Trends in Patients' Exposure Doses during Radiographic Examination in Japan

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Abstract: We have investigated changes in exposure doses in Japan in terms of the same items since 1974. An assessment was made of changes in exposure doses during a period of 37 years. Nationwide investigation was conducted 9 times from 1974 to 2011 with regard to 16 target areas (20 kinds of projections). Entrance surface doses were evaluated in terms of the respective exposure conditions based on basic experiment. The results showed that the exposure doses decreased to less than 50% during a 20-year period till 1994, with the exposure doses in 1974 assumed to be 100%. The exposure doses in 2011 were equivalent to, or increased over the exposure doses in 2001 in some areas. A comparison with the IAEA, that is, the so-called guidance level, indicated that the exposure doses in 2011 were less than the standard in all areas. The comparison with past investigations also demonstrated that F/S system using film-intensifying screen has been increasingly replaced with digital radiography (DR) system using imaging plates (IP) and flat panel digital radiography (FPD) system. A transition from F/S to digital systems occurred in 2003 for general radiography, and in 2007 for mammography. As far as the 2011 survey data is concerned, the majority of institutions have digitized their systems, with F/S still being used at only 5 % of all institutions. Lumber spine AP, Chest PA and Guthmann. Overall, the doses decreased widely from 1974 to 1993, followed by a slightly increasing tendency. In chest radiography in particular, there have been remarkable increases; the dose became 96 % in 2003 and reached 113 % in 2007. In 2011, however, the dose decreased to the same level of 96 % as the 2003 dose. Further investigation is necessary to confirm this data.

KEY WORDS: *patient exposure; diagnostic radiography; entrance surface dose; guidance level*

1. Introduction

Radiation doses received by patients during diagnostic radiography, especially x-ray radiography, have been reported by the United Nations Science Committee[1)], but there are not many data from Japan. Consequently, we shall report the results of earlier surveys [2)- 9)] and the recent state of affairs regarding exposure during x-ray diagnosis. We shall also attempt to compare the data with the standards published by the International Atomic Energy Association (IAEA).

The IAEA published Safety series No. 115[10)] in February 1996. It lists doses for representative adult

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diagnostic radiography examinations, CT examinations, and mammography and dose rates for fluoroscopy examinations published as guidance levels for radiography examinations in the diagnostic area. These guidance levels have been interpreted as the minimum doses that do not compromise the quality of diagnosis. In other words, standard values according to the IAEA recommendations for doses received by patients in the diagnostic area are shown. With the exception of mammography and CT examinations, the dose evaluations are entrance surface doses. The doses at the entrance surface are the largest doses in the diagnostic area.

We have used these doses as the exposure doses in this report, except for mammography. We will explain the dose evaluation methods for mammography in a concise manner later.

This report estimates the doses received by patients in the diagnostic x-ray area in Japan. In addition, digital radiography (CR) that computed radiography (CR) uses imaging plate (IP) and flat panel digital radiography (FPD) instead of the conventional film/ screens (F/S) is now being used at many medical institutions. Radiation dose comparisons between DR and F/S were also conducted.

2. Methods

2.1. Questionnaire surveys

Nationwide questionnaire surveys on the same items were carried out at medical institutions throughout the country where medical radiological technologists were employed. The surveys have been conducted a total of 9 times, the first time in 1974, and again in 1979, 1989, 1993, 1997, 2001,2003,2007 and 2011. From the first to third times, 200 institutions were randomly selected by 2-stage sampling from the membership list of the Japan Association of Radiological Technologists, and the fourth and fifth times, 1000 institutions, sixth to ninth, 3000 institutions were selected in a similar manner by 2-stage sampling from the membership list of the Japan Society of Radiological Technology. The valid reply rate was about 35%. Table 1 and 2 show target areas and items examined.

Table 1. Survey examination parts

*Examination for a typical adult patient
1. Head, frontal and lateral view 2. Cervical spine, frontal view
3. Thoracic spine, frontal and lateral view 4. Chest, low, quasi-high, high voltage
5. Lumber spine, frontal and lateral view 6. Abdomen, frontal view
7. Pelvis, frontal view 8. Femur, proximal 9. Forearm bones
10. Ankle 11. Guthmann 12. Maritius 13. Mammography
*Examination for a typical child patient
14. Hip, small child 15. Chest, small chiid 16. Chest, child

Table 2. Survey items and radiographic conditions

1.Generation type
2.Thickness of total filtration
3.Image receptor : F/S, CR, FPD
4.Tube voltage, tube current, exposure time
5.Grid ratio
6.Source surface distance

2.2. Dose evaluation

Doses were evaluated based on the actual measured values at 100 institutions in the Chubu District. The entrance surface doses were calculated by classifying the values obtained by actual measurement from the exposure conditions for each of the generator types and filter thicknesses. Whenever the generator type was unknown, it was assumed to be 3-phase 12-peak, and whenever total filtration was unknown, it was assumed to be 3 millimeters aluminum equivalent.

Mammography was evaluated by the average mammary glandular dose[11)]. The breast glandular and adipose tissue ratio to the air dose in the entrance surface area was calculated as 50%-50%, and the mammary glandular dose was calculated by multiplying this value by the mammany glandular absorbed-dose conversion coefficient for middle-aged women.

3. Results of the Surveys

Table 3 shows the numbers of institutions used to make the calculations, the 3/4 quantile doses (75 % doses), means, standard deviations, and IAEA guidance levels. The 75 % dose is the dose at the institution in the 75 % position, and it means that 75 % of the institutions are at or below that dose. The 75 % doses were higher than the mean dose. Particularly at sites where the dose was large, i.e., the thoracic spine lateral view, lumbar spine lateral view and Martius sites, the 75% dose was about 1-3 mGy larger than the mean. Comparisons with the guidance levels showed that all 9 sites were 60 % to 20 %.

Table 3. Exposure Sites Surveyed in 2011 and Dose Comparisons

Exposure sites	No.of institutions calculated	75% dose	Mean	Standard deviation	IAEA Guidance level
Head, frontal view	580	1.99	1.68	1.27	5
Head, lateral view	575	1.55	1.31	1.10	3
Cervical spine, frontal view	587	0.76	0.66	0.62	–
Thoracic spine, frontal view	576	2.81	2.32	1.93	7
Thoracic spine, lateral view	574	5.99	4.70	5.20	
Chest, low voltage	198	0.40	0.35	0.36	–
Chest, quasi-high voltage	217	0.50	0.42	0.45	–
Chest, high voltage	634	0.24	0.23	0.33	0.4
Lumber spine, frontal view	586	3.81	3.13	2.61	10
Lumber spine, lateral view	585	12.82	9.68	6.71	30
Abdomen, frontal view	602	2.32	2.04	2.27	10
Pelvis, frontal view	585	2.54	2.01	1.52	–
Femur, proximal	579	1.59	1.29	1.07	–
Forearm bones	585	0.15	0.13	0.12	–
Ankle	585	0.20	0.17	0.17	–
Guthmann	287	6.27	4.51	4.95	–
Maritius	267	7.09	5.18	5.33	–
Hip, small child	385	0.17	0.15	0.17	–
Chest, small chiid	386	0.14	0.11	0.12	–
Chest, child	408	0.17	0.14	0.12	–
Mammography	468	1.91	1.58	0.48	*3

*Withgrid: 3mGy (not classified according to whether a grid wasused or not).

The DR use rates in the 1997 survey were about 15 %, in the 2011 survey were about 95 % (Table 4-1). In the 2011 survey, the higher exposure dose was higher with CR (Table 4-2).

The changes in doses at 10 representative sites in the body between 1974 and 2011 are shown in Table 5. The changes are shown by letting "100" represent the dose (%) at each site in 1974. During the 37-period the dose decreased 76 % for “head, frontal view”, 62 % for "lumbar spine, frontal view", 57 % for 'lumbar spine, lateral view", 4 % for "chest, high voltage", 61 % for "ankle". The dose for mammography decreased to 7 %, less than 1/10 the dose in 1974. No large changes in doses were observed between the 2003 survey and the 2011 survey, but the doses were increased slightly.

Table 4-1. X-ray examinations except mammography

X-ray examinations except mammography	1997	2001	2003	2007	2011
Digital	15.2	48.1	70.3	88.9	95.0
Film/Screen	84.8	51.9	29.7	11.1	5.0

Mammography	1997	2001	2003	2007	2011
Digital	24.1	28.3	34.0	72.8	95.0
Film/Screen	75.9	71.7	66.0	21.7	5.0

[%]

Table 4-2. Cr, FPD and F/S doses

Chest (High voltage)					
CR	n=495	0.24	±	0.34	mGy
FPD	n=111	0.18	±	0.29	mGy
F/S	n=19	0.12	±	0.07	mGy
Total		0.23	±	0.33	mGy

Lumber spine, lateral view					
CR	n=476	10.25	±	6.83	mGy
FPD	n=75	6.03	±	5.02	mGy
F/S	n=15	11.24	±	7.19	mGy
Total		9.68	±	6.71	mGy

Forearm bones					
CR	n=526	0.128	±	0.052	mGy
FPD	n=16	0.134	±	0.242	mGy
F/S	n=13	0.107	±	0.057	mGy
Total		0.127	±	0.122	mGy

Table 5. Exposure Doses for Imaging at 10 Sites in Body
– Changes between 1974 and 2011 –

Exposure sites	1974 Dose	1979 Dose	1989 Dose	1993 Dose	1997 Dose	2001 Dose	2003 Dose	2007 Dose	2011 Dose
Head, frontal view	7.11	5.34 (75)	3.84 (54)	2.49 (35)	2.28(32)	2.18 (31)	2.14 (30)	2.39 (34)	1.68 (24)
Lumber spine, frontal view	8.21	5.99 (73)	4.19 (51)	3.61 (44)	3.63 (44)	3.40 (41)	4.52 (55)	4.06 (49)	3.13 (38)
Lumber spine, lateral view	22.30	15.61 (70)	9.37 (42)	10.48 (47)	11.08 (50)	8.62 (39)	9.85 (44)	11.34 (51)	9.68 (43)
Pelvis, frontal view	6.74	5.12 (76)	3.10 (46)	2.49 (37)	2.42 (36)	2.41 (36)	2.52 (37)	3.12 (46)	2.01 (30)
Chest, high voltage (over 100 kV)	0.23	0.18 (78)	0.13 (57)	0.13 (57)	0.18 (78)	0.21 (91)	0.22 (96)	0.26 (113)	0.22 (96)
Ankle	0.44	0.31 (70)	0.21 (48)	0.17 (39)	0.21 (48)	0.20 (45)	0.19 (43)	0.21 (48)	0.17 (39)
Hip, small child	0.50	0.37 (74)	0.23 (46)	0.12 (24)	0.13 (26)	0.19 (38)	0.14 (28)	0.19 (38)	0.15 (30.0)
Chest, small chiid	0.56	0.39 (69)	0.24 (43)	0.12 (21)	0.18 (32)	0.13 (23)	0.10 (18)	0.18 (32)	0.11 (20)
Guthmann	24.26	16.74 (69)	7.28 (30)	5.58 (23)	6.49 (27)	6.26 (26)	4.30 (18)	5.65 (23)	4.51 (19)
Mammography	22.50	10.35 (46)	4.28 (19)	1.80 (8)	1.42 (6)	1.46 (6)	1.44 (6)	1.61 (7)	1.58((7)

4. Discussion

The doses that have been published internationally as guidance levels were used for the exposure dose evaluation in this study. The doses are expressed as mean breast doses for mammography and as the entrance surface doses for other x-ray examinations. Entrance surface doses are treated as exposure doses in the general diagnostic area.

The survey spanned 37 years. Because it was anticipated that rapid changes in equipment and digitalization had progressed, the goal of determining how exposure doses had changed was in the background of the 2011 survey (Table 5). It was obvious that inverter-type high-voltage generators had come into widespread use. In this situation, the exposure did not decrease even though the irradiation time became shorter. It is important to be sufficiently aware that sometimes the exposure dose does not increase despite lower irradiation conditions as a result of improvements in the equipment.

Table 6. Percentages of units used for generating radiography in 1993 to 2011

	1993	1997	2001	2003	2007	2011
Single phase	18	17	9	8	5	5
Three phase	41	30	16	8	4	4
Inverter type	39	47	70	80	85	85
Constant voltage	1	1	0	0	0	0
Unknown	1	5	5	4	6	6

Examination of the dispersions of the doses at each site exposed in the 2011 survey for Japan as a whole shows that there is a great deal of room for an assessment. Even when the error of the questionnaire survey is included, they are not very small. There was a great difference between the changes in doses in the surveys up to 1993 and the changes since 1993, with not as much fluctuation in the two most recent surveys. This does not appear to have occurred because there has been a lack of effort to reduce the doses, but because the optimal doses have been established to ensure the quality of diagnosis. This is clear even from the example of mammography.

It appears that in the future there will be a transition from examinations that use x-ray film to those that use digital images. Under the present circumstances, the doses are on the same level as those used for film, but since digital image quality increases with the radiation dose, the likelihood of the exposure dose exceeding the dose used for film is a problem. This cannot be resolved by technology alone, and the manufacturers also must make an effort.

With the exception of mammography, the standard doses for each of the exposure sites shown by the IAEA have not been clearly shown in Japan. First the standards should be decided, and then some form of advice should be given to institutions that exceed the standards and to institutions that are far below the standards. Improving both should ultimately make it possible to define the most appropriate dose that ensures image quality. Confronted with this situation it is necessary to immediately set the radiation doses that patients receive in radiological examinations in Japan and the guidance levels[11)].

5. Conclusion

We have reported on the current situation regarding the doses received by patients who undergo diagnostic radiography examinations in Japan based on the results of surveys conducted over a 33-year period. Reductions in the doses were observed, but there is still a good deal of room for improvement. Physicians, dentists, and radiological technologists who are responsible for radiation therapy carry a heavy burden. Faced with the prospect of digitalization in the future, efforts must be made to decrease exposure so that the doses do not become even higher than they are now. We hope that this report has served as an opportunity for you to learn about the current situation regarding the radiation doses to which patients are exposed during diagnostic radiography.

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