trends to 1959 is possible for both cities. Yearly

Table 7. Dental radiography performed in Hiroshima and Nagasaki Cities by year

| Year | Total radiography | | Radiography per person | |
|------|-------------------|-----------|------------------------|----------|
| | Hiroshima* | Nagasaki* | Hiroshima | Nagasaki |
| 1959 | 16.5 | 7.7 | 0.037 | 0.023 |
| 1960 | 10.8 | 4.9 | 0.025 | 0.014 |
| 1961 | 20.5 | 9.2 | 0.046 | 0.026 |
| 1962 | 20.7 | 10.0 | 0.044 | 0.027 |
| 1963 | 34.2 | 15.9 | 0.070 | 0.040 |
| 1964 | 58.9 | 25.1 | 0.12 | 0.063 |
| 1965 | 66.9 | 50.2 | 0.13 | 0.12 |
| 1966 | 99.0 | 68.7 | 0.19 | 0.17 |
| 1967 | 128 | 56.6 | 0.24 | 0.14 |
| 1968 | 215 | 98.5 | 0.39 | 0.24 |
| 1969 | 243 | 112 | 0.44 | 0.27 |
| 1970 | 288 | 133 | 0.52 | 0.31 |

*Thousands

trends in dental radiography in both cities and per capita per year in each city are shown in Table 7 and Appendix D¹⁶⁾.

All statements for dental care submitted by institutions in Hiroshima and Nagasaki Cities in October 1970 were surveyed. The reported dental X-ray exposures were 24,011 in Hiroshima and 8,390 in Nagasaki (Appendix C). Our estimated values for 1970 were 24,000 and 11,100 for the cities, respectively. The values according to the two sources were therefore in good agreement.

Discussion

Numbers of medical and dental X-ray examinations, radiation treatments, and radioisotope examinations performed under the Government-Managed Health Insurance Program, published in Reports of Annual Medical Care Survey⁴⁾⁵⁾¹⁷⁾ were estimated. The rates of medical and dental care under this insurance as opposed to the total insured medical and dental care throughout Japan were estimated by confirmed point scores each year, described in Fund Office's Annual Reports⁶⁾ and National Health Insurance Activity Annual Reports⁹⁾. These rates were approximately 3.7 for medical and 3.4 for dental care for the years covered by the present study. Accordingly, 27% and 29% of the total medical and dental care, respectively, were performed under the auspices of the Government-Managed Health Insurance Program.

Though the sample for surveying medical and dental institutions has been slightly modified yearly, the methods for surveying have been nearly the same since 1959. Furthermore, the institutions have been randomly sampled from all prefectures in Japan. These provide data for statistical analysis and estimating annual trends throughout Japan. However, radiological examinations and treatments were only 5% to 6% of the total medical and dental care, as determined from the percent distribution of point scores for medical care⁴⁾. Furthermore, for less frequent examinations and treatments, errors may be larger, as with the data for 1968-70 for the "other examination" category of dental radiography and the yearly trends in radiation therapy.

The reason for the values being lower than the regression line for most of the medical and dental

examinations in 1960 is not known.

The annual differences between the estimated values and the linear regression during and after 1959 were sought. For fluoroscopy the maximum variation was 35%, and the average overall variation, 16%; for radiography, these were 25% and 12%; and for periapical dental radiography, 29% and 20%, respectively. For fluoroscopy and radiography, the rate of increase with time was less when compared to the linear regression to 1970.

The annual variations were assumed to have been 12% for medical and 20% for dental practice, as derived from data of the Government-Managed Health Insurance, and the ratio of radiologic examinations to all examinations was assumed to have been the same in those covered by all insurance programs and by public funds. The estimated error may exceed 12% because of (1) the high frequency of X-ray examinations under Social Health Insurance and some public funds, the Tuberculosis Prevention Law (D₁), the ABSMTL (D₇), and (2) the low frequency of coverage by National Health Insurance and other public funds.

Some variations in medical and dental care occur by prefecture, as in Hiroshima and Nagasaki, where many A-bomb survivors apply for medical care. In 1970 their ratios to those of all of Japan under this Law were 54% for Hiroshima and 35% for Nagasaki Prefectures. Although these were much higher than values for other prefectures, their contribution to the total insurance was small.

Application of the numbers of dental X-ray examinations in Hiroshima and Nagasaki Cities to those of the actual number investigated in October 1970 showed good agreement. As compared with National Health Insurance, the rate of frequency of dental X-ray examinations to total treatments covered by social insurances was greater by only 11% in Hiroshima and 14% in Nagasaki (Appendix C). Those covered by public funds were also not so high. Therefore, the apparent error for dental radiography mentioned above may be an overestimate. Furthermore, in the routine X-ray examinations which are usually covered by insurance, there is almost no need to consider such expensive dental treatments as prosthetics which requires a large outlay of insurance funds to the patient. Rather, the patients' expenditures which were used here should be regarded as having been received without taking steps for the use of insurance.

In 1960, Miyakawa et al.¹⁸⁾¹⁹⁾ estimated 32.0×10^6 to be the total radiography examinations, and 4.82×10^6 to be the total fluoroscopies in Japan. These are numbers of exposures rather than numbers of examinations, and they are being used to estimate genetically significant dose. Our data consist of numbers of examinations; therefore some differences between these values can be expected. In a 1964–65 survey of medical X-ray exposure factors in Hiroshima and Nagasaki, the numbers of exposures per examination averaged 2.5 in both cities²⁰⁾. If the total number of radiography examinations by our estimate (Table 4) is corrected using this value, there is good agreement with the values of Miyakawa et al.¹⁸⁾¹⁹⁾.

According to Miyakawa et al.¹⁸⁾¹⁹⁾, the total number of dental exposures in 1960 was 0.27×10^6 . This value is considerably lower than our estimate (Table 4). The reason for such a difference is probably that their survey was conducted mainly in dental departments of large hospitals; whereas, we know the frequency of dental examinations and treatments is relatively low³⁾.

In 1969, Hashizume et al.²¹⁾²²⁾ also estimated the genetically significant dose and bone marrow

dose for Japan. The annual number of radiographic examinations, including dental, was 179×10^6 . For the same year, our estimate was 138×10^6 for medical and dental radiography—lower than their value. However, their value consisted of numbers of exposures, and taking this into account, our estimate should be higher than theirs. In addition, they reported the total numbers of fluoroscopies in 1969 to be 20×10^6 , greater than our estimated 12.4×10^6 (Table 4). In spite of differences in methods of estimation, these two values are in generally good agreement by order of magnitude.

Our present estimates of total radiologic practice may be somewhat low for the following reasons. First, medical care under the Workmen's Accident Compensation Insurance (B) (7.1% of total medical care), and Mutual-Aid Association of the Japanese National Railway which includes 1,330,000 persons, and is 10% of Mutual-Aid Association insured group members; 0.9% of the total medical care was not included in our estimates. Second, there are differences between the point scores claimed by institutions and the confirmed point scores. By agreement with the insurance carriers, the numbers of films used or exposures reported by each institution are limited for reimbursement, although for excess films, the purchase price is paid. Therefore, estimates are considered to be less than the actual numbers of exposures incurred. Third, concerning the numbers of films consumed, as described in the Report of the Annual Medical Care Survey in 1960⁴⁾, under Government-Managed Health Insurance, kymography, tomography, and angiocardiology were each considered to consist of a single film, regardless of the numbers of films actually used.

Photofluorographic examinations were not considered in the present estimates because adequate data were unobtainable from insurance programs.

The present study established nationwide radiological trends for comparison with those by linear regression for Hiroshima and Nagasaki, and elsewhere²⁾. The complete data and analysis are described in detail in the Atomic Bomb Casualty Commission Technical Report 18-75¹⁵⁾.

Acknowledgements

Our deep appreciation is extended to Drs. Yukio Kawamura and Tetsuo Shibukawa, presidents of the Hiroshima Prefectural and Hiroshima City Dental Associations for their important suggestions in the planning of the present study, without which it could not have been accomplished. We greatly appreciate the assistance of the Hiroshima Prefectural Office of the Social Insurance Medical Fee Payment Fund, the Hiroshima Federation of the National Health Insurance Organizations, the Osaka Prefectural Dental Association, the Hiroshima Branch of Fuji X-ray Company, Limited, and the Hiroshima A-bomb Casualty Council for providing data sources. We are deeply indebted to Dr. Osamu Yamamoto of the Insurance Bureau of the Ministry of Health and Welfare for his valuable guidance in making these estimates. We also appreciate Dr. Walter J. Russell's suggestions for this study, Mr. Nobuhiro Mizushima's collecting some of the data, and Mrs. Grace Masumoto's assistance in preparing the manuscript.

Requests for reprints:

Walter J. Russell, M.D., D.M.Sc.

Radiation Effects Research Foundation

5-2 Hijiyama Park, Hiroshima 730

Appendix A. Confirmed medical and dental care benefits from insurance and public funds by prefecture, 1970

| Insurance and public funds | Percent of total care | Prefecture/Japan (%) | |
|----------------------------|-----------------------|----------------------|----------|
| | | Hiroshima | Nagasaki |
| A ₁ | 25.3 | 3.4 | 1.4 |
| A ₂ | 15.1 | 2.5 | 1.2 |
| A _{Others} | 10.0 | 3.0 | 2.3 |
| B | 7.1 | — | — |
| C | 30.3 | — | — |
| D ₁ | 2.4 | 2.1 | 2.3 |
| D ₇ | 0.3 | 54.0 | 35.0 |
| D _{Others} | 9.4 | — | — |

- A₁: Government-Managed Health Insurance
 A₂: Society-Managed Health Insurance, which is available from the Health Insurance Society jointly sponsored by employers and employees
 A_{Others}: All others of the Social Health Insurance including Mutual-Aid Associations
 B: Workmen's Accident Compensation Insurance¹¹⁾
 C: National Health Insurance
 D₁: Public Fund for Tuberculosis Prevention Law
 D₇: Public Fund for A-bomb Survivors Medical Treatment Law (ABSMTL)
 D_{Others}: Other Public Funds, which are available under the auspices of eight laws as of 1970

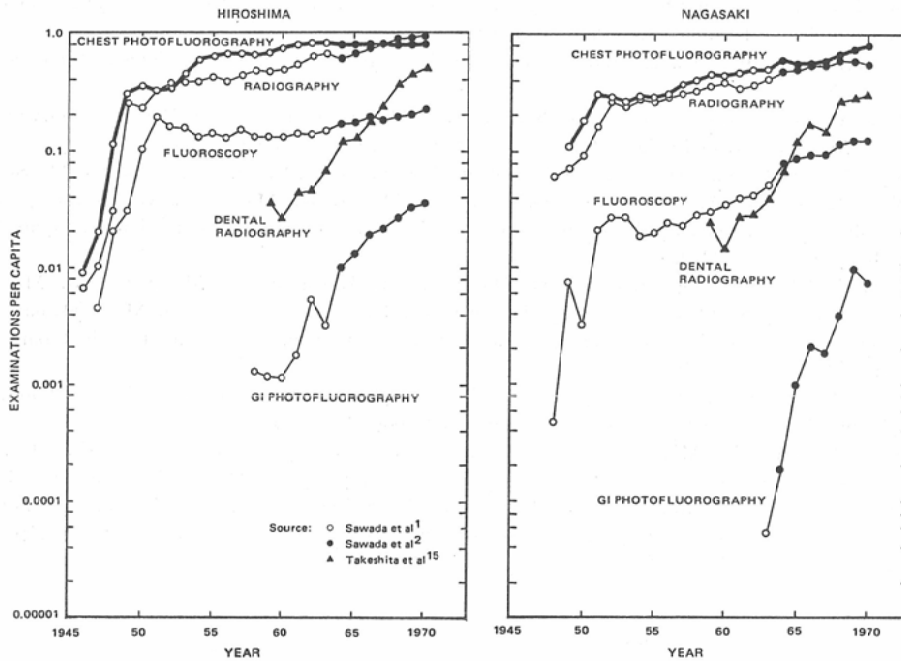
Appendix B. Survivors with ABSMTL* Handbooks, populations, physicians and dentists, 1970

| | Hiroshima | | Nagasaki | |
|------------|------------|---------|------------|---------|
| | Prefecture | City | Prefecture | City |
| Survivors | 171,569 | 90,336 | 103,728 | 82,344 |
| Population | 2,436,135 | 568,014 | 1,570,245 | 424,780 |
| Physicians | 3,320 | 1,209 | 2,209 | 1,070 |
| Dentists | 954 | 317 | 497 | 173 |

*A-bomb Survivors Medical Treatment Law

Appendix C. Dental activity survey by type of insurance program, Hiroshima and Nagasaki Cities, October 1970

| Insurance | Number of hospitals & clinics | Total patients | Total treatments | Total patients radiographed | Total numbers of exposures | | |
|-----------------|-------------------------------|----------------|------------------|-----------------------------|----------------------------|----------------|-------|
| | | | | | Periapical type | Panoramic type | Other |
| Hiroshima | | | | | | | |
| Social Health | 217 | 41069 | 161566 | 10036 | 19196 | 55 | 69 |
| National Health | 221 | 13665 | 52411 | 2985 | 4815 | 26 | 60 |
| Total | 438 | 54734 | 213977 | 13021 | 24011 | 81 | 129 |
| Nagasaki | | | | | | | |
| Social Health | 131 | 20757 | 84277 | 3579 | 6357 | 0 | 8 |
| National Health | 143 | 9060 | 37488 | 1152 | 2033 | 8 | 1 |
| Total | 274 | 29817 | 121765 | 4731 | 8390 | 8 | 9 |



Appendix D. Examinations per capita by city and by year.

References

- 1) Sawada, S., Wakabayashi, T., Takeshita, K., Yoshinaga, H. and Russell, W.J.: Radiologic practice since the atomic bombs, Hiroshima and Nagasaki. *Am. J. Public Health*, 61: 2455—2468, 1971
- 2) Sawada, S., Fujita, S., Russell, W.J. and Takeshita, K.: Radiologic practice in Hiroshima and Nagasaki, trends from 1964 to 1970. *Am. J. Public Health*, 65: 622—633, 1975
- 3) Kihara, T., Antoku, S., Fujita, S., Beach, D.R., Mizuno, M. and Nishio, S.: Technical factors in dental radiography in Hiroshima and Nagasaki. *J. Am. Dent. Assoc.*, 88: 367—377, 1974
- 4) Health and Welfare Statistics Department, Secretariat of Minister of Health and Welfare: Reports of Annual Medical Care Survey under Government-Managed Health Insurance in 1958—1970. Japanese Government, 1960—1971
- 5) Health and Welfare Statistics Department, Secretariat of Minister of Health and Welfare: Report of Medical Care Survey in April 1955 and Survey of National Health Insurance Benefits. Japanese Government, 1956
- 6) Social Insurance Medical Fee Payment Fund: Fund Office's Annual Reports 1951—1970. 1952—1971
- 7) Social Insurance Agency: Outline of Social Insurance in Japan. Japanese Government, 1970
- 8) Ministry of Health and Welfare: A Brief Report on Public Health Administration in Japan. Japanese Government, 1972
- 9) Insurance Bureau, Ministry of Health and Welfare: National Health Insurance Activity Annual Reports 1962—1971
- 10) Ministry of Health and Welfare: The Health and Welfare White Papers in 1961 and 1970. Japanese Government, 1966 and 1971
- 11) Prime Ministers Office, Bureau of Statistics: Statistics of Japan, 1976. Japanese Government, 1977
- 12) Ministry of International Trade and Industry: Statistics on Chemical Industry, 1962—1970
- 13) Ministry of Finance: Statistics on Custom Clearance, 1962—1970
- 14) Health and Welfare Ministry: A-bomb Survivors Medical Treatment Law. Enacted 3 March 1957 (Law No. 41); Amended 1 August 1960 (Law No. 1365); Amended 3 March 1961 (Government Ordinance No. 89)

- 15) Takeshita, K., Kihara, T. and Sawada, S.: Medical and dental radiological trends in Japan. Atomic Bomb Casualty Commission Technical Report 18—75, 1975
 - 16) Russell, W.J.: Radiation damage and medical radiation exposure. *Jpn. J. Radiological Technology*, 31: 578—591, 1976
 - 17) Health and Welfare Statistics Department, Secretariat of Minister of Health and Welfare: Survey Report on Business Management of Medical Practice, Part I. Japanese Government, 1958
 - 18) Miyakawa, T., Adachi, T., Egawa, J., Eto, H., Okajima, S., Onai, Y., Kawamura, F., Sakka, M., Sugahara, T., Tajima, E., Tamaki, M., Nozaki, S., Hashizume, T., Misono, K., Masuyama, M., Yoshinaga, H. and Wakabayashi, M.: The genetically significant dose by the X-ray diagnostic examinations in Japan. *Nippon Acta Radiol.*, 20: 2211—2229, 1960
 - 19) Miyakawa, T., Adachi, T., Egawa, J., Eto, H., Hashizume, T., Kawamura, F., Masuyama, M., Misono, K., Nozaki, S., Okajima, S., Onai, Y., Sakka, M., Sugahara, T., Tajima, E., Tamaki, M., Wakabayashi, M. and Yoshinaga, H.: The genetically significant dose by the X-ray diagnostic examinations in Japan. *Nippon Acta Radiol.*, 21: 565—616, 1961
 - 20) Sawada, S., Russell, W.J. and Wakabayashi, T.: Radiography and fluoroscopy techniques in hospitals and clinics. Atomic Bomb Casualty Commission Technical Report, 2—68, 1968
 - 21) Hashizume, T., Kato, Y., Maruyama, T., Kumamoto, Y., Shiragai, A. and Nishimura, A.: Genetically significant dose from diagnostic medical X-ray examinations in Japan, 1969. *Health Phys.*, 23: 827—843, 1972
 - 22) Hashizume, T., Kato, Y., Maruyama, T., Kumamoto, Y., Shiragai, A. and Nishimura, A.: Population mean marrow dose and leukaemia significant dose from diagnostic medical X-ray examinations in Japan, 1969. *Health Phys.*, 23: 845—853, 1972
-