



The influence of revised ordinance on radiation protection management in Japanese hospitals: device deployment and involvement of radiology technologists

Arman Nessipkhan¹ · Naoki Matsuda² · Noboru Takamura³ · Noboru Oriuchi⁴ · Hiroshi Ito⁵ · Kazuo Awai⁶ · Takashi Kudo⁷

Received: 21 July 2024 / Accepted: 27 August 2024 / Published online: 28 September 2024

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Abstract

Purpose This study evaluates the impact of the 2021 revision of Japan's Ordinance on the Prevention of Ionizing Radiation Hazards on radiation protection practices, focusing on the deployment of radiation protection devices and the involvement of radiology technologists in Japanese hospitals.

Methods A two-phase web-based questionnaire survey was conducted among hospitals registered as training facilities with the Japanese Radiological Society. The survey included 53 questions covering facility information, radiation worker management, training, and working environment.

Results The use of lens-specific dosimeters significantly increased post-revision ($p=0.005$). Protective eyewear availability showed minor improvements, particularly in angiographic rooms ($p=0.019$). The involvement of radiology technologists remained high in angiographic rooms but showed no significant changes in endoscopy and fluoroscopy rooms. Larger hospitals exhibited better compliance with protective measures, though gaps in resource allocation persisted.

Conclusion The ordinance revision led to significant improvements in dosimeter usage but only minor changes in protective eyewear deployment and technologist involvement.

Keywords Radiation protection · Radiology technologists · Radiation exposure · Dosimeters · Protective devices · Japanese hospitals

Introduction

Occupational radiation exposure among medical workers has become a significant area of concern due to its potential health risks. Medical workers, particularly those who receive more than 5 mSv/year, are at the forefront of this issue. The management of radiation exposure has long been a critical

aspect of the healthcare industry, with the increasing use of ionizing radiation for diagnostic and therapeutic procedures necessitating stringent safety measures [1, 2]. Notably, among Japanese workers exposed to ionizing radiation, those exceeding 20 mSv/year are predominantly medical workers [3]. In response to evolving safety standards and recommendations from the International Commission on Radiological

✉ Arman Nessipkhan
armani_94vg@mail.ru

¹ Department of Radioisotope Medicine, Nagasaki University Graduate School of Biomedical Sciences, Nagasaki University, Sakamoto 1-12-4, Nagasaki 852-8523, Japan

² Department of Radiation Biology and Protection, Atomic Bomb Disease Institute, Nagasaki University, Nagasaki, Japan

³ Department of Global Health, Medicine and Welfare, Atomic Bomb Disease Institute, Nagasaki University, Nagasaki, Japan

⁴ Advanced Clinical Research Center, Fukushima Global Medical Science Center, Fukushima Medical University, Fukushima, Japan

⁵ Department of Radiology and Nuclear Medicine, School of Medicine, Fukushima Medical University, Fukushima, Japan

⁶ Department of Diagnostic Radiology, Graduate School of Biomedical and Health Science, Hiroshima University, Hiroshima, Japan

⁷ Department of Radioisotope Medicine, Atomic Bomb Disease Institute, Nagasaki University, Nagasaki, Japan

Protection (ICRP), the Ministry of Health, Labour and Welfare of Japan (MHLW) made significant revisions to the Ordinance on the Prevention of Ionizing Radiation Hazards in 2021 (MHLW 2021)[4]. Under this revision, the limit for the equivalent dose to the lens was reduced from 150 mSv per year to 100 mSv over a 5 year period (and not to exceed 50 mSv in any one year). The revision also includes some administrative changes such as the method of measurement, calculation of doses, and reporting forms, as well as the addition of a storage period for lens doses. Although this revision focuses on stricter control of lens doses, it is easy to anticipate that it will have an impact on overall radiation management in the medical field given the current situation in which high-dose radiation workers are concentrated in the medical field. These revisions aimed to enhance radiation protection measures and improve radiation management practices in hospitals [1]. However, the impact of this revision on radiation protection in actual medical practice has not been thoroughly investigated. Previously, we examined changes in the exposure doses of medical workers before and after the revision at three university hospitals and found that while actual exposure doses did not change significantly [5], the management practices did. To explore the effectiveness of the revised ordinance, we conducted a questionnaire survey among hospitals registered as “Training Facilities” with the Japanese Radiological Society (JRS). The questionnaire comprises 53 questions (Appendix) and is broadly divided into four parts: (1) basic information about the facility, (2) management of radiation workers, (3) training, and (4) working environment. The scope of the questionnaire was too broad to be covered in a single article. In this article, we report the results of the working environment section of the questionnaire. The aim of this study is to determine the current state of the working environment in real-world hospital settings, to protect medical workers from radiation exposure, and to assess how the revision of the ordinance has influenced improvements in the working environment. This study is supported by a research grant from MHLW (Clinical Research Project for Work-related Diseases, focusing on the health impacts of occupational radiation exposure).

Methods

Study design and participants

This study employed a web-based questionnaire survey to gather data on radiation management practices among medical institutions in Japan. The survey was conducted in two phases: the first phase from January 17 to February 15, 2021, before the ordinance revision became active, and the second phase from December 1, 2021, to January 14, 2022, after the ordinance revision became active. The list of participating

training facilities was obtained from the Japanese Radiological Society (JRS) secretariat with approval from the JRS executive committee.

Questionnaire design

The questionnaire was meticulously designed to capture detailed information on various aspects of radiation management practices. It included both multiple-choice and open-ended questions to gather quantitative and qualitative data. The first phase questionnaire consisted of 48 questions. Following the data collection in the first phase, the radiation safety committee of JRS reviewed the questionnaire and added five additional questions (Q49–53) for the second phase based on their recommendations. The questionnaire was administered in Japanese. The full list of questions is provided in the appendix. This article focuses on the analysis of the deployment of radiation protection/monitoring devices and human resources in the working environment. As shown, the total number of questions was too large, and the scope was too broad to analyze in one article. In this article, we analyzed the deployment of devices for radiation protection/monitoring and human resources in the working environment. Following are the questions evaluated in this article (the full list of questions is listed in the supplement). Q49–53 was only included in the questionnaire in 2022.

Q2: Type of hospital

1. University Hospital / 2. General Hospital / 3. Specialty Hospital (e.g., Cardiovascular Center) / 4. Others.

Q3: Number of beds

1. 600 or more / 2. 400 to less than 600 / 3. 200 to less than 400 / 4. 50 to less than 200 / 5. Less than 50

Q39: Are you using radiation measurement devices specifically for the lens worn inside radiation protective glasses for exposure management?

1. Not using → Please answer Q40, then proceed to Q41. / 2. Using → Proceed to Q41. (Q40: Free answer for conditions under which lens-specific dosimeters are used.)

Q41: Are radiation protective glasses available in all X-ray rooms where vascular IVR is performed?

1. Sufficiently available / 2. Mostly available / 3. Significantly insufficient / 4. Not available at all / 5. Not applicable

Q42: Are radiation protective glasses available in endoscopy rooms where X-ray equipment is installed?

1. Sufficiently available / 2. Available but not sufficient / 3. Not available at all / 4. Not applicable / Q43: Are radiation-protective glasses provided in general X-ray fluoroscopy rooms?

(1–4: Same options as Q43)

Q44: Are radiation protective glasses provided in operating rooms?

(1–4: Same options as Q43)

Q45: The approximate rate of involvement of radiology technologists in vascular IVR.

1. 100% / 2. More than 90% / 3. More than 80% / 4. More than 60% / 5. More than 40% / 6. More than 20% / 7. Less than 20% / 8. Not applicable

Q46: The approximate rate of involvement of radiology technologists in endoscopic room using X-ray (e.g., ERCP).

(1–8: Same options as Q45)

Q47: The approximate rate of involvement of radiology technologists in the endoscopic room using a nonvascular IVR fluoroscopy room.

(1–8: Same options as Q45)

Q48: The approximate rate of involvement of radiology technologists in the operation room using X-ray fluoroscopy.

(1–8: Same options as Q45)

Q49: Who bears the cost of purchasing radiation protective glasses? (multiple answers allowed)

1. Hospital/Facility / 2. Department/Division / 3. Individual user / 4. Not using

Q50: Are ceiling-mounted protective shields installed in all X-ray rooms where vascular IVR is performed?

1. All installed / 2. Mostly installed / 3. Partially installed / 4. Not installed at all / 5. Not applicable

Q51: Are radiation protective drapes for X-ray equipment available in endoscopy rooms where X-ray equipment is installed?

1. Available / 2. Not available / 3. Not applicable

Q52: Do you display radiation dose distribution maps inside or outside of X-ray rooms where vascular IVR is performed?

1. Yes / 2. No / 3. Not applicable

Q53: Do you display the protective effects of ceiling-mounted radiation shields and protective clothing inside or outside the X-ray room?

1. Yes / 2. No / 3. Not applicable

Data analysis

The collected data were meticulously analyzed to compare before and after the ordinance revision. The relationship between hospital size (bed number) and each answer was also analyzed. Due to the pronounced departure of the data from a normal distribution, all analyses utilized non-parametric methods. For inferential statistics, the Mann–Whitney *U* test was used to compare radiation management practices between two independent groups (before and after the ordinance revision). The Pearson's chi-square test was employed to examine relationships between categorical variables, such as the type of hospital and compliance with radiation management practices. Statistical analyses were performed using JMP Pro 17. A *p* value of less than 0.05 was considered statistically significant for all tests.

Ethical considerations

The study was conducted in accordance with ethical guidelines and received approval from the ethics committee of the Nagasaki University Graduate School of Biomedical Sciences (No. 20082802). Participation was voluntary, and the confidentiality and anonymity of the participants were maintained throughout the study.

Results

Basic information

In the first phase, URLs to answer questionnaires were sent to 895 hospitals for which the JRS office provided a list, with a response rate of 37.5% (336 hospitals). In the second phase, URLs to answer questionnaires were sent to 774 hospitals, with a response rate of 30.9% (239 hospitals). Despite the slight decrease in the response rate in the second phase, the study gathered comprehensive data from a significant number of institutions, providing a robust basis for analysis. There was a slight decrease in the percentage of general hospitals and the percentage of hospitals with 600–400 beds after the revision, although it does not reach statistical significance (for the type of hospital: $p = 0.494$, for the size of the hospital: $p = 0.056$). Table 1 provides an overview of the participating institutions categorized by type and number of beds. The majority of respondents were from general hospitals, with university hospitals and specific centers made up the rest. This distribution remained relatively consistent across both phases of the survey.

Table 1 Type of institute and bed number

	FY2020 (before)		FY2021 (after)	
	<i>n</i>	(%)	<i>n</i>	(%)
Type of institute				
University hospital	53	15.80	45	18.80
General hospital	247	73.50	166	69.50
Specific center	15	4.50	8	3.40
Others	21	6.30	20	8.40
Bed number				
Over 600	91	27.10	73	30.50
600–400	127	37.80	70	29.30
400–200	104	31.00	76	31.80
200–50	13	3.90	20	8.40
Less than 50	1	0.30	0	0.00
Sum	336		239	

Use of *lens*-specific dosimeter

One of the most significant improvements observed post-revision was the increased use of lens-specific dosimeters (p value = 0.005) (Fig. 1). Prior to the revision, only a small percentage of facilities used these dosimeters, but their usage significantly increased afterward. More than half of the facilities use lens-specific dosimeters after the revision, indicating a positive effect of the ordinance revision towards better management of radiation monitoring of the lens.

Availability of protective eyewear

In angiographic room

We analyzed the availability of protective eyewear in four specific conditions: the angiographic room involved in IVR, the endoscopy room using X-ray, the fluoroscopy room, which was not involved in IVR procedures, and the operating room using X-ray. In the angiographic room which

Comparison of Radiation Management Practices Among Medical Institutions in Japan

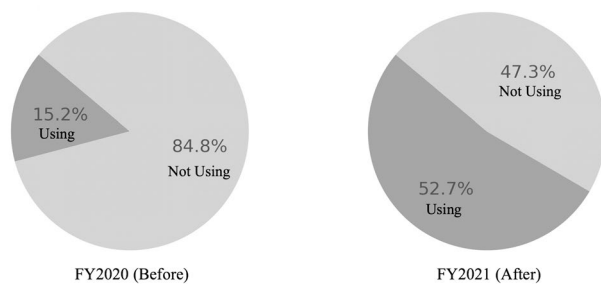


Fig. 1 Usage of lens-specific dosimeter

is shown in Table 2, there was a slight but significant difference between before and after the revision of the ordinance ($p = 0.019$). This difference was due to an increase in the ratio of facilities responding, “About enough” and a decrease in the ratio of facilities responding, “Not quite enough”. When we analyzed the change in each group of hospital size, only the group of hospitals with 400–200 beds showed a significant difference between before and after the revision ($p = 0.0383$). There was no relationship between the answer and hospital type.

In the endoscopy room

In the endoscopy room using X-ray, there was an equivocal tendency of improvement, although it did not reach a statistically significant difference ($p = 0.058$). In hospitals with over 600, 600–400, and 400–200 beds, the number of institutions that answered “Not at all” decreased slightly after the revision. However, a statistical analysis comparing the before and after results in each group of hospital size showed no significant differences (Table 3).

In the fluoroscopy room

In the fluoroscopy room, which was not involved in IVR procedures, there was no significant difference between the periods before and after the revision ($p = 0.300$). No group of hospital size showed a significant difference between the periods before and after the revision (Table 3).

In the operating room

In the operating room using X-ray, there was an equivocal tendency of improvement, although it did not reach a

Table 2 Availability of protective eyewear in angiographic room

		Hospital size	Enough (row %)	About enough (row %)	Not quite enough (row %)	Not at all (row %)	Total
Angiographic room	Before	Over 600	40 (43.9%)	41 (45.1%)	10 (10.9%)	0 (0.0%)	91
		600–400	54 (42.6%)	54 (42.6%)	17 (13.4%)	2 (1.6%)	127
		400–200	37 (35.6%)	42 (40.4%)	23 (22.1%)	2 (1.9%)	104
		200–50	4 (30.8%)	4 (30.8%)	3 (23.1%)	2 (15.4%)	13
		Less 50	1 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1
		Total	136 (40.5%)	141 (41.9%)	53 (15.8%)	6 (1.8%)	336
	After	Over 600	31 (42.5%)	39 (53.4%)	3 (4.1%)	0 (0.0%)	73
		600–400	32 (45.8%)	31 (44.3%)	7 (10.0%)	0 (0.0%)	70
		400–200	23 (31.6%)	43 (58.9%)	6 (8.2%)	1 (1.4%)	73
		200–50	23 (31.6%)	5 (33.3%)	4 (26.7%)	0 (0.0%)	15
		Less 50	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0
		Total	92 (39.9%)	118 (51.1%)	20 (8.7%)	1 (0.4%)	231

Table 3 Availability of protective eyewear in Endoscopic, fluoroscopic and operation room

		Hospital size	Enough (Row %)	About enough (Row %)	Not at all (Row %)	Total
Endoscopic room	Before	Over 600	37 (40.7%)	43 (47.3%)	11 (12.1%)	91
		600–400	63 (49.6%)	55 (43.3%)	9 (7.1%)	127
		400–200	40 (38.5%)	50 (48.1%)	14 (13.5%)	104
		200–50	2 (15.4%)	6 (46.2%)	5 (38.5%)	13
		Less 50	0 (0.0%)	1 (100.0%)	0 (0.0%)	1
		Total	142 (42.3%)	155 (46.1%)	39 (11.6%)	336
	After	Over 600	28 (39.4%)	39 (54.9%)	4 (5.6%)	71
		600–400	35 (57.4%)	23 (37.7%)	3 (4.9%)	61
		400–200	31 (46.3%)	32 (47.8%)	4 (5.9%)	67
		200–50	5 (33.3%)	9 (60.0%)	1 (6.7%)	15
		Less 50	0 (0.0%)	0 (0.0%)	0 (0.0%)	0
		Total	99 (46.3%)	103 (48.1%)	12 (5.6%)	214
Fluoroscopic room	Before	Over 600	26 (28.6%)	54 (59.3%)	11 (12.1%)	91
		600–400	43 (33.9%)	68 (53.5%)	16 (12.6%)	127
		400–200	31 (29.8%)	52 (50.0%)	21 (20.2%)	104
		200–50	1 (7.7%)	9 (69.2%)	3 (23.1%)	13
		Less 50	0 (0.0%)	1 (100.0%)	0 (0.0%)	1
		Total	101 (30.1%)	184 (54.8%)	51 (15.2%)	336
	After	Over 600	26 (35.6%)	44 (60.3%)	3 (4.1%)	73
		600–400	33 (47.1%)	29 (41.4%)	8 (11.4%)	70
		400–200	19 (26.0%)	43 (58.9%)	11 (15.1%)	73
		200–50	5 (27.8%)	7 (38.9%)	6 (33.3%)	18
		Less 50	0 (0.0%)	0 (0.0%)	0 (0.0%)	0
		Total	83 (35.5%)	123 (52.6%)	28 (11.9%)	234
Operation room	Before	Over 600	13 (14.3%)	44 (48.4%)	34 (37.4%)	91
		600–400	21 (16.5%)	64 (50.4%)	42 (33.1%)	127
		400–200	17 (16.4%)	40 (38.5%)	47 (45.2%)	104
		200–50	1 (7.7%)	6 (46.2%)	6 (46.2%)	13
		Less 50	0 (0.0%)	1 (100.0%)	0 (0.0%)	1
		Total	52 (15.5%)	155 (46.1%)	129 (38.4%)	336
	After	Over 600	18 (25.0%)	41 (56.9%)	13 (18.1%)	72
		600–400	19 (27.1%)	28 (40.0%)	23 (32.9%)	70
		400–200	12 (16.00%)	31 (41.3%)	32 (42.7%)	75
		200–50	5 (27.78%)	5 (27.8%)	8 (44.4%)	18
		Less 50	0 (0.0%)	0 (0.0%)	0 (0.0%)	0
		Total	54 (22.9%)	105 (44.7%)	76 (32.3%)	235

statistically significant difference overall ($p=0.058$). Statistical analysis comparing the results before and after the revision in each group of hospital size revealed that only hospitals with over 600 beds showed a significant difference ($p=0.016$). This group demonstrated a decreased ratio of institutions answering, “Not at all” and an increased ratio of those answering “Enough” (Table 3).

In summary, regarding the deployment of eye protective equipment, there was some significant but minor improvement found between before and after the revision. Although some association with hospital size was observed for this improvement, the relationship between hospital size and

improvement was not clear due to the small degree of improvement itself.

Involvement of radiology technologists in radiology working environments

We analyzed the involvement of radiology technologists in procedures across the angiographic room involved in IVR, the endoscopy room using X-ray, the fluoroscopy room, which was not involved in IVR procedures, and the operating room using X-ray.

In angiographic room

There was no significant difference in the involvement of radiology technologists before and after the revision of the ordinance ($p=0.236$). When we analyzed the same data in relation to the size of the hospitals, we found a significant relationship between hospital size only before the revision. This trend is due to the fact that the percentage of “100%” was slightly lower among hospitals with more than 600 beds and those with less than 200 beds than among other hospitals. However, the majority of facilities other than those with less than 200 beds responded “100%”. In the survey after the revision, most facilities responded “100%”, so the relationship with the number of beds has completely disappeared ($p=0.956$) (Table 4).

In the endoscopy room

In the endoscopy room, there was no significant difference in the involvement of radiology technologists between before and after the revision of the ordinance ($p=0.712$). About half of the hospitals reported “100%” involvement, while approximately 30% reported “less than 30%” involvement, indicating a binary pattern of distribution. Although there is no significant difference between the pre- and post-revision periods, an intriguing pattern was observed when analyzing the data based on hospital size. Larger hospitals tend to have a lower rate of involvement of radiology technologists. This trend is consistent in both pre- ($p=0.021$) and post-revision periods ($p=0.003$), with no observed change or improvement (Fig. 2) (Table 4).

In the fluoroscopy room

In the fluoroscopy room, there was no significant difference in the involvement of radiology technologists between before and after the revision of the ordinance ($p=0.640$). About half of the hospitals reported “100%” involvement, with the remaining responses distributed relatively evenly across “over 90%” to “less than 20%”. A similar pattern observed in the endoscopy room was also observed in the fluoroscopy room, where larger hospitals tend to have a smaller percentage of “100%” involvement of radiology technologists. This pattern is consistent both before and after the revision, although it does not reach statistical significance as found in the endoscopy room ($p=0.484$ for before, $p=0.376$ for after) (Table 4).

In the operating room

In the operating room, there was no significant difference in the involvement of radiology technologists between before and after the revision of the ordinance ($p=0.946$). About

half of the hospitals reported “100%” involvement, with the remaining responses distributed relatively evenly across “over 90%” to “less than 20%”. No significant relationship was found between the involvement of radiology technologists and hospital size in the operating room. Regardless of hospital size, about half of the facilities reported “less than 20%” involvement. This indicates that the involvement of radiology technologists in operating rooms where X-rays are used is generally low, independent of hospital size or the revision status ($p=0.552$ and $p=0.590$ for before and after, respectively) (Table 4).

In summary, regarding the involvement of radiology technologists, the tendency was clearly different from the tendency of deployment of eye protective equipment. When analyzing the relationship between this pattern and the size of the facilities, no significant changes were found between the pre- and post-revision periods. However, an interesting relationship between size and involvement of radiology technologists was noted in the endoscopy room, which indicates that large hospitals may have some problems in the management of radiology protection, which is common and not improved after the revision.

Questions which performed only after revision

From Q49 to 53 was only performed in the survey after revision.

Who bears the cost of purchasing radiation protective glasses? (Q49: multiple answers allowed) (Table 5)

We analyzed the relationship between hospital size and the payer of protective eyewear. We could not find any significant relationship between hospital size and institutions that answered, “Paid by Hospital/University” ($p=0.264$) or “Paid by Department” ($p=0.234$). Only the institutions that answered “Paid by Individual” showed a threshold relationship with hospital size ($p=0.049$).

Usage of ceiling-mounted protective shields in vascular IVR room (Q50, Table 6)

A significant majority have ceiling-mounted protective shields installed, with variation across hospital sizes ($p=0.002$). More than 75% of institute uses ceiling-mounted shields except for small hospital with 200–50 bed.

Usage of radiation protective drapes in endoscopy room (Q51, Table 7)

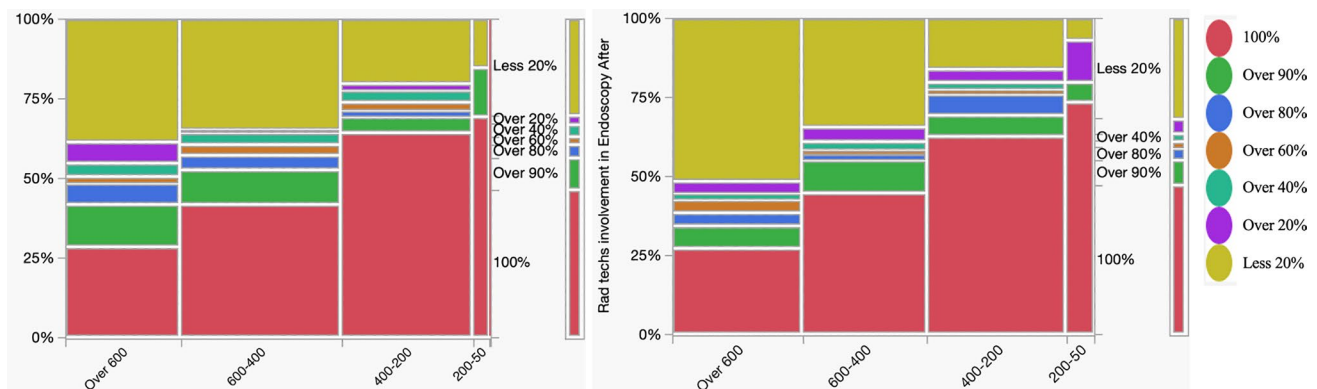
Most respondents reported having protective drapes, especially in larger hospitals, with statistically significant differences across hospital sizes ($p=0.001$). This indicates that the

Table 4 Involvement of radiology technologists in radiology working environments

Group	100%	Over 90%	Over 80%	Over 60%	Over 40%	Over 20%	Less 20%	Total
Angio rad tech								
Before								
Over 600	79 (86.8%)	7 (7.7%)	5 (5.5%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	91
600–400	115 (90.6%)	4 (3.2%)	2 (1.6%)	2 (1.6%)	2 (1.6%)	0 (0.0%)	2 (1.6%)	127
400–200	97 (93.3%)	1 (0.9%)	0 (0.0%)	1 (0.9%)	0 (0.0%)	1 (0.9%)	4 (3.9%)	104
200–50	9 (69.2%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	4 (30.8%)	13
Less 50	1 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1
Total	301 (89.6%)	12 (3.6%)	7 (2.1%)	3 (0.9%)	2 (0.6%)	1 (0.3%)	10 (2.9%)	336
After								
Over 600	65 (89.0%)	6 (8.2%)	1 (1.4%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (1.4%)	73
600–400	62 (88.6%)	5 (7.1%)	1 (1.4%)	0 (0.0%)	1 (1.4%)	0 (0.0%)	1 (1.4%)	70
400–200	68 (93.2%)	3 (4.1%)	1 (1.4%)	0 (0.0%)	0 (0.0%)	1 (1.4%)	0 (0.0%)	73
200–50	14 (93.3%)	1 (6.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	15
Less 50	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0
Total	209 (90.5%)	15 (6.5%)	3 (1.3%)	0 (0.0%)	1 (0.4%)	1 (0.4%)	2 (0.9%)	231
Fluoro rad tech								
Before								
Over 600	35 (38.5%)	23 (25.3%)	13 (14.3%)	7 (7.7%)	5 (5.5%)	1 (1.1%)	7 (7.7%)	91
600–400	61 (48.0%)	27 (21.3%)	12 (9.5%)	7 (5.5%)	6 (4.7%)	7 (5.5%)	7 (5.5%)	127
400–200	57 (54.8%)	13 (12.5%)	12 (11.5%)	3 (2.9%)	6 (5.8%)	3 (2.9%)	10 (9.6%)	104
200–50	8 (61.5%)	2 (15.4%)	0 (0.0%)	0 (0.0%)	1 (7.7%)	0 (0.0%)	2 (15.4%)	13
Less 50	0 (0.0%)	1 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1
Total	161 (47.9%)	66 (19.6%)	37 (11.0%)	17 (5.1%)	18 (5.4%)	11 (3.3%)	26 (7.7%)	336
After								
Over 600	25 (34.3%)	18 (24.7%)	9 (12.3%)	6 (8.2%)	4 (5.5%)	2 (2.7%)	9 (12.3%)	73
600–400	29 (41.4%)	19 (27.1%)	9 (12.9%)	4 (5.7%)	3 (4.3%)	0 (0.0%)	6 (8.6%)	70
400–200	44 (58.7%)	14 (18.7%)	9 (12.0%)	2 (2.7%)	1 (1.3%)	1 (1.3%)	4 (5.3%)	75
200–50	12 (70.6%)	2 (11.8%)	1 (5.9%)	1 (5.9%)	0 (0.0%)	0 (0.0%)	1 (5.9%)	17
Less 50	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0
Total	110 (46.8%)	53 (22.6%)	28 (11.9%)	13 (5.5%)	8 (3.4%)	3 (1.3%)	20 (8.5%)	235
Group	1	Over 90%	Over 80%	Over 60%	Over 40%	Over 20%	Less 20%	Total
Endoscope rad tech								
Before								
Over 600	26 (28.6%)	12 (13.2%)	6 (6.6%)	2 (2.2%)	4 (4.4%)	6 (6.6%)	35 (38.5%)	91
600–400	53 (41.8%)	14 (11.0%)	6 (4.7%)	4 (3.2%)	5 (3.9%)	1 (0.8%)	44 (34.7%)	127
400–200	67 (64.4%)	5 (4.8%)	2 (1.9%)	3 (2.9%)	4 (3.9%)	2 (1.9%)	21 (20.2%)	104
200–50	9 (69.2%)	2 (15.4%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (15.4%)	13
Less 50	1 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1
Total	156 (46.4%)	33 (9.8%)	14 (4.2%)	9 (2.7%)	13 (3.9%)	9 (2.7%)	102 (30.7%)	336
After								
Over 600	19 (27.1%)	5 (7.1%)	3 (4.3%)	3 (4.3%)	1 (1.4%)	3 (4.3%)	36 (51.4%)	70
600–400	30 (44.8%)	7 (10.5%)	1 (1.5%)	1 (1.5%)	2 (2.3%)	3 (4.5%)	23 (34.3%)	67
400–200	47 (62.7%)	5 (6.7%)	5 (6.67%)	1 (1.3%)	2 (2.7%)	3 (4.0%)	12 (16.0%)	75
200–50	11 (73.3%)	1 (6.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (13.3%)	1 (6.7%)	15
Less 50	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0
Total	107 (47.1%)	18 (7.9%)	9 (3.9%)	5 (2.2%)	5 (2.2%)	11 (4.9%)	72 (31.7%)	227
Ope rad tech								
Before								
Over 600	11 (12.1%)	8 (8.8%)	7 (7.7%)	7 (7.7%)	8 (8.8%)	7 (7.69%)	43 (47.25%)	91

Table 4 (continued)

Group	1	Over 90%	Over 80%	Over 60%	Over 40%	Over 20%	Less 20%	Total
600–400	24 (18.9%)	8 (6.3%)	9 (7.1%)	6 (4.7%)	8 (6.3%)	13 (10.24%)	59 (46.46%)	127
400–200	18 (17.3%)	13 (12.5%)	6 (5.8%)	6 (5.8%)	7 (6.7%)	5 (4.81%)	49 (47.12%)	104
200–50	6 (46.2%)	2 (15.4%)	0 (0.0%)	0 (0.0%)	1 (7.7%)	0 (0.00%)	4 (30.77%)	13
Less 50	1 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.00%)	0 (0.00%)	1
Total	60 (17.9%)	31 (9.2%)	22 (6.6%)	19 (5.8%)	24 (7.1%)	25 (7.44%)	155 (46.1%)	336
After								
Over 600	9 (12.5%)	6 (8.3%)	5 (6.9%)	5 (6.9%)	8 (11.1%)	7 (9.7%)	32 (44.4%)	72
600–400	13 (19.1%)	4 (5.9%)	4 (5.9%)	5 (7.4%)	5 (7.4%)	6 (8.8%)	31 (45.6%)	68
400–200	21 (28.4%)	5 (6.8%)	3 (4.1%)	4 (5.4%)	3 (4.1%)	5 (6.8%)	33 (44.6%)	74
200–50	6 (35.3%)	3 (17.7%)	0 (0.0%)	0 (0.0%)	1 (5.9%)	0 (0.0%)	7 (41.2%)	17
Less 50	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0
Total	49 (21.2%)	18 (7.8%)	12 (5.2%)	14 (6.1%)	17 (7.4%)	18 (7.8%)	103 (44.6%)	231

**Fig. 2** Radiology technologist's involvement**Table 5** Distribution of responsibility for purchasing radiation protective glasses by hospital size

Hospital size	Payed by hospital/ university	Payed by department	Payed by individual	Not using protec- tive eyewear	Total
Over 600	64 (87.7%)	4 (5.5%)	30 (41.1%)	0 (0.0%)	73
600–400	60 (85.7%)	2 (2.9%)	27 (38.6%)	0 (0.0%)	70
400–200	65 (85.5%)	0 (0.0%)	23 (30.3%)	0 (0.0%)	76
200–50	14 (70.0%)	1 (5.0%)	2 (10.0%)	1 (5.0%)	20
Less 50	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0
Total	203	7	82	1	239

This question accepts multiple answer, thus sum of the number in all cells exceeds total number

workers working in smaller hospitals especially bed size below 200 tend to poorly protected compared to large hospitals.

Display of radiation dose distribution diagrams inside or outside IVR room (Q52, Table 7)

More than half of the larger hospitals use dose maps, but there is a significant variation with smaller hospitals less

likely to use them ($p = 0.004$). This suggests that larger hospitals are more likely to use dose distribution diagrams. However, even among large hospitals, more than a quarter of the facilities do not use it.

Table 6 Usage of ceiling-mounted protective shields in vascular IVR rooms by hospital size

Hospital size	All equipped (count, row %)	Mostly equipped (count, row %)	Partially equipped (count, row %)	Not equipped (count, row %)	Total
Over 600	56 (76.7%)	13 (17.8%)	4 (5.5%)	0 (0.0%)	73
600–400	58 (82.9%)	5 (7.1%)	6 (8.6%)	1 (1.4%)	70
400–200	55 (76.4%)	6 (8.3%)	9 (12.5%)	2 (2.8%)	72
200–50	7 (50.0%)	1 (7.1%)	3 (21.4%)	3 (21.4%)	14
Less 50	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0
Total	176	25	22	6	229

Table 7 Q51, Q52 and Q53

Hospital size	Yes (Q51)	Total (Q51)	Yes (Q52)	Total (Q52)	Yes (Q53)	Total (Q53)
Over 600	59 (85.5%)	69	45 (61.6%)	73	31 (42.5%)	73
600–400	43 (65.2%)	66	34 (49.3%)	69	19 (27.9%)	68
400–200	43 (63.2%)	68	21 (28.8%)	73	12 (16.0%)	75
200–50	6 (42.9%)	14	4 (26.7%)	15	3 (18.8%)	16
Less 50	0 (0.0%)	0	0 (0.0%)	0	0 (0.0%)	0

Display showing the protective effects of ceiling-mounted radiation shields and protective clothing inside or outside the X-ray room (Q53, Table 7)

Only about 28% of respondents use such diagrams, with significant differences across hospital sizes ($p=0.003$), indicating that although larger hospitals tended to have these displays, it was still clear that the use of such displays are poor, with less than half of the hospitals using the displays.

These findings highlight significant variations in the implementation and utilization of radiology protection measures across hospitals of different sizes, with larger hospitals generally providing more resources and protections.

Discussion

Our comprehensive study provides significant insights into the impact of the revised Ordinance on the Prevention of Ionizing Radiation Hazards on radiation protection practices in Japanese hospitals. This article focuses on the deployment of equipment such as lens-specific dosimeters, protective eyewear, and the involvement of radiology technologists. Major findings from our survey can be summarized as follows: (1) clear improvement in the usage of lens-specific dosimeters after the revision; (2) minor improvement in the deployment of protective eyewear; and (3) no improvement in human resource deployment, with some clear relationships with hospital size. Our study evaluates the real-world effects of these regulatory changes on the deployment of protective devices and the involvement of radiology technologists in various hospital environments.

Deployment of *lens*-specific dosimeters

One of the most noteworthy outcomes of the ordinance revision is the increased utilization of lens-specific dosimeters. Before the revision, the use of these dosimeters was limited, but post-revision, over half of the surveyed facilities adopted these protective devices. The ordinance, revised in 2021 by the Ministry of Health, Labour and Welfare (MHLW) of Japan [4], was intended to elevate safety standards and enhance the management of radiation exposure, particularly in medical settings. Since one of the goals of this revision was to conform to the ICRP's lowering of lens dose limits, it is natural that improvements regarding lens dose limits should occur. There was a clear trend of increased usage of personal dosimeters for head and neck observed recent 10 years [6]. Our present finding indicates that the trend of estimation of lens dose moving forward to more precise measurements.

According to a study on the dosimetry of occupational eye lens dose using a novel direct eye dosimeter during interventional radiology procedures, the use of specialized dosimeters allows for more accurate measurement of eye radiation dose, which is crucial for compliance with new safety standards [7]. Additionally, a review of the basis and impact of ICRP recommendations highlights the importance of adhering to revised dose limits to protect medical workers' eye lenses [8]. Our findings which showed clear improvement of the usage of lens-specific dosimeter may reflect a change in hospital behavior with respect to strict adherence to revised lens dose limits.

Deployment of protective devices

On the other hand, the improvement in the use of protective eyewear was not as clear as the improvement in the use of lens-specific dosimeters. Only in the angiography room did the improvement reach significance. In the endoscopy room and the operating room, there was a trend toward improvement after the revision, although it did not reach statistical significance. It is difficult to explain why the clear improvement seen with the lens-specific dosimeters was not seen with protective eyewear. We speculate that cost and who pays for the protective eyewear may influence its low usage. The survey was conducted during the COVID-19 pandemic. Since protective eyewear is in direct contact with the skin, shared use might be avoided from an infection control perspective. Therefore, survey after revision, a question of asking who bears the burden of purchasing protective eyewear was added. However, we could not find any relationship between the payer and the usage of protective eyewear in any of the angiographic, endoscopy, fluoroscopy and operation rooms.

The physical burden associated with the use of heavy protective eyewear may be a factor in the lack of improvement in the use of the protective eyewear found in the present survey. A review on minimizing radiation exposure during endoscopic retrograde cholangiopancreatography (ERCP) highlights that adequate protection for medical personnel requires various protective devices, including protective eyewear [9]. Additionally, the effectiveness of the equipment without physical burden (Zero Gravity radiation protection system) during endovascular aneurysm repair (EVAR) procedures shows that innovative protective devices can offer significant advantages, although user experience and ergonomic factors also play a crucial role [10]. Improvements and innovations in more worker-friendly protective equipment should be necessary to promote the use of protective equipment in hospitals.

Involvement of radiology technologists

The involvement of radiology technologists in radiology procedures varied across different hospital settings and showed mixed results post-revision. In angiographic rooms, a slight but statistically significant improvement was noted, particularly in hospitals with 200–400 beds. However, the overall involvement remained high (100%) in most hospitals both before and after the revision, indicating that the ordinance had a limited additional impact in this already well-managed area.

In endoscopy rooms, no significant improvements were observed, and larger hospitals continued to report lower technologist involvement rates. This persistent trend suggests systemic issues within larger hospitals that may hinder

the effective management and allocation of technologists to endoscopic procedures. We believe this should be one of the most important radiation safety findings in our survey. In the other study which we conducted on occupational radiation dose in three university hospitals, we found that nurses working in the endoscopy room had significantly higher radiation doses compared to other workplaces such as the radiology department and ER/ICU [5]. There is no direct evidence to link these findings. However, it is natural to assume that the low involvement of radiology technologists correlates with the high radiation dose of nurses working in the endoscopy room.

A study on the difference in the level of patient treatment safety analyzed by the years of experience of radiology technologists found that more experienced technologists tend to be more concerned about patient safety, which may influence compliance with radiation protection standards [11]. Additionally, a survey on radiation training and protection practices among US therapeutic endoscopists revealed that formal training in fluoroscopy and radiation protection is not widely emphasized, indicating a need for improved education and training [12]. Considering these facts, it is crucial to involve radiology technologists in every working place which uses X-ray, including the endoscopy room. Involvement of radiology technologists in radiation protection practices is vital to reducing radiation doses, not only for radiology technologists themselves but also for all occupations. However, the requirement for years of experience may discourage younger technologists from active participation. This issue highlights the lack of an established and comprehensive radiation protection education system for young radiology technologists. Considering that the radiation doses of radiologists as a group were higher than those of other occupational groups, the establishment of a system to educate and train young technologists as a group, for example through activities at academic societies, is essential. Addressing this educational gap could encourage more young technologists to engage in radiation safety practices, ultimately enhancing overall compliance and safety standards.

Cost and resource allocation

The financial burden of implementing radiation protective measures reveals notable differences across hospital sizes. Data shows a significant relationship ($p=0.049$) between hospital size and the incidence of “pay private,” where individuals cover the cost of protective equipment themselves. Contrary to initial assumptions, the ratio of “pay private” instances is larger in larger hospitals compared to smaller hospitals. However, in Q50–53 which asked usage of protective devices such as ceiling-mounted shields, protective drapes, dose distribution diagrams and diagrams showing

protective effects, there is a clear tendency that the larger the hospital size, better the usage of such device/information. It may indicate better cost/resource support in larger hospitals.

A radiation safety audit in a high-volume nuclear medicine department highlighted that adequate radiation protection measures and resource allocation are essential even in high-throughput environments [13]. Furthermore, a study on occupational radiation exposure among medical personnel in university and general hospitals in Japan revealed that workers in general hospitals experience slightly higher radiation doses compared to those in university hospitals, emphasizing the need for better resource allocation and protective measures in general hospitals [1]. The resource disparities between larger and smaller hospitals underscore the necessity for targeted support to ensure uniform compliance with radiation safety standards. Addressing these disparities is crucial for achieving comprehensive radiation protection for medical workers across all hospital sizes. Future research should focus on developing strategies to enhance radiation safety in smaller hospitals and evaluate the long-term effects of the revised ordinance on occupational radiation exposure and health outcomes among medical workers.

It is of interest to note that the majority of hospitals answered they are using physical protection measures such as ceiling-mounted shields, and protective drapes, but less answered usage of providing educational information such as dose distribution diagrams and diagrams showing protective effects. A questionnaire survey on radiation protection education in hospitals underscores the importance of ongoing educational programs to raise awareness and improve radiation protection practices [3, 14]. It is of interest that the level of knowledge in radiation protection may be not satisfactory in hospitals and the level of experience and education can affect the attitude of medical professionals [14]. Providing information and education requires human effort but is less costly than providing physical measures. Our results suggest that there is still much room for improvement in providing information and education and that this could significantly improve radiation management of radiology working environment in hospitals.

This study has several limitations. First, this study was conducted as a questionnaire survey using web-based methods. It is not free from the bias such as non-response and selection bias. There is no statistically significant difference in the distribution of hospital size and type between the surveys before and after revision. However, minor differences such as non-response from hospitals less than 50 bed after revision, slightly decreased ratio of hospitals between 600 and 400 bed size, decreased response rate on the survey after revision. Second, the survey was conducted separately twice before and after revision. Thus, analysis of direct change in each hospital was not performed. Thirdly, the response rate is not as high as approximately 30%. Therefore, it is not

certain that the results of the survey accurately reflect reality. Fourth, a notable limitation of this study is the response rate and the number of facilities that participated in both the pre- and post-revision surveys. Only 120 facilities, which account for roughly one-third of the total responses before the revision and about half of the responses after the revision, provided data for both periods. This discrepancy raises concerns about the representativeness and consistency of the responses. It is possible that the differences observed between the pre- and post-revision periods may be influenced by the varying composition of the responding facilities. Despite these non-negligible limitations, the survey presented in this study should provide valuable information for future management of radiation in healthcare facilities and provide useful information for improvement.

Conclusion

This study highlights the importance of ongoing efforts to advance radiation safety in medical settings. The findings provide a foundation for further policy enhancements and strategic resource allocation to improve radiation protection practices nationwide.

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s11604-024-01653-w>.

Acknowledgements We are deeply grateful to the Japan Radiology Society (JRS), especially the Committee on Radiation Safety, for allowing us to conduct the survey at JRS educational facilities, and to the members in JRS educational facilities for their cooperation in the survey.

Funding This study was funded by the Japan Ministry of Health, Labour, and Welfare study grant “Grant for clinical study for occupational disease. Grant number: 190701-01). We deeply appreciate the support of MHLH.

Declarations

Conflict of interest The authors of this article declare that there is no conflict of interest that could influence the content or interpretation of the information presented herein.

Ethical approval The study protocol was reviewed by the Ethics Committee of Nagasaki university graduate school of biomedical sciences. Written informed consent was waived. (Approval No: 20082802).

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