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Journal of JART
—English edition—

2021

The Japan Association of Radiological Technologists

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Note: The contents of this magazine are those that have been published in JART magazine.

Overview of the Japan Association of Radiological Technologists

The Japan Association of Radiological Technologists, a public interest incorporated association under the jurisdiction of the Ministry of Health, Labour and Welfare, was established in 1947 with the purpose of contributing to the health of citizens through raising the professional ethics of members, improving and furthering the study of medical radiology and medical radiological technology, and enhancing public health.

In light of the startling progress being made in the fields of image diagnostics and radiation therapy where radiological technologists work, it is necessary to stay constantly aware of the latest know-how and technology. JART collaborates with other certification agencies to enhance the capacity of all radiological technologists in general through providing lifelong learning seminars, short courses, academic conferences and numerous other learning opportunities. We believe that such activities constitute our obligation as medical professionals to the general public.

As the only medical profession that has “radiological” in its name, we strive to limit medical exposure, to raise the standing of our profession, and to realize a profession of specialist technologists that can be advertised. And we are committed to promoting services with you all for the provision of safe and secure medical care.

general principles

We will render our services to those in need of health care.

We will act as individual members of a health care team.

We will perform our duties in our field of specialty.

We will continue to study for the benefit of mankind.

We will respect and practice the policy of informed consent.

Regarding Publication of the English Edition

UEDA Katsuhiko (President)

The journal of the JART English version issues every year. It has a favorable reception for we members of the world and general people. As well as this issue, 12 articles to be useful for radiological technologists are issued.

We will feature clinical, educational, and research-based achievements by radiological technologists in the monthly issues of the JART journal, and continually work to improve the magazine. I truly hope that this English edition will benefit radiological technicians worldwide.

To give our radiological technologists from across the globe an insight into our business, I will briefly explain the history of the JART. In March 1896, we succeeded in taking the first X-ray image in Japan. In 1897, Shimadzu Corporation released an X-ray generator for educational use. In 1925, there were approximately 1,500 X-ray technicians. In 1927, the first Shimadzu X-ray Technician Training Institute was established, and evidence-based education was put in place. The JART was founded in 1947 to make "radiological technologist" a national qualification. Since its establishment, we have worked towards broad acceptance of this national qualification, in collaboration with the government, the Diet, the Japanese Medical Association, and occupational military authorities.

As a result in June 1951, we were finally able to see the promulgation of the Radiology X-ray Technicians Act, Act No.226 of 1951. Since then, we have responded to the changing needs of the society, revising the original act to get the Radiology X-ray Technicians Act of 1968 passed, and partially revising that to get the Radiology Technicians Act and Radiology X-ray Technicians Act of 1983 passed, and finally getting the Radiology Technicians Act, which is in place currently, passed. Back then, the scope of work was limited to general X-ray testing, television X-ray testing, angiography, X-ray computed tomography scanning, RI scanning, and radiation therapy. In 1993, the Radiology Technicians Act was further revised, and MRI scanning, ultrasonic testing, and non-mydriatic fundus camera examination were added to the list. In 2010, image interpretation assistance, radiation examination explanation, and consultation work were added. In April 2015, intravenous contrast agent injection using automated contrast injectors, needle removal and hemostasis, lower digestive tract examination (anal catheter insertion and administration of contrast medium), anal catheter insertion, and oxygen inhalation during radiation therapy were added as operations that could be performed by radiological technologists.

In the latter half of 2021, the needle insertion for examinations of contrasting of the examination for CT, MRI, Ultrasound and Radioisotope will be further added as the new operation that can be performed by radiological technologists.

The JART will continue to respond to the needs of the medical industry, and we hope to broaden the operational scope of radiological technologists based on our foundation in scientific evidence.

History of The Japan Association of Radiological Technologists (JART)

1947

- Establishment of JART (July 13)

1951

- Promulgation of the Act on Medical Radiographers (June 11)
- Authorization for Establishment of the Japan Association of Radiographers (June 13)

1954

- First national examination for Medical Radiographers (May 30)

1956

- Event to commemorate the 10th anniversary of founding, attended by Her Imperial Highness Princess Chichibunomiya

1962

- Event to commemorate the 15th anniversary of founding and 10th anniversary of enactment of the Act on Medical Radiographers, attended by Her Imperial Highness Princess Chichibunomiya

1968

- Promulgation of the Act to Partially Revise the Act on Medical Radiographers (establishment of two professions) (May 23)
- First national examination for radiological technologists

1969

- Renaming as the JART
- Staging of the 4th International Society of Radiographers & Radiological Technologist (ISRRT) World Congress at Tokyo Palace Hotel, attended by Her Imperial Highness Princess Chichibunomiya

1975

- Event to commemorate the 80th anniversary of the discovery of X-rays, attended by Her Imperial Highness Princess Chichibunomiya

1979

- Completion of the Education Center for JART

1983

- Partial revision of the Act on Medical Radiographers and the Act on Radiological Technologists (unification of the professions)

1985

- Event to commemorate the 90th anniversary of the discovery of X-rays, attended by Her Imperial Highness Princess Chichibunomiya
- Staging of the 1st Japan Conference of Radiological Technologists

1987

- General assembly resolution for establishment of the New Education Center and a four-year university

1989

- Completion of the New Education Center (Suzuka City)

1991

- Opening of Suzuka University of Medical Science

1993

- The Act to Partially Revise the Act on Radiological Technologists, and Ministerial Ordinance to Partially Revise the Enforcement Orders (April 28)

1994

- Appointment of the President of JART as the 11th President of ISRRT

1995

- Event to commemorate the 100th anniversary of the discovery of X-ray, attended by Her Imperial Highness Prince Akishinomiya

1996

- Start of the Medical Imaging and Radiologic Systems Manager certification system

1998

- Staging of the 11th ISRRT World Congress at Makuhari

1999

- Start of the Radiation Safety Manager certification system

2000

- "Presentation of the Medical Exposure Guidelines (Reduction Targets)" for patients

2001

- Start of the Radiological Technologists Liability Insurance System

2003

- Enactment of X-Ray Week

2004

- Relocation of offices to the World Trade Center Building in Tokyo

2005

- Start of the Medical Imaging Information Administrator certification system

2006

- Staging of a joint academic conference between Japan, South Korea, and Taiwan
- Revision of the Medical Exposure Guidelines

2008

- Establishment of the committee on Autopsy imaging (Ai)

2009

- Revision to the national examination for radiological technologists
- Launch of the Team Medicine Promotion Conference, with the President of JART as its representative
- Appointment of the President of JART as chairperson of the Central Social Insurance Medical Council specialist committee

2010

- Health Policy Bureau Director's notification concerning promotion of team medicine

2011

- Support activities following the Great East Japan Earthquake
- Staging of an extraordinary general meeting concerning transition to a public interest incorporated association

2012

- Registration of transition to a public interest incorporated association (April 1)
- Event to mark the 65th anniversary of founding and transition to a public interest incorporated association (June 2)
- Renaming as public interest incorporated association JART
- Launch of the Radiological Technologists Liability Insurance System with participation by all members

2013

- Signing of the Comprehensive Mutual Cooperation Agreement on Prevention of Radiation Exposure (September 21)

2014

- Consignment of work to measure personal exposure of residents
- Revision of the Act on Radiological Technologists, Government Ordinance to Partially Revise the Enforcement Orders, and Revision of the Enforcement Regulations (June 25)
- Launch of the radiation exposure advisor certification system

2015

- Event to commemorate the 120th anniversary of the discovery of X-rays

2017

- Event to mark the 70th anniversary of founding and transition to a public interest incorporated association (June 2)

2018

- Notice from the Regional Medical Care Planning Division Director, Health Policy Bureau, Ministry of Health, Labour and Welfare, and Director of the Economic Affairs Division regarding Operational Considerations for Securing a System for Safety Management pertaining to Medical Equipment

2019

- Notice from the Health Policy Bureau on a Safety Management System for Medicinal Use of Radiation

2020

- Partial revision of the Ordinance on Prevention of Ionizing Radiation Hazards

2021

- Relocation of offices to the Mita Kokusai Building in Tokyo
- Partial revision of the designation regulation for radiological technologist training school

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Analysis of Facility Policy on Allocating Pregnant Staff for MR Imaging Duty: Comparison of Decision-Making Processes between MR Imaging Duty and Other Alternative Duties

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Key words: MRI workers, Pregnant Staff, Safety management

【Abstract】

Previous studies (Yamaguchi: JJMRM, 38, 2018) have observed variations in assignment of pregnant workers to magnetic resonance imaging (MRI) duty. This study analyzed background factors of the 7.6% "Proactive Personnel Placement" from the previous research. "Workers' personal attributes" and "workplace characteristics" were rarely involved. However, "physical loads" played an important role. When MRI work was regarded as an alternative work placement, "exposure protectability" and "flexible work arrangements" were considered critical, and reduction of the physical load for workers was an option. Concerns regarding exposure (residual risk) warranted precaution. Providing information on the elements of concern is important while assigning MRI work placement.

Introduction

Magnetic resonance imaging (MRI) is a medical imaging modality that actively uses non-ionizing radiation (NIR: radio waves with wavelengths of 0.3 THz or less, infrared rays, visible light, and some ultraviolet rays). A survey conducted in 2017 revealed that women accounted for ≥30% of MRI equipment operators [1). Similar to other modalities, life events such as pregnancy and childbirth must be considered while assigning MRI scan duty.

MRI operators are routinely exposed to moderate to severe static magnetic fields (SMFs) from the MRI equipment, ranging from a minimum of several tens of gauss (G) up to around 1 T upon entering the scan room [3), 4)]. The operators are also exposed to weak pulsed fields and high-frequency electromagnetic fields of several tens of MHz when they enter the room during data acquisition. The MRI scan duty also involves physical tasks, such as transporting the imaging coil or assisting patient transfer, as in other modalities. Extensive research has been conducted on the effects of NIR from MRI scans, such as the effect on reproduction and development, ranging from the cellular to the animal level, through epidemiological research. To date, a clear effect of SMF on development and reproduction has not been reported [5), 6), 7), 8)]. Further, there is no uniform opinion regarding MRI scan duty for pregnant operators, even at a global level. Government or academic bodies in each country mainly advise that "pregnant operators should not enter the room while scanning is in operation" [5), 6), 9)]; however, the reality is that operating standards differ at the hospital level [10)].

It was assumed that conditions would be similar in Japan. Based on the characteristics of the MRI scan duty [1], our group hypothesized that two factors could be contributing towards the discrepancies in deployment policies. The first was the inability to eliminate the remaining risk associated with the uncertainty concerning the hazardous effect of NIR (especially strong SMFs) on reproduction and development, which was named “Differences in awareness about NIR.” The second was the attitude toward safety regarding handling of physical load, such as patient transfer and coil installation. This factor was named as “Considerations regarding the working conditions.”

In a previous study, the authors developed a questionnaire on the aforementioned hypotheses, which set five categories of questions. Four of them were raised from the factor “Differences in awareness about NIR,” namely, 1: “Interest,” 2: “Concerns of adverse health effects,” 3: “Ease of Protection from exposure,” and 4: “Temporal symptoms caused by non-ionizing radiation,” which are known to be present near the MRI equipment [11), 12)]. The final one was 5: “Physical load” and it reflected the “Considerations regarding the working conditions” factor of the hypothesis. The questionnaire was sent to 5,769 facilities nationwide in November 2017. The questionnaire responses revealed that the policies on allocation of MRI scan duty to pregnant operators vary in Japan[1]. The majority of the responses stated that operators had a “less-promoted allocation pattern” (52.6%), indicating a tendency to refrain from allocating these duties to pregnant women. The authors investigated background factors for “less-promoted allocation pattern” using the decision tree analysis and logistic regression analysis and reported that the respondents’ sex and age are considerable factors added to the aforementioned two hypothesized factors [2].

In contrast, the results of the questionnaire also showed that 7.6% of respondents stated “proactive personnel placement.” This allocation pattern essentially increases the number of allocations compared before pregnancy. Investigating background factors that affect this type of selection may provide supporting material for pregnant employees and also provide information for a flexible system of allocation. Furthermore, “proactive personnel placement” may indicate that MRI scans are treated as alternative work duties for pregnant employees; therefore, comparing the reasons for selection with other modalities will lead to the proposal of rational alternative work duties for pregnant employees.

Thus, this study focused on “proactive personnel placement” where an increase was reported in the number of allocations after pregnancy and examined background factors involved in the selection of this option. First, we investigated the background factors underlying selection. Second, regarding the decision of alternative duties, factors affecting the selection were analyzed by comparing the case of MRI scan duty and other duties. Third, we classified free responses on allocation policies and discussed the contents to further deepen our understanding of the allocation situation.

Methods

1. Questionnaire distribution and collection

The protocols have already been reported in our previous study [1]. Specifically, we created a list of facilities to be surveyed, based on the list of facilities with MRI equipment installed, according to the 2017 Data Book of Medical Devices and Systems. The survey was conducted with personnel responsible for the MRI scan duty. The questionnaire was sent to 5,769 facilities on the above list on November 7, 2017. Among the facilities, 5,763 were set as the total number of facilities, excluding six facilities where the questionnaire was not delivered. The questionnaire comprised four sections: I) Basic Information, II) General Matters Relating to Employee Pregnancy, III) Policies Regarding MRI Examination Duties During Pregnancy, Matters Considered in MRI Examination Duties, and Concepts of Alternative Duties During Pregnancy, and IV) Opinions on Non-ionizing Radiation in General and Future Policies on MRI Examination Duties during Pregnancy. There were 34 questions (in sections I to IV) and free comments (in section V). The response deadline was set at approximately 3 weeks after the recipient had received the questionnaire. Finally, the valid response rate was 36.0%, with 2,072 valid responses, after excluding 31 completely blank non-response questionnaires from the collected questionnaires.

2. Classification of allocation policy and data sets

The policy for allocation of MRI work to pregnant employees was recoded into three groups based on the responses: proactive personnel placement (n=157, 7.6%), maintained status quo (n=679, 32.8%), and less-promoted allocation pattern (n=1,088, 52.5%), and datasets were created with "proactive personnel placement" set to 1, and the rest being set as 0. If the respondents answered as "others (questions did not match the actual situation in the facility)" we asked for specific reasons and feasible content in the free responses (n=485). The free responses were classified based on the strength of allocation awareness, as follows: "Aggressive arrangement," "Continual arrangement," "Principle allocation in consideration," "Appropriate response on the consent of the person," and "Other allocation arrangement."

3. Question classifications

The definitions of the questions are based on our previous studies [1), 2)]. The analysis set included only typical answers. Other responses, including free comments, were excluded from the analysis.

a) Personal attributes and facility characteristics

There were five items for the respondents' personal attributes: "Sex," "Age," "Years of employment," "Years of employment at the present institute," and "Deciding for allocation." There were 13 items for the facility characteristics: "Type of institute," "Number of beds," "Type of MRI scanner," "Number of modalities at the institute," "Female ratio (at the department)," "Female ratio (at MRI scan duty)," "Allocation pattern (at the department)," "Work overtime," "Hours of employment per week," "Staff sufficiency," "Allocation pattern (at MRI scan duty)," "Occurrence of additional support at MRI scan duty," and "Number of MRI examinations per month."

b) Opinions on NIR

Opinions on NIR were classified into four items: "Interest," "Concern of adverse health effects," "Ease of protection from exposure," and "Temporal symptom caused by non-ionizing radiation." For "Interest," the degree of interest was set as "High," "Low," and "Not interested" based on the combination of the level of interest and acquisition of safety information. In this study, the target of "Interest" was legislation and guidelines on NIR emitted from home appliances. "Concern of adverse health effects" was classified into four items: "No," "Feel necessary for precautionary action," "Yes," and "Not a basis for the decision." "Ease of protection from exposure" was classified into three items: "Easy," "Not easy," and "Not basis for the decision." "Temporal symptom caused by non-ionizing radiation" was set as "Experienced and familiar with the occurrence mechanism," "Experienced but not familiar with the occurrence mechanism," "Not experienced but familiar with the occurrence mechanism," and "Neither experienced nor familiar with the occurrence mechanism."

c) Opinions on physical load

For questions regarding measures adopted for physical work owing to patient transfer and coil setting, three items were included to define the concept of physical load: "Low or reducible," "High or not-reducible," and "Not a basis for the decision."

4. Factors for selecting alternative work duties

Factors for selecting alternative work duties (except for MRI scan duty) were set as "Ease of protection from exposure," "Reduction of physical load," and "Adoption of work role". Differences in factors underlying the selection were examined and compared with those of selection in MRI scan duty. For MRI scan duty, the factors for "Ease of protection from exposure" and "Reduction of physical load" were inferred from the work options as described below.

Work options were classified into the following five groups: "Access restriction during data acquisition (NIR1)," "Reduction of physiological load (PL)," "Simultaneous selection of NIR1 + PL (NIR1+PL)," "Access restriction for MRI scan room (NIR2)," and "No given option (None)." The answer NIR1+NIR2 was merged into NIR2, as the NIR2 includes strong access restriction to the MRI room and covers the situation of NIR1. The reasons for adoption of the work role were derived from the related questions in the questionnaire.

Each facility entered a maximum of four reasons for the three candidates on alternative work duties other than MRI. Thus, all three responses for the 2,072 facilities were merged (N=6,216, including non-responses and invalid responses) and analyzed. Answers selecting MRI scan duty as alternative work were excluded; however, they were still analyzed as described above. The selection status of the aforementioned three reasons for selection was derived from the applicable questions in the questionnaire.

5. Analysis

SPSS 22 (IBM corp, Armonk, NY, USA) was used as the analysis software, and the statistical significance was set at $p<0.05$. The association between personal attributes and facility characteristics and opinions on NIR and physical load was examined using Fisher's exact test and chi-squared test after cross-tabulation. Background awareness of NIR protection and opinions on physical load were investigated based on the responses in the related sections of the questionnaire. The relationship between exposure protection, physical load, and working status was examined using correspondence analysis for alternative work duties besides MRI scan after primary tabulation.

Results

1. Investigation of the background factors for selecting "proactive personnel placement"

The results of the cross-tabulation of personal attributes and facility characteristics in the selection of "proactive personnel placement" are shown in Table 1. A significant difference was seen only in the number of examinations per month, and the breakdown revealed an increase in the selection rate in facilities that performed 500–999 examinations per month. Women and younger individuals tended to select this option; this preference was not statistically significant. Therefore, the contribution of personal attributes and facility characteristics is considered to be limited.

Table 2 shows the differences in awareness of NIR and considerations based on working status in the selection of "proactive personnel placement."

A significant difference was observed for all factors other than "Temporal symptoms caused by non-ionizing radiation" (χ^2 test, df=2 or 3; the p-value was $p<0.05$ for "Interest" and $p<0.0001$ for all others). In terms of "Interest," the respondents who selected "proactive personnel placement" selected the "not interested" response more frequently. The most common response for "Concern of adverse health effects" was "No (46.3%)," which reflects a mindset that stems from the fact that reports regarding adverse effects on development and reproduction are lacking." The frequency of this answer among this group was more than twice the percentage from the "others" group (21.9%). The frequency of the response "Feel necessary

Table 1 Results of cross-tabulation of personal attributes and facility characteristics. Invalid responses were excluded from the summary.

	Promoted allocation pattern (n=157)		Others (n=1,915)		Total	
	n	%	n	%	n	%
Sex N.S.						
Male	129	82.2%	1,541	87.5%	1,670	87.1%
Female	28	17.8%	220	12.5%	248	12.9%
Total	157	100.0%	1,761	100.0%	1,918	100.0%
Age N.S.						
20-29	11	7.0%	81	4.6%	92	4.8%
30-39	50	31.8%	454	25.8%	504	26.3%
40-49	52	33.1%	618	35.1%	670	35.0%
50-59	37	23.6%	515	29.3%	552	28.8%
>60	7	4.5%	92	5.2%	99	5.2%
Total	157	100.0%	1,760	100.0%	1,917	100.0%
Years of employment N.S.						
<9	24	15.3%	216	12.3%	240	12.6%
10-19	50	31.8%	623	35.5%	673	35.2%
20-29	51	32.5%	545	31.1%	596	31.2%
>30	32	20.4%	369	21.0%	401	21.0%
Total	157	100.0%	1,753	100.0%	1,910	100.0%
Years of employment at the present institute N.S.						
<9	55	35.0%	621	35.4%	676	35.3%
10-19	50	31.8%	605	34.5%	655	34.2%
20-29	40	25.5%	349	19.9%	389	20.3%
>30	12	7.6%	181	10.3%	193	10.1%
Total	157	100.0%	1,756	100.0%	1,913	100.0%
Making decision for allocation N.S.						
No	82	54.7%	904	55.2%	986	55.1%
Yes	68	45.3%	734	44.8%	802	44.9%
Total	150	100.0%	1,638	100.0%	1,788	100.0%
Type of institute N.S.						
University hospital	3	1.9%	84	4.8%	87	4.5%
Public hospital	41	26.1%	490	27.8%	531	27.7%
Other hospital	112	71.3%	1,146	65.1%	1,258	65.6%
Others	1	0.6%	41	2.3%	42	2.2%
Total	157	100.0%	1,761	100.0%	1,918	100.0%
Number of beds N.S.						
<99	54	34.4%	641	36.6%	695	36.4%
100-199	35	22.3%	386	22.1%	421	22.1%
200-299	20	12.7%	236	13.5%	256	13.4%
300-399	22	14.0%	199	11.4%	221	11.6%
>400	26	16.6%	288	16.5%	314	16.5%
Total	157	100.0%	1,750	100.0%	1,907	100.0%
Type of MRI scanner N.S.						
0.5 T MRI scanner (only)	35	22.4%	342	19.4%	377	19.7%
1.5 T MRI scanner (only)	84	53.8%	1,009	57.4%	1,093	57.1%
1.5 T and 3 T MRI scanner	29	18.6%	264	15.0%	293	15.3%
3 T MRI scanner (only)	7	4.5%	94	5.3%	101	5.3%
Others	1	0.6%	50	2.8%	51	2.7%
Total	156	100.0%	1,759	100.0%	1,915	100.0%
Number of modalities at the institute N.S.						
<= 5	39	24.8%	460	26.0%	499	25.9%
6-8	52	33.1%	575	32.5%	627	32.6%
9-10	39	24.8%	399	22.6%	438	22.8%
11+	27	17.2%	333	18.8%	360	18.7%
Total	157	100.0%	1,767	100.0%	1,924	100.0%
Female ratio (at the department) N.S.						
<= 16.7	33	24.8%	374	25.2%	407	25.1%
16.8-25.0	31	23.3%	367	24.7%	398	24.6%
25.1-37.5	41	30.8%	364	24.5%	405	25.0%
37.6+	28	21.1%	382	25.7%	410	25.3%
Total	133	100.0%	1,487	100.0%	1,620	100.0%

Female ratio (at MRI scan duty) N.S.						
<= 17.14	34	28.3%	320	23.9%	354	24.3%
17.15-29.41	26	21.7%	346	25.9%	372	25.5%
29.42-44.44	35	29.2%	313	23.4%	348	23.9%
44.45+	25	20.8%	359	26.8%	384	26.3%
Total	120	100.0%	1,338	100.0%	1,458	100.0%
Allocation pattern (at the department) N.S.						
Fixed	21	14.0%	312	18.2%	333	17.9%
Rotation (2-3 modalities)	55	36.7%	561	32.7%	616	33.0%
Rotation (all modalities)	63	42.0%	643	37.5%	706	37.9%
Others	11	7.3%	198	11.6%	209	11.2%
Total	150	100.0%	1,714	100.0%	1,864	100.0%
Work overtime N.S.						
Yes	126	81.3%	1,382	78.9%	1,508	79.1%
No	27	17.4%	349	19.9%	376	19.7%
Others	2	1.3%	20	1.1%	22	1.2%
Total	155	100.0%	1,751	100.0%	1,906	100.0%
Hours of employment per week N.S.						
<39	40	25.6%	329	18.8%	369	19.3%
40-49	104	66.7%	1,261	72.0%	1,365	71.5%
50-59	9	5.8%	134	7.6%	143	7.5%
60-64	2	1.3%	17	1.0%	19	1.0%
>65	1	0.6%	11	0.6%	12	0.6%
Total	156	100.0%	1,752	100.0%	1,908	100.0%
Staff sufficiency N.S.						
Sufficient	87	55.8%	910	52.2%	997	52.5%
Partially insufficient	58	37.2%	637	36.5%	695	36.6%
Insufficient	11	7.1%	196	11.2%	207	10.9%
Total	156	100.0%	1,743	100.0%	1,899	100.0%
Allocation pattern (at MRI scan duty) N.S.						
Fixed	25	16.7%	354	20.7%	379	20.4%
Not fixed (a part of the rotation pattern)	109	72.7%	1,150	67.4%	1,259	67.8%
Others	16	10.7%	203	11.9%	219	11.8%
Total	150	100.0%	1,707	100.0%	1,857	100.0%
Occurrence of additional support at MRI scan duty N.S.						
Frequently	51	32.9%	479	27.7%	530	28.2%
Occasionally	45	29.0%	574	33.2%	619	32.9%
Rarely	39	25.2%	438	25.4%	477	25.3%
None	20	12.9%	236	13.7%	256	13.6%
Total	155	100.0%	1,727	100.0%	1,882	100.0%
Number of MRI examination per month $p<0.05$						
<499	107	68.6%	1,297	74.2%	1,404	73.7%
500-999	42	26.9%	312	17.8%	354	18.6%
>1,000	7	4.5%	139	8.0%	146	7.7%
Total	156	100.0%	1,748	100.0%	1,904	100.0%

Table 2 Relationship between selection of allocation policies and their reasons. Considerations based on respondents' awareness of nonionizing radiation and work situation in the selection. Invalid responses were excluded from the summary. Chi-squared test.

		Promoted allocation pattern (n=157)		Others (n=1,915)		Total	
		n	%	n	%	n	%
"Interest"	High	39	25.5%	390	22.7%	429	22.9%
$p<0.05$	Low	93	60.8%	1,201	69.8%	1,294	69.1%
	Not interested	21	13.7%	129	7.5%	150	8.0%
	Total	153	100.0%	1,720	100.0%	1,873	100.0%
"Concern of adverse health effects"	No	68	46.3%	370	21.9%	438	23.8%
$p<0.0001$	Feel necessary for precautionary action	63	42.9%	1,082	63.9%	1,145	62.3%
	Yes	1	0.7%	77	4.6%	78	4.2%
	Not basis for decision	15	10.2%	163	9.6%	178	9.7%
	Total	147	100.0%	1,692	100.0%	1,839	100.0%

"Ease of protection from exposure"	Easy	62	41.1%	467	28.2%	529	29.3%
$p<0.0001$	Not easy	15	9.9%	448	27.1%	463	25.6%
	Not basis for decision	74	49.0%	740	44.7%	814	45.1%
	Total	151	100.0%	1,655	100.0%	1,806	100.0%
"Temporal symptom caused by non-ionizing radiation"	Experienced and familiar with the occurrence mechanism	34	22.2%	383	22.0%	417	22.0%
N.S.	Experienced but not familiar with the occurrence mechanism	23	15.0%	272	15.6%	295	15.6%
	Not-experienced but familiar with the occurrence mechanism	31	20.3%	403	23.1%	434	22.9%
	Neither experienced nor familiar with the occurrence mechanism	65	42.5%	686	39.3%	751	39.6%
	Total	153	100.0%	1,744	100.0%	1,897	100.0%
"Physical load"	Low or reducible	113	76.9%	660	39.7%	773	42.7%
$p<0.0001$	High or not-reducible	11	7.5%	515	31.0%	526	29.1%
	Not basis for decision	23	15.6%	487	29.3%	510	28.2%
	Total	147	100.0%	1,662	100.0%	1,809	100.0%

Table 3 Rates of work options in the promoted allocation pattern. NIR1 or 2 represents consideration of "ease of exposure protection," whereas PL shows the consideration of "reduction of physiological load." NIR = Non-Ionizing radiation; PL = Physical load.

Given work options	Abbreviations	n	%
Access restriction during data acquisition (Protect from exposure to time-varying and radio frequency electromagnetic fields)	NIR1	13	8.3
Reduction of physiological load	PL	14	8.9
NIR1+PL	NIR1+PL	16	10.2
Access restriction for MRI scan room (Protection from static magnetic field exposure)	NIR2	62	39.5
No given option	None	40	25.5
No responses or invalid answers		12	7.6
Total		157	100.0

for precautionary action" was 42.9%. When "Protection from Exposure" was considered a problem, answers were divided into two major groups: 41.1% responded that it is easy to formulate measures for NIR exposure during work; however, 49.0% responded that selection of this factor was not a basis for the decision. Regarding "Physical load," 76.9% of respondents who selected "proactive personnel placement" answered that the physical load is small (or it is possible to assign personnel to reduce the load), which was higher than the number of respondents who selected this answer in the "others" group (39.7%).

2. Factors for selecting alternative work duties – Comparison of MRI scan duties (proactive personnel placement) and another modality selection

Factors for selecting alternative work duties ("Ease of protection from exposure," "Reduction of physical load," "Adoption of work role") were compared to the factors for selecting MRI scan duties (Tables 3–5, Fig.1). The status of factors for selecting MRI scan duties as alternative work are shown in Table 3 and Fig.1. As described in the methods, "Ease of exposure protection" and "Reduction of physical load" were investigated based on the status of granting work options (Table 3).

Overall, 25.5% of respondents were not granted any particular work options, while the

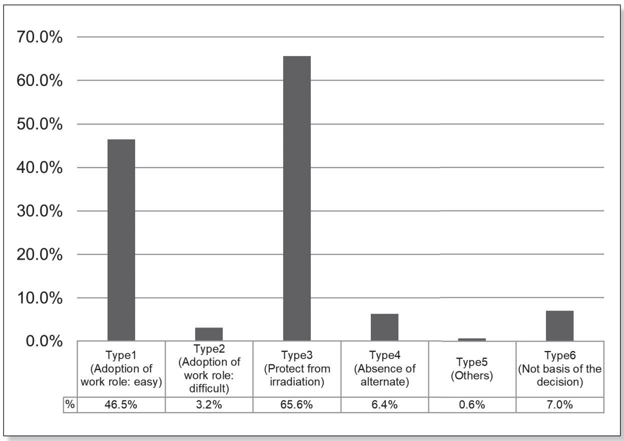

Figure 1 Rates of "adoption of work role" in the promoted allocation pattern.

remaining 66.9% were granted some kind of work option. The summative total of work options based on the premise of exposure avoidance (NIR1, NIR1+PL, NIR2) was 58.0%. In contrast, work options that considered PL alone accounted for 8.9%.

The reasons for selection relating to "Adoption of work role" for the group that implemented "proactive personnel placement" are illustrated in Fig.1. Type 1 corresponds to "Adoption of work role: easy," Type 2 corresponds to "Adoption of work role: difficult," Type 3 corresponds to "To prevent ionizing-radiation exposure," Type 4 corresponds to "Absence of alternate duties," Type 5 corresponds to "Other," and Type 6 corresponds to "Not a basis for the decision." The selection rate for type 1 (46.5%), type 2 (3.2%), type 3 (65.6%), type 4 (6.4%), type 5 (0.6%), and type 6 (7.0%) included multiple answers.

These results suggest that "Ease of protection from exposure" is a clear countermeasure, although the countermeasures for "Reduction of physical load" alone are infrequently applied. The results also suggested that Types 1 and 3 are the main factors to be considered for the adoption of work roles.

The frequency of and reasons for selection of alternative work duties for pregnant employees are shown in Tables 4 and 5. Computed tomography (CT) was the alternative work duty most often selected for pregnant employees, and the reasons included "Ease of protection from exposure" and "Reduction of physical load," while "Adoption of work role" was not prioritized. The second most commonly selected reason for the selection was "reduction of physical load," with the person being assigned to reception duties or analysis of medical information.

These options account for ≥ 8.0% of the seven duties listed in Table 4 (CT, receptionist, general radiography, bone density scans, ultrasound, mammography, and X-ray TV), and were examined by corresponding analysis to visualize the relationship with factors affecting selection (Fig.2). Figure 2 illustrates the strength of the association between these three factors and the selected factors. The closer the plot position to the factor, the stronger the association between the selected item and factor. For example, Table 5 shows that the answer 'general radiography' is at the first position for "Adoption of work role" (54.6%), seventh position for "Ease of protection from exposure" (82.5%), and twelfth position for "Reduction of physical load" (51.4%), therefore, it is easy to

Table 4 Selection rate for alternative work duties for pregnant employees. (Reference) 810 for MRI scanning.

Alternative duty during the pregnancy	n	%
CT	865	20.8
Receptionist, analysis of medical information, office works	646	15.6
Radiography	599	14.4
Bone density test	577	13.9
Ultrasound	410	9.9
Mammography	386	9.3
X-ray TV; Fluoroscopy	370	8.9
Fundus examination	77	1.9
Radiation therapy	72	1.7
Other	69	1.7
Angiography	35	0.8
Mobile C-arm	23	0.6
Nuclear medicine	14	0.3
Mobile X-ray	8	0.2
Total	4,151	100.0

Table 5 Reasons for choosing alternative work duties for pregnant employees. % indicates the value for the total of each duty. The total percentage is not displayed in the table; it exceeds 100% because of the multiple choice format.

Alternative duty during the pregnancy	Ease of protection from exposure		Reduction of physical load		Adoption of work role		Others		Number of selection (see in Table 4)
	n	%	n	%	n	%	n	%	n
CT	770	89.0%	633	73.2%	334	38.6%	66	7.6%	865
Receptionist, analysis of medical information, office works	438	67.8%	545	84.4%	217	33.6%	24	3.7%	646
X-ray imaging	494	82.5%	308	51.4%	327	54.6%	52	8.7%	599
Bone density test	508	88.0%	507	87.9%	185	32.1%	6	1.0%	577
Ultrasound	282	68.8%	318	77.6%	98	23.9%	16	3.9%	410
Mammography	358	92.7%	264	68.4%	167	43.3%	9	2.3%	386
X-ray TV; Fluoroscopy	331	89.5%	327	88.4%	125	33.8%	17	4.6%	370
Fundus examination	51	66.2%	69	89.6%	17	22.1%	2	2.6%	77
Radiation therapy	63	87.5%	43	59.7%	16	22.2%	7	9.7%	72
Other	39	56.5%	38	55.1%	27	39.1%	15	21.7%	69
Angiography	33	94.3%	30	85.7%	8	22.9%	2	5.7%	35
Mobile C-arm	15	65.2%	6	26.1%	7	30.4%	2	8.7%	23
Nuclear medicine	9	64.3%	12	85.7%	3	21.4%	0	0.0%	14
Mobile X-ray	2	25.0%	4	50.0%	4	50.0%	0	0.0%	8
Total	3,393		3,104		1,535		218		4,151

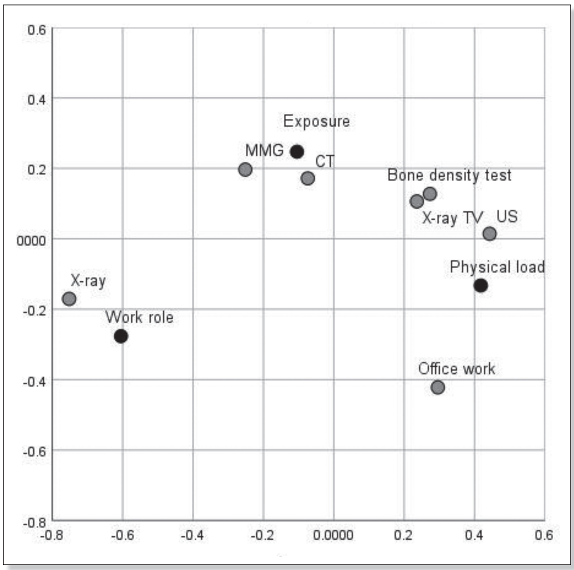

Figure 2 Results of correspondence analysis among seven alternative work duties and selection reasons. Office work: Receptionist, analysis of medical information, office works. X-ray: X-ray imaging. US: Ultrasound. MMG: Mammography. X-ray TV: Fluoroscopy.

predict that general radiography has a strong association with "Adoption of work role" only. In contrast, the answer 'X-ray TV' is at the third position for "Ease of protection from exposure" (89.5%), second position for "Reduction of physical load" (88.4%), and sixth position for "Adoption of work role" (33.8%), which suggests an association with "Ease of protection from exposure" and "Reduction of physical load." Thus, to visualize the relationship between selected alternative duties and these factors, the results are displayed on a two-dimensional diagram, as shown in Fig.2. As predicted from Table 5, general radiography was plotted closest to "adoption of the work role," demonstrating the strong association between these two elements, while there is an association between CT and mammography and "Ease of protection from exposure," while bone density scans, X-ray TV, and ultrasounds demonstrated a strong association with "Reduction of physical load."

3. Summary of classification of free comments

Table 6 shows a summary of the 485 free comments that described the specific reason and the selected "not applicable" for the policies regarding assignment of MRI scan duties for pregnant employees. Based on the content of the free comments, 30.0% of pregnant employees are actively allocated, continue allocation, or are usually allocated to MRI while considering the situation. In contrast, 21.0% of responses were left up to the judgment of the

Table 6 Summary of classification and content of a free comments

The allocation situations to the MRI scan duties	① Youre facility implementation content		② Opinions on place		①+② Total	
Aggressive arrangement	2	0.6%	5	3.1%	7	1.0%
Continual arrangement	41	12.7%	20	12.3%	61	13.0%
Principle allocation in consideration	52	16.1%	24	14.7%	76	16.0%
Appropriate response on consent of the person	68	21.1%	33	20.2%	101	21.0%
Other allocation arrangement	69	21.4%	26	16.0%	95	20.0%
Other	76	23.6%	28	17.2%	104	21.0%
Request	14	4.3%	27	16.6%	41	8.0%
Total	322	100.0%	163	100.0%	485	100.0%

individual. Furthermore, 20.0% of responses were classified as transfers to other duties. Combining these two made up a total of 41.0% of responses that were classified as "careful or negative placement." Twenty-nine percent of the responses were classified as "others," including requests from the staff. The summary of free comments shows that a high percentage of people are cautious about placement or have a negative opinion based on general unease regarding NIR exposure (residual risk).

Discussion

This study examined the influence of awareness of NIR (work options: NIR1 or NIR2) or considerations based on differences (work option: PL) in the decision-making process for assignment of MRI scan duties to pregnant employees. In addition, the effects of personal attributes and facility characteristics of respondents were investigated. The data from Table 1 shows that "proactive personnel placement" tends to be more common among women in their 20s and 30s, although this observation is not statistically significant. These results demonstrate that career development is prioritized among the younger generation and women. It is assumed that these results reflect the awareness of professional employees and may show a more rational attitude of pregnant workers accepting risk communication for MRI scan duties. However, analysis of "less-promoted allocation pattern" showed a significantly high number of men and older respondents [2]. This result may reflect concerns about the lack of clear guidelines on the safety management of NIR duties for pregnant employees among men, especially those from older age groups. It is assumed that these respondents prioritize avoidance of risk owing to pregnant women performing MRI scan duties and management of workplace organization management.

Furthermore, the number of MRI scans was the only facility characteristic with a significant difference, with higher levels of "proactive personnel placement" in the group that performed 500–999 scans per month, than in the group that performed 1000+ scans monthly (Table 1, p<0.05). Based on the number of MRI scans per unit, large-scale facilities are assumed to fall in the 1000+ group, while medium-scale facilities with two MRI equipment are assumed to fall in the 500–999 group. Alternatively, the number of scans is presumed to reflect the scale of the facility (department), and in the medium-sized facility group, the options for alternative work duties are affected by the environment and conditions related to the work roles. In a previous study, the ratio of "less-promoted allocation pattern" (59.0%) was highest in the medium-sized facility group as well as "proactive personnel placement" compared to the small-scale and large-scale facility groups [2].

Thus, the characteristics of facilities at this scale indicate the diversity of alternative work options.

Regarding the concern of adverse health effects as background factors in selecting "proactive personnel placement," the most common response for selection was "No," (46.3%) (Table 2). However, a high percentage of respondents (42.9%) stated that they "Feel necessity for precautionary action." This might be reflected in the results regarding work options (Table 3), as the total work options (NIR1, NIR1 + PL, NIR2), including access restrictions to the exposure source, were high (58.0%). This was also observed in free comments as a high percentage (70.0%) of the combined response rate of careful/negative opinions in allocating pregnant employees and other/requests for allocation. Given that the "Ease" of exposure protection accounts for 41.1% of the reasons for selection (Table 2), it is assumed that countermeasures to enable protection against risks are more frequently selected. This suggests that measures like access restriction (NIR1 or NIR2) are incorporated as a means of controlling the exposure (58.0%, a total percentage of NIR1, NIR1+PL, NIR2 in Table 3).

However, 49.0% of respondents stated that the ease of controlling protection against exposure to MRI scans is "Not a basis for the decision;" therefore, these respondents may consider physical load as a priority factor. Focusing on "Physical loads" as a background factor for allocation, the highest reason was "low or reducible (76.9%)" indicating that this may be the main factor in the decision of alternative work placement (Table 2). On the contrary, only 8.9% of respondents added that they selected work options only in response to PL (Table 3). However, based on the conditions of other work options, physical loads were reduced by imposing access restrictions to the MRI scan room (NIR2: 39.5%) and simultaneous additional access restrictions during scanning (NIR1 + PL: 10.2%). This also implies that it is easy to reduce the physical load through a set of measures combined with NIR protection measures. These results suggest that personal attributes and facility characteristics are rarely involved as background factors for selecting active personnel placement; however, there is a relationship between differences in awareness of NIR and considerations based on work situations as hypothesized in the present study. In particular, "Physical load" plays an important role in the selection of "proactive personnel placement."

As shown in Table 4, seven jobs (CT, reception work, general radiography, bone density tests, ultrasound, mammography, and X-ray TV) accounted for the majority of allocated duties. However, when the factors affecting selection were examined with correspondence analysis (Fig.2), the characteristics of the reason for selection differed depending on the equipment. CT, which was the most common selection, emphasized "Ease of protection from exposure" and as a work option, it is similar to MRI scan duty considering the rate of exposure avoidance (58.0%). MRI scan duty may also be selected as it prevents exposure to X-rays (Table 3, Fig.1). Regardless of the exposure source, the selection process for CT and MRI scan duty is similar. However, selection for MRI scans emphasizes both "Ease of protection from exposure" and "Adoption of the work role," suggesting that the selection characteristics differ from those of CT, which is strongly associated with "Ease of protection from exposure," and general radiography, which is strongly associated with "Adoption of the work role." Further, selection of alternative duties such as reception work or analysis of medical information is strongly associated with "reduction of physical load" (Tables 4 and 5). However, this may also be related to the gestation period, from the point of view of maternity protection, considering that physical load is a common and prioritized factor considered while selecting alternative work.

Conclusion

This study considered the background factors for the selection of "proactive personnel placement," which increases the number of placements to MRI scan duties after reporting a pregnancy, focusing on differences in awareness about NIR and considerations based on work situations.

Results showed that although there was little involvement of personal attributes and facility characteristics, there was a relationship between differences in awareness of NIR and considerations based on work situations. "Physical load" was a particularly important selection factor, and it was a common factor with the group that selected alternative work assignments other than MRI scan duties. There was also a difference in awareness of "residual risk" owing to the general unease regarding MRI scans, and this was a factor where there were different views. For MRI scans, the issue seems to be disseminating information on the residual risk as a precautionary measure.

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Regional Uneven Distribution of Healthcare Resources Related to Medical Imaging

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Key words: Radiological Technologists, Medical Imaging, Healthcare resources, Regional uneven distribution

【Summary】

The purpose of this study was to address regional uneven distribution of healthcare resources related to medical imaging. We measured Gini's coefficient and the coefficient of variation based on the "*Survey of Medical Institutions*" (number of Radiological Technologists, Serial angiography, Mammography, RI exam, PET, CT, MRI, 3D image processing) to compare potential regional differences. In addition, we evaluated regional features using a hierarchical cluster analysis. Our study reveals that the number of "*Radiological Technologists*" presented a lower regional difference compared to physicians, as opposed to "*Medical imaging*" that presented a higher regional difference than physicians. Furthermore, our study classified all 47 prefectures into seven clusters that describe and define the features of each region. We suggest that the results of this study will be useful for the efficient planning and improvement of the medical care provision system in each prefecture.

1. Background and purpose

One of the most challenging and worrisome issues in Japan involves the potential shortage of doctors, nurses, and healthcare workers due to the so-called "*2025 Problem*" associated with Japan's aging population. More specifically, this problem refers to Japan's declining birthrate and aging population, which is expected to cause a rapid increase in the number of elderly people and a significant change in the demographic structure of Japan in 2025. As a countermeasure, the Ministry of Health, Labor and Welfare (MHLW) has recently established the "*Investigative commission about the demand of the healthcare worker*" in 2015 to discuss the outlook for supply and demand of healthcare workers. Consequently, the objective of this commission was to introduce efficient measures to ensure supply and demand, thus combating regional uneven distribution of healthcare workers [1]. Radiological technologists were not initially included in this greater discussion as a study group. Recently, however, the number of radiological technologists has been increasing due to the establishment of new radiological technologists' school. Therefore, this triggered the implementation of various surveys and studies that have evaluated the supply and demand situation of radiological technologists.

The supply and demand of each category of medical workers has been thoroughly investigated, and necessary measures have been taken based on the operation of healthcare delivery system. In fact, there is a significant number of research papers and reports published that assess the supply and demand among physicians and nurses. In contrast, there are only a few studies focusing on the supply and demand of radiological technologists. Kodama estimated the future demand for radiological technologists as a function of their available numbers and the number of hospitals, based on statistical data from the Medical Institution Survey and hospital reports [2]. As a result, the authors identified that the demand for radiological technologists was expected to decrease following the peak year of 2008 [2]. In addition, Muto investigated the demand for radiological technologists and their respective salary system based on related job-opening information, reported the current and future demand for radiological technologists [3, 4]. We have also conducted a secondary analysis based on statistical data from medical facility surveys and hospital reports, and reported on the supply and demand situation of radiological technologists engaged in CT scanning and their future projections [5]. As a result, it was feared that the demand for radiological technologists would decrease because the number of CT would decrease along with the decrease in medical demand [5]. However, many reports on the supply and demand of radiological technologists do not engage into a meaningful and efficient discussion to provide a comparison of their supply and demand with that of physicians and nurses. However, the extent of this research topic involves the whole of Japan, and, to our knowledge, there is no research report evaluating the uneven distribution of Japan's regions.

In this study, we investigate the regional uneven distribution in the provision of diagnostic imaging based on the Medical Institution Survey. The purpose of this study was to identify the regional uneven distribution in radiological technologists and diagnostic imaging devices, and to use this study for the introduction and subsequent establishment of a medical care provision system.

2. Subjects and methods

2-1 Subjects

The data used in our analysis involved eight distinct items of the static/dynamic survey of medical institutions report, published by the MHLW, in 2017 [6]. These eight items used in the survey of medical institutions are the following: the number of "*Radiological Technologists*," the number of institutions for "*Serial angiography*" and "*3D image processing*," and the number of devices for "*Mammography*," "*RI exam*," "*PET*," "*CT*," and "*MRI*". More specifically, "*PET*" was defined as the total number of "*PET*" and "*PET-CT*" examinations, "*CT*" was defined as the total number of "*multi-slice CT*" and "*other CT*" examinations; whereas, "*MRI*" was defined as the total of "*3.0T or more*," "*1.5T or more and less than 3.0T*," and "*less than 1.5T*" examinations. Furthermore, the data used to describe and define each item involve the total of "*hospitals*" and "*medical clinics*" included in this report. Each item was then expressed as per 100,000 population using the data for each prefecture of the population estimates published by the Ministry of Internal Affairs and Communications in 2017 [7]. Finally, we refined our data according to each prefecture so as to represent the number of physicians per 100,000 population, as shown in the Survey of Doctors, Dentists, and Pharmacists, 2016 [8].

2-2 Gini's coefficient and coefficient of variation

In this study, the Gini's coefficient and the coefficient of variation (CV), were measured and compared to identify potential regional differences. Gini's coefficient is defined as the ratio of the area enclosed by the Lorenz curve and the equal distribution line to the area below the equal distribution line, and is calculated from the following equation (1).

$$\text{Gini's coefficient} = \frac{1}{2n^2\bar{y}} \sum_{i=1}^{n} \sum_{j=1}^{n} |y_i - y_j| \quad \cdots (1),$$

where n is the number of prefectures, and y represents the data for each prefecture. Gini's coefficient is a number between 0 and 1, and a higher value indicates greater regional differences. The CV is an index shows the extent of variability of the data, and is calculated from the following equation (2):

$$\mathrm{CV} = \frac{\sigma}{\bar{y}} \times 100 \quad \cdots (2),$$

where σ is the standard deviation of each item. Higher values of the CV indicate greater regional differences.

2-3 Regional difference index and Hierarchical cluster analysis

In this study, the "*regional difference index*" was evaluated by dividing the data for each item over the national average for each prefecture. The overall evaluation was based on the average of the "*regional difference index*" of each item. Furthermore, a hierarchical cluster analysis was performed using itemized "*regional difference indices*" in order to categorize the respective prefectures. The Ward method was then used as the cluster merger method. The distance between the objects used for classification is the Eugrid square distance. Statistical analysis was performed using the SPSS Statistics 25 software.

3. Results

3-1 Descriptive Statistics, Gini's coefficient, and coefficient of variation

The descriptive statistics, Gini's coefficient, and CV for each item are shown in Table 1 and Fig.1. Gini's coefficient and CV of the "*radiological technologist*" were 0.08 and 12.0, respectively, and are slightly lower than the values obtained for physicians (0.10 and 16.3, respectively). Therefore, it can be suggested that the regional difference is small. In contrast, Gini's coefficient and CV for "*diagnostic imaging system*" was the highest the "*PET*" item (Gini's coefficient: 0.20, and CV: 37.1). The following with the next highest values were "*RI exam*" (0.18, 30.3), "*CT*" (0.17, 30.0), "*MRI*" (0.15, 25.3), "*Serial angiography*" (0.15, 24.5), "*3D imaging*" (0.14, 23.3), "*Mammography*" (0.13, 21.6). Gini's coefficient and CV for "*diagnostic imaging system*" were higher than those of "*physician*" and the regional difference was large.

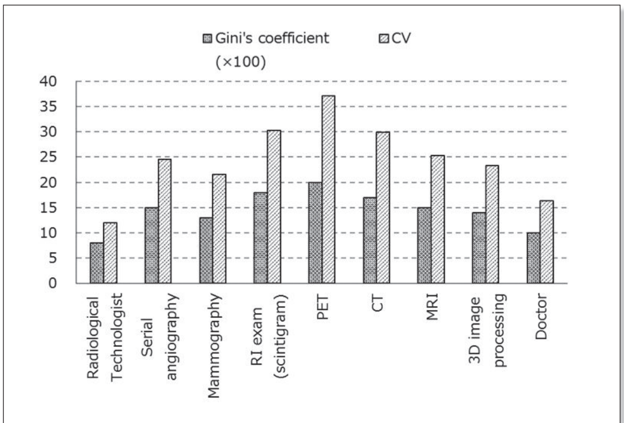

Fig.1 Result of Gini's coefficient and Coefficient of variation (CV)

3-2 Regional difference index by prefecture

The regional difference indices for each item by prefecture are shown in Table 2, and the highest and lowest prefectures for each item are summarized in Table 3. There were many prefectures in Western Japan that exceeded the national average such as Oita (124.9), Kagoshima (123.9), Kochi (122.3), and Toyama (115.2). However, the regional difference index for "*Radiological Technologist*" was the highest in the Hokkaido region (127.3, i.e., 56.4 people/100,000 population). On the other hand, Saitama had lowest regional difference index for "*Radiological Technologist*" (75.5, i.e., 33.4 people/100,000 population). Consequently, our findings suggest that the regional difference index is about 1.7 times higher in Hokkaido than in Saitama. Finally, many prefectures in Eastern Japan had a significantly lower regional difference index compared to the national average such as Saitama (75.5), Chiba (81.5), and Kanagawa (77.9).

In addition, the regional difference index for "*Serial angiography*" was the highest in Kagoshima with 151.6 (2.46 facilities/100,000 population). The prefectures with the next highest values were Kagawa (146.5), Saga (142.1), Ehime (140.0), and Tottori (130.8). Similar to the findings of the "*Radiological Technologist*" item, there were many prefectures in Western Japan that exceeded the national average. In contrast, the regional difference index for "*Serial angiography*" was the lowest in Saitama (52.3, i.e., 0.85 facilities/100,000 population). Therefore, it is shown that the regional difference index was approxi-

Table 1 Number of health resources related to medical imaging (per 100,000 Population)

Prefecture	Number of Radiological Technologists	Number of Serial angiography	Number of Mammography	Number of RI exam (scintigram)	Number of PET	Number of CT	Number of MRI	Number of 3D image processing	Number of doctors
Hokkaido	56.4	2.09	3.23	2.03	0.66	15.9	8.2	2.69	248.7
Aomori	43.0	1.41	4.23	1.25	0.47	15.7	6.9	3.13	209.0
Iwate	37.9	1.04	3.03	1.43	0.56	13.9	8.0	2.15	207.5
Miyagi	40.4	1.29	2.93	1.46	0.47	9.6	5.8	1.81	242.6
Akita	43.8	1.10	4.52	1.71	0.20	10.8	6.3	2.31	236.0
Yamagata	43.1	1.54	5.26	1.36	0.36	11.0	6.2	2.09	233.3
Fukushima	44.5	1.49	3.88	1.01	0.53	12.2	5.4	2.13	204.5
Ibaraki	40.5	1.35	2.49	0.66	0.17	10.9	5.6	2.14	189.8
Tochigi	41.8	1.23	3.47	0.87	0.41	11.0	5.2	2.66	228.8
Gunma	44.9	1.79	3.98	1.33	0.61	12.4	5.9	2.50	234.9
Saitama	33.4	0.85	2.72	0.63	0.26	8.2	3.9	1.55	167.0
Chiba	36.1	0.98	3.17	0.82	0.34	7.9	4.7	1.76	196.9
Tokyo	43.2	1.12	3.48	1.14	0.43	8.2	4.4	1.84	324.0
Kanagawa	34.5	0.99	2.58	0.84	0.24	6.8	3.7	1.51	213.0
Niigata	41.3	1.28	4.46	1.76	0.31	10.8	5.8	2.12	205.5
Toyama	51.0	1.99	3.98	1.80	0.47	14.1	7.1	1.99	256.6
Ishikawa	47.6	1.92	3.92	2.09	0.96	12.4	7.5	3.05	295.8
Fukui	50.5	1.67	3.85	1.80	0.77	13.4	7.8	2.44	256.0
Yamanashi	36.5	1.58	3.89	1.22	0.49	10.7	6.2	2.19	239.8
Nagano	42.4	1.78	4.05	1.06	0.58	11.5	5.1	2.36	236.1
Gifu	43.2	1.69	3.64	1.49	0.65	12.8	5.7	2.24	215.5
Shizuoka	39.8	1.44	2.97	1.03	0.57	9.8	5.3	2.15	207.8
Aichi	40.1	1.01	2.88	0.93	0.48	9.4	4.8	1.74	218.6
Mie	38.2	1.67	3.83	1.00	0.56	11.1	5.2	1.83	225.7
Shiga	37.8	1.49	2.55	1.34	0.50	7.8	4.3	3.26	231.4
Kyoto	45.5	1.50	3.54	1.23	0.50	9.1	4.7	2.62	334.9
Osaka	45.8	1.43	2.89	0.90	0.53	9.9	4.6	2.28	283.1
Hyogo	42.9	1.54	3.18	1.18	0.55	10.8	5.0	2.34	253.2
Nara	43.3	1.41	2.82	1.04	0.59	9.8	4.8	2.52	251.3
Wakayama	47.3	1.80	4.44	1.27	0.32	17.1	6.1	2.75	300.6
Tottori	41.1	2.12	4.96	1.77	0.53	13.1	5.0	2.83	316.7
Shimane	44.4	1.61	4.23	2.04	1.17	12.6	5.7	2.77	286.2
Okayama	50.4	1.31	3.83	1.15	0.63	14.4	6.1	2.67	312.0
Hiroshima	42.3	1.66	4.14	0.95	0.46	13.8	7.0	2.79	265.6
Yamaguchi	43.4	1.88	5.50	1.66	0.58	16.6	6.9	3.54	259.3
Tokushima	47.8	1.75	5.25	1.08	0.40	22.9	7.0	2.69	333.3
Kagawa	48.4	2.38	4.86	1.65	0.52	16.8	10.0	3.72	289.4
Ehime	43.5	2.27	4.03	1.91	0.88	16.2	8.1	3.01	272.4
Kochi	54.2	2.10	3.08	1.12	0.70	23.4	10.8	3.50	315.7
Fukuoka	47.4	1.84	3.50	1.35	0.47	13.3	6.6	2.49	313.4
Saga	48.1	2.31	5.10	0.73	0.24	16.4	8.6	3.03	287.1
Nagasaki	45.2	1.99	4.43	0.89	0.44	16.0	6.6	3.55	308.6
Kumamoto	47.5	1.59	4.48	1.13	0.40	17.2	7.6	2.66	294.8
Oita	55.4	2.00	5.90	1.13	0.43	19.9	8.1	2.60	278.4
Miyazaki	50.0	2.11	3.67	1.65	0.64	17.3	8.1	3.03	251.3
Kagoshima	54.9	2.46	4.24	1.60	0.43	21.1	9.5	4.24	272.5
Okinawa	42.4	1.46	3.40	0.83	0.35	9.8	5.5	2.15	250.8
Average	44.3	1.62	3.84	1.28	0.51	13.1	6.3	2.54	256.5
S.D.	5.3	0.40	0.83	0.39	0.19	3.9	1.6	0.59	41.9
minimum	33.4	0.85	2.49	0.63	0.17	6.8	3.7	1.51	167.0
maximum	56.4	2.46	5.90	2.09	1.17	23.4	10.8	4.24	334.9
Gini's	0.08	0.15	0.13	0.18	0.20	0.17	0.15	0.14	0.10
CV	12.0	24.5	21.6	30.3	37.1	30.0	25.3	23.3	16.3

"Serial angiography" and "3D image processing" is the number of facilities.

mately 2.9 times higher in Kagoshima than in Saitama.

The regional difference index for "*Mammography*" was the highest in Oita with (153.8, i.e., 5.90 units/100,000 population). The prefectures with the next highest values were Yamaguchi (143.1), Yamagata (137.1), Tokushima (136.7), and Saga (132.8). Conversely, the regional difference index for "*Mammography*" was the lowest in Ibaraki (64.8, i.e., 2.49 units/100,000 population). Therefore, it is shown that the regional difference index was approximately 2.4

Table 2 Regional difference index of each prefecture

Prefecture	Radiological Technologist	Serial angiography	Mammography	RI exam (scintigram)	PET	CT	MRI	3D image processing	overall evaluation
Hokkaido	127.3	128.5	84.2	158.1	129.9	121.6	129.1	105.8	123.1
Aomori	97.0	86.8	110.1	97.5	92.7	120.1	109.0	123.2	104.5
Iwate	85.4	63.8	78.9	111.7	110.1	105.9	126.1	84.7	95.8
Miyagi	91.1	79.6	76.2	114.0	93.5	73.6	91.3	71.2	86.3
Akita	98.8	68.0	117.7	133.0	39.7	82.8	100.1	90.9	91.4
Yamagata	97.2	95.0	137.1	106.0	71.7	83.8	97.7	82.1	96.3
Fukushima	100.5	91.7	101.0	78.6	104.9	93.3	85.8	83.6	92.4
Ibaraki	91.4	83.1	64.8	51.2	34.1	83.2	88.1	84.4	72.5
Tochigi	94.3	75.6	90.5	67.7	80.7	83.9	81.7	104.6	84.9
Gunma	101.3	110.0	103.7	103.3	120.9	95.1	93.7	98.4	103.3
Saitama	75.5	52.3	70.9	49.0	51.3	62.3	61.3	60.8	60.4
Chiba	81.5	60.2	82.6	63.6	66.4	60.4	74.0	69.3	69.7
Tokyo	97.4	69.1	90.5	88.5	84.9	63.0	69.3	72.6	79.4
Kanagawa	77.9	61.2	67.1	65.5	47.4	51.7	59.1	59.3	61.2
Niigata	93.2	78.8	116.0	137.5	61.0	82.2	91.4	83.3	92.9
Toyama	115.2	122.5	103.6	140.2	93.5	107.7	112.4	78.3	109.2
Ishikawa	107.5	118.2	102.2	163.0	189.4	94.5	118.7	120.1	126.7
Fukui	114.0	102.8	100.3	140.0	152.1	101.9	123.9	96.0	116.4
Yamanashi	82.2	97.3	101.3	94.7	96.0	81.6	98.1	86.1	92.2
Nagano	95.6	109.8	105.4	82.6	114.2	87.5	80.0	92.9	96.0
Gifu	97.4	104.3	94.7	116.4	127.9	97.7	89.8	88.2	102.0
Shizuoka	89.9	88.8	77.3	80.6	112.8	75.0	83.1	84.6	86.5
Aichi	90.5	62.2	75.1	72.5	94.5	71.4	75.5	68.5	76.3
Mie	86.1	102.7	99.8	77.9	109.7	84.8	82.6	72.2	89.5
Shiga	85.2	91.6	66.4	104.7	97.8	59.4	68.3	128.1	87.7
Kyoto	102.7	92.4	92.2	95.9	98.8	69.3	74.9	103.0	91.2
Osaka	103.4	88.0	75.3	69.8	105.2	75.8	72.3	89.7	84.9
Hyogo	96.9	95.2	82.8	92.0	107.7	82.1	79.1	92.3	91.0
Nara	97.6	86.8	73.4	80.9	117.2	74.8	76.3	99.3	88.3
Wakayama	106.7	110.8	115.8	98.9	62.7	130.9	97.1	108.3	103.9
Tottori	92.8	130.8	129.1	137.9	104.9	100.0	78.4	111.4	110.7
Shimane	100.1	98.9	110.3	159.2	230.6	95.9	90.1	109.2	124.3
Okayama	113.8	80.8	99.7	89.9	124.3	110.1	97.1	105.2	102.6
Hiroshima	95.5	102.4	107.7	74.3	90.7	105.0	110.2	109.9	99.5
Yamaguchi	97.8	115.8	143.1	129.6	114.2	126.4	108.7	139.4	121.9
Tokushima	107.8	107.8	136.7	83.9	79.7	174.7	110.8	105.9	113.4
Kagawa	109.3	146.5	126.6	128.9	102.1	127.9	158.7	146.5	130.8
Ehime	98.2	140.0	105.0	148.5	173.7	123.7	127.6	118.3	129.4
Kochi	122.3	129.4	80.3	87.3	138.3	178.6	170.7	137.8	130.6
Fukuoka	106.9	113.4	91.3	105.3	92.8	101.7	104.1	97.9	101.7
Saga	108.5	142.1	132.8	56.7	47.9	125.1	136.4	119.4	108.6
Nagasaki	102.0	122.9	115.4	69.0	87.5	122.4	104.0	139.5	107.8
Kumamoto	107.1	97.7	116.6	88.3	78.3	131.5	120.1	104.8	105.6
Oita	124.9	123.0	153.8	87.9	85.7	151.8	127.8	102.5	119.7
Miyazaki	112.8	130.1	95.7	128.8	126.9	131.8	127.9	119.3	121.7
Kagoshima	123.9	151.6	110.5	124.6	85.0	161.1	149.9	167.0	134.2
Okinawa	95.7	89.7	88.4	64.8	68.4	74.6	87.7	84.5	81.7

times higher in Oita than in Ibaraki.

The regional difference index for "*RI exam*" was the highest in Ishikawa (163.0, i.e., 2.09 units/100,000 population). The prefectures with the next highest values were Shimane (159.2), Hokkaido (158.1), Ehime (148.5), and Toyama (140.2). In contrast, Saitama had the lowest regional difference index for "*RI exam*" (49.0, i.e., 0.63 units/100,000 population). Therefore, it is shown that the regional difference index was approximately 3.3 times higher in Ishikawa than in Saitama.

Moreover, Shimane had the highest regional difference index for "*PET*" (230.6, i.e., 1.17

Table 3 Regional difference of health resources related to medical imaging

	Highest		Lowest		Regional differences	Regional differences ratio
Overall	Kagoshima	134.2	Saitama	60.4	73.8	2.22
Radiological Technologist	Hokkaido	127.3	Saitama	75.5	51.8	1.69
Serial angiography	Kagoshima	151.6	Saitama	52.3	99.3	2.90
Mammography	Oita	153.8	Ibaraki	64.8	88.9	2.37
RI exam (scintigram)	Ishikawa	163.0	Saitama	49.0	114.0	3.33
PET	Shimane	230.6	Ibaraki	34.1	196.5	6.76
CT	Kochi	178.6	Kanagawa	51.7	126.9	3.46
MRI	Kochi	170.7	Kanagawa	59.1	111.6	2.89
3D image processing	Kagoshima	167.0	Kanagawa	59.3	107.7	2.82

Regional differences = Highest - Lowest
Regional differences ratio = Highest / Lowest

units/100,000 population). The prefectures with the next highest values were Ishikawa (189.4), Ehime (173.7), Fukui (152.1), and Kochi (138.3). In contrast, Ibaraki had the lowest regional difference index for "*PET*" (34.1, i.e., 0.17 units/100,000 population). Therefore, it is shown that the regional difference index was approximately 6.8 times higher in Shimane than in Ibaraki.

Kochi had the highest regional difference index for "*CT*" and for "*MRI*" (178.6, i.e., 23.4 units/100,000 population, and 170.7, i.e., 10.8 units/100,000 population, respectively). With respect to "*CT*," the prefectures with the next highest values were Tokushima (174.7), Kagoshima (161.1), Oita (151.8), and Miyazaki (131.8), whereas Kagawa (158.7), Kagoshima (149.9), Saga (136.4), and Hokkaido (129.1) were the prefectures with the next highest values for "*MRI*." In contrast, Kanagawa had the lowest regional difference index for both "*CT*" and "*MRI*" (51.7, i.e., 6.8 units/100,000 population, 59.1, i.e., 3.7 units/100,000 population, respectively). Therefore, it is shown that the regional difference indices for "*CT*" and "*MRI*" were approximately 3.5 and 2.9 times higher in Kochi than in Kanagawa, respectively.

Furthermore, Kagoshima had the highest regional difference index for "*3D image processing*" (167.0, i.e., 4.24 facilities/100,000 population), followed by Kagawa (146.5), Nagasaki (139.5), Yamaguchi (139.4), and Kochi (137.8). In contrast, Kanagawa had the lowest regional difference index (59.3, i.e., 1.51 facilities/100,000 population, approximately 2.8 times lower than Kagoshima.

Overall, the highest regional difference index was in Kagoshima (134.2) followed by Kagawa (130.8), Kochi (130.6), Ehime (129.4), and Ishikawa (126.7). Conversely, Saitama had the lowest overall evaluation of regional difference index (60.4). The prefectures with an overall evaluation of the regional difference index of 80 or less were Tokyo (79.4), Aichi (76.3), Ibaraki (72.5), Chiba (69.7), and Kanagawa (61.2).

3-3 Hierarchical cluster analysis

As a result of a hierarchical cluster analysis, we classified the 47 prefectures into seven clusters. The dendrogram is a tree diagram that shows how individuals are clustered together in a cluster analysis (Fig.2). The mean item value for each of the seven clusters is shown in Table 4. We designated the cluster with the highest mean value in the regional difference index for each item as Cluster 1, and in descending order from Cluster 1 to Cluster 7.

Cluster 1 consisted of 3 prefectures: Kagawa, Kochi, and Kagoshima. Cluster 1 was charac-

Table 4 Average of regional difference index to each cluster

	Prefecture	Radiological Technologist	Serial angiography	Mammography	RI exam (scintigram)	PET	CT	MRI	3D image processing
Cluster 1	Kagawa, Kochi, Kagoshima	118.5	142.5	105.8	113.6	108.5	155.9	159.8	150.4
Cluster 2	Ishikawa, Shimane, Ehime	101.9	119.0	105.8	156.9	197.9	104.7	112.1	115.8
Cluster 3	Hokkaido, Toyama, Fukui, Tottori, Yamaguchi, Miyazaki	110.0	121.8	109.3	139.1	120.3	114.9	113.4	108.4
Cluster 4	Aomori, Wakayama, Hiroshima, Tokushima, Saga, Nagasaki, Kumamoto, Oita	106.2	111.7	123.6	82.1	78.2	132.7	114.4	114.2
Cluster 5	Akita, Yamagata, Niigata	96.4	80.6	123.6	125.5	57.4	82.9	96.4	85.4
Cluster 6	Iwate, Miyagi, Fukushima, Gunma, Tokyo, Yamanashi, Nagano, Gifu, Shizuoka, Aichi, Mie, Shiga, Kyoto, Osaka, Hyogo, Nara, Okayama, Fukuoka	95.8	90.4	88.1	92.2	106.3	83.5	86.0	89.9
Cluster 7	Ibaraki, Tochigi, Saitama, Chiba, Kanagawa, Okinawa	86.0	70.3	77.4	60.3	58.1	69.3	75.3	77.2

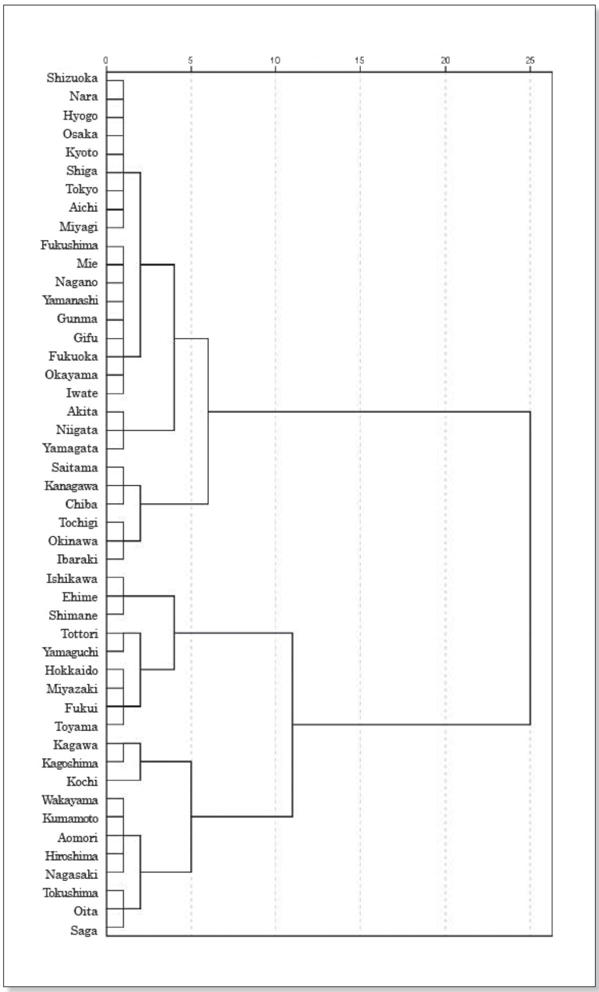

Fig.2 Dendrogram

terized as a region with abundant healthcare resources that greatly exceeded the national average for all items, especially for "*Serial angiography*," "*CT*," and "*MRI*".

Cluster 2 consisted of 3 prefectures: Ishikawa, Shimane, and Ehime. Cluster 2 was characterized as a region with abundant healthcare resources, where all items were higher than the national average, and where the "*RI exam*" and "*PET*" were particularly high.

Cluster 3 consisted of 6 prefectures: Hokkaido, Toyama, Fukui, Tottori, Yamaguchi, and Miyazaki. Cluster 3 was characterized as a region with abundant healthcare resources where all characteristics exceed the national average.

Cluster 4 consisted of 8 prefectures: Aomori, Wakayama, Hiroshima, Tokushima, Saga, Nagasaki, Kumamoto, and Oita. Cluster 4 was characterized by a lack of healthcare resources for nuclear medicine examinations, with "*RI exam*" and "*PET*" below the national average.

Cluster 5 consisted of 3 prefectures: Akita, Yamagata, and Niigata. Cluster 5 was characterized by prefectures where the scores for "*Mammography*" and "*RI exam*" were significantly higher than the national average, whereas the scores for "*PET*" were significantly lower.

Cluster 6 consisted of 18 prefectures: Iwate, Miyagi, Fukushima, Gunma, Tokyo, Yamanashi, Nagano, Gifu, Shizuoka, Aichi, Mie, Shiga, Kyoto, Osaka, Hyogo, Nara, Okayama, and Fukuoka. Cluster 6 was characterized by a well-balanced region with efficient healthcare resources.

Cluster 7 consisted of 6 prefectures: Ibaraki, Tochigi, Saitama, Chiba, Kanagawa, and Okinawa. Cluster 7 was characterized as a region with poor healthcare resources, falling below the national average in all categories.

4. Discussion

In this study, we evaluated potential regional differences using Gini's coefficient and CV based on the number of "*radiological technologists*" and the number of "*diagnostic imaging devices*" reported in the Medical Institution Survey. We also categorized regional characteristics in healthcare resources related to medical imaging using a hierarchical cluster analysis. Our results show that both Gini's coefficient and the CV for "*radiological technologist*" were lower than those for "*physician*" with low regional differences. On the other hand, both coefficients for each diagnostic imaging device were higher than those for "*physician*," with high regional differences. In particular, "*PET*" exhibited the largest regional differences among all the diagnostic imaging devices investigated in this study. Regional uneven distribution is influenced by medical demand, demographic structure, and geography [9]. Therefore, we had assumed that the healthcare resources related to medical imaging, especially in prefectures with low population density such as Hokkaido, would have been high nationwide. However, in order to provide high-quality healthcare in all prefectures, diagnostic imaging devices and radiological technologists are needed, even in small population prefectures. Therefore, we expect that eliminating regional uneven distribution will be a very challenging and difficult issue.

Saitama, Chiba, and Kanagawa, which have a low overall regional difference index, have limited healthcare resources for their populations. In particular, it was identified that Saitama and Chiba lack both healthcare resources related to medical imaging, but also healthcare resources such as physicians, nurses, and hospitals [10]. Till now, there are two prevalent reasons that explain why the scarcity of healthcare resources in Saitama and Chiba has not had a major impact on the respective populations. The first reason is that the populations are still relatively young and disease prevalence is low. The second reason is that a significant portion of these populations work in Tokyo, therefore, they often choose to go to a medical institution in Tokyo, should they fall sick [10]. According to the statistical survey of the daytime population of Tokyo in the 2015 census, the population inflow to Tokyo was 936,100 people from Saitama, 716,881 people from Chiba, and 1,068,505 people from Kanagawa. Overall, this number comes to approximately 2.9 million people, when including the population inflow from other prefectures [11]. Consequently, the daytime population of Tokyo increases by approximately 2.4 million people, even after subtracting population outflow from Japan's capital city. Therefore, the overall regional differential index using the daytime population would be significantly higher in Saitama, Chiba, and Kanagawa prefectures than the results found in this study. Similarly, if we calculate the overall regional difference index of Tokyo on the basis of its daytime population, then it would be significantly lower than the results provided in this study. As a result, it is necessary to calculate the overall regional difference index that considers not only the population but also the characteristics of the region, such as the daytime population. The medical demand is expected to increase in Saitama, Chiba, and Kanagawa in the future for two reasons [10]. The first reason is the rapid increase in aging populations, whereas, the other reason is the increase in the use of local medical institutions due to retirement. Therefore, it is necessary to consider both the inflow and outflow of the population when planning and improving the medical care provision system for medical imaging. In Okinawa, where the aging rate is the lowest in Japan, the overall regional difference index is bound to be higher than the results shown in this study. Similarly, in Akita, where the aging rate is the highest in Japan, the overall regional difference index is slightly lower than the national average. However, if the calculations are based on the aging rate, the overall regional difference index will further decrease, and the region will seem to have scarce healthcare resources. Therefore, it is necessary to consider not only the results of this study, but also the inflow/outflow of populations, and the aging rate in order to plan and improve the medical care provision system.

A hierarchical cluster analysis enabled us to classify our data into 7 clusters, thus providing us with a greater insight regarding their characteristics. The regional difference indices in clusters 1 and 3 were above the average for all items included, i.e., indicate prefectures with abundant healthcare resources. Nuclear medicine examinations with "*RI exam*" and "*PET*" had a significant impact on this classification. Cluster 2 indicates prefectures where nuclear medicine examinations were abundant, whereas cluster 4 indicates prefectures where nuclear medicine examinations were poor. Furthermore, cluster 5 indicates prefectures that are abundant in "*RI exam*" but poor in "*PET*." All 18 prefectures included in cluster 6 were average and well-balanced prefectures with well-developed healthcare resources. We suggest that Cluster 6 could be helpful in terms of planning and improving the medical care provision system. In all six prefectures of cluster 7, healthcare resources were generally scarce. These prefectures were in fact the bottom three prefectures in the overall regional difference index (Saitama, Chiba, and Kanagawa), Ibaraki, Tochigi, and Okinawa. Therefore, we suggest that it is necessary to review the medical care provision system for medical imaging after assessing future changes in medical demand such as population inflow/outflow and aging rate.

Currently, each prefecture is planning a medical care provision system that considers the characteristics of each prefecture. In addition, shared use of diagnostic imaging devices is being promoted in order to provide efficient medical care. Therefore, it is necessary to plan and improve the medical care provision system by not merely considering individual hospitals but the entire prefecture. The results of this study are extremely useful for the development of the medical care provision system in each prefecture. However, the development of the medical care provision system requires more detailed data analysis of secondary medical areas. Here, the secondary medical area could be a medical administration area set for each large city or wide area municipality in the regional healthcare plan. For example, in Tochigi prefecture, there are six medical regions: "*North*," "*West*," "*Utsunomiya*," "*East*," "*Ryomo*," and "*South*," and there are multiple medical regions in each prefecture. In addition, the development of this system requires continuous research.

Furthermore, there is no gold standard that defines the required number of radiological technologists. Therefore, it is difficult to understand the potential excess and/or lack of radiological technologists. This study is a relative survey of the presence or absence of regional uneven distribution in healthcare resources related to medical imaging. Therefore, the excess and/or lack of radiological technologists is not captured. It can be inferred that the factors causing regional differences include medical demand, demographic structure, and geographical conditions. In the future, detailed factor analysis of the excess and/or lack of radiological technologists and regional uneven distribution must be an essential issue to consider.

5. Conclusion

In this study, we evaluated regional uneven distribution and used a hierarchical cluster analysis to categorize each item based on the number of radiological technologists and the number of diagnostic imaging devices reported in the medical institutions survey. Gini's coefficient and the CV underline that the regional differences were lower for radiological technologists compared to physicians, whereas the regional differences were larger for diagnostic imaging devices than for physicians. The results of this hierarchical cluster analysis showed that the 47 prefectures could be classified into seven clusters with distinct and well-defined characteristics. We hope that the results of this study will be used for the efficient planning and improvement of the medical care provision system in each prefecture.

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The Usefulness of Bone Suppression Image-Based Temporal Subtraction Processing for the Improvement of Lung Nodule Detection on Chest Radiograph Images

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Key words: Digital Chest X-Ray Images, CAD, Temporal Subtraction Processing, Bone Suppression Processing, Improved Detection

【Summary】
Chest X-ray (CXR) is the most commonly used diagnostic examination in lung cancer screening. The temporal subtraction (TS) processing of CXRs using computer-aided diagnosis (CAD) software is a technique in which a previous CXR is used to enhance evaluation of changes in an intervening time. However, if the superpositioning of the two images is not accurate, excessive misregistration artifacts will make it difficult for radiologists to differentiate between true changes and simple artifacts. In this study, we aimed to use bone suppression (BS) processing as a method to reduce artifacts when detecting a lesion became difficult due to the occurrence of artifacts between two images. The contrast-to-noise ratios (CNRs) of TS processing images with and without BS processing were calculated and compared based on several types of positions including anterior inclination, lateral inclination, right anterior oblique (RAO), and left anterior oblique (LAO). Our results showed that CNRs were significantly improved with BS processing.

1. Introduction

According to the Ministry of Health, Labor, and Welfare 2018, cancer is the leading cause of death in Japan. Lung cancer is increasing in incidence in both males and females [1]. Currently, greater emphasis is given on preventive medicine for the early detection and treatment of lung cancer.

Lung cancer screening is generally performed with sputum examination and chest radiography, although high-performance computed tomography (CT) is also widely used. CT screening is usually used for treatment determination. Sputum examination is performed on high-risk patients with a history of smoking; however, chest radiography is critical for the early detection of lung cancer. Chest radiography can be promptly and effortlessly performed and has the advantages of low cost and low exposure to radiation. More than 80 different lesions have been shown to exist in the lung, and images may additionally include the presence of overlapping ribs and normal tissue, making the detection of pale, small, and early lesions of lung cancer challenging. Approximately 95% of missed lung cancer lesions overlapped with the ribs and clavicles [2].

Research and development of computer-aided diagnosis (CAD) using artificial intelligence technology have been employed in the field of diagnostic imaging. However, the reading efficiency and diagnostic accuracy must be improved. Temporal subtraction (TS) processing of chest radiographs involves superimposing two images of the same person, one from the past and one from the present; then, the changes over time are identified. This is known as a computer-aided detection system, which identifies lesions and presents the results for assessment. TS processing is useful to improve the visibility of lesions that overlap with normal tissue and may be overlooked by doctors [3), 4)].

In TS processing, two images of the same patient, one current image and one past image, acquired with digital radiography and computed radiography are subjected to differential processing. Specifically, to superimpose the two images, first, a global matching process is performed on the past image to roughly match the thorax. Second, a local matching process corrects the distortion of the lung structure. This two-step nonlinear image superimposition process emphasizes the shades that changed over time [5)]. The artifacts are reduced with nonlinear image deformation, which is useful for detecting changes over time [6)]. However, removing sharp linear artifacts in the rib edges and fine artifacts in the pulmonary vessels is complex as artifacts may persist even after performing the imaging deformations [7)]. Thus, TS greatly affects the reproducibility of past and current images [8)]. If the superimposition of the two images in a chronological sequence is not accurate, strong artifacts will appear in the entire lung field, which will interfere with image reading.

In the present study, we employed a method to improve lesion detection in cases of poor detection due to artifacts triggered by a misalignment between two images. Although there have been reports on improvement of lesion detection by modifying the algorithm of TS processing systems [7)], the use of both TS and bone suppression (BS) processing has not been reported. The BS process is a CAD application for chest radiographs. This CAD application depresses the signals of the ribs and clavicles from the lung field and can be generated as a single image [9)]. The detection rate of lesions is improved by enhancing visibility with BS processing, even for radiologists who are not specialists in chest radiology [10)]. Previous reports have demonstrated that BS processing is not significantly affected by positioning [11)]. In the present study, BS processing was used as a preprocessor for TS processing, and TS images were generated for both the past and present images. We compared the effect of lesion detection on TS images generated from the original and BS images using physical evaluation.

2. Materials

The present study used the radiographic system, Radnext 50 (Hitachi Medical Corporation), and the flat panel detector (FPD) [AeroDR (A50C-50438) by Konica Minolta, Inc. NEOVISTA I-PACS EX (A791-0304)] for TS and BS processing. Kyoto Kagaku Co., Ltd. N-1 LUNGMAN was used for the chest phantom. ImageJ (1.50i) was used for statistical analysis of the contrast-to-noise ratio (CNR) region of interest (ROI).

3. Methods

In this study, for investigating the effect of positioning on the CNR in TS processing images, we calculated the CNR for each angular change in positioning using images of a chest phantom with an attached simulated nodule. Additionally, we calculated and compared the CNRs of TS images generated from the original and BS images to determine whether BS processing improved detection of poor lesions when artifacts occurred due to mispositioning. For TS images after BS processing, the latter was performed on the reference image and all comparison images with varying positioning angles, which were differentially processed. Subsequently, the mean and standard deviation of the CNR of TS images with and without BS processing, as well as the improvement rate of the CNR, were calculated. We also performed a significant difference test for TS images with and without BS processing using the Mann-Whitney U test for CNR. The significance level was set at 5%.

3-1 N-1 LUNGMAN

In this study, experiments were conducted using images of a simulated nodule mounted in the lung field of a chest phantom. This phantom was composed of a soft tissue substitute and artificial bone with an absorption rate similar to that of the human body. The phantom had simulated blood vessels arranged in the lung field. Therefore, the concentration changes were the same as observed in the human body. The inner structure of the lung field was detachable, and a simulated lesion was placed inside.

3-2 Simulated nodules

A simulated nodule with a diameter of 1 cm and a CT value of 50 HU was used. Figure 1 illustrates nodules were attached to the left under the clavicle, left heart edge, right middle lung field, or right hilar area.

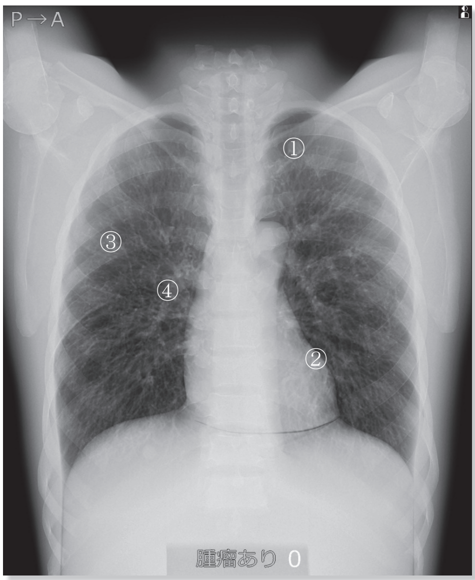


Figure 1 Mounting position of the simulated nodule: 1) left under the clavicle; 2) left edge of the heart; 3) right lobumediusu, middle lobe; and 4) right hilus pulmonis

3-3 CNR

The CNR of the simulated nodules was calculated as quantitative evaluation of the physical characteristics of the visibility of lesion shadows on TS images.

We defined the boundaries of the simulated nodule as visually recognized using ImageJ (1.50i). Figure 2 illustrates S was set as the inner signal region. The donut-shaped background region outside the nodule was set as B. The size of the background region B was set to 5 mm in width, which ensured that the characteristics of the lung fields would not be lost.

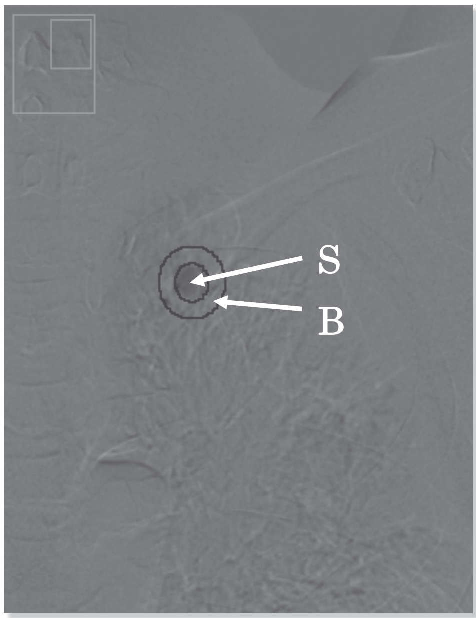


Figure 2 The position of the region of interest

$$\mathrm{CNR} = \frac{|S_{ave} - B_{ave}|}{B_{sd}}$$

where S_{ave} is the average luminance value in the signal region, B_{ave} is the average luminance value in the background region, and B_{sd} is the standard deviation of the background luminance value. Since the value of CNR fluctuated depending on the ROI, the average of the two measurements was used for analysis.

3-4 Reference and comparison images

The displacement of positioning was evaluated by focusing on the angle of displacement from the posterior-anterior (PA) direction, which is often used in lung cancer screening, and was assessed in the following directions: anterior tilt, right anterior oblique (RAO), left anterior oblique (LAO), right-lateral flexion, and left lateral flexion. The comparison images were processed by differentiating the images with different positioning angles. The comparison image was shifted from the reference image by 1°– 9° in each direction in 1° increments. If a nodule was not correctly positioned or the edges of the simulated nodule were indistinguishable from the surrounding artifacts, the ROI could not be identified; therefore, we compared the data up to the angle at which all the simulated nodules could be measured.

3-5 TS and BS processing

The processing was executed on the I-PACS EX screen. The processed images were automatically generated with the output in approximately 1 s. An initial display image was used.

4. Results

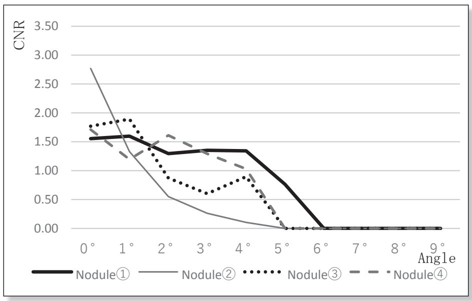
Figure 3 illustrates the graphs of CNR showing the changes in the positioning of TS images with and without BS processing. In the anterior tilt TS images without BS processing, simulated nodules two, three, and four could not be measured at 5°, and all the simulated nodules above 6° could not be measured. In TS images with BS processing, simulated nodule two could not be measured at 5°, and simulated nodule four could not be measured at 6°. In the RAO TS images without BS processing, simulated nodule four could not be measured at 5°, and simulated nodule two could not be measured at 6°. In the TS images with BS processing, all the simulated nodules could be measured at all angles. In the LAO TS images without BS processing, simulated nodules two and four could not be measured at 5°. In TS images with BS processing, all simulated nodules could be measured at all angles. At both right and left lateral flexion, all the simulated nodules could be measured up to 9° in the TS images with and without BS processing.

All the simulated nodules were measured in all positions up to 4° as CNRs. Table 1 illustrates the means, standard deviations, and improvement rates of the CNRs of simulated nodules one to four in the TS images with and without BS processing. In the anterior tilt, RAO, and LAO, the improvement in CNR was higher for TS images with BS processing than for those without BS processing in the simulated nodule. In the anterior tilt position, improvement in the CNR was 10.2% in simulated nodule one; however, the highest was in simulated nodule three at 51.0%. In RAO and LAO, simulated nodule three was low at approximately 10%; however, simulated nodule four was the highest at 34.7% and 61.6%. The improvement rates for right and left lateral flexions were low, with some nodules showing a negative improvement rate. Even after TS processing alone, the CNR was stable and relatively high and was detected at around 2.0.

Figure 4 illustrates the mean and standard deviation of the CNR of TS images with and without BS processing. There was a significant difference in the anterior tilt, RAO, and LAO. There was no significant difference between the right and left lateral flexions.

5. Discussion

Chest X-ray (CXR) imaging is an excellent examination method as it has the advantages of low cost, easy to use, and low exposure dose, despite the considerable amount of information obtained. However, reading CXR images is highly cumbersome for radiologists, who must take multiple pictures in a short period, to minimize misdiagnosis. TS processing can improve detection as it allows instantaneous visualization of changes in lesions over time [12]. However, artifacts occur when there is a misalignment between the two images due to the influence of the reproducibility of the past and current images. This artifact makes it difficult to distinguish between detection of changes over time and simple artifacts [13]. The main features of the artifacts are the linearity of the



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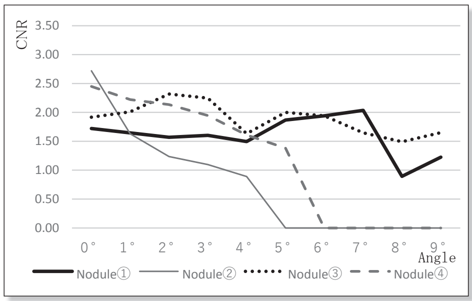
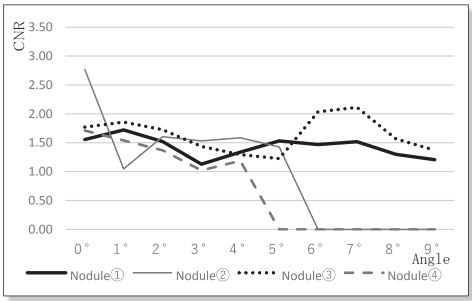


(a) − 2



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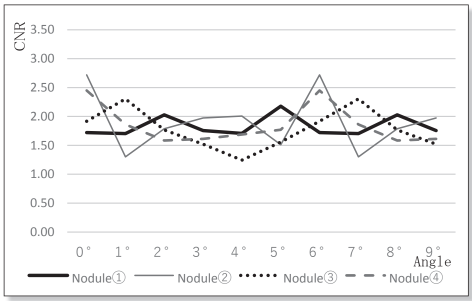

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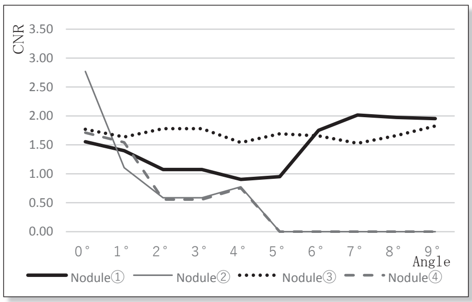

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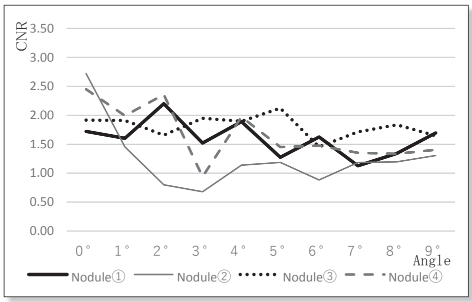

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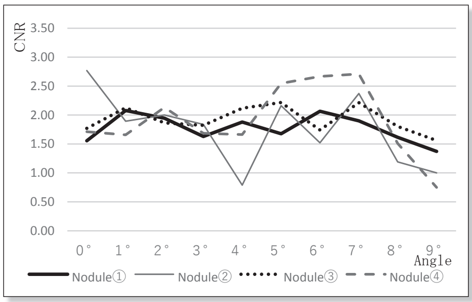

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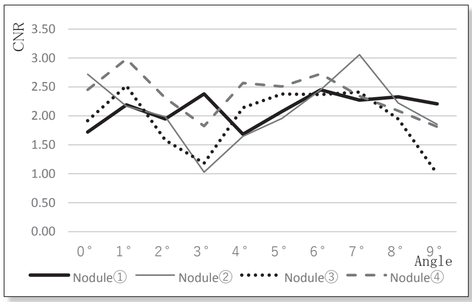

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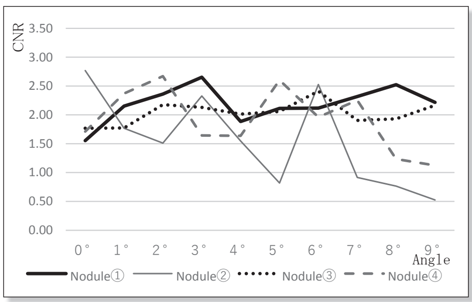

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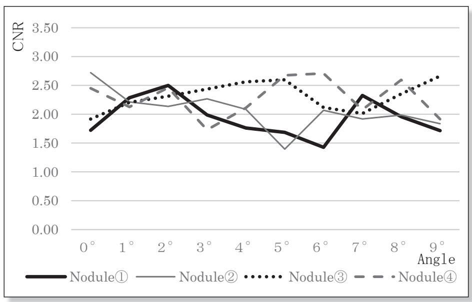

(e) − 2

Figure 3 Graphs of CNRs showing changes in the positioning of TS images with and without BS processing

(a) Anterior tilt (b) Right anterior oblique (RAO) (c) Left anterior oblique (LAO) (d) Right lateral flexion (e) Left lateral flexion
1. TS images without BS processing 2. TS images with BS processing

Table1 Values of CNRs for each simulated nodule on temporal subtraction images with and without bone suppression
(a) Anterior tilt
(b) Right anterior oblique (RAO)
(c) Left anterior oblique (LAO)
(d) Right lateral flexion
(e) Left lateral flexion

Simulated Nodule	①		②		③		④	
Ave/Std	Ave	Std	Ave	Std	Ave	Std	Ave	Std
TSI without BS	1.51	0.11	1.11	0.88	1.37	0.47	1.50	0.28
TSI with BS	1.66	0.05	1.49	0.65	2.07	0.24	2.08	0.28
Improvement rate (%)	10.2		34.5		51.0		38.1	

(a)

Simulated Nodule	①		②		③		④	
Ave/Std	Ave	Std	Ave	Std	Ave	Std	Ave	Std
TSI without BS	1.45	0.20	1.71	0.57	1.62	0.21	1.37	0.25
TSI with BS	1.78	0.12	1.96	0.46	1.75	0.36	1.84	0.32
Improvement rate (%)	22.8		14.7		8.3		34.7	

(b)

Simulated Nodule	①		②		③		④	
Ave/Std	Ave	Std	Ave	Std	Ave	Std	Ave	Std
TSI without BS	1.27	0.24	1.19	0.81	1.69	0.09	1.20	0.46
TSI with BS	1.79	0.24	1.36	0.73	1.87	0.11	1.94	0.54
Improvement rate (%)	40.3		14.2		10.1		61.6	

(c)

Simulated Nodule	①		②		③		④	
Ave/Std	Ave	Std	Ave	Std	Ave	Std	Ave	Std
TSI without BS	1.82	0.20	1.86	0.63	1.94	0.15	1.77	0.18
TSI with BS	1.98	0.27	1.91	0.56	1.87	0.46	2.43	0.38
Improvement rate (%)	9.2		2.8		-3.7		37.2	

(d)

Simulated Nodule	①		②		③		④	
Ave/Std	Ave	Std	Ave	Std	Ave	Std	Ave	Std
TSI without BS	2.12	0.38	1.98	0.49	1.97	0.17	2.01	0.43
TSI with BS	2.05	0.30	2.28	0.23	2.29	0.22	2.17	0.27
Improvement rate (%)	-3.3		15.1		15.9		8.4	

(e)

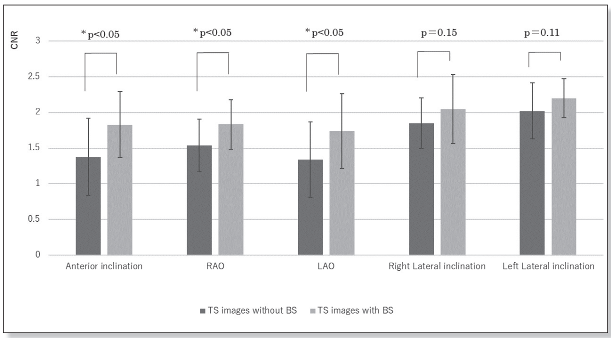

Figure 4 Comparison of CNRs for TS images with and without BS processing of four positions. Mean value and standard deviation of the CNR

rib edges and the complexity of fine pulmonary vessels.

In this study, we generated artifacts by shifting the positioning of the comparison image by 1° in the forward-leaning, RAO, LAO, right-lateral bending, and left lateral bending positions against the reference image. The results were divided into two groups: anterior tilt, RAO and LAO, and right and left lateral flexions.

Although the variations in CNR were large for deviations to the right and left lateral bends, the superposition of TS processing was sufficient to produce TS images with few artifacts within a range of up to 9°. These were two-dimensional misalignments in the X and Y axes, occurring by the rotation of the FPD with the front surface of the chest attached. The misalignment was corrected with the global matching process of TS processing and was detected by TS processing alone. Therefore, the CNR did not improve, even for TS images with BS processing.

In contrast, in the cases of an anterior tilt, RAO, and LAO, a part of the body is separated from the FPD and is displaced not only in the X-Y axis but also in the Z-axis. Although a complex warping process was performed in the local matching after the global matching process, it was inadequate to cope with the increasing displacement of the body. Therefore, artifacts and simulated nodules appeared in the TS images, where the edges cannot be seen beyond 5°. In this case, we first generated BS images, followed by the TS images. All the simulated nodules were measured up to 9° in the RAO and LAO positions. In the anterior tilt position, simulated nodules one and three were measured up to 9°. Simulated nodules two and four could be measured up to 4°, with no significant differences between TS images with and without BS processing. The calculated anterior tilt of 4° was defined as a state in which the panel and body were 3 cm apart at the lower end of the FPD. Although it is possible in elderly patients with bent hips, it is considered to be no problem in medical examinations.

The Mann-Whitney U test demonstrated that there was a statistically significant difference in the CNR values for the anterior tilt, RAO, and LAO positions between the TS images with and without BS processing. For the artifacts caused by three-dimensional misalignment, the CNR was improved by generating a BS processed image first, followed by a TS image. Consequently, the detections of all simulated nodules in the anterior tilt, RAO, and LAO positions were improved.

The improvement rate for CNRs was higher than 30% in the hilar area. This area contains a mixture of two complex artifacts: linear rib edges and fine pulmonary vessels. The results suggested that the rib shadows in the entire lung field were attenuated by the BS and TS processes. The complex superposition process was reduced by combining the artifacts into a single factor, and the CNR was improved. However, the templates of the TS treatment superposition also included the thorax and pulmonary vessels of normal tissue and the ribs. Nevertheless, the possible reduction of accuracy with the weakening of the ribs has not been tested. Areas with many vessels can be accurately superimposed on the ribs when they are weakened; however, they may not be aligned as the number of vessels decreases.

In the case of poor lesion detection due to artifacts caused by the inadequate superimposition of past and current images, we read the TS images automatically generated using picture archiving and the communication system. However, in this study, as a method to improve lesion detection in clinical practice, we demonstrated that TS processing after BS processing using two images improved lesion detection. The diagnostic accuracy of TS images is expected to improve with improvement in the detection capability.

In the present study, we focused on the angle in the upright frontal PA direction, often used in medical examinations. However, since various imaging methods are used in clinical examinations, the associated discrepancies must be evaluated. In the future, we must investigate the effect of Z-axis misalignment on the magnification rate and radiograph centerline, as well as respiratory misalignment and other lesions that are limited by phantom experiments. The variety in lesions must be studied in the future. Additionally, we assessed both physical and visual evaluations, such as receiver operating characteristic observer experiments, for maximizing its use in clinical practice.

6. Conclusion

In TS processing, artifacts tend to appear due to the mismatch of past and current images, which further complicates the temporal changes of lesions. In the present study, the nodules were unable to cope with three-dimensional misalignment, reducing the detectability of the nodules. Using BS processing in advance improved the CNR and was useful for nodule detection.

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New Quantitative Calculation method of Contrast Values in Slot Scan Image

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Key words: long length radiography, slot scan image, contrast, blur

【Summary】

The slot scan technology for long-length radiography installed in the fluoroscopic imaging equipment performs continuous radiographing while the X-ray tube and the light-receiving unit simultaneously move in parallel, creating a long-length image. The disadvantage is that the exposure while moving creates a blurred image looking with reduced contrast, contributing to low image quality. Although the cause is related to the combination of exposure time and tube voltage, the conventional contrast improvement method cannot be applied due to the influence of blurring, and there is no physical evaluation report, only a visual evaluation report.

In this study, we analyze the blur part and propose a method to calculate the source of the new concept of contrast quantitatively.

Background

Long-length radiography systems aimed at full spine imaging and full leg imaging is classified into the general X-ray radiography equipment and the fluoroscopy radiography equipment.

The general X-ray equipment includes a system in length of which the X-ray tube and the light-receiving unit move in parallel (Fig.1 a1), the X-ray tube inclines (Fig.1 a2), and images are taken at a time in light irradiation field (Fig.1 a3).

The fluoroscopy radiography equipment includes a system in which the X-ray tube and light-receiving surface move in parallel (Fig.1 b1), images are taken in the large field of view, and images are taken in sequence while moving (Fig.1 b2). It is introduced and operated according to the circumstances of each hospital.

The light-receiving surface changed from analog to digital computed-radiography (CR) and flat-panel detector (FPD), and the image quality improved digital image processing. FPD system can output the X-ray signal as a digital signal in real-time. It is characterized by images with a large field of view, less distortion, a broad dynamic range, and high detective quantum efficiency. Therefore, it has a possibility to reduce radiation dose.

In contrast, the slot scan technology for long

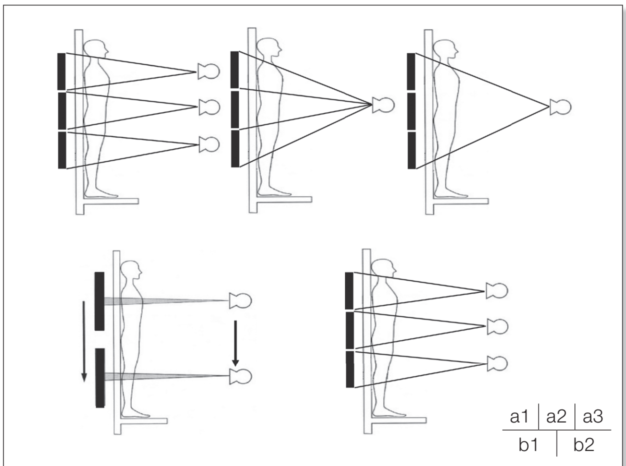


Fig.1 Long length radiographic system

(a1), (a2), (a3): X-ray general radiographic system
(b1), (b2): Fluoroscopic radiographic system

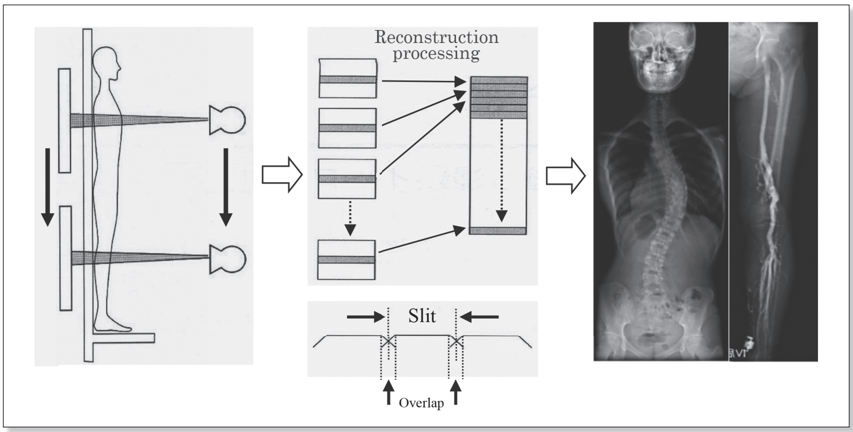


Fig.2 Image creation process with slot scan technology (from exposure to image creation)
(a) Image Acquisition (b) Stitching (c) Long length image

images in FPD-mounted fluoroscopy X-ray radiology equipment makes the examination easy for patients because it takes only 1–2 min from radiation to the end of image processing. It is good for throughput with easy handling, fast processing of images, and short examination time (Fig.2) [1-3].

The imaging method continuously irradiates an X-ray beam with a slit-shaped (2 or 4 cm) collimator, produce more than 10 images, and make one long-length image.

Since an X-ray beam radiates vertically toward an object, it has a constant scale with less distortion.

Consequently, in the field of orthopedics, it is often used to measure alignment and evaluate a patient's condition before and after operation [4, 5]. It is also applied to leg angiography in the field of surgery due to its continuous imaging [6].

The imaging method is that the X-ray tube and the light-receiving part (FPD, 17 × 17 inch) simultaneously move from the head to the foot side at a constant speed (HS mode: 150 mm/sec, HQ mode: 75 mm/sec) and have a slit shape (HS mode: 4 cm, HQ mode: 2 cm), irradiates an X-ray beam from a collimator for continuous exposure.

The tube voltage can output from 60 to 130 kV with a exposure time of 1.0–20.0 msec. The modes available include three-way, 110 cm, 120 cm, or 150cm on source image receptor distance. Slit images become one long image through superposition. The image mode has the HS mode, which is standard image quality, and the HQ mode, which is high quality (Table 1). The tube voltage (kV), tube current (mA), and exposure time (s) must be set manually because the automatic exposure control cannot be used. Because an X-ray is radiated while moving, this results in blurred and low-quality images (Fig.3). A picture taken in a moving vehicle may be blurred in normal mode but can be taken when in an almost stationary state at a short exposure speed.

Thus, this image is slightly or strongly

Table 1 Exposure techniques with slot scan technology (2 types)
Tube current [mA]: 400 mA (constant)

Mode	Moving Speed [mm/sec]	Slit width [cm]	Tube voltage [kV]	Exposure time [msec]	SID [cm]
HS	150	4	60–130	1.0–20.0	110/120/150
HQ	75	2	60–130	1.0–20.0	110/120/150

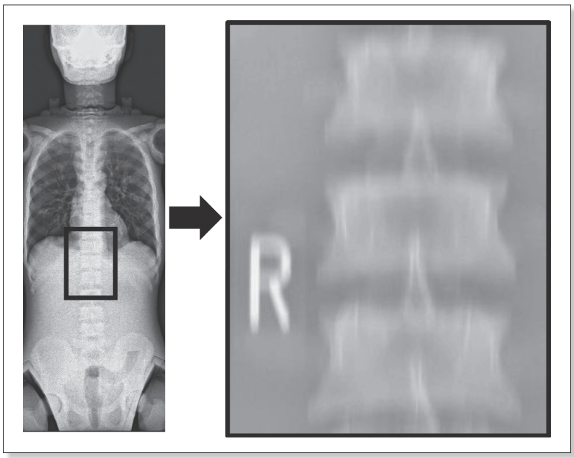


Fig.3 Features of slot scan images (blurred image)
Blur appears in the x-ray tube traveling direction

blurred, leading to a degree of contrast. Similarly, the slot scan images can be stationary at a short exposure speed.

However, it is necessary to increase the tube voltage because the image quality decrease depending on the exposure speed. Based on these findings, it is important to consider the tube voltage and not only the exposure speed to take fine slot scan images. Due to the influence of blurring, a highly accurate physical evaluation, such as the contrast noise ratio

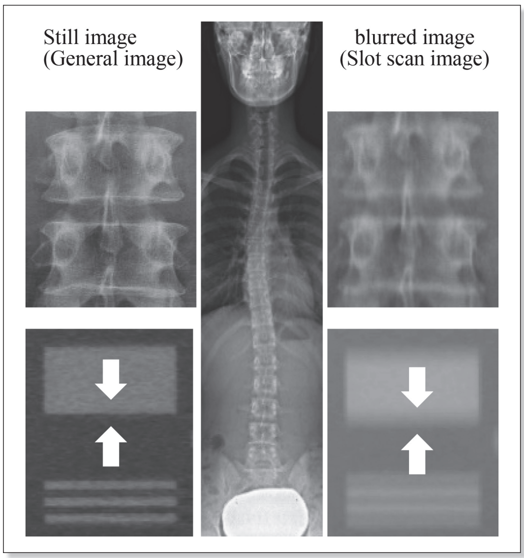


Fig.4 Difference between still image and blurred image

Still image: Concentration boundary is clear (sharp)
Blurred image: Concentration boundary is unclear (slightly change)

(CNR), and some method must be considered necessary in capturing slot scan images.

In this study, we suggest methods that evaluate the contrast in slot scan images quantitatively by analyzing the blur it produces.

1. Methods

1-1 Definition of contrast in slot scan images

1-1-1 Difference between general radiographic images and slot scan images

Images contain motion elements and are expressed as a blur since the X-ray tube and imaging unit continuously radiate an X-ray beam while moving in slot scan images. In the area indicated by the arrows in Fig.4, the concentration of contrast rapidly changes in still images, but it changes by gradation in the blur of slot scan images. Furthermore, when the range is broad the image is difficult to observe. When the range is narrow it is easy to observe the image, which is almost stationary. This blurred range is observed like low contrast images due to the vague concentration of contrast (Fig.5). We define this as the contrast in visual effects.

1-1-2 The feature of slot scan images

Regarding the blurring in slot scan images, the width of the blur can be improved by shortening the imaging time. On the other

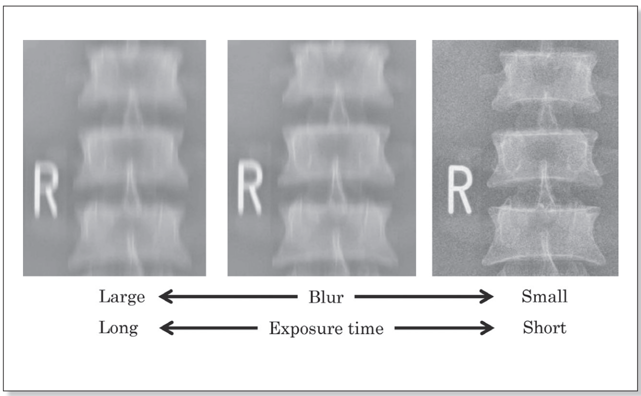


Fig.5 Difference of blurred size　a | b | c

The size of the blur is affected by the exposure time
(a) Large blur image, exposure time is long
(b) Middle blur image, exposure time is middle
(c) Small blur image, exposure time is short

hand, the apparent contrast is also affected by image quality caused by the tube voltage. Therefore, the tube voltage must also be considered.

The relationship between image and X-ray dose can be expressed as the photo effect (P.E.) in the following equation:

$$P.E = V^n \cdot I \cdot t / r^2 \cdots\cdots\cdots\cdots (1),$$

where V is the tube voltage, n is the tube voltage index (2–6), I is the tube current, t is the imaging time, and r is the distance.

Equation (1) shows that when the imaging time (t) is shortened, the image effects can be kept constant by increasing the tube voltage (V), and the image effects can be maintained at a constant level. However, when the tube voltage (V) is increased, the image changes in decreasing contrast, owing to the change in the X-ray image quality. This is the case for both general radiographic imaging and slot scan imaging.

In general radiographic imaging, decreasing the tube voltage and extending the imaging time improves the contrast. On the other hand, the contrast does not improve in slot scan imaging. This is because extending the imaging time increases the blur and decreases the contrast in visual effects. If the imaging time is shortened, the amount of blur is reduced, and the contrast tends to improve. However, when the tube voltage increases, the contrast drops due to changes in the X-ray image quality. Thus, there is a contradictory relationship between the imaging time and tube voltage with respect to the change in image quality. To improve the image quality of slot scan images, it is insufficient to decrease the blur width; however, it is also necessary to consider the X-ray image quality caused by the tube voltage. Since a change in the blur is affected by both the imaging time and the tube voltage, we define this change as the amount of blur.

Therefore, it is assumed that an optimal combination of the imaging time and tube voltage can maintain an optimal visual contrast in slot scan images.

1-1-3 Analysis of the amount of blur (contrast in visual effects)

The profile curve (image) of the blurred area is measured from an image obtained by slot scan imaging (Fig.6a). While the density of a still image abruptly changes, the density (signal value) of a slot scan image gradually changes due to the effect of blurring, showing a curve like that of an X-ray (Fig.6b). The curve is characterized by a slight curve at first, reaching a maximum near the center and reverting to a slight curve.

Next, the rate of change is calculated by differentiating the values obtained from the profile curve. As shown in Fig.6c, the calculated values are graphed as a spike-shaped graph for the still image and a mountain-shaped graph for the slot scan image.

From both graphs, the height value can be considered the value when the concentration change is at the maximum, defined as the contrast in the still image, and the contrast in a

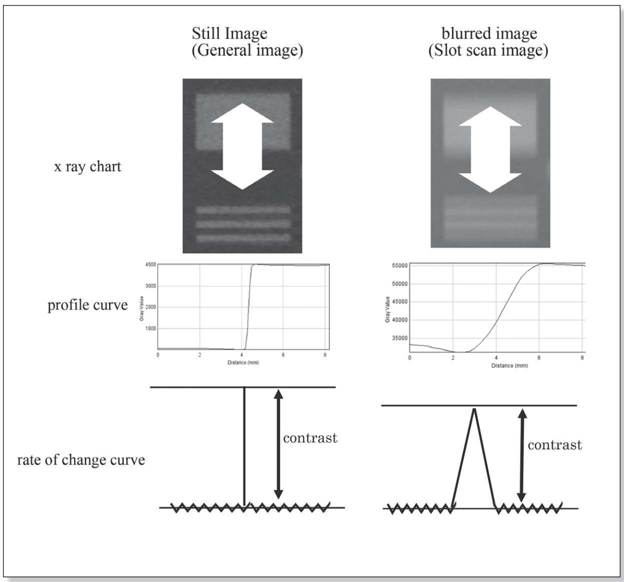


Fig.6 Contrast analysis method

(a) measurement range on the chart
(b) profile curve by imagej
(c) rate of change curve (differential)

a / b / c

visual effect is the contrast in the slot scan image. We define the contrast value in a visual effect as the Cp (contrast peak value) value. Since the Cp value varies with the combination of imaging time and the tube voltage, it can be regarded as one of the image quality evaluation parameters. By using the method described above, the best value of contrast in visual effect is obtained from the combination of imaging time and tube voltage, and the imaging conditions (imaging time and tube voltage) at that time are considered to be the optimal imaging conditions for slot scan images.

1-2 Equipment and materials

- Fluoroscopy equipment: FPD-mounted X-ray fluoroscopy equipment: SONIAL VISION G4 (Shimadzu Corporation)
- Phantom: Water phantom (ph-40) 40 × 40 cm (Kyoto Science)
- X Line chart: R-1 fluoroscopy chart
- Analysis tool: Image-J 1.48 (2014)

1-3 Acquisition of captured images

1-3-1 Preparing materials

The simulated materials for slot scan imaging were made in a tough water phantom (hereafter called a phantom) with thickness as follows: 10, 15, and 20 cm. An X-line chart for the control of fluoroscopy imaging accuracy (hereafter called an X-line chart) was placed on the phantom. Figure 7 shows the layout.

1-3-2 Imaging conditions

There are 11 imaging conditions in combining the tube voltage with the imaging time and was described as follows: 70 kV–25.0 msec, 75 kV–20.0 msec, 80 kV–16.0 msec, 85 kV–12.0 msec, 90 kV–8.0 msec, 95 kV–5.6 msec, 100 kV–3.6 msec, 105 kV–2.5 msec, 110 kV–1.8 msec, 115 kV–1.4 msec, and 120 kV–1.0 msec.

Regarding the setting, in order to obtain the same image effect, the digital value (SS value) was set under the condition of 400 (within ± 15%), and the tube current was kept constant at 400 mA.

The measurement was performed three times each and the average value was obtained. Table 2 shows the imaging conditions.

Note) The SS value is defined as a value that is inversely proportional to the incident X-ray dose, as 200 when the incident X-ray is 1 mR.

1-3-3 Imaging

The slot scan radiography (11 ways) was performed in an HS mode with the upper end of the phantom as the imaging start point and

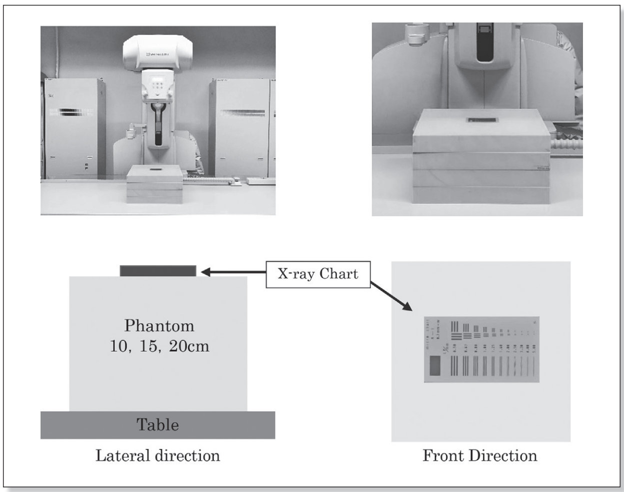


Fig.7 Arrangement of image acquisition (phantom and x-ray chart) a/b

(a) Phantom on the top of which the X-ray chart is positioned
(b) Illustrated arrangement of phantom and X-ray chart

Table 2 Imaging condition
Each combination of tube voltage and exposure time keeps almost same SS value

Tube voltage (kV)	Exposure Time (msec)
70	25.0
75	20.0
80	16.0
85	12.0
90	8.0
95	5.6
100	3.6
105	2.5
110	1.8
115	1.4
120	1.0

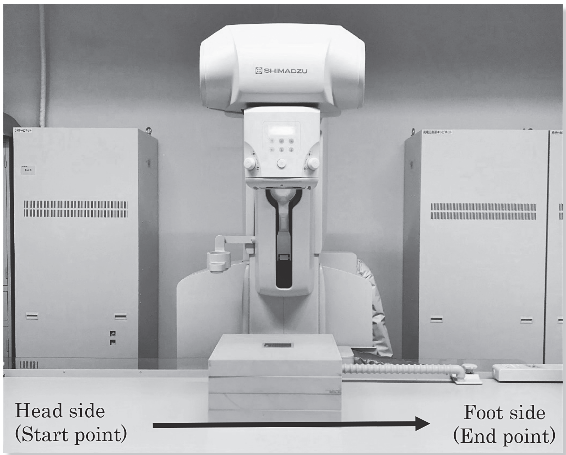


Fig.8 Scanning direction of slot scan technique
The arrow shows the scanning direction

the lower end as the end point. Figure 8 shows the imaging situation. The X-ray chart is arranged so that the slit is perpendicular to the advancing direction of the tube.

1-3-4 Measurement data

Since the image obtained from the slot scan imaging is subjected to frequency processing, such as dynamic range compression after stitching processing, the projected image (raw image) before processing was used for measurement.

1-3-5 Image analysis

Figure 9 shows the measurement processing method. Using the widest slit at the top of the X-ray chart, profile curves were measured in the scanning direction for adjacent parts with different densities (blurred parts) in the direction of the X-ray tube (Fig.9 a, b).

1-3-6 Rate of change measurement

The measured profile curve was converted into a numerical value, and differential processing was then performed to obtain the rate of change (Fig.9c).

1-3-7 Calculation of the Cp value

From the change in rate measurement results obtained in 1-3-6, the maximum Cp value was obtained for each phantom thickness.

2. Results

2-1 Change to Cp value of the tube voltage

Figure 10 shows the Cp value for each imaging condition at each phantom thickness. It became a mountain-shaped graph for each phantom thickness. In addition, the Cp value was different among the phantoms. Specifically, an increase in phantom thickness causes the Cp value to shift to the high voltage side, and the Cp value becomes 440.499 for a phantom thickness of 10 cm, 236.242 for 15 cm, and 96.830 for 20 cm. As for the value, an increase in phantom thickness results in a lower optimum Cp value. Table 3 shows the Cp values for each imaging condition.

2-2 Blur width in X-ray chart

Fig.11 shows the slot scan image of the X-ray chart. In the region of 0.5 LP/mm, the blur width is large and non-identifying at the tube

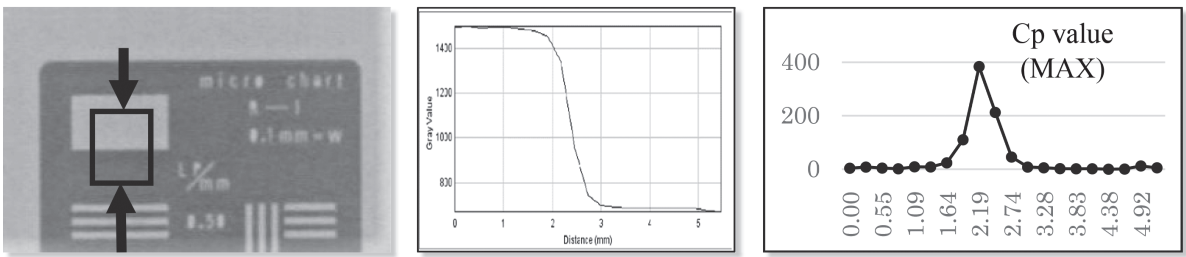


Fig.9 Measurement of the contrast peak value (Cp) from the slot scan image a | b | c
(a) X-ray chart (Black frame: Profile measurement area)
(b) Profile curve (c) Rate of change (differential data of profile curve)

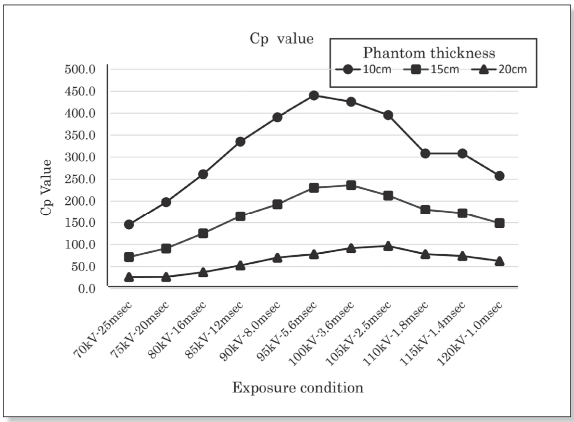
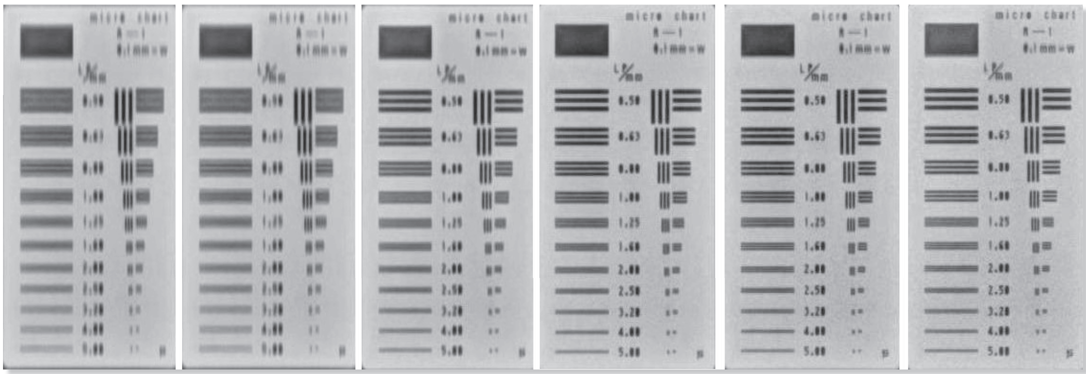


Fig.10 Variation of Cp value with exposure condition

Table 3 Contrast peak value (Cp) measurement result

Tube voltage [kV]	Exposure time [msec]	Cp Value		
		10 cm	15 cm	20 cm
70	25.0	145.716	71.844	26.380
75	20.0	197.639	91.250	26.627
80	16.0	261.348	125.428	37.121
85	12.0	335.359	164.965	52.490
90	8.0	390.654	192.634	70.167
95	5.6	440.499	230.378	78.002
100	3.6	426.030	236.242	92.060
105	2.5	395.724	212.733	96.830
110	1.8	308.392	179.988	78.289
115	1.4	308.392	172.301	74.025
120	1.0	257.417	148.798	62.535

0.5 LP/mm ➡



70 kV–25 msec 80 kV–16 msec 90 kV–8 msec 100 kV–3.6 msec 110 kV–1.8 msec 120 kV–1.0 msec

Fig.11 X-ray chart image (10 cm) according to the difference of imaging conditions

voltage of approximately 70–80 kV. On the other hand, at a tube voltage of 110–120 kV, since the exposure time was shortened, the blur width reduced, and the identification capability improved.

2-3 Imaging conditions and Cp value

The optimal combinations of imaging conditions were, 95 kV–5.6 msec at a phantom thickness of 10 cm, 100 kV–3.6 msec at 15 cm, and 105 kV–2.5 msec at 20 cm. The more the phantom thickness increased, the more it shifted to the high tube voltage and the short time exposure side. Also, in each phantom, the Cp value tended to be higher in the high tube voltage-short time imaging range of approximately 95–105 kV than in the low tube voltage-long time imaging range of approximately 70–80 kV (Table 4).

Table 4 Imaging condition with optimum Cp value

Phantom thickness [cm]	Exposure condition [kV–msec]
10	95 kV–5.6 msec
15	100 kV–3.6 msec
20	105 kV–2.5 msec

3. Discussion

3-1 On existence of Cp value

Regarding the optimal measurement of Cp value, it became a graph with a mountain-shaped peak in each phantom. For still images, the lower the voltage showed a higher contrast, and the lower contrast at a higher voltage tend to decrease at a constant rate. On the other hand, the slot scan image had a low Cp value in the low tube voltage range, and better results were shown in the high tube voltage range. It is presumed that the quality of image will improve by shortening the imaging time, because the improvement of the identification capability in the short time imaging-high tube voltage range was also recognized as shown in the X-ray chart in Fig.10. However, despite the shortest imaging time, the Cp value did not show the best value because it is affected by the radiation quality caused by the tube voltage (Fig.10). From the above, it seems that the Cp value is related to both the imaging time and tube voltage.

3-2 Characteristics of Cp value (Part 1)

The Cp value tends to be high in the high tube voltage range, but the Cp value changes depending on the phantom thickness. As the phantom thickness changed from 10 to 20 cm, the optimum exposure conditions changed from 95 kV–5.6 msec to 105 kV–2.5 msec. This is the same as the general X-ray imaging area and is similar to the fact that a low voltage is an optimum condition for thin subjects and that the thicker the subject, the higher the voltage range. Regarding the exposure time, the fact that the exposure time was different depending on the phantom thicknesses suggests that the optimum Cp value cannot be determined only by the exposure time. Inferring from the apparent contrast, in the case of a thin phantom, the Cp value changes predominantly in the tube voltage, and it is considered that the exposure time predominates as the thickness increases. This is considered to be a characteristic of the change in the apparent contrast in a slot scan image. Furthermore, in clinical practice, the thickness of the subject varies from person to person, so it is possible to estimate the setting of the optimum conditions according to thickness.

3-3 Features of Cp value (Part 2 the viewpoint of slot scan technology)

In general X-ray photography, when the phantom thickness is 10–20 cm, the standard tube voltage used is approximately 70–90 kV, but the 95–105 kV obtained in this study tended to be high. Therefore, slot scan photography is performed continuously using a narrow collimator with a width of 4 cm. For this reason, the generation of scattered X-rays is minimized even in a high voltage range. It is considered that the effect of scattered X-rays on the contrast is insignificant even in a relatively high tube voltage range.

This is considered to be a structural feature of the slot scan technology.

3-4 Validity of evaluation by Cp value

In this study, the Cp value was assumed to have the best visual contrast among the combination of exposure time and the tube voltage. In order to maintain the same image effect, the imaging conditions were set by estimating the SS values, and the results were measured for 11-way different images, changing the long-time exposure to low voltage to short time exposure to high voltage. In other words, it is considered that the image obtained from the maximum Cp value is the image that maintains the best apparent contrast, while the width of blurring is caused by the exposure time, and the X-ray imaging quality is caused by the tube voltage change. In the slot scan image, different Cp values were shown for changes in exposure time, tube voltage, and phantom thickness, indicating that the amount of blur changes at a constant rate with respect to these changing factors. The obtained Cp value is considered to be a quantitatively changed value. From the above, it is considered that the quantitative calculation of the contrast in the slot scan image was suggested.

3-5 Possibility of Cp value

Since the automatic exposure control cannot be set in the slot scan technology, it is difficult to set the optimum exposure conditions. As a result, it is known that there are a few facilities that take pictures due to the excessive dose. In the future, based on this result, we consider the possibility of quantitatively calculating the superiority or inferiority of image quality, including the possibility of CNR measurement.

The slot scan technology produces an image that contains a negative factor called a blur. However, the whole spine imaging is performed in all age groups, and includes highly radiosensitive areas, such as the mammary spine and gonads. Nowadays, a single examination includes the standing (anterior-posterior and lateral) and the recumbent imaging, and regular (follow-up) imaging with overall doses from other modalities will require radiation in the future. It has the potential to increase the risk of disability and increase the risk of cancer. Under such circumstances, this study makes it possible to approach dose evaluation and provide a foothold for dose reduction [7, 8].

We believe that the quantitative analysis of blurred images obtained in this study can be applied to the analysis of blurring and moving images, such as moving images and pulse fluoroscopy. We proposed a method to analyze image blurring using slot scan technology and proposed a quantitative calculation method in image quality contrast.

4. Limit

In this study, we proposed a method to quantitatively analyze the blurring factors in slot scan images. However, we have not examined the evaluation of clinical images, and the indication for test images remains unknown.

5. Conclusions

Images obtained from the slot scan technology are blurred. By analyzing the blurring, we established a new method to calculate the apparent contrast (Cp value) quantitatively.

6. Acknowledgments

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Invention of Surface Contamination Screening Method in a Nuclear Disaster –Segment Method–

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Key words: nuclear disaster, screening, survey meter, radiation external exposure, surveyor

【Abstract】
The conventional manual for surface contamination screening method following a nuclear disaster dictates that the required screening processes should last for 3 minutes. However, the manual did not describe the specific procedure that should be followed. As a result, surveyors performed many unnecessary operations, which, in turn, facilitated increased fatigue and exhaustion. Therefore, the Yokosuka and Miura Radiological Technologists' Association special dispatch team for nuclear disasters devised the segment method with the purpose to screen populations at a rate of 3 minutes per person. The segment method divides the whole body into six regions and screens in one-stroke sketch manner. As a result, we were able to clarify the precise time allocation and to stabilize the operation speed. Furthermore the segment method is easy to operate, prevents potential errors or omissions in the screening areas, and also reduces the physical burden on the surveyor.

Introduction

The general anxiety regarding a nuclear disaster increased in Japan after the Tokai Village JCO critical accident on September 30, 1999 [1)]. Yokosuka City has been a port of call for nuclear vessels of the US Navy since 1966 [2)], and a nuclear fuel processing plant was built in 1967. Therefore, nuclear disaster crisis awareness is acute, and safety measures against possible nuclear disasters are necessary in Yokosuka, especially since the Yokosuka Port was designated as the home port of a nuclear-powered aircraft carrier in 2008 [3)].

The Yokosuka and Miura Radiological Technologists' Association, a regional organization of the Kanagawa Association of Radiological Technologists, organized the Nuclear Accident Screening Support (NAS) Team in 2004. This team aims to conduct radioactive contamination screening, which is a necessary protective measure in the event of a nuclear disaster. The team was organized with the request of the Yokosuka Medical Association, and its core members are radiological technologists certified by the Japan Association of Radiological Technologists (JART). The conventional manual for screening of surface contamination of people affected by a nuclear disaster [4)] states that "*screening is completed within 3 minutes*." However, there are no details provided regarding the screening process, thus, the speed and moves tend to be ad hoc. Consequently, this ambiguity is bound to induce prominent issues when unnecessary moves are performed, which can in turn render the process as significantly more time-consuming than what was anticipated but also result in surveyor's exhaustion. Another manual [5)] describes the speed with which the probe should move and a rough order of the body parts to be measured. However, the precise time that is required to screen the total body is not provided. Therefore, in this article we report a screening method that we developed where “screening of one person in 3 minutes” can be certainly implemented.

1. Methods (design guidelines)

The following design guidelines were used to standardize a consistent screening method for a single person over 3 minutes. The segment method was designed based on the following guidelines:

① Clarifying the time allocation
② Stabilizing operation speed
③ Simple operation
④ Preventing omissions in screening regions
⑤ Alleviating physical burden on the surveyor

1-1. Clarifying time allocation and stabilizing operation speed

To clarify the time allocation and stabilize the operation speed, the total body surface was split into six segments for screening. Each segment and its screening time are shown in Fig.1 [6].

The first segment involves the front of the head, face, neck, and shoulder, whereas the second segment includes the front of the upper body, including the upper limbs. Furthermore, the third and fourth segments include the front of the lower body and the rear of the head and upper body, respectively. Finally, the fifth and sixth segments involve the rear of the lower body, including the sole of the shoes, and regions that need additional care, such as the palm and back of the hands, respectively. The regulated screening time for each segment is 20, 40, 30, 30, 30, and 30 seconds, respectively, which collectively results in a total screening time of 3 minutes.

1-2. Simple operation and preventing omissions in screening regions

Fig.2 shows the screening method developed. To ensure that this operation will be simple and to prevent omissions in screening regions, a one-stroke sketch procedure is adopted where scanning is performed sideways toward the lower body. Subjects place their upper limbs toward their bodies and bend the back of their hands slightly forward. The surveyor screens sideways in one stroke from face to right shoulder, right side of the head, top of the head, left side of the head, and left shoulder. Consequently, the surveyor screens the front of the upper body, including the upper limbs and palm of the hands, and then the front of the lower body while squatting. The sides of the upper limbs are screened together with the front during this procedure. Screening

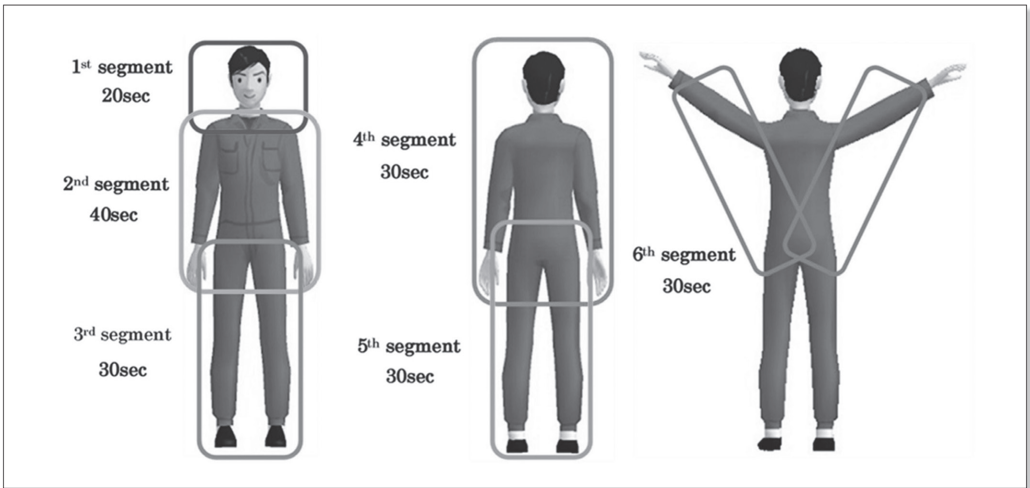

Fig.1 Screening time for each segment

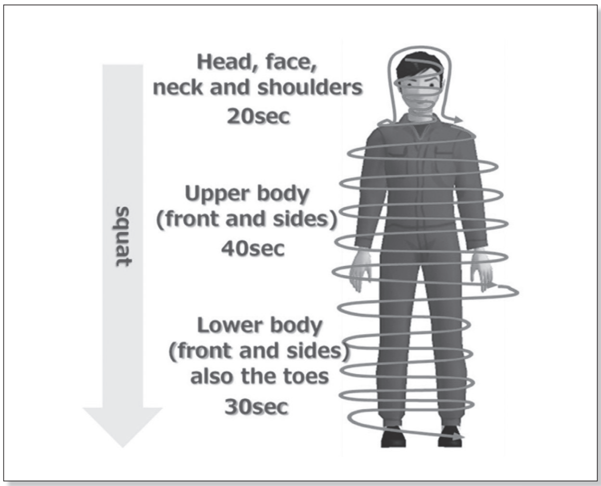

Fig.2 Screening method for the front and both sides of the body

is continuously performed from the upper half to the lower body and along both sides toward the toes.

Following screening of the front of the body, subjects are asked to turn around. The surveyor screens their lower body, including the sole of the shoes, and their upper body, and then their head while standing up. Finally, subjects are asked to raise both their hands, and the screening process then focuses on the inner sides of the upper limbs, both armpits, both sides of the belly, and then on the regions that need additional care, such as the palm and the back of the hands, as necessary (**Fig.3**).

2. Results

2-1. Clarifying the time allocation and stabilizing the operation speed

Conventional screening methods did not provide any predetermined details or protocols regarding the screening procedure, and the speed and moves tend to be ad hoc. Therefore, the precise definition and designation of the time required for screening each segment clarified the time allocation and stabilized the speed with which the survey meter should move. An easy-to-understand video describing the procedure is provided at the Yokosuka and Miura Radiological Technologists' Association website [6].

2-2. Simple operation and preventing omissions in screening regions

A one-stroke survey meter operation results in a simple and efficient screening process where all necessary areas of the human body to be scanned are covered, while at the same time eliminating any unnecessary operations. Three members of the NAS team participated in the first dispatch team of the JART responding to the Great East Japan Earthquake and the nuclear disaster at the Fukushima Daiichi Power Plant of Tokyo Electric Power on March 11, 2011 (Fukushima nuclear accident). However,

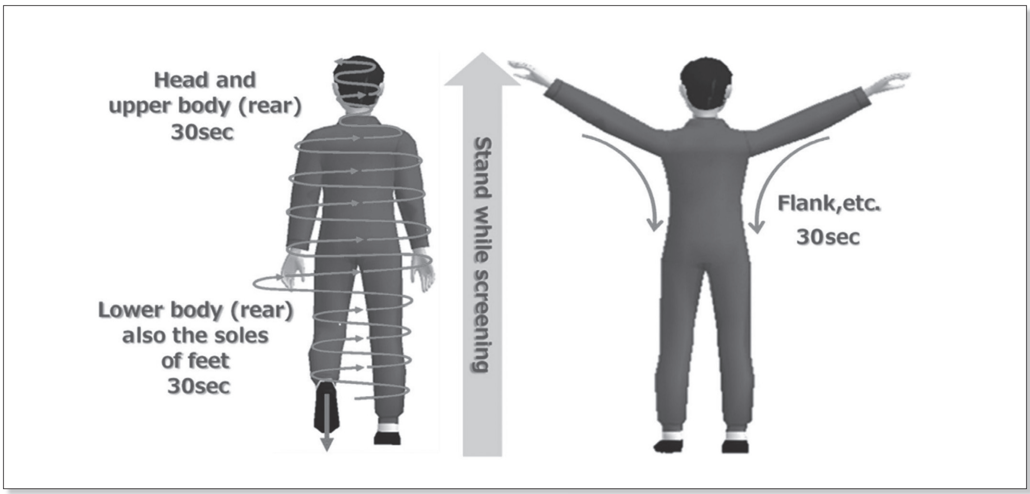

Fig.3 Screening method for the rear and other parts of the body

the on-site screening level in this disaster relief mission was significantly altered. The affected area was substantially larger, and the number of affected individuals was so immense that the individual scanning process should have been completed in approximately one and a half minutes, as opposed to the conventional 3 minutes. Adjustment to these requirements dictated the use of the one-stroke segment method that doubled the screening speed in an efficient manner. The 3-minute segment method has a screening speed of approximately 3–6 cm/s, whereas the one and a half-minute method can screen twice as fast, i.e., 6–12 cm/s (Fig.4).

2-3. Alleviating physical burden on the surveyor

The conventional screening manual did not elaborate on the exact body region that needs to be screened nor did it provide any instructions regarding the order of screening that needs to be followed. Therefore, the surveyor had to squat several times when moving the survey meter up and down. Prior to the Fukushima nuclear accident, the segment method required screening in a one-stroke direction, thus the number of squats was reduced to only two. However, two squats per screening induced a prominent burden on the surveyors because the number of affected individuals in the evacuation zone of the Fukushima nuclear accident was significant high. As a result, based on our experiences from the Fukushima nuclear accident, the initial screening of the fifth segment and then of the fourth segment while standing up manages to reduce the number of squats to one, thereby further reducing the burden on the surveyor. The one-squat method was then defined as the segment method.

3. Discussion

The segment method has demonstrated its applicability and flexibility in nuclear disaster situations. However, contamination from the Fukushima nuclear accident can be described as an exceptional situation, thus the segment method should, in principle, be performed over 3 minutes, as outlined in the manual. The screening level required for a whole-body decontamination process was elevated for the evacuation zone of the Fukushima nuclear accident, and contamination levels requiring simplified decontamination [7], namely partial wipe-off decontamination, were easily detectable. The survey meter reading started to increase even before initiating any measurements to determine the decontamination level, and all individuals successfully participated in the “one and a half-minute method” scanning process in

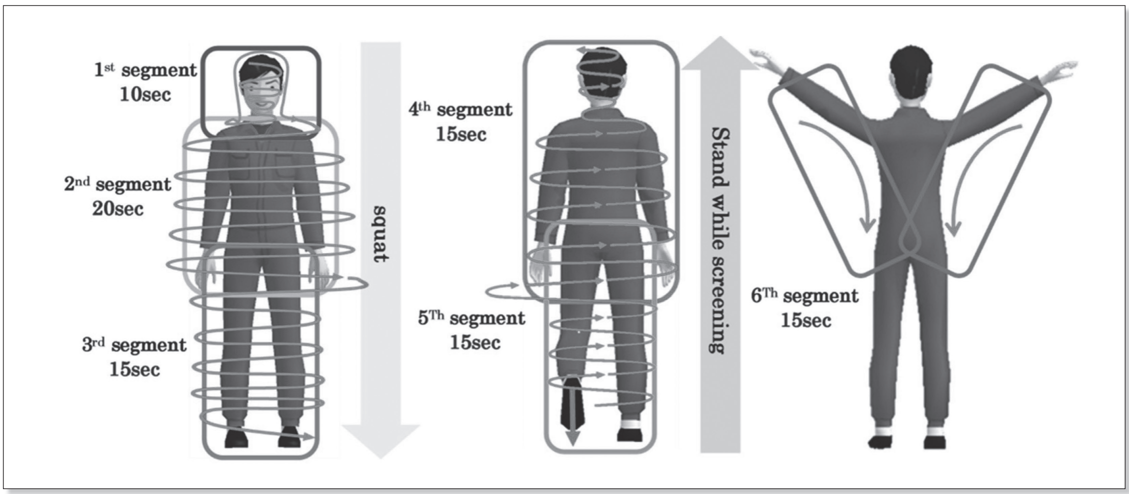

Fig.4 Segment method–One and a half-minute version

Table 1 Screening results from the first dispatch team

Date (2011)	Screening location	Number of people	
Mar.16	Koriyama Gymnasium	140	140
Mar.17	Koriyama City	510	1,334
	Tamura City	824	
Mar.18	Koriyama Gymnasium	360	1,199
	Tamura Gymnasium	87	
	Ogoe Gymnasium	138	
	Takine Gymnasium	256	
	Denso east Corporation (Tamura City)	100	
	Old Ishimori Elementary School Gymnasium	258	
Mar.19	Koriyama Gymnasium	665	1,489
	Old Haruyama Elementary School	517	
	Tokiwa Gymnasium	217	
	Tokiwa Health Center	90	
Mar.20	Tamura Gymnasium	321	859
	Koriyama big palette	220	
	Koriyama Gymnasium	318	
Total			5,021

the Fukushima nuclear accident. The first dispatch team of the JART managed to screen 5,021 residents affected by the Fukushima nuclear accident over a period of 5 days, from the 16^{th} to 20^{th} of March, 2011 (Table 1)[8].

Among the 12 surveyors, five individuals, i.e., three NAS team members and two members of the Kanagawa Prefecture Radiation Safety Manager Committee that worked together with the NAS team had already practiced in the segment method. More specifically, each surveyor had screened approximately 80 people based on a simple average. Continuous squatting during this process can be extremely straining, thus the standardization of the screening method minimized the number of squats performed and reduced the inflicted burden on the surveyors. In addition to those dispatched by the JART, surveyors in the NAS team conducting screening for the Fukushima nuclear accident included two individuals dispatched from hospitals and two individuals that were requested by the Ministry of Health, Labor and Welfare. A nuclear power plant accident, as in this case, where the extent of the affects population requiring screening is very large, translates into a situation where one surveyor is responsible to screen a high number of people over several consecutive days. Therefore, the significance of the segment method was that it demonstrated its applicability and usefulness in terms of reducing the burden on surveyors.

4. Conclusions

We developed a segment method that provides solid instructions for screening individuals in case of a nuclear disaster, such as a nuclear power plant accident, in the future. The whole body is divided into six regions (segments) and it is screened in a one-stroke sketch. The advantages of this procedure are that it clarifies time allocation, stabilizes the operation speed, it is easy to operate, prevents potential errors or omissions in screening regions, and alleviates the physical burden on the surveyor. This segment method demonstrated its ability but also its flexibility in terms of reducing the screening times in the Fukushima nuclear accident, where the scale and ratio of screening had significantly changed.

Moreover, the segment method contributes to a distinct burden reduction of the surveyors conducting screening processes that need to include greater populations. Therefore, the segment method should be adopted as a standard screening procedure in case of a nuclear disaster.

Acknowledgements

We deeply thank the members of the Yokosuka and Miura Radiological Technologists' Association and the Kanagawa Prefecture Radiation Safety Manager Committee, who provided continuous guidance to the authors, upon drafting this paper.

The abstract of this paper was presented in the 27th Japan Conference of Radiological Technologists (2011, held at Aomori) and received an award of excellence. As a consequence, the Japan Association of Radiological Technologists recommended us to write this paper. The contents of this paper were also presented in the 19th International Society of Radiographers and Radiological Technologists World Congress (2016, held at Seoul).

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Effectiveness of the Assistance in Image Interpretation Using the Image Reproduction Function in Radiography

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Key words: assistance in image interpretation, double-check, image reproduction function

【Summary】
In recent years, through questionnaire surveys, the importance of radiographic assistance in interpretation for medical examinations and emergency care has become clear. However, there have been no reports on radiographic assistance in interpretation in general imaging in daily practice, where it is considered to be the most frequently used. Therefore, we constructed a radiographic assistance in interpretation for general imaging, using the image reproduction function. As a result, we could prevent the oversight of abnormal findings in three cases out of a total of 57 cases, in which image replication was performed within 1 year, from September 1, 2017 to August 31, 2018. These facts suggest that the radiographic assistance in interpretation provided by medical radiologists, who use the image reproduction function, also plays a role in double-checking general imaging work in daily practice, revealing its usefulness.

Introduction

In recent years, although the sophistication and specialization of medical care have increased, a critical shortage of physicians has become a challenge.

Therefore, in April 2010, the Director of the Ministry of Health Labor and Welfare of the Health Policy Bureau notified regarding the promotion of medical team [1].

In accordance with this, "it should be encouraged to utilize radiologists clarifying that they can assist in the reading of diagnostic images and provide explanations and consultations about radiological examinations" the law was amended to make recommendations for the active use of the radiologists and expansion of their duties.

Accordingly, the studies on the assistance in image interpretation by radiologists, questionnaires on such assistance, and their usefulness had been conducted [2-6].

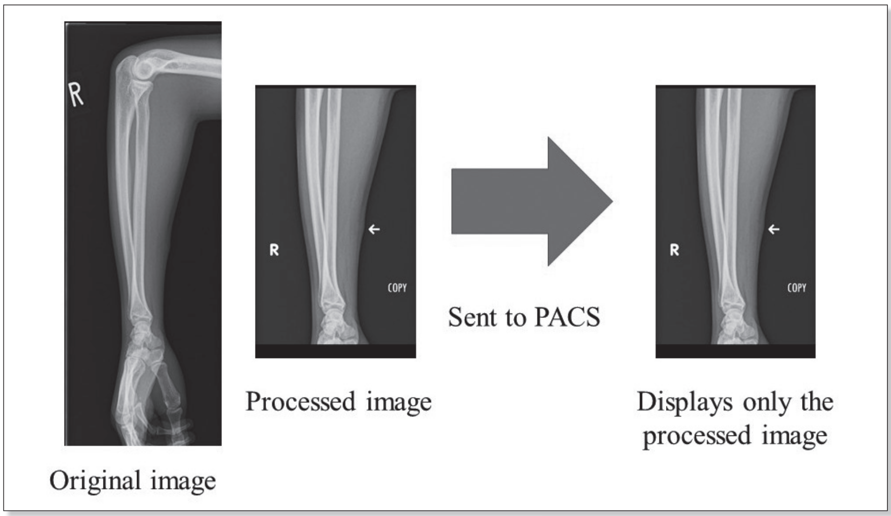
Although we are a clinic with beds that do not provide emergency care and medical examinations, we have experienced requests for imaging advice from the requesting physicians in the course of our daily general radiology work, and we became aware of the need for assistance in image interpretation of general imaging.

However, the reports have been on reports of gastrointestinal contrast imaging, ultrasonography, mammography, etc., and holiday and nocturnal computed tomography (CT) and magnetic resonance imaging (MRI) in the field of emergency medicine [2-6], the assistance in image interpretation by radiologists in the field of general radiography in daily practice has not been reported.

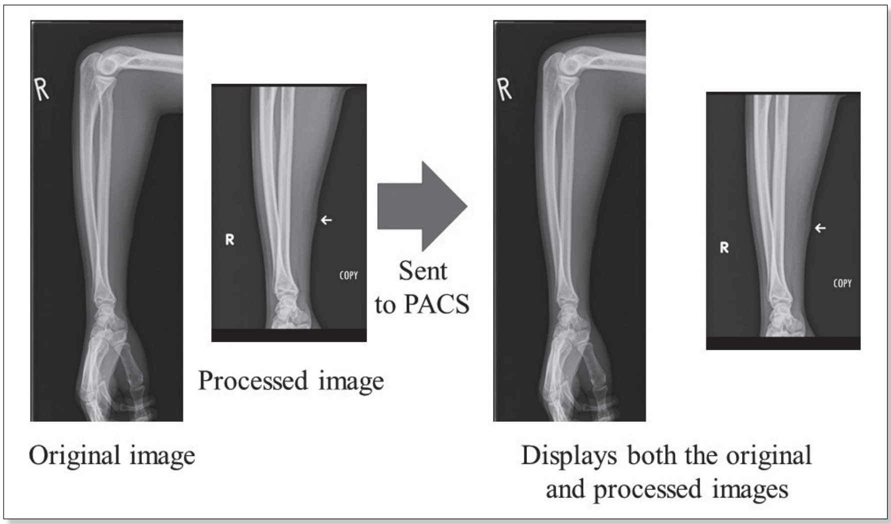
In this study, we reported the usefulness of image replication as a method of assistance in image interpretation for general radiography.

Equipment

The image processing equipment Console



(a)



(b)

Fig.1 The explanation for the image reproduction function

(a) Not using the reproduction function
(b) Using the reproduction function

Advance (DR-ID300CL [Version 10]. Fujifilm) was used.

What is image replication function?

Image replication function creates an image of unique identifier (UID) that is different from the original image. The replicated and original images are processed by a radiologist and stored as separate images in picture archiving and communication system (PACS).

In traditional image processing, the original image is overwritten by the processed image because the UID are the same (Fig.1-a).

However, in the image replication function, the replicated image is given a new UID and can be displayed as a different image than the original (Fig.1-b).

Methods

Arrangements for the use of image replication function

To avoid an unnecessary increase in the number of images due to replication and the time required for physicians to check the images, we discussed with our full-time physicians (N=2) and determined for image replication as follows.

1. A lesion contrary to the patient's complaint (non-examining side).
2. Neoplastic lesions (soft tissue masses, bone tumors, etc.), and foreign bodies.
3. An oversight at another hospital (Radiographs at other hospitals were diagnosed as normal; however, our radiographs demonstrated a lesion).
4. The presence of a lesion at a distance from the painful area.

The images were replicated for these four items, and the images were processed according to the purpose of each item (for example, magnification of the lesion site by partial cropping, the addition of markers to the lesion, and adjustment of the density of soft tissue conditions).

1. Classification and calculation of the cases with image replication

The number of cases of image replication during a year from September 1, 2017, to August 31, 2018, when this system was first implemented, was classified into the above categories (1–4) and calculated.

2. The predicted number of missed imaging diagnoses in the absence of assistance in image interpretation by replication image

With the help of our full-time physicians (N=2), we calculated the number of cases possibly missed in the absence of image replication.

3. Evaluation of the assistance in image interpretation with image replication

Our full-time physicians (N=2) were asked to evaluate and give their opinions on the use of the image replication function to the assistance in image interpretation for 1 year.

Results

1. Classification and calculation of cases with image replication

A total of 57 cases were replicated during the period from September 1, 2017, to August 31, 2018, and tumor lesions and foreign bodies were the most common items (46 cases). The least common item was an oversight at another hospital (2 cases) (Fig.2).

2. The predicted number of missed imaging diagnoses in the absence of assistance in image interpretation by replication image

The number of missed cases avoided by the assistance in image interpretation with the image replication feature was 3 out of 57 cases per year.

3. Evaluation of the assistance in image interpretation with image replication

Our full-time physicians (N=2) had the following opinion on the use of image replication to assist in image interpretation.

1. Lesion recognition and explanation of the lesion to the patient became easier.
2. The time and effort required for image manipulation (density adjustment and magnification) on PACS were reduced.
3. Reduced the risk of missed lesions.

The following evaluations and opinions were given.

Typical clinical examples of image replica-

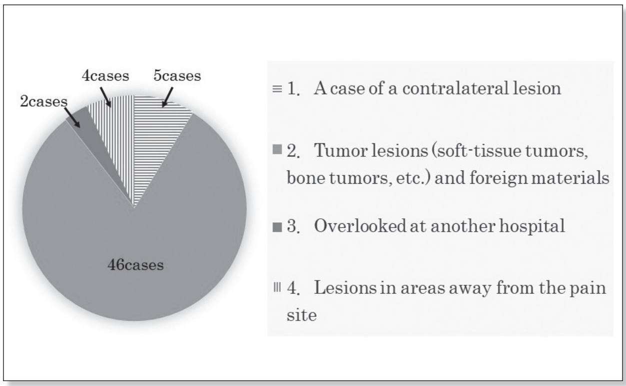


Fig.2 Number of cases of image reproduction

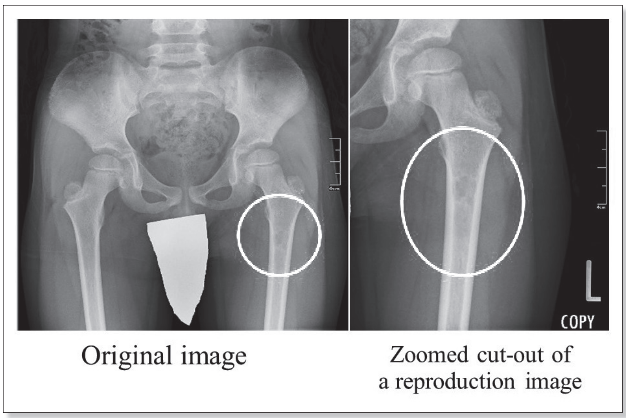


Fig.3 A case of a contralateral lesion
Chief complaint: right hip joint pain

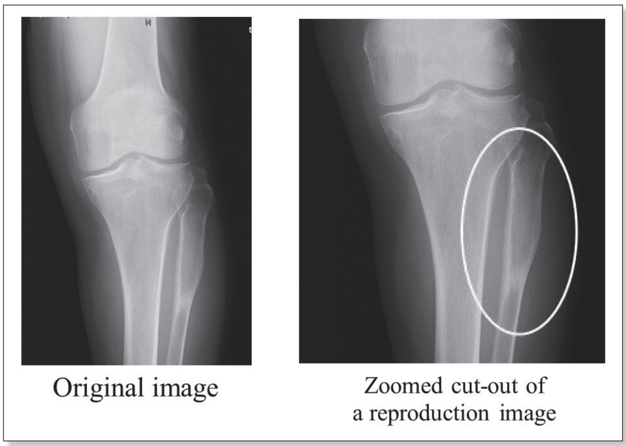


Fig.4 Lesions in areas away from the pain site
Chief complaint: inside left knee pain

tion are shown in Fig.3 and 4.

Fig.3 demonstrates hyperpenetration in the left femur (white circles in the figure) opposite to the site of the chief complaint on the right hip pain, which is replicated, cut out, and enlarged.

In Fig.4, a patient complained of medial left knee pain; however, since a neoplastic lesion (white circle in the figure) was observed on the fibula, the image was replicated, cut out, and enlarged.

Discussion

In the past, these cases of image replication required the physician to change the window level and window width and to enlarge the image for a patient explanation, which made the physician's work more complicated. However, if the radiologist uses the image replication function to change the window level and window width to suit the patient's needs, the physician can eliminate the procedure and reduce the burden of examination work.

Also, the most important aspect of the assistance in image interpretation was the oversight of abnormal findings. The failure to recognize abnormal findings accounts for approximately 80% of diagnostic imaging errors [7].

In our hospital, to prevent errors in imaging diagnosis, if an abnormal finding is found when the radiologist takes pictures or confirms images, the radiologist goes to the examination room or confirms with the physician over the telephone.

However, in a small facility, a single physician needs to examine and treat patients by himself, which often results in a lack of communication and work stagnation.

However, since the start of the image replication function, the physician can check the images added by image replication and contact the radiologist in charge only when necessary to confirm the abnormal findings.

From these observations, it is considered that the pickup of abnormal findings by the image replication function by radiologists can efficiently double-check to prevent oversight, and it is an important factor in reducing diagnostic imaging errors [2, 3].

Additionally, this kind of assistance in general radiography may promote the importance of recruiting radiologists in small facilities that do not have large equipment (e.g., CT, MRI), that do not provide nighttime or emergency care.

Conclusion

The assistance image interpretation in general radiography using the image replication function was useful for preventing oversight and improving work efficiency.

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Long Term Characteristics Change of n-type Semiconductor Rectal Dosimeter

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Key words: semiconductor, n-type silicon, irradiation history, brachytherapy, rectal dosimeter

【Abstract】

Semiconductor rectal dosimeters are useful for patient monitoring during brachytherapy. Many authors have reported a variety of characteristics such as a decrease in sensitivity with irradiation history. Additional characteristics such as the dose rate dependence, dose per pulse dependence, sensitivity variation with temperature, dose linearity, and directional dependence have also been reported. However, the trend of these characteristics with irradiation history has not been well investigated. Approximately three years have passed since we introduced a new n-type silicon semiconductor rectal dosimeter in our hospital. Therefore, the purpose of this study is to investigate sensitivity, dark current noise, dose rate dependence, sensitivity variation with temperature of the semiconductor rectal dosimeter, and changes in the characteristics with brachytherapy irradiation history.

An n-type silicon semiconductor rectal dosimeter system (Intracavitary Detector IDF-5 channels) was used in this study. Measurements were performed with a High Dose Rate (HDR) Iridium-192 brachytherapy source. The radiation source was placed between the semiconductor detector and the Farmer-type ion chamber in a water phantom system. The ratio of the reading by the semiconductor dosimeter to the absorbed dose by the Farmer chamber as a reference was defined as the sensitivity index value of the semiconductor. Several characteristics were investigated by evaluating their sensitivity index.

For all the channels, the relative sensitivity decreased to approximately 0.92−0.95, with an irradiation history of approximately 200 Gy. Dark current noise values tended to converge towards zero according to the irradiation history. Dose rate dependence for HDR source strength was not observed, and it was not related to the irradiation history. Although there was sensitivity variation with temperature, it was small after irradiation history.

The identified characteristics may affect the actual measurement results. However, when sensitivity calibration is performed under appropriate conditions, they can be effectively used for rectal dose monitoring during brachytherapy.

1. Introduction

Real-time monitoring of rectal dose is essential for intracavitary brachytherapy in the treatment of gynecological malignancies [1)]. Monitoring is used to ensure that the treatment is accurately performed with the intended dose distribution. In addition, if administration differs from the intended dose and an unexpected dose increase to risk organs is identified, it is possible to respond promptly [2), 3)].

In our hospital, an n-type silicon semiconductor rectal dosimeter is used for real-time monitoring. Semiconductor dosimeters provide real-time readout, high sensitivity, small dimensions, simple instrumentation and the absence of bias voltages. As such, they are well-suited for in-vivo measurements during treatment [4)].

However, as a physical phenomenon, when radiation is incident on the detector, excessive electron-hole pairs are created throughout the semiconductor. Minority carriers (holes in n-type) are swept across the junction by built-in potential and are measured by an electrometer. The minority lifetime of the carriers affects the sensitivity of semiconductors with irradiation history integrated dose, although this is dependent on the electrical properties of the semiconductor crystal and adversely affects the minority carrier lifetime [5)-7)]. These phenomena in semiconductor dosimeters cause various characteristics.

Previous studies on semiconductors [4), 8)-13)] have revealed that they exhibit a variety of characteristics such as a decrease in sensitivity, dose rate dependence, dose per pulse dependence, sensitivity variation with temperature, dose linearity and directional dependence. However, there is limited research on the dependence of the characteristics on the irradiation history with the exception of sensitivity decrease [14)].

Therefore, in this study, we investigated characteristics that could be observed over the long term, such as the sensitivity change and the change in the dark current noise with irradiation history. In addition, the dose rate dependence and its change, and sensitivity variation with temperature and its change were investigated for a semiconductor rectal dosimeter.

2. Materials and Methods

2-1 Experiment setup

The measurements were performed with a High Dose Rate (HDR) Iridium-192 (denoted hereafter as Ir-192) brachytherapy source (microSelectron-v2 HDR Ir-192; Nucletron B.V., Veenendaal, The Netherlands). The unit was equipped with an Ir-192 source with an average apparent activity of 370 GBq. The source was replaced approximately every six months.

A 5-channel n-type silicon semiconductor dosimeter system (denoted hereafter as semiconductor dosimeter) is the subject of this study. The semiconductor dosimeter was an Intracavitary Detector IDF-5 (IBA Dosimetry, Schwarzenbruck, Germany) and was connected to a DPD12pc electrometer (IBA) to measure the dose. It consists of a flexible probe structure and rectal interstitial type with five semiconductors channels placed 20 mm apart. The probes were connected to a computerized control system. A computerized control system is a combination of an adapter, personal computer, and software. The reading value was output in units of 16 bits ADU. ADU is an analog-to-digital conversion unit that facilitates the monitoring of ionization output using a personal computer.

Fig.1 (a) shows the schematic of the experimental setup in a modification of the so-called sandwich method [15)]. A water phantom system (IDF-Calibration Phantom, IBA) consisting of water cubes of $20 \times 20 \times 20$ cm^3 in size was used. The Ir-192 source was sandwiched using

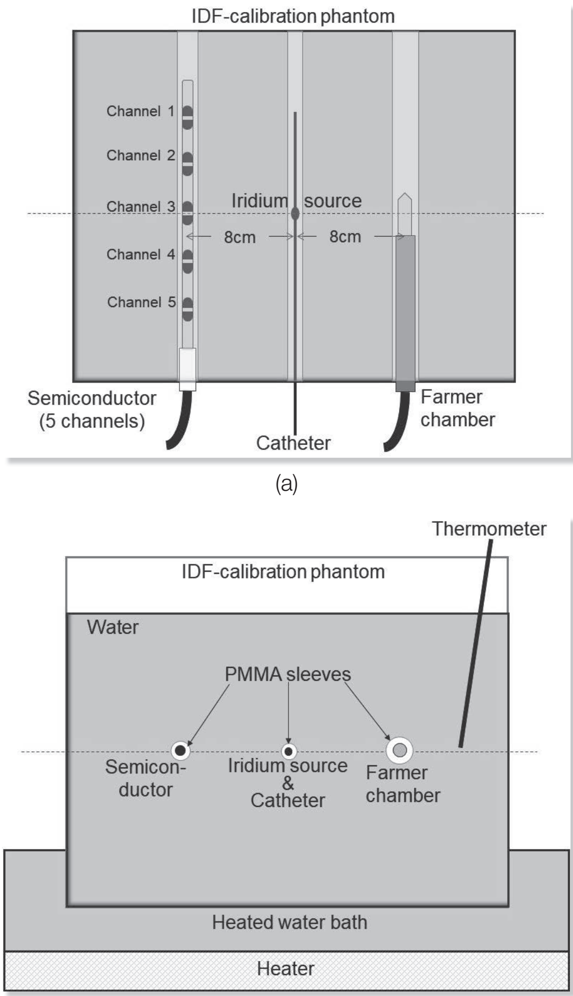

Fig.1 A schematic diagram of the experimental setup, (a) coronal plane and (b) axial plane. The two detectors were positioned in a water phantom with sleeves at a distance of 8 cm on either side of the Ir-192 source. The water phantom temperature was maintained using heated water.

the semiconductor detector and Farmer-type ionization chamber (PTW-30013, Freiburg, Germany). As shown in Fig.1 (b), both detectors were fixed using a poly-methyl methacrylate (PMMA) sleeve. Both sleeves were located in a phantom system with a separation of 8 cm each from the Ir-192 source. The phantom was immersed in a water bath heated by a heater. This allowed the preset temperature to be maintained with an accuracy of ±0.2°C. For all measurements, a current was applied 1 hour before the start of the measurement and pre-irradiation was performed for 15 minutes immediately before the measurement.

All measurements were read simultaneously by the semiconductor and the farmer as a reference. The ratio of the reading by the semiconductor dosimeter to the absorbed dose by the Farmer chamber as a reference was defined as the sensitivity index value. This is the same principle of diode sensitivity calibration [16].

2-2 Sensitivity index and Ir-192 dosimetry

Both detectors were irradiated for 15 min with an Ir-192 radiation source, as shown in Fig.1. To minimize the influence of the transition time, the preset time was 15 minutes (maximum time). The measurements were repeated three times and the background was measured as dark current noise without a radiation source.

Referring to equation [14], for diode sensitivity calibration, the sensitivity index (denoted hereafter as *SI*) is expressed as:

$$SI = \frac{R_{actual}[ADU]}{D_{water}^{Ir-192}\,[cGy]} \quad (1)$$

D_{water}^{Ir-192} is determined from Farmers absorbed dose to water with the Ir-192 source:

$$D_{water}^{Ir-192} = MN_{D,w}^{Co-60}k_{Ir} \quad (2)$$

M is the chamber readings measured with the Ir-192 source, which is corrected for temperature and pressure, ion recombination, and polarity [17]. k_{Ir} is the beam quality conversion factor for Co-60 to Ir-192 sources, as indicated in the work by Araki et al [15].

R_{actual} is the actual reading from the semiconductor dosimeter with the background subtracted.

$$R_{actual} = R_{raw} - R_{background} \quad (3)$$

R_{raw} is the original raw reading and $R_{background}$ is the background noise. $R_{background}$ was measured as dark current noise without a radiation source. It was measured for 15 minutes in the same manner as the radiation source.

2-3 Evaluated characteristics

The following four characteristics were examined in this study.

2-3-1 Sensitivity change with the irradiation history

Sensitivity change with irradiation history was examined using *SI* over a three-year period and assessed as a relative value with the first *SI* value at the introduction of the semiconductor dosimeter set to 1.00. *SI* was measured at the time of introduction and thereafter periodically approximately every six weeks. The irradiation history recorded all irradiated doses in clinical use and experiments.

2-3-2 Change of dark current noise with the irradiation history

The background was measured as dark current noise without a radiation source. As shown in equations (1) and (3), dark current noise was measured each time *SI* was measured. Similar to the sensitivity change, dark current noise changes were observed with radiation history over a 3-year period.

In addition, $R_{background}/R_{raw}$ at each source strength was evaluated as a ratio of the dark current to determine the effect of the dark current noise on the source strength. This is the ratio of the dark current to the total reading of the semiconductor dosimeter including the dark current noise, which indicates the degree of uncertainty if this value is not accurately quantified. The maximum source strength for the three years holding the radiation source was defined as 1.0 and compared.

2-3-3 Dose rate dependence and its change

The dose rate dependence for the sensitivity of the semiconductor dosimeter was evaluated. The *SI* investigated in the 2-3-1 study was evaluated for each dose rate. Furthermore, the first year of the evaluated three years was classified as "Initial" and the third year as "Irradiated". The dose rate at the time of maximum source strength for the three years holding the radiation source was defined as 1.0.

2-3-4 Sensitivity variation with temperature and its change

To investigate the sensitivity of the semiconductor dosimeter dependence on temperature, *SI* was measured while changing the water temperature. Using the geometry shown in Fig.1, the temperature was set to 40, 38.5, 37, 35.5, 34°C with the body temperature set to 37°C [18]. Temperature and pressure correction was only performed for the farmer chamber reading. The sensitivity at a temperature of 37°C was normalized to 1.00 and the correlation with the sensitivity to temperature was observed. The temperature coefficient, defined as (dSI/dT) where *SI* is the sensitivity index and *T* is the temperature, was then determined via linear regression of the data. The temperature coefficient is expressed as 1%/°C as an *SI* increase per unit temperature.

This experiment was performed at the time of the new introduction. This is defined as "Initial". In addition, approximately 2 years after the irradiation history, the experimental procedure was repeated at almost the same dose rate. This is defined as "Irradiated". The two results were compared.

3. Results

3-1 Sensitivity change with irradiation history

[Fig.2 (a)–(e)] shows that sensitivity change for the irradiation history for each semiconductor detector channel. The x-axis represents all the irradiation history doses over a three-year term. The y-axis represents the relative *SI*.

The scale of the x-axis varies from channel to channel for clinical use, and the geometry is shown in Fig.1. The *SI* decreased to approximately 0.92–0.95 with an irradiation history of 200 Gy. Notably, an initial exponential reduction was observed.

3-2 Change of dark current noise with the irradiation history

The change of the dark current noise of the semiconductor dosimeter is shown in Fig.3. The y-axis represents the dark current noise at a given time. With respect to the dark current noise, individual differences among channels of the semiconductor detector were observed. Channel 3 had the highest dark current value. Negative currents were observed in channels 2 and 4. The dark current noise for channel 5 only from the time of introduction was almost zero. For the channels 1–4, the dark current noise converged to 0 from the introduction time.

Fig.4 shows the scatter plots of $R_{background}/R_{raw}$ versus the relative source strength. When the source strength was approximately 0.2, the percentage of dark current noise was approximately 6%. When the source strength is approximately 0.7 or more, it is 1% or less.

3-3 Dose rate dependence and its change

[Fig.5 (a)–(e)] shows the result for the dose rate dependence. The y-axis represents the relative *SI* and the x-axis represents the relative dose rate. The white dots represent "Initial", and the black dots represent "Irradiated". As a rough estimate, the dose rate 1.0 corresponds to approximately 6.85 Gy/h and the dose rate

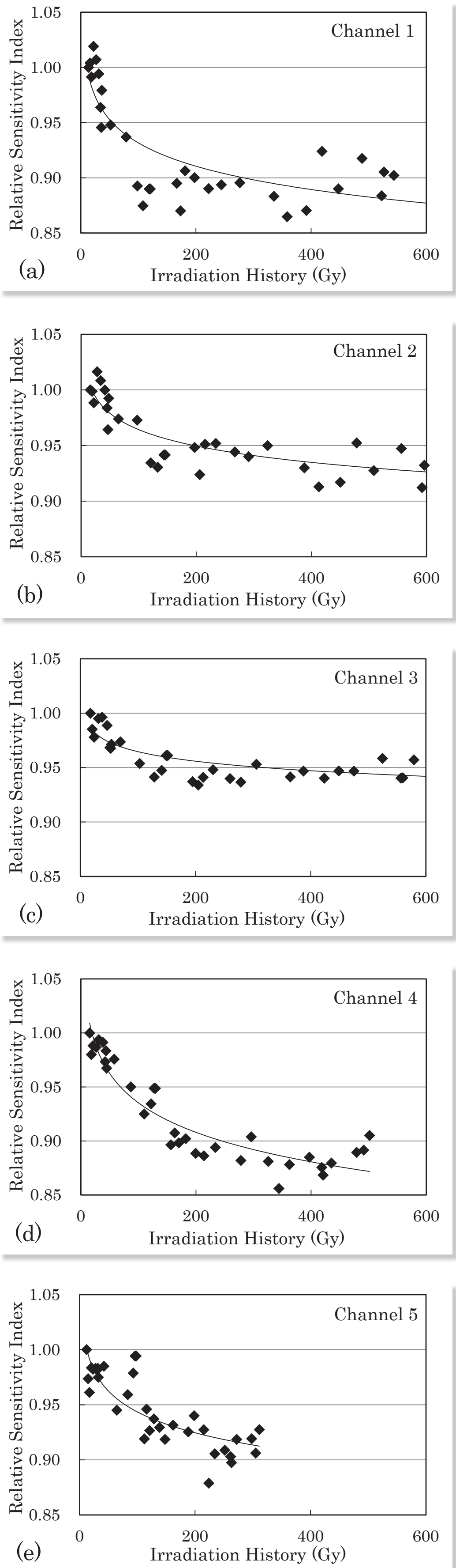

Fig.2 (a)–(e) Sensitivity change with the irradiation history

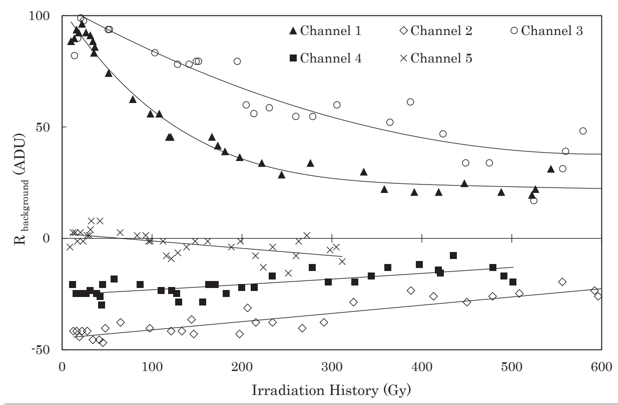

Fig.3 Change of dark current noise with the irradiation history

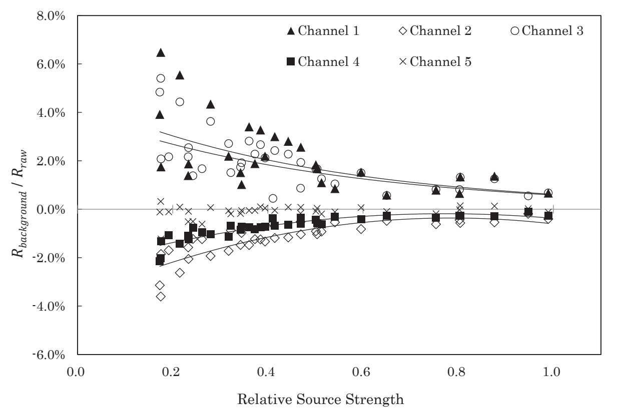

Fig.4 Ratio of dark current noise to source strength

0.2 corresponds to approximately 1.45 Gy/h. At dose rates in the range of 1.45 Gy/h to 6.85 Gy/h, there is no correlation between the dose rate and *SI* both during the "Initial" and "Irradiated" term. Moreover, even when the term and the term are compared, there was no clear result that was common to all semiconductor detectors channels.

3-4 Sensitivity variation with temperature and its change

As shown in [Fig.6 (a)–(e)], the results are plotted as the *SI* versus temperature. The white dots represent the "Initial" whereas the black dots represent "Irradiated". For all semiconductor detectors channels, the temperature coefficient was 0.2–0.4%/°C at the initial stage of introduction. However, it was 0.1%/°C or less after the irradiation history.

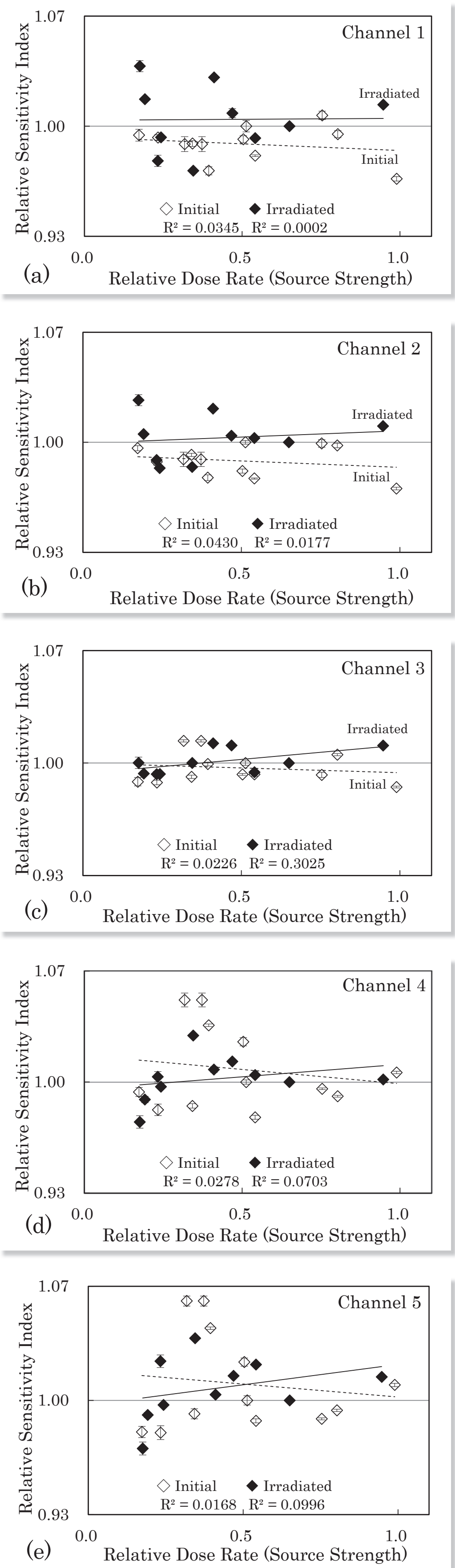

Fig.5 (a)–(e) Dose rate dependence and its change

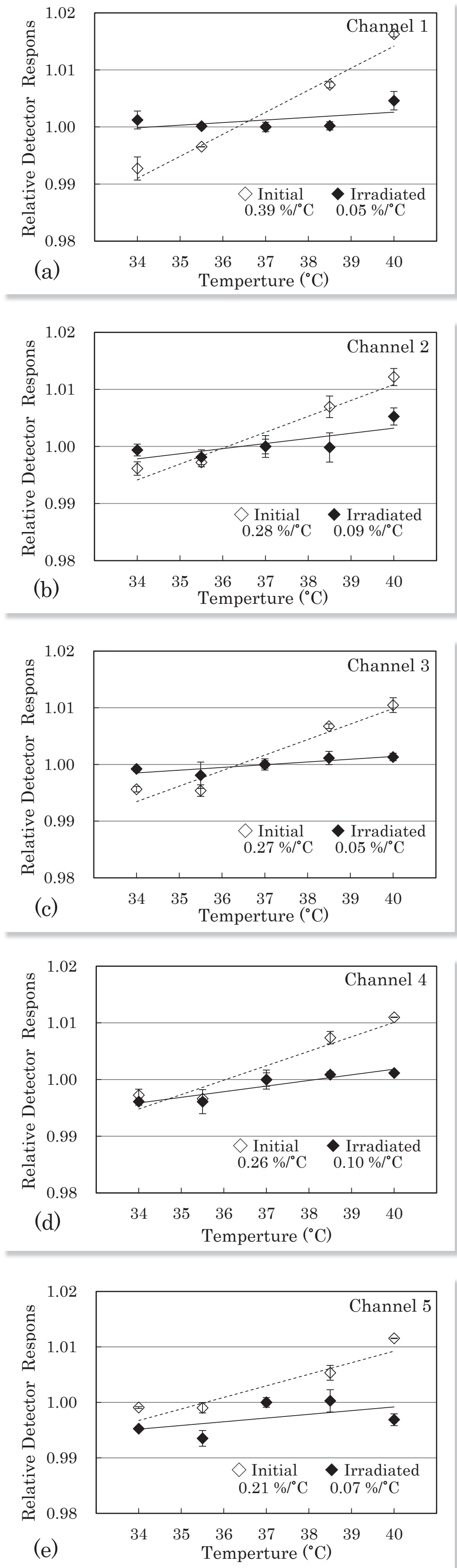

Fig.6 (a)–(e) Sensitivity variation with temperature and its change

4. Discussion

Semiconductor dosimeters must be quantified under any clinical conditions for intracavitary brachytherapy to maximize their accuracy and clinical utility. Without accurate sensitivity calibration, it is not possible to determine if a reading is due to abnormal dose values or other errors. In this study, we focused on the sensitivity and dark current noise, dose rate, and temperature of the detector.

Regarding the decrease in the sensitivity associated with the irradiation, the result was in agreement with previously reported findings [4)-7), 13)], indicating an initial exponential reduction, which subsequently slowed down. From the experiments, it was determined that there was the sensitivity decreased to approximately 0.92−0.95 with irradiation. According to the guidelines of the American Association of Physicists in Medicine (AAPM) task group No.138, 3.4% of the total dose calculation uncertainty of high-energy HDR is recommended, and a 5−8% decrease is not negligible because it is higher than [19)]. Therefore, sensitivity calibration is required before use. Then, it is necessary to record the change in sensitivity over time and observe that the sensitivity gradually becomes moderate. To accomplish this, the historical irradiated dose delivered to the detector must be recorded if possible.

There are limited publications on dark current noise. In addition to the aforementioned phenomenon that the sensitivity with the Ir-192 source decreases with the irradiation history, the response to dark current noise also decreases. It has been determined that some semiconductor channels have a negative dark current noise. In addition, when the source strength was low, (i.e. before source replacement), the ratio of the dark current noise exceeded 6%, and it was not negligible, given that it exceeded the uncertainty 3.4% set by the AAPM as in the aforementioned sensitivity decrease. Depending on the treatment plan, the rectum may be far away from the iridium source and there may be channels that receive little or no radiation. Therefore, it is necessary to quantify the zero signal as exactly zero.

Investigations at high dose rates of 60 Gy/h[12)] were not feasible in this study. The dose rate dependence at rates from 1.8 Gy/h to 2.4 Gy/h has been reported as negligible [13)]. In addition, a dose rate dependence was not observed at dose rates of 1.4 Gy/h to 6.8 Gy/h in this study. The results were the same for “Initial” and “Irradiated”. As such, the decrease in the source strength due to the decay of the Ir-192 source with an average apparent activity of 370 GBq can be interpreted as not affecting the accuracy of sensitivity calibration. In other words, there was no dose rate dependence and no change due to irradiation history.

In terms of the sensitivity variation with temperature, for the case of “Initial”, the result was in agreement with reference [8)-11)]. Furthermore, it was determined in this study that the tendency becomes moderate with irradiation. Thus, it was considered that temperature dependence reduced with irradiation. However, it was challenging to determine whether the temperature of the element was owing to the temperature dependence of the electronic circuit system, and it can only be considered to affect the final reading. In actual clinical dose monitoring, the detector is inserted into the rectum. Therefore, it is desirable to perform sensitivity calibration while accurately maintaining the phantom temperature at 37°C, especially when irradiation is initially low.

For all the characteristics of the semiconductor dosimeter, the results show that there are no large individual differences among the 5 channels. In actual clinical practice, there are cases in which treatment is performed over multiple fractions and the insertion position of each fraction into the rectum may be evaluated based on the ratio of the measurement values of the 5 channels. Therefore, the absence of individual differences is a very important characteristic.

5. Conclusion

In this study, we examined characteristics that were evaluated using a semiconductor rectal dosimeter over a three-year period. The sensitivity changed with irradiation history and it was determined that there is a sensitivity variation with temperature, which changed with irradiation history.

It should be noted these characteristics may affect the actual measurement results. However, when sensitivity calibration is performed under appropriate conditions, it can be effectively used for rectal dose monitoring during brachytherapy.

Acknowledgments

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Conflict of interest

We have nothing to declare for this study.

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Standardization of a Daily Inspection Protocol for Angiography System

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Key words: Angiography system, quality control, daily inspection, standardization

【Abstract】

Around 10 years ago the Japan Medical Imaging and Radiological Systems Industries Association (JIRA) published a checklist to be followed at start-up and end-of-work of radiation-related equipment. However, recent angiography systems are diversified in model and function, and there is a possibility that the daily inspection being performed as per the published inspection table is insufficient. Upon investigating the daily inspection table of each facility, we observed that 13.5% of the apparatuses use the JIRA inspection table, and the contents and quality of inspection are diverse.

In this study, we developed a daily inspection table with respect to the currently used models and applications for the purpose of correcting the disparity in daily inspection protocols among facilities and standardizing the daily quality control of systems. We propose that incorporation and implementation of the inspection items described in this study can improve the quality control output.

Introduction

Since the partial revision of the Medical Care Act in April 2007 [1)], medical institutions are required to ensure the efficiency and safety of management systems for drugs and medical devices. Under this revision, the Japan Medical Imaging and Radiological Systems Industries Association (JIRA) has released information regarding the appropriate maintenance of radiation-related systems, such as the inspection table [2)] and the guidelines for equipment delivery [3)].

Since then, a study on inspection items for the maintenance and safe use of cardiovascular imaging systems [4)], and a specific guideline for the use and maintenance of the examination and treatment equipment in cardiovascular care [5)] have proposed distinct methods for start-up and end-of-work inspections. However, in recent years, angiography systems have become significantly diverse so as to include models equipped with computed tomography system (hereinafter IVR-CT), cone beam CT (hereinafter CBCT), and those compatible with operating rooms (hereinafter hybrid). Therefore, each facility has been devising ways to review and anticipate for items that are not specifically presented in the JIRA's start-up and end-of-work inspection table. In this study, we report the inspection table which we have devised according to the models currently in use. Furthermore, we discuss and highlight its purpose that intends to rectify the current disparities observed among facilities by standardizing the daily quality control procedures.

Materials and Methods

1. Collection of start-up and end-of-work inspection items

We collected inspection items from the start-up and end-of-work checklist for angiography systems used at each facility. All inspection items were collected from checklists submitted by candidates who took their 2017 certification examinations through the Japan Professional Accreditation Board of Radiological Technologist for Angiography and Intervention and applicants that are currently renewing their certifications. Next, we compared the collected inspection items with those of the JIRA.

2. Selection of start-up and end-of-work inspection items

The inspection items were shortlisted based on the guidelines for equipment delivery for cardiovascular imaging systems [3] from among the collected inspection items. For the start-up inspection, we selected items that evaluated the operation and safety of each part of the system, which ensures that the day's work can be performed in a smooth and unhindered manner. For the end-of-work inspection, the selected items included cleaning and organizing systems contaminated with contrast media, blood, and other substances, as well as records of malfunctions and problematic issues that occurred while using the system. Consequently, using the same criteria as described above, we selected items related to the CBCT, IVR-CT, and hybrid models, which are not listed in the JIRA start-up and end-of-work checklist. We excluded items that were difficult to standardize, such as items from the inspection table that are not common to all system manufacturers or items that have different inspection frequencies. These items were highlighted on the inspection table so that they can be performed for each system as per the system's requirement and configuration.

3. Development of the start-up and end-of-work inspection table

The selected inspection items were divided into two groups: the start-up inspection items and the end-of-work inspection items. Both groups were further classified according to the respective environment, system, peripherals, and model. In addition, items in each category were organized in a well-defined manner so that they can be performed sequentially.

4. Consideration of a daily quality control

In addition to the items in our checklist, we discussed the quality controls that users should implement on a daily basis to identify potential abnormalities of the equipment at an early stage.

Results

1. Collection of start-up and end-of-work inspection items

We used 400 start-up and end-of-work inspection tables collected from 152 facilities. Table 1 shows the number of inspection items collected from each system and from the JIRA start-up and end-of-work checklist. The breakdown of the number of systems is listed in Table 2. Our findings demonstrate that there were 153 items for the start-up inspection and 72 items for the end-of-work inspection, including similar items. For the JIRA inspection items, there were 30 items for the start-up inspection and 23 items for the end-of-work inspection. In addition, 54 of the 400 systems used the entire JIRA inspection table or used items extracted from it, thus accounting for 13.5% of the total systems under consideration in this study.

In contrast, of the systems that did not use the JIRA inspection table, 23 out of 28 (82.1%) IVR-CT models (including two hybrid models equipped with CT) had IVR-CT-specific inspection items added to the inspection checklist, and 21 out of 32 (65.6%) hybrid models had hybrid-specific inspection items added. The CBCT-specific inspection items were added in 11 out of 173 (6.4%) angiography systems, except for the systems used exclusively for cardiovascular imaging.

Table 1 The number of collected inspection items

Collection source of inspection items		Daily inspection table for each facility				JIRA's daily inspection table
		angio	IVR-CT	Hybrid	total	
start-up inspection items	environment	28	21	15	28	8
	angiography system	64	52	53	64	16
	peripherals	18	12	16	19	6
	CBCT	4	1	3	4	–
	CT	–	28	2	28	–
	Hybrid	–	–	10	10	–
	total	114	114	99	153	30
end-of-work inspection items	environment	19	15	17	19	8
	angiography system	26	19	21	26	9
	peripherals	16	13	13	16	6
	CBCT	0	0	0	0	–
	CT	–	8	2	8	–
	Hybrid	–	–	3	3	–
	total	61	55	56	72	23

Table 2 The breakdown of the number of systems by model

Model	angio (%)	IVR-CT (%)	Hybrid (%)	total (%)
The number of facilities	147	26	28	152
The number of systems	342 (85.5)	26 (6.5)	32 (8.0)	400 (100)
The number of systems using JIRA checklist	46 (85.2)	2 (3.7)	6 (11.1)	54 (100)
The number of systems using other check lists	296 (85.6)	24 (6.9)	26 (7.5)	346 (100)
The number of systems that perform specific inspection items	11 (20.0)	23 (41.8)	21 (38.2)	55 (100)
The number of apparatuses that have not undergone end-of-work inspection	42 (84.0)	6 (12.0)	2 (4.0)	50 (100)

2. Selection of start-up and end-of-work inspection items

Based on the guidelines for equipment delivery for cardiovascular imaging system [3], 22 items were selected as the start-up inspection items and 17 items were selected as the end-of-work inspection items. We selected two items for CBCT-specific, two items for hybrid-specific, seven items for IVR-CT-specific models in the start-up inspection, and five items for IVR-CT-specific models in the end-of-work inspection.

We employed the daily consistency test for imaging display systems as a new item for start-up inspection because this was a common item in all systems under consideration in this study. In addition, we adopted confirmation of remaining hard disk capacity of the system, the number of protective aprons, cleaning, and the number of radiographic aids and supplies solely at the end-of-work inspection to improve the efficiency of the start-up inspection. Due to the differences in necessity of daily inspection and frequency of inspection among different systems, warm-up and calibration of the X-ray tube, proper operation of the emergency stop button, brake test of the robotic arm, and calibration of the surgical bed were excluded from start-up and end-of-work inspection items.

3. Development of a start-up and end-of-work inspection table

The start-up inspection table is shown in Fig.1, and the end-of-work inspection table is shown in Fig.2. The inspection items for CBCT, hybrid, and CT models are designed to be performed additionally in each model. In contrast,

Start-up inspection	date		
environment	Air conditioning management of machine room and inspection room is done. (temperature / humidity)		
	Checking the surveillance camera		
	Check microphone / intercom		
	Operation check of oxygen, suction device, etc.		
	There is no obstacle in the operating range of the equipment, and it is in a fixed position.		
	Appearance check and cleaning of equipment		
angiography system	The “in use” indicator light is on when the unit is operating.		
	The system starts up normally and there is no error display.		
	Checking the display time		
	No abnormal noise or smell		
	Checking the operation of the support arm		
	Operation check of patient table		
	Operation check of X-ray aperture / filter / field switching		
	Operation check of touch sensor and irradiation prohibition switch		
	Operation check of fluoroscopy and radiography (Including image irregularities and artifacts)		
	Operation check of irradiation indicator		
	Operation check and remaining capacity check of external recording device		
	(Constancy test of imaging display system)		
peripherals	The workstation starts up normally and there is no error display.		
	Operation and appearance check of contrast medium injector		
	There is no problem starting the HIS-RIS system.		
	Operation check of peripheral equipment related to inspection and treatment		
CBCT	Rotating radiography operation check		
	Confirming image transfer operation to the workstation		
Hybrid	Checking the multi-monitor connection and display		
	Check the placement and operation of the operating table		
CT	The system starts up normally and there is no error display.		
	No abnormal noise or smell		
	Gantry running / tilting operation check		
	Checking the lighting and displacement of the pointer		
	X-ray tube warm-up		
	The phantom is scanned and there are no abnormalities in the CT and SD values.		
	There is no artifact in the scanned phantom image.		
	inspector		

※Other inspection items recommended by the manufacturer should be performed as necessary.

Fig.1 Start-up inspection table

excluding the above inspection items, all remaining items are designed to be performed in exclusive cardiovascular imaging systems.

4. Consideration of an additional daily quality control

From the collected inspection items, we identified 57 of the 400 systems (14.3%) included in our study were checking and recording the X-ray output conditions as an inspection item. Since confirmation of the daily X-ray output reproducibility is an important item to ensure the stable operation of the system, we examined whether this can be added to start-up or end-of-work inspections as a quality control item. As a result, we noticed that if “*Operation check of fluoroscopy and radiography*” proposed in Fig.1 is performed at the time of start-up inspection with a defined geometric arrangement, and then it can be used to assess the consistency of the daily X-ray output. An example of geometric arrangement is shown in Fig.3. The recording of the X-ray loading factor was separated from the start-up and end-of-work inspection tables in another sheet. The X-ray output recording sheet is shown in Fig.4.

End-of-work inspection	date		
environment	Check the temperature and humidity in the inspection room		
	There is no obstacle in the operating range of the equipment, and it is in a fixed position.		
	Confirmation and replenishment of necessary items		
	There is no loss or damage to the radiographic aids.		
	Oxygen and suction device must be cleaned up.		
angiography system	Appearance check and cleaning of the system		
	The support arm is retracted.		
	No abnormal noise or smell		
	Check if an error message is displayed		
	Transfer images / There are no unprocessed images.		
	Confirmation of the remaining hard disk capacity		
	The system ends normally.		
peripherals	Contrast medium injector (cleaning and shut down)		
	Confirmation of normal shutdown of HIS-RIS system		
	Other equipment (cleaning and shut down)		
	X-ray protector (number / cleaning)		
CT	Appearance check and cleaning of the system		
	The gantry is retracted.		
	Transfer images / There are no unprocessed images.		
	Confirmation of the remaining hard disk capacity		
	The system ends normally.		
general	No abnormality during inspection / Reporting and description when there is an abnormality		
	inspector		

※Other inspection items recommended by the manufacturer should be performed as necessary.

Fig.2 End-of-work inspection table

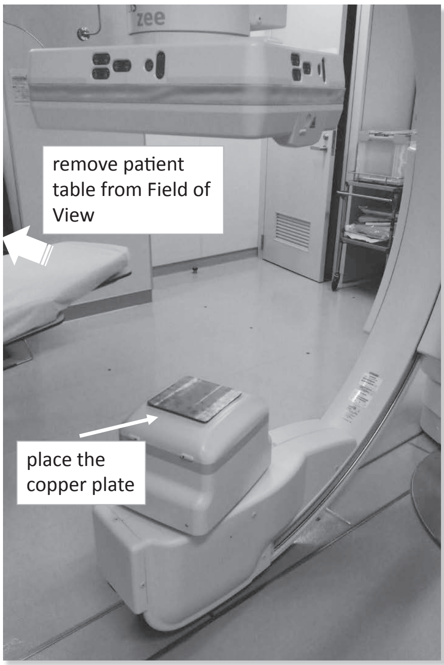

Fig.3 An example of geometric arrangement for X-ray output check

Discussion

The inspection items collected from the checklist of each facility enabled us to identify that inspection items and contents varied not only according to the model and purpose of each system, but also due to other potential differences between the facilities. Therefore, standardization of the inspection contents necessitated the establishment of items that were common to all angiography systems. Moreover, it was important to consider the items designed to be performed according to the functions and purposes of use of the systems. In addition, we decided to execute the inspection items listed in both, start-up and end-of-work, inspection tables proposed by JIRA [2] solely for the start-up or end-of-work inspection to improve efficiency based on the selection criteria shown in method 2. This is taking into consideration the fact that the number of inspection items is expected to increase with the recent advancements in the functions of the respective systems.

Since the start-up inspection is required to be performed within a limited time before commencing any task or emergency examina-

X-ray output check sheet

FoV : inch fluoroscopy program :
SID : cm radiography program : exposure time : sec
phantom : mmCu ＊ if you can't set exposure time,
for DSA, record in "mGy/f" , for DA, record in "mGy/s".

	fluoroscopy			radiography					
date	tube voltage (kV)	tube current (mA)	pulse time (ms)	tube voltage (kV)	tube current (mA)	pulse time (ms)	air karma (mGy)*	inspector	note

Fig.4 Check sheet of X-ray output

tions, we investigated the time required to carry out the inspection of the environment, system, and peripherals, which are common items of the start-up inspection. The average time required was 11 minutes and 45 seconds. We believe that "*items that can be inspected in 10 to 15 minutes*," described in the main criterion for selection of inspection items by the Safety Management Manual Preparation working group of JIRA [6], are sufficient and can be implemented.

When selecting the inspection items, we employed the daily monitor constancy test as one of the start-up inspection items that is common to all systems. This is because regular inspection of the monitors is performed by each system manufacturer during maintenance and inspection. However, the "*Quality Assurance (QA) Guideline for Medical Display Systems*" [7] recommends that the constancy test for a medical image display monitor used in diagnostic imaging should be performed on a daily basis [7]. Therefore, it is preferable that daily constancy test should be performed by the user.

Currently, each system can display the test pattern that is used in the overall daily evaluation test. However, there are systems that can display the test pattern only in service mode. We believe that it is necessary to consider this issue together with manufacturers, and thus assess the means with which users can implement appropriate monitor quality control.

We propose a record of the X-ray output as a daily quality control item. This facilitates an efficient quality assurance of the system as well as early detection of potential abnormalities, because the daily variation of X-ray output values can be graphed and analyzed by recording the X-ray output conditions in a separate table.

Image quality evaluations, such as spatial resolution and contrast resolution of images, were also considered as an additional daily quality control. However, it is difficult to ensure standardization because only certain facilities have phantoms for image quality evaluation. The "*Evaluation and routine testing in medical imaging departments–Part 2-9: Constancy tests–Equipment for indirect fluoroscopy and indirect radiography JIS4752-2-9*" [8] states that "*the frequency of constancy tests shall be performed at least every three months in the ab-*

sence of information on the frequency of testing" [8]. Therefore, it is necessary for each facility to have its own image evaluation phantoms to supplement the inspections that cannot be performed during the manufacturer's maintenance.

Conclusion

In this study, we propose a new daily inspection method for angiography systems. We believe that the effective implementation of daily inspection items adapted as per the model and purpose of use can facilitate the efficient and appropriate equipment management of each device. In addition, the use of the proposed daily inspection is expected to standardize daily inspections and improve system management by users.

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Survey of the relationship between radiological technology students' modalities of interest and their level of understanding of technical terms −Questionnaire survey of RT students−

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Key words: radiological technology students, radiological technologist education, modalities of interest, questionnaire survey

【Abstract】

Purpose. This study aimed to investigate the relationship between students' modalities of interest in clinical practical training during radiological technologist education and their degree of learning for those modalities. ***Methods***. The target is 2019 fourth-year students of Suzuka University of Medical Science. The same questionnaire survey was administered to participating students before and after clinical training. In the first part of the questionnaire, students ranked the modalities of radiological technologists' duties by their level of interest. The second part of the questionnaire assessed their learning level for each modality. In this study, the technical term for each modality was presented individually, and participants' level of understanding of these technical terms was defined as the learning level for that modality. ***Results***. The modalities of the radiological technologists' work in which students were most interested were general radiography, computed tomography, and magnetic resonance. The interest in these modalities did not change between before and after clinical training. Students' learning levels were particularly high in the modalities of interest. ***Conclusion***. We investigated changes in students' interest in modalities attributable to clinical practical training during radiological technologist education and identified the relevance of the degree of learning for those modalities. We aim to use these data to inform educational improvements.

1. Introduction

In Japan, universities that train radiological technologists provide fourth-year education. In the Department of Radiological Technology at Suzuka University of Health Sciences, all specialized subjects related to radiological technologists' clinical practice are acquired by the end of the third year, and students then advance to the fourth year. During the fourth year, students return to their hometown from May to August, and are offered clinical training at a local hospital. Every year, all fourth-year students choose specialized subjects to guide their clinical practice. We were interested in students' perceptions relating to three specific points. First, we assessed students' interest in modalities involved in the practice of a radiological technologist during clinical practice after covering all specialized subjects in on-campus training. Second, we evaluated whether students' modalities of interest had changed after they received clinical education from radiological technologists during their clinical training. Third, we investigated whether students' learning levels differed between modalities of interest and those in which they were not interested. We thought that as clinical training offers opportunity to understand the importance of clinical work that cannot be experienced through on-campus training[1], there may be differences in students' modalities of interest between before and after clinical training. Clarifying these three points will build understanding of students' modalities of interest and weak parts of learning, which can be used to guide student education. Therefore, the purpose of this study was to investigate the relationship between students' modalities of interest in clinical practical training and their degree of learning for those modalities.

2. Materials and Methods

2-1. Targets

The present questionnaire survey targeted 2019 fourth-year students at Suzuka University of Health Sciences, Department of Radiological Technology Science (100 students: 69 men, 31 women). The questionnaire survey was conducted both before and after clinical training (two times in total). The questionnaire was completed via the campus portal system. All personal information was anonymized and discarded. Informed consent was obtained from all participating students. In addition, this study was approved by the Ethics Committee of the Suzuka University of Medical Science.

2-2. Survey items

The same questionnaire survey was administered before and after clinical training. The first part of the questionnaire asked participating students to rank each modality based on their interest. The six modalities representing radiological technologists' practice presented in the questionnaire were: general radiography (GR), computed tomography (CT), magnetic resonance (MR), nuclear medicine (NM), radiotherapy, and angiography. Mammography and X-ray TV inspections were included in GR. The work of radiological technologists also involves ultrasound. However, ultrasound was excluded from the present survey because there were many facilities where radiological technologists did not perform ultrasound. We also investigated the reason students' chose their first-ranked modality using free description.

The second part of the survey covered students' learning level in relation to each modality. In this study, the technical term for each modality was presented individually, and students' level of understanding of these technical terms was used to define their learning level for that modality. To extract the terminology of each modality, we first set the difficulty level of explaining the terminology of each modality in three levels: easy, normal, and difficult. Of the three difficulty levels, in this study, we adopted technical terms extracted as "normal" as questionnaire material. For each technical term, students who could explain that term chose "A", students who knew the term but could not explain it chose "B", and students who did not know the term chose "C". The technical terms presented by each modality are shown in Table 1. The terminology was determined through consultation with faculty members in each specialized field, and technical terms with roughly the same level of difficulty were extracted.

2-3. Data processing

The modalities of interest were scored based on students' ranking. The scores for each modality are shown in Table 2. The score for each modality was calculated as the total score rate (%) of each modality by the following equation (1).

$$Total\ score\ rate\ for\ each\ modality\ (\%) = \frac{Total\ score\ for\ each\ modality}{Total\ score\ for\ all\ modalities} \times 100 \qquad (1)$$

This total score rate was compared among modalities and for each modality before and after clinical training. Based on the learning level for each modality as recorded in the surveys, the recognition level and level of understanding of technical term for each modality were calculated using formulas (2) and (3).

$$Recognition\ level\ (\%) = \frac{A+B}{A+B+C} \times 100 \qquad (2)$$

$$Understanding\ level\ (\%) = \frac{A}{A+B+C} \times 100 \qquad (3)$$

Table 1 Technical terms presented for each modality

modality	general radiography (GR)	computed tomography (CT)	nuclear magnetic resonance (NMR)	nuclear medicine (NM)	radiation therapy	angiography
terminology	Jacobi line	maximum intensity projection (MIP)	diffusion weighted image (DWI)	autoradiography (ARG)	tissue maximum ratio (TMR)	seldinger

Table 2 Conversion of ranking to points

Rank	1st place	2nd place	3rd place	4th place	5th place	6th place
Score	6 point	5 point	4 point	3 point	2 point	1 point

The levels of recognition and understanding for each modality were compared for each modality and any changes before and after clinical training were evaluated. We also investigated students' free descriptions for the top three modalities of interest.

2-4. Statistical analysis

The Pearson chi-square test was used for statistical analysis of significant differences from the results of questionnaire surveys before and after clinical training. Using this significant difference test, the recognition level of technical term before and after clinical training was compared. In addition, we compared the level of understanding of technical term before and after clinical training.

3. Results

3-1. Survey collection rate

The questionnaire response rate before clinical training was 99% (69 men, 30 women), and the response rate after clinical training was 97% (67 men, 30 women).

3-2. Modalities of interest ranking

Figure 1 shows the results of the total score rate for each modality before and after clinical training. The total score rates before clinical training were 20.7% for GR, 21.9% for CT, 21.6% for MR, 11.9% for NM, 15.6% for radiotherapy, and 8.4% for angiography. The total score rates after clinical training were 16.5% for GR, 1.3% for CT, 20.5% for MR, 12.7% for NM, 16.2% for radiotherapy, and 12.8% for angiography. The top three modalities of interest for students both before and after clinical practice were CT, MR, and GR, in that order.

3-3. Learning level for each modality

Figure 2 shows the results for the recognition level of technical term for each modality before and after clinical training. Before clinical training, the recognition level of technical term for each modality were 91.9% for GR, 100% for CT, 100% for MR, 97.0% for NM, 97.0% for radiotherapy, and 51.5% for angiography. After clinical training, the recognition level for technical term for each modality were 97.9% for GR, 100% for CT, 100% for MR, 97.0% for NM, 97.0% for radiotherapy, and 90.7% for angiography. There was a significant difference in the recognition level of GR before and after clini-

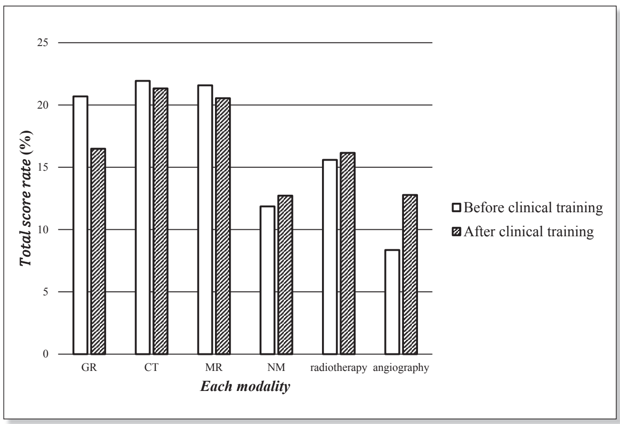

Figure 1 Results of the total score rate for each modality before and after clinical training

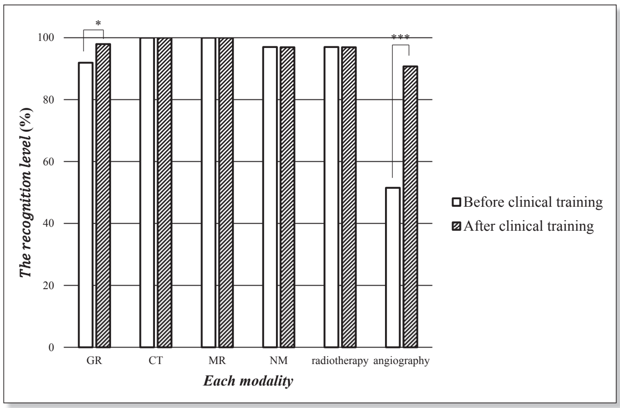

Figure 2　Comparison of recognition of technical terms for each modality before and after clinical training

The Pearson chi-square test was used for the significance test.
* : $p<0.05$, *** : $p<0.001$

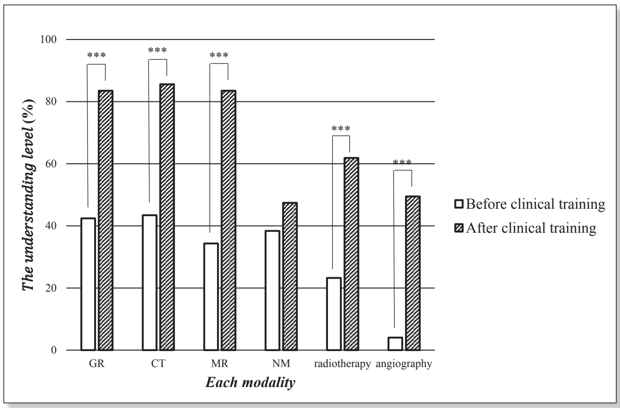

Figure 3　Comparison of level of understanding of technical terms for each modality before and after clinical training

The Pearson chi-square test was used for the significance test.
*** : $p<0.001$

cal training ($p<0.05$). In addition, there was a significant difference in the recognition level of angiography before and after clinical training ($p<0.001$).

Figure 3 shows the results for the level of understanding of technical term for each modality before and after clinical training. Before clinical training, the level of understanding of technical term for each modality were 42.4% for GR, 43.4% for CT, 34.3% for MR, 38.4% for NM, 23.2% for radiotherapy, and 4.0% for angiography. After clinical training, the level of understanding of technical term for each modality improved to 83.5% for GR, 85.6% for CT, 83.5% for MR, 47.4% for NM, 61.9% for radiotherapy, and 49.5% for angiography. There was a significant difference in the recognition level before and after clinical training of GR, CT, MR, radiotherapy, and angiography ($p<0.001$).

3-4. Free description of reasons for first choice of modality

For the top three modalities of interest, we investigated the free descriptions of why students' ranked these as their first choice. Before clinical training the free descriptions of students who chose GR included comments such as "I am interested in mammography" and "the basics of radiological technologist work is GR." For CT, the comments included "main work of radiation work" and "CT is a convenient and important examination." Comments relating to MR included "I actually experienced MR through on-campus training and deepened my desire to be involved in MR in the future." After clinical training the descriptions of students who chose GR included comments such as "I felt that GR was a basic modality in the work of radiological technologist and that it should be learned first through clinical training." For CT, the comments included "there was enthusiasm taught by the person in charge of CT in clinical practice" and "I was able to operate CT during clinical training." For MR, the comments included "I felt the fun of MR by listening to MR imaging technicians about the imaging principle."

4. Discussion

In this study, we investigated changes in students' modalities of interest by clinical training education and the relationship between interest and the degree of learning for that modality. GR, CT, and MR were the modalities of most interest to students who had acquired all specialized subjects both before and after their clinical training. First, before clinical training, participants mentioned that these three modalities offered many opportunities to come into contact with the devices used in these modalities during the third-year of on-campus training. In this way, students could get a sense of actual clinical work by handling the relevant devices. In addition, it was thought that the students may have deepened their knowledge and become interested by studying the devices. GR was also popular with female students interested in mammography. However, our university does not have the devices used for the three modalities with the least interest (NM, radiotherapy, and angiography). Therefore, it is possible that students were not interested in these modalities because they had not handled the devices associated with these modalities. In addition, few lectures are given on angiography during on-campus education, and there is no on-campus practical training. As a result, angiography was not interesting to students, and was scored the lowest of the six modalities. Participatory training leads to more improvement in learning motivation and study compared with visit-type training, and has been reported to be effective[2)]. In addition, there are reports that participatory training also improves communication skills[3-7)]. We think that some kind of participatory training should be offered, even for modalities for which universities do not have the necessary equipment. The modalities of most interest to students after clinical training were those in which they had many opportunities to handle the devices during clinical training and be involved in performing these modalities. Numerous clinical practice hospitals are able to perform imaging position or device operation in these modalities, meaning that these modalities were of most interest to students. In addition, it is thought that the enthusiasm of the radiological technologist instructor at the hospital who was in charge of students during their clinical training was also an influential factor. The enthusiasm of the instructor may also increase satisfaction with clinical practice[8)]. Some students were interested in modalities about which their instructors were enthusiastic. In contrast, clinical training in modalities of less interest to students tended to be those for which visit-type training was offered. These lower-level modalities were also taught with enthusiasm from instructors in clinical practice, but it is thought that students were more interested in participatory practice than in visit-type practice. At present, clinical training is limited to visit-type clinical training in some hospitals in Japan[9)]. However, participatory training is being promoted in current clinical training[10)]. There are many participatory clinical training sessions in clinical training for other medical occupations[11)]. The instructor's leadership is indispensable for participatory training. The clinical training instructor needs to be able to understand students' acquisition of specialized knowledge and examine the content of the training[12)]. Participatory practical training has been promoted in all training modalities for radiological technologists. For all modalities, instructors are expected to improve their teaching skills and introduce participatory training, mainly in communication skills education, in both on-campus and clinical training. It is thought that students' motivation will increase through such high-quality clinical training.

Next, we considered students' learning level for each modality. Before clinical practice, the recognition of the technical term "Seldinger" used in angiography was 51.5%, which was the lowest value. Seldinger is a common term in the clinical setting; however, because of the small number of lectures on angiography in our university, this term was less familiar for students. However, students' learned about Seldinger through clinical practice, and the level of recognition of this term increased to 90.7% after clinical practice. Through clinical training, the recognition level of this term has increased significantly. Moreover, the recognition of the "Jacoby line", which is a GR term, also increased after clinical training ($p<0.05$). However, the recognition level of the Jacoby line before clinical training was 91.9%, and it is considered that the students who did not recognize it increased after learning the Jacoby line during clinical training. The technical term for other modalities had recognition levels of 90% or more before and after clinical training, which indicated that technical terms with almost the same difficulty were selected. However, students' level of understanding of technical term for all modalities was lower than the recognition level. The level of understanding for technical terms increased through clinical training, and there was a significant increase in GR, CT, MR, radiography, and angiography ($p<0.001$). In particular, the understanding level for angiography before clinical training was 4%, but improved to 49.5% after clinical training. The level of understanding of angiography-related technical term before clinical training was extremely low, which may also be attributable to the few angiography lectures at our university. Therefore, we should increase the number of lectures on angiography and offer more opportunities for students to study angiography. In addition, the knowledge gained from pre-clinical training lacks relevance to clinical training[13]. It is necessary to educate the students so that the knowledge gained from pre-clinical training can be related to clinical training. The level of understanding of autoradiography (ARG), which was used as a terminology for NM examinations, was 38.4% before clinical training and 47.4% after clinical training (n.s.). This percentage increase in understanding level was the lowest compared with other modalities. The ARG method is a quantitative test used for brain perfusion single photon emission computed tomography (SPECT). Many hospitals in Japan do not use the ARG method of brain perfusion SPECT in clinical training, meaning there would be no opportunity to study the ARG method, which may explain the low rate of increase in understanding. In addition, the level of understanding after clinical training for the most interesting modalities was 83.5% for GR, 85.6% for CT, and 83.5% for MR. The percentage of understanding level for these modalities was higher than the understanding level of modalities with less student interest. This suggests that students' were learned more about their modalities of interest. Participatory training may therefore contribute to more improvement in learning motivation and studying compared with visit-based training.

In addition, the terminology of each modality used this time was examined and selected by the teachers. However, it should be noted that there is a possibility that the difficulty level of the technical term of each modality is not unified. In this research, we set the degree of difficulty of each modality terminology to "easy", "normal", and "difficult", and adopted the term corresponding to "normal". In the next research, we would like to consider a method of selecting words that are more consistent than this time.

In this questionnaire, we excluded ultrasonography. Currently in Japan, radiological technologists and clinical laboratory technologists are technicians involved in ultrasound. Ultrasound was excluded from the present study because few hospitals in Japan have radiological technologists performing ultrasound. However, ultrasound is one of the tasks of radiological technologists. In the questionnaire survey planned for next year, we intend to include ultrasound as an option. In addition, there were modalities for which good results could not be obtained by extracting technical terms. We aim to carefully examine the extraction of technical terms for the questionnaire survey planned for next year.

Our study showed that the most interesting modalities for students were GR, CT, and MR. These modalities also had high levels of learning. In hospitals in Japan, young radiological technologists can play an active role in any modality, and there is a need for multi-utility radiological technologists that can respond immediately, even if new equipment is introduced. The current work of radiological technologist continues to increase and become more complex[14]. In addition, with the advancement of medical care, the technology expected of health care worker such as radiological technologist is increasing[15-16]. Therefore, we want students to be interested in all modalities and study all modalities without bias. This means on-campus training and clinical training should include participatory training for all modalities. It is hoped that students' interest and willingness to learn will be increased by such changes. We want to contribute to the development of high-quality radiological technologists required by hospitals. Therefore, we plan to use this data to inform educational improvements.

As a future research topic, this study does not compare the results of the questionnaire with the student's basic academic ability. In the future, we would like to evaluate the relationship between the results of this questionnaire and basic academic ability. The results of this study are limited to students of Suzuka University of Medical Science. Since different schools have different teaching methods, the same research may produce different results at other schools. In the future, we would like to conduct research on student education that goes beyond the boundaries of schools through joint research with other schools.

5. Conclusion

The purpose of this study was to investigate the relationship between students' modalities of interest in clinical training and their level of learning for those modalities. Modalities of most interest to students were GR, CT, and MR, and the level of learning for these modalities was particularly high. We will improve our education program based on the results of the present questionnaire to contribute to the training of high-quality radiological technologists.

Data Availability

The data used to support the findings of this article are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Effects and Limitations of Visceral Fat Area Evaluation and Written Instruction by X-ray Computed Tomography

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Key words: Visceral Fat Accumulation, CT Scan, Metabolic Syndrome, Obesity

【Abstract】

This study aimed to evaluate the effects of visceral fat area, abdominal circumference, and body mass index (BMI) on X-ray computed tomography (CT) and the effect of comments on results.

In this study, subjects were recruited for 94 months, and 232 subjects were assessed for visceral fat area, BMI, and abdominal circumference, and images and guidance comments were distributed as reports to the subjects.

As a result, 57.6% of the subjects had visceral fat accumulation. These subjects were instructed to improve their lifestyle after 6 months and reexamined. However, only 9.7% of the subjects followed it. Those who followed the reexamination instructions did not reduce BMI or abdominal circumference but tended to reduce visceral fat area.

We conclude that the motivating effect of this study is limited. However, it was estimated that visceral fat area was likely to be reduced, even if the reexamination did not reduce weight and abdominal circumference.

Introduction

People in modern society consume more nutrients while consuming less total calories.

As a result, the problems caused by malnutrition have decreased, but the increase in the number of obese individuals have led to an increase in the incidence of various diseases. Obesity is a problem not only in Japan but also worldwide. The countries with the highest percentage of overweight with a BMI ≥ 25 are the United States, Mexico, Australia, the United Kingdom, and China. More than 60% of the population in these countries is overweight.

The 2002 World Health Report by the World Health Organization pointed out the importance of measures against cardiovascular diseases, which are rapidly increasing in developed countries and China and Asian countries, as global health measures [1)]. The percentage of overweight in Japan is 22.4%, which is lower compared to that of other countries. However, the number of obese individuals is increasing due to the rapid westernization of eating habits that has changed in the last 50 years. Against this background, even mildly obese individuals with a relatively low BMI develop lifestyle-related diseases. Thus, Japanese individuals have low tolerance to obesity and are at greater risk of obese individuals for lifestyle-related diseases than individuals of Western countries.

In 1996, the Ministry of Health, Labour and Welfare focused on individual lifestyle involvement in the factors responsible for obesity, type 2 diabetes, dyslipidemia, hypertension, and cardiovascular disease. Moreover, the basic policy of disease management was formulated [2)]. Subsequently, in 2000, focusing on multiple risk factor syndrome, a secondary health checkup benefit system was implemented with workers' accident compensation insurance [3)]. LDL cholesterol is the greatest risk factor for atherosclerosis, but the accumulation of other risk factors has been shown to worsen the onset and prognosis of heart disease. When risk factors are accumulated, it is called metabolic syndrome. Particularly, visceral fat-accumulating obesity is considered one of the pathological causes of metabolic syndrome.

The initiation of the process of establishing metabolic syndrome is based on fat accumulation around the abdominal organs, such as the gastroepiploic artery and mesentery. Moreover, when risk factors, such as insulin resistance and impaired glucose tolerance, arteriosclerosis-inducing lipoprotein abnormality, and hypertension, are accumulated, heart disease is likely to develop. Metabolic syndrome is established through such a process.

The diagnostic criteria for metabolic syndrome were established in April 2005 by the International Diabetes Federation and eight related academic societies in Japan [4]. The diagnostic criteria in Japan were abdominal circumference of ≥ 85 cm in men and ≥ 90 cm in women and visceral fat area around the navel of > 100 cm^2 defined as visceral fat obesity. Moreover, among those with visceral fat-fat obesity, those with at least two of hypertension, hyperglycemia, and cholesterol abnormalities were defined as metabolic syndrome. In addition, X-ray computed tomography (CT) is recommended to evaluate the visceral fat area [5), 6)]. It is presumed that the reason that the standard value of abdominal circumference is higher in women is that subcutaneous fat is generally higher in women. Our study found that more women have normal abdominal circumference measurements, even though their visceral fat area is > 100 cm^2. The ratio was 2.4 times higher in women than in men [7]. Subcutaneous fat is not a direct cause of arteriosclerosis like visceral fat, and it is difficult to reduce compared with visceral fat. If a subject with subcutaneous fat obesity uses the abdominal circumference measurement method to determine visceral fat loss effect due to exercise or the like, it becomes difficult to determine the effect of visceral fat loss. As a result, when the abdominal circumference measurement method is used to determine the visceral fat loss effect, there is a concern that the motivation of the subject who attempts to reduce visceral fat may be reduced. If the visceral fat area is evaluated using X-ray CT, problems like abdominal circumference measurement method do not occur.

Moreover, an example of the X-ray CT examination method and image display method used in the visceral fat area evaluation is presented in the obesity clinical practice guidelines [8]. However, they are not based on clear grounds, and it is presumed that they copied the exposed conditions of abdominal CT used clinically. In a previous study, we instructed subjects with visceral fat accumulation assessed by X-ray CT to obtain written guidance and reexamination after 6 months. Subsequent reexaminations investigated the body weight and abdominal circumference of subjects whose visceral fat area decreased by ≥ 10%. As a result, there was no significant difference in the mean weight and abdominal circumference of the subjects whose visceral fat area decreased. In some cases, the body weight and abdominal circumference increased even though the visceral fat area decreased [9].

This study aimed to examine how the visceral fat area evaluation and written guidance using X-ray CT affect the subjects.

Method

From July 2010 to December 2017 (94 months), we recruited subjects for bulletin boards, pamphlets, and optional examination of complete medical examination (Ningen dock). There were 232 (male/female ratio 107: 125) subjects in the study. We performed CT of the umbilical region of these subjects and analyzed the visceral fat region, BMI, and abdominal circumference using visceral fat region analysis software. Subjects were categorized based on ab-

Table 1 Classification of subjects by diagnosis and comments of medical doctors

CATEGORY	Vicseral Fat Area (VFA)	BMI	Abdominal Circumference	Comments and Instructions
Threshold	100cm^2 or more	25 or more	male: 85cm or more Female: 90cm or more	
	+	+	+	You are obese and your abdominal circumference is above normal, and you have a buildup of visceral fat. You need to improve your lifestyle and exercise habits. You should improve your lifestyle and reexamination 6 months later.
	+	+	−	Your abdominal circumference is normal. but you have obesity and visceral fat accumulation. You should improve your lifestyle, mainly exercise therapy, and reexamination after 6 months.
	+	−	+	You are not obese, but you abdominal circumference is above normal and you have accumulated visceral fat. You should improve your lifestyle, mainly exercise therapy, and reexamination after 6 months.
	+	−	−	You have a normal range of obesity and abdominal circumference, but you have accumulated visceral fat. You should improve your lifestyle and reexamination 6 months later.
	−	+	+	You have excess abdominal circumference and obesity. However, there is no visceral fat accumulation. You should try to control your weight.
	−	+	−	You have a normal abdominal circumference and no buildup of visceral fat. But you are obese. You should try to control your weight.
	−	−	+	You have no obesity and no visceral fat accumulation. You are only above the normal range of abdominal circumference. You should develop an exercise habit.
	−	−	−	You have normal abdominal circumference, no obesity, and no buildup of visceral fat. You should maintain your current lifestyle.

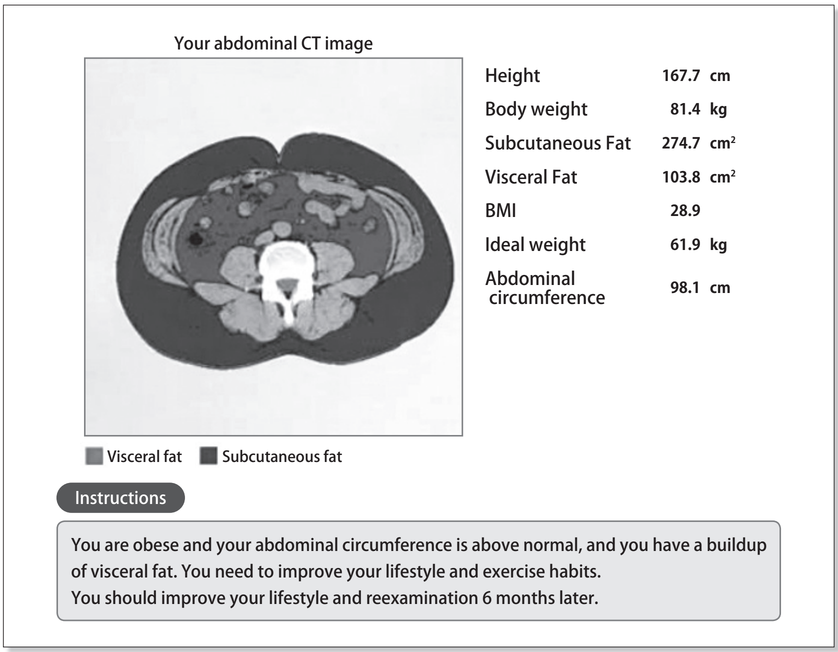

Fig.1 Report example issued to the subject

dominal circumference of 85 cm in men and 90 cm in women, BMI of 25, and visceral fat area in 100 cm^2. The guidance comments shown in Table 1 and the captured images were attached to the report and results mailed to the subjects. (Fig.1 shows an example of a report to the subjects.) Moreover, 134 (male/female ratio, 91: 43) subjects had visceral fat area > 100 cm^2. We instructed them to undergo reexamination after 6 months.

Then, we investigated changes in visceral fat area, abdominal circumference, and BMI before and after the initial examination and reexamination of subjects. If the subject underwent reexamination > 4 months after the initial examination or within 14 months, the result was determined to be valid. Subjects who underwent reexamination earlier or later were excluded from the analysis. Concurrently, we also observed the compliance rate for reexamination. The deadline for accepting new examination was May 2017, and for subsequent tests, only those who were reexamined were counted. The subject paid a cost of 3,000 yen (JPY) (+ 8% tax) for each examination. The equipment used was Aquilion64 manufactured by Canon Medical Systems Corporation, and the visceral fat analysis software used was Slim Vision manufactured by Cybernet. The imaging conditions were tube voltage of 120 kVp, tube current of 300 mA, rotation time of 0.5 s, slice thickness of 6 mm, reconstruction filter function for abdomen (FC10), and slice-and-scan imaging method. This study was approved after undergoing an ethical review at the medical institution that collected the data.

Results

Table 2 shows the subjects who underwent reexamination and the subjects who were instructed to undergo reexamination but did not respond (ignored).

Of 134 subjects who were instructed to undergo reexamination, 121 subjects did not respond (male/female ratio, 77: 44), and 13 subjects responded to the reexamination instructions. Subjects reexamination compliance rate was 9.7%. Table 3 shows the initial examination and reexamination of 13 subjects who responded to the instruction.

The subjects had a male-female ratio of 7: 6, an average age of 56.6 ± 11.0 years, an average visceral fat area of 130.2 ± 29.4 cm^2 at the

Table 2 The average value of the gender ratio, age, BMI, abdominal circumference and visceral fat area of the group that had been reexamined and were not reexamined (ignored)

	Re-Ex	Ignore
Male: Female	7: 6	77: 44
Age (yo)	56.6 ± 11.0	60.3 ± 11.5
VFA (cm^2)	130.2 ± 29.4	137.9 ± 31.5
BMI	26.6 ± 1.9	26.7 ± 3.3
Abdominal Circumference (cm)	89.7 ± 5.7	93.2 ± 7.5

Table 3 Comparison of initial and reexamination of subjects who have undergone reexamination

n = 13 (Male: 7, Female: 6)	Before	Re-Ex
VFA (cm^2)	130.2 ± 29.4	119.3 ± 31.4
BMI	26.6 ± 1.9	26.5 ± 2.1
Abdominal Circumference (cm)	89.7 ± 5.7	89.9 ± 5.5

first examination, and an average visceral fat area of 119.3 ± 31.4 cm^2 at the reexamination. Moreover, the subjects had an average BMI of 26.6 ± 1.9 at the first examination, average BMI of 26.5 ± 2.1 at the reexamination, average abdominal circumference of 89.7 ± 5.7 cm at the first examination, and average abdominal circumference of 89.9 ± 5.5 cm at the reexamination. Nine subjects (male/female ratio, 6: 3) exceeded the standard values in all items of visceral fat area, BMI, and body weight. In the three subjects (male/female ratio 1: 2), the visceral fat area and BMI exceeded the standard values and the abdominal circumference was within the standard values. In one subject (male/female ratio, 0: 1), the visceral fat area exceeded the standard value, and the BMI and abdominal circumference were within the standard value. In the paired t-test, the P-value of visceral fat area was 0.06, the P-value of BMI was 0.39, and the P-value of abdominal circumference was 0.84. Comparing the mean values between the initial examination and reexamination of the subjects, there was no significant difference at 5% level. However, the visceral fat area of four subjects was < 100 cm^2 at the time of reexamination, and the visceral fat accumulation disease was resolved (elimination rate of visceral fat accumulation disease, 30.8%) (Fig.2).

The average observation period until the subject underwent reexamination was 351.1 ± 86.2 days. The average age of 121 subjects who did not undergo reexamination was 60.3 ± 11.5 years, the average visceral fat area at the first examination was 137.9 ± 31.5 cm^2, the average BMI at the first examination was 26.7 ± 3.3, and the average abdominal circumference at the first examination was 93.2 ± 7.5 cm. Comparing the subjects who did not respond to the reexamination and the subjects who responded to the reexamination instructions using the Mann-Whitney U test, visceral fat area showed P = 0.33, BMI showed P = 0.89, abdominal circumference showed P = 0.14, and age showed P = 0.52 (Fig.3). The percentage of subjects who could confirm that the visceral fat accumulation disease had disappeared was 3.0% (4/134).

Discussion

In this study, we performed abdominal CT

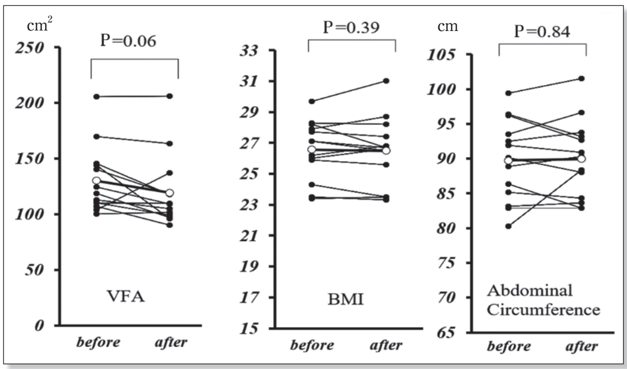

Fig.2 Changes in indicators according to instructions for reinspection

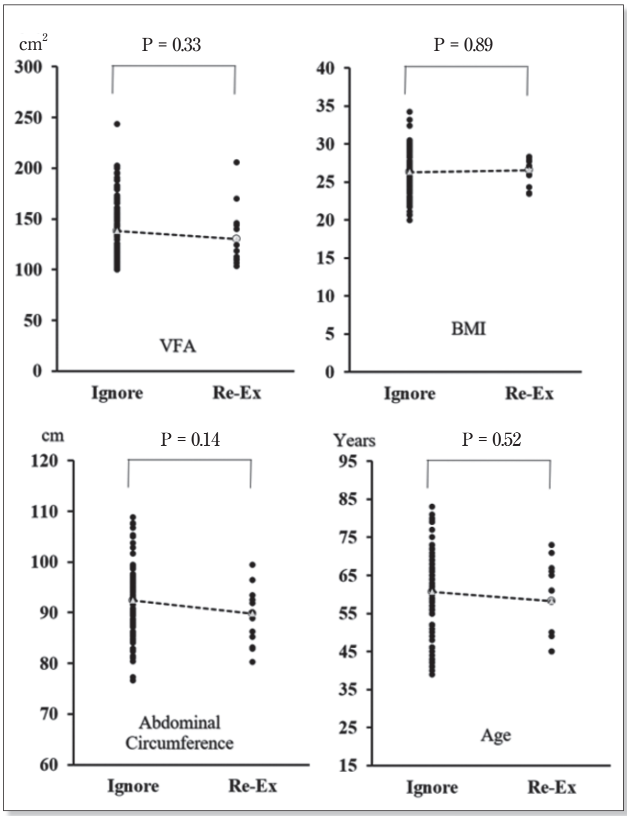

Fig.3 Comparison of people who responded to instructions for reinspection and those who did not respond

examinations on 232 subjects who were concerned about visceral fat accumulation and desired to undergo evaluation of the visceral fat area. As a result, 57.6% (134 subjects) of the subjects had visceral fat accumulation disease. These subjects were instructed by mail to undergo reexamination after 6 months by improving their lifestyle, such as exercise and diet. However, only 9.7% (13 subjects) of the subjects complied with the reexamination instructions, and 90.3% (121 subjects) did not undergo reexamination.

We believed that the reasons that the subjects did not undergo reexamination were as follows:

"The subject forgot that he was instructed to undergo reexamination."

"The subject was interested in own visceral fat area and wanted to undergo examination only once."

"The subject died or had difficulty in moving freely."

"Subjects were not retested because they were not convinced that they had succeeded in reducing visceral fat."

Fig.2 shows the group that complied with the reexamination instructions.

From this figure, the average visceral fat area tends to decrease even though BMI and abdominal circumference do not decrease. The results of this study indicate that the effect of reducing visceral fat area cannot be indirectly inferred from BMI and abdominal circumference. We are presumed that the subjects who received the instruction for reexamination used BMI (or body weight) and abdominal circumference as indicators of progress. However, since many subjects could not confirm the weight reduction effect of BMI (or body weight) and abdominal circumference, it is considered that the motivation of the subjects to continue the weight reduction effort was reduced. As a result, we can infer that many subjects did not undergo reexamination. The fact that the decrease in BMI and abdominal circumference cannot be confirmed despite the decrease in visceral fat area is consistent with the results of our previous studies [8]. The low reexamination compliance rate of the subjects is a direct factor that only 3.0% can confirm the resolution of visceral fat accumulation disease.

Subjects who desired to measure the visceral fat area themselves are a group that is concerned about their own visceral fat accumulation and wants to know the fact. Thus, it can be said that this group of subjects has a high interest in health. Comparing the subjects who responded to the reexamination and those who did not respond to the reexamination, there was no significant difference in all items (visceral fat area, abdominal circumference, BMI, and age). There is no significant difference between the retested group and non-retested group. Therefore, it can be inferred that the subjects with decreased visceral fat area were not small in the group that did not undergo reexamination. The average visceral fat area of 13 subjects who adhered to the reexamination instructions tended to decrease overall from 130.2 ± 29.4 cm^2 to 119.3 ± 31.4 cm^2, but the P-value was 0.06 in the paired t-test. It has not reached 5% significance level. This is due to the statistical examination that included subjects with significantly increased visceral fat area. The limitation of this study is that the sample size is small. However, among the subjects who underwent reexamination, the elimination rate of visceral fat accumulation disease was 30.8% (4 of 13).

In addition, 53.8% (7 of 13) of the subjects who underwent reexamination had a visceral fat area decreased by ≥ 10%. It can be inferred that these test subjects adhered to the written instruction of the physician. Written instructions by a physician provide some motivation. However, 90.3% of the subjects did not respond to the reexamination instruction.

Moreover, the subjects who responded to the reexamination instruction were often significantly delayed even though they were instructed after 6 months.

Thus, the written instruction of a physician alone has a limited motivational effect.

Takenaka et al. point out that it can be explained that "health checkups are difficult to sell"[10]. The problems are that the subjects must pay for the reexamination and that he has to visit the medical institution again for reexamination. We can expect an improvement in the subject's reexamination rate by improving the service to the subject. Eventually, we believe that the number of subjects who can confirm the elimination of visceral fat accumulation disease will increase.

Conclusion

If the subjects were evaluated for visceral fat area by abdominal CT and the subjects who pointed out visceral fat accumulation were instructed to undergo reexamination in writing after 6 months, ≥ 90% of the subjects would not respond to the reexamination instruction. The reason is that it is difficult to determine the decrease in visceral fat area by body weight measurement (BMI calculation) or abdominal circumference measurement.

It is presumed that the subjects' motivation decreased because the only methods for confirming the progress until the reexamination were body weight measurement (BMI calculation) and abdominal circumference measurement. Although the number of samples was small, the visceral fat area of the subjects who responded to the reexamination tended to decrease, and 30.8% of the subjects had resolution of visceral fat accumulation disease. Only 3.0% of subjects with visceral fat accumulation were finally confirmed to have resolved visceral fat accumulation. The main reason is that many subjects do not respond to our reexamination instructions.

We conclude that the motivational effect of abdominal CT on visceral fat accumulation disease in subjects is limited. However, we speculated that the visceral fat area of the subjects was likely to be reduced even if the body weight (BMI) and abdominal circumference were not reduced.

*There is no conflict of interest in this study.

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Basic Evaluations of JIS Certified Radiation Protection Eyewear for Eye Lenses Using Different Evaluation Methods

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【Abstract】

In 2011 the International Commission on Radiological Protection recommended that "the threshold dose for cataracts and the lens equivalent dose limit should be significantly reduced", and the Ministry of Health, Labour and Welfare has notified medical institutions to strengthen measures to protect eye lenses from radiation exposure. This shows the necessity to protect medical professionals by using equipment with increased levels of protection.

This study developed new radiation protective eyewear in accordance with Japanese Industrial Standards (JIS) for eye lens exposure, and conducted basic evaluations of the protection efficiency in angiography, general radiography, fluoroscopy, and C-arm applications. The results showed that these newly developed radiation protective eyewear provide a high level of radiation protection.

Introduction

In recent years, medical devices using radiation have advanced remarkably, and they are widely used clinically, from diagnosis to treatment. However, patient exposure to radiation has become an issue. In 1977, the International Commission on Radiological Protection (ICRP) has recommended three basic principles in radiation protection: legitimacy, protection optimization, and dose limits. In clinical settings, there are numerous situations where both medical professionals and patients are exposed to radiation. In particular, the eye lens is a highly radiosensitive organ, and if the dose of radiation exposure exceeds threshold limits, it may cause radiation damage such as cataracts. For this reason, in 2011 the ICRP has conducted epidemiological studies and announced that the threshold doses recommended in 1990 and 2007 for prevention of lens opacity (5 Gy) and impaired sight (8 Gy) were underestimated, and has amended the values to 0.5 mSv. Along with this, the ICRP suggested that the lens equivalent dose limit should not exceed 20 mSv / year on average for 5 years and 50 mSv in any one year [1-2]. Under the current regulations, with the exposure dose evaluated indirectly by attaching a personal dosimeter, which measures the 1 cm dose equivalent or 70 μm dose equivalent, to the chest and abdomen or the head and neck, it is difficult to evaluate eye lens exposure accurately. This evaluation method is based on the assumption that if the dose limits are ensured for a 1 cm dose equivalent of effective dosage and the 70 μm dose equivalent for the skin equivalent dose, the dose limit for the eye lens is also assured. However, as the shielding effects of protection eyewear have not been considered, a previous study by Kato et al. (2020) [3)] reported the development of protection eyewear that comply with Japanese Industrial Standards (JIS) (JIS T 61331-3) [4)] to achieve further reductions in the exposure in order to protect eye lenses in clinical settings. In the present study, we conducted basic evaluations of the eye lens protection efficiencies of protection eyewear used in cardiovascular examinations, chest radiography, fluoroscopy, and intraoperative examinations, and examined the effectiveness.

Methods

1. Dosimetry

After attaching JIS certified protection eyewear, Dr. B-Go® (manufactured by Dr. Japan Co., Ltd.), to a phantom, and assuming a clinical standing position, the scattered dose was measured with an optically stimulated luminescence (OSL) dosimeter. We used a small OSL dosimeter, nano Dot (manufactured by Nagase Landauer Co., Ltd.) for the dosimeter, PMMA (W × D × H) 20 cm as the scatterer phantom, and THRA-1 (manufactured by Kyoto Scientific Co., Ltd.) as the human body equivalent phantom. The measurement conditions were the same as they would be in actual clinical use in all tests. Doses were calculated by correcting the used energy of the OSL dosimeter and the calibration value for each element involved. The OSL dosimeters were placed inside and outside of the front surface of the protection eyewear, inside and outside the frame for the lateral direction, and above both eyes. Without protection eyewear, the doses were measured only directly above both eyes (Fig.1). We used the following devices: Allura Xper FD10/10 (manufactured by Phillips Japan Co., Ltd.) as the angiography device; CUREVISTA (manufactured by Hitachi, Ltd.) as the X-ray fluoroscope; CALINEO (manufactured by Fujifilm Medical Co., Ltd.) as the X-ray device; and OEC9900 (manufactured by GE Healthcare Japan Co., Ltd.) as a C arm. We also used Marbic, lead equivalent 0.5 mmPb (manufactured by Getinge Group Japan Co., Ltd.) for the X-ray protection plate of the heart catheter (protection plate); and a scattered ray protection cloth NP (protection cloth), lead equivalent 2.5 mmPb (manufactured by Hoshina Seisakusho Co., Ltd.) for the fluoroscope. The measured values were the average of three measurements.

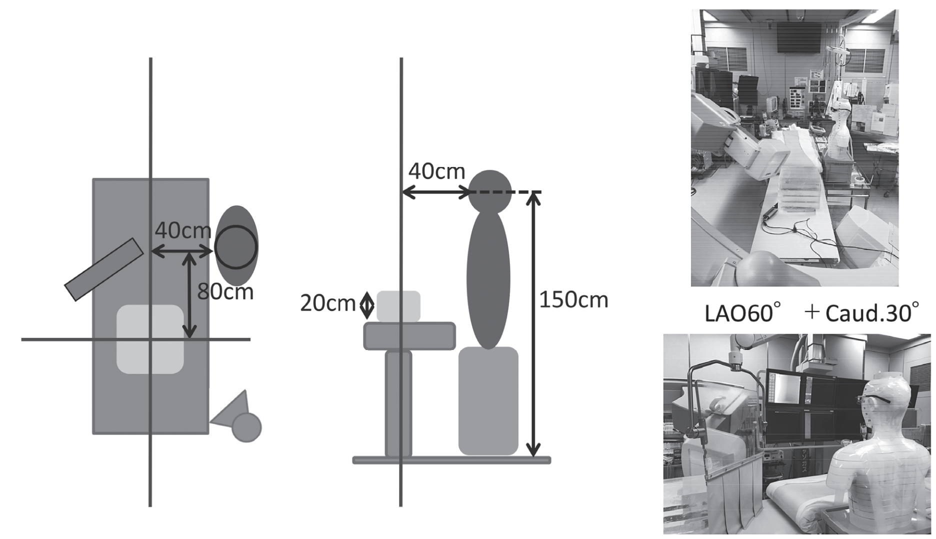
1-1

The measurement angle for the cardiovascular radiography was LAO 60 degrees + Caud 30 degrees, the maximum dose in the previous

Front　　Side

Fig.1　Placement of radiation protective eyewear and dosimeters

①eyewear lens surface　②On the top of the eye
③Inside eyewear　④Outside of eyewear



	kV	mA	Inch size	SFD (cm)	Filter	Time (min)
Fluoro	82	4.5	12	110	0.4mm Cu+1.0mm Al	10
DA	120	200	12	110	0.1mm Cu+1.0mm Al	1

Fig.2　Measurement geometry and measurement conditions in Angiography

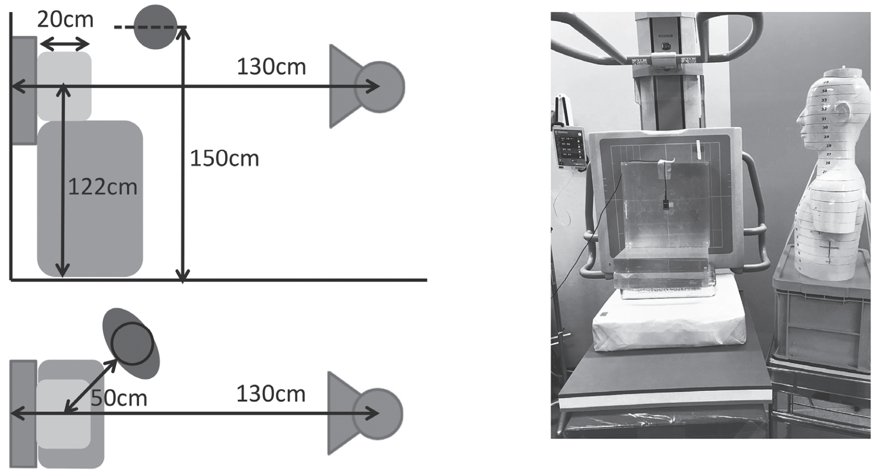
study. The X-ray field was 12 × 12 inches (30.5 × 30.5 cm), and the source flat panel detector distance (SFD) was 110 cm, with the height of the treatment bed 85 cm from the floor. Assuming a standing position of a technologist, the position of the phantom was set 40 cm in front of and 80 cm away from the middle (centerline) of the bed at the surface of the eye, and 150 cm from the floor to the eye lenses. The tube voltage and current were set as Full Auto for PMMA 20 cm. For filters we used 0.1 mm Cu + 1.0 mm Al in the radiography, and 0.4 mm Cu + 1.0 mm Al for the fluoroscopy. The irradiation durations were 1 minute for imaging and 10 minutes for the fluoroscopy. The fluoroscopy was operated at 15 frames / sec (Fig.2).

1-2

For the chest radiography, assuming a technologist assisting a patient, the phantom was placed 50 cm from the middle (centerline) of the patient phantom. The SFD was 130 cm, and the height of the centerline of the detector was 122 cm from the floor. The human phantom was at 150 cm from the floor, at 50 cm to the surface of the eye lenses, and 150 cm from the floor to the eye lenses. The irradiation angle, fluoroscopy / imaging conditions, and position of the dosimeter were tube voltage / current 90 kV / 20 mAs for the PMMA of 20 cm. The irradiation field was 17 × 17 inches (43.2 × 43.2 cm), and the filter was 0.1 mm Cu at the time of the radiography ; with 10 times of imaging (Fig.3).

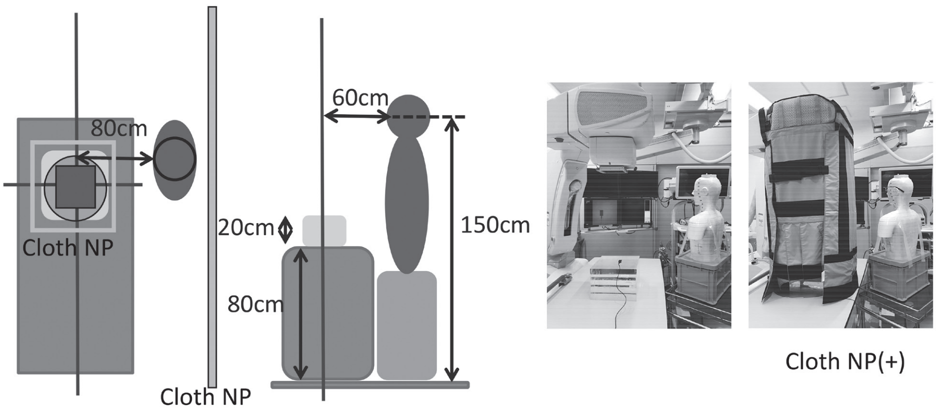
1-3

In the fluoroscopy, a scattered radiation protection cloth NP was attached to the device, and assuming a standing position of the technologist, the position of the surface of the eye lenses of the phantom was 60 cm in front of and 80 cm away from the middle of the bed, and the distance from the floor to the eye lenses was 150 cm. In the fluoroscopy, the tube voltage and current were set as Full Auto for PMMA 20 cm, 92 kV, 0.7 mA, 21 × 21 inches (53.3 × 53.3 cm), and a 120 cm source-image distance (SID), at 6.3 Pulse / sec for 10 min-



	kV	mAs	Inch size	SFD(cm)	Filter	Exposure Time
Fluoro	90	20	17×17	130	0.1mm Cu	10

Fig.3 Measurement geometry and measurement conditions in General radiography



	kV	mA	Inch size	SID(cm)		Time(min)	Exposure Time
Fluoro	92	0.7	21×21	120	6.3p/s	10	—
DA	82	200	21×21	120	1shot	—	20

Fig.4 Measurement geometry and measurement conditions in Fluoroscopy

utes. In the radiography, the tube voltage and current were 82 kV, 200 mA; 21 × 21 inches (53.3 × 53.3 cm); 120 cm SID; with 20 times of imaging (Fig.4).

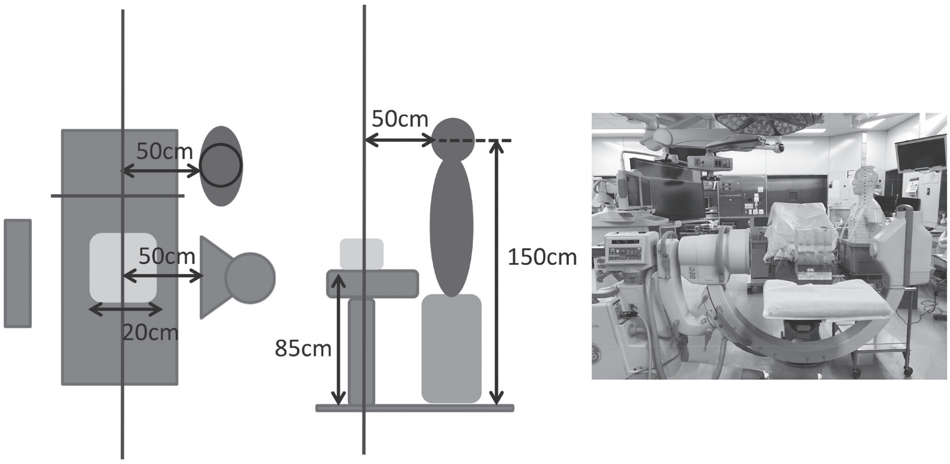
1-4

In the fluoroscopy for an intraoperative C-arm, assuming a standing position of the technologist, the human body phantom was set at a distance of 50 cm in front of and 50 cm away from the middle of the bed to the surface of the eye lenses, and 150 cm from the floor to the eye lenses. Other conditions were 85 kV, 3.5 mA, SID 120 cm, 4 Pulse/sec, and a 5 min duration (Fig.5).

Results

1-1

Table 1 shows the results of the measure-



	kV	mA	Inch size	SID (cm)	Pulse rate (p/s)	Fluoro Time (min)
Fluoro	85	3.5	9.0	120	4	5

Fig.5 Measurement geometry and measurement conditions in C-arm

ments with the angiography settings. The values with protection eyewear and without protection plate and with protection eyewear and protection plate at each position were as follows: 0.339 mGy and 0.095 mGy (lateral-external side of the left eyewear), 0.179 mGy and 0.052 mGy (lateral-internal side of the left eyewear), 0.263 mGy and 0.080 mGy (front-external side of the left eyewear), 0.050 mGy and 0.018 mGy (front-internal side of the left eyewear), 0.124 mGy and 0.038 mGy (front-external side of the right eyewear), 0.036 mGy and 0.014 mGy (front-internal side of the right eyewear), 0.088 mGy and 0.016 mGy (lateral-external side of the right eyewear), and 0.026 mGy and 0.001 mGy (lateral-internal side of the right eyewear). Immediately above the left and right eyes without protection eyewear and protection plate: 0.091 mGy and 0.078 mGy;the left and right eyes with protection eyewear and

Table 1 Radiation protection dose by radiation protection eyewear and protective plate in Angiography

Angiography	eyewear (+) : protective plate (−)	eyewear (+) : protective plate (+)
Left side: Outside of eyewear	0.339	0.095
Left side: Inside eyewear	0.179	0.052
Left front: Outside of eyewear	0.263	0.080
Left front: Inside eyewear	0.050	0.018
Right front: Outside of eyewear	0.124	0.038
Right front: Inside eyewear	0.036	0.014
Right side: Outside of eyewear	0.088	0.016
Right side: Inside eyewear	0.026	0.001
On the top of the left eye	0.091	0.078
On the top of the right eye	0.114	0.030
	eyewear (−) : protective plate (−)	eyewear (−) : protective plate (+)
On the top of the left eye	0.300	0.090
On the top of the right eye	0.130	0.036

(mGy)

Table 2 Radiation protection dose by radiation protection eyewear in General radiography

General radiography	eyewear (+)	eyewear (−)
Left side: Outside of eyewear	0.098	–
Left side: Inside eyewear	0.083	–
Left front: Outside of eyewear	0.139	–
Left front: Inside eyewear	0.012	–
Right front: Outside of eyewear	0.009	–
Right front: Inside eyewear	0.007	–
Right side: Outside of eyewear	0.087	–
Right side: Inside eyewear	0.028	–
On the top of the left eye	0.022	0.150
On the top of the right eye	0.099	0.131

(mGy)

Table 3 Radiation protection dose by radiation protection eyewear and protective cross in Fluoroscopy

Fluoroscopy	eyewear (+) : protective cross (−)	eyewear (+) : protective cross (+)
Left side: Outside of eyewear	0.166	0.006
Left side: Inside eyewear	0.045	0.006
Left front: Outside of eyewear	0.163	0.002
Left front: Inside eyewear	0.016	0.003
Right front: Outside of eyewear	0.125	0.015
Right front: Inside eyewear	0.009	0.002
Right side: Outside of eyewear	0.021	0.001
Right side: Inside eyewear	0.036	0.001
On the top of the left eye	0.030	0.002
On the top of the right eye	0.031	0.002
	eyewear (−) : protective cross (−)	eyewear (−) : protective cross (+)
On the top of the left eye	0.156	0.006
On the top of the right eye	0.087	0.003

(mGy)

protection plate: 0.114 mGy and 0.030 mGy.

Immediately above the left and right eyes without protection eyewear and protection plate vs. without protection eyewear and with protection plate were 0.300 mGy and 0.090 mGy (left), 0.130 mGy and 0.036 mGy (right).

1-2

Table 2 shows the measurement results with the general radiography. Values with protection eyewear at each position were as follows: 0.098 mGy (lateral-external side of the left eyewear), 0.083 mGy (lateral-internal side of the left eyewear), 0.139 mGy (front-external side of the left eyewear), 0.012 mGy (front-internal side of the left eyewear), 0.009 mGy (front-external side of the right eyewear), 0.007 mGy (front-internal side of the right eyewear), 0.087 mGy (lateral-external side of the right eyewear), 0.028 mGy (lateral-internal side of the right eyewear). Values immediately above the left eye with protection eyewear vs. without protection eyewear were 0.022 mGy and 0.150 mGy; those of the right eye were 0.099 mGy and 0.131 mGy.

1-3

Table 3 shows the measurement results with the fluoroscopy. Values with protection eyewear and without protection cloth and with protection eyewear and protection cloth at each position were as follows: 0.166 mGy and

0.006 mGy (lateral-external side of the left eyewear), 0.045 mGy and 0.006 mGy (lateral-internal side of the left eyewear), 0.163 mGy and 0.002 mGy (front-external side of the left eyewear), 0.016 mGy and 0.003 mGy (front-internal side of the left eyewear), 0.125 mGy and 0.015 mGy (front-external side of the right eyewear), 0.009 mGy and 0.002 mGy (front-internal side of the right eyewear), 0.021 mGy and 0.001 mGy (lateral-external side of the right eyewear), 0.036 mGy and 0.001 mGy (lateralinternal side of the right eyewear). Immediately above the left and right eyes without protection eyewear and protection cloth vs. with protection eyewear and protection cloth were 0.030 mGy and 0.002 mGy (left), 0.031 mGy and 0.002 mGy (right).

Values immediately above the left eye without protection eyewear and without protection cloth vs. without protection eyewear and with protection cloth were 0.156 mGy and 0.006 mGy; those of the right eye were 0.087 mGy and 0.003 mGy.

1-4

Table 4 shows the measurement results with the fluoroscopy for an intraoperative C-arm. Values with protection eyewear at each place were as follows: 0.017 mGy (lateral-external side of the left eyewear), 0.007 mGy (lateralinternal side of the left eyewear), 0.018 mGy (front-external side of the left eyewear), 0.002 mGy (front-internal side of the left eyewear), 0.015 mGy (front-external side of right eyewear), 0.001 mGy (front-internal side of the right eyewear), 0.001 mGy (lateral-external side of the right eyewear), 0.012 mGy (lateralinternal side of the right eyewear).

Values immediately above the eyes were 0.006 mGy (left) and 0.006 mGy (right). Without protection eyewear, values immediately above eyes were 0.011 mGy (left) and 0.010 mGy (right).

Discussion

The developed protection eyewear use eyewear lenses containing high-density lead, a lead equivalent of 0.88 mmPb. In addition, since the frame is also lead-coated, the frame provides protection also for the direct radiation. Further, for the scattered radiation from the vertical and lateral directions there is also a protective effect as the frame is designed to reduce the gap between the frame and the surface of the skin. In the basic measurements in previous studies using only protection eyewear, a 98% or better protection against exposure to direct frontal radiation over the full range from 80 kV to 140 kV. There was also protection against direct lateral radiation: the maximum was 80% or better, and the minimum was 66% or better.

Table 4 Radiation protection dose by radiation protection eyewear in C-arm

C–arm	eyewear (+)	eyewear (−)
Left side: Outside of eyewear	0.017	–
Left side: Inside eyewear	0.007	–
Left front: Outside of eyewear	0.018	–
Left front: Inside eyewear	0.002	–
Right front: Outside of eyewear	0.015	–
Right front: Inside eyewear	0.001	–
Right side: Outside of eyewear	0.001	–
Right side: Inside eyewear	0.012	–
On the top of the left eye	0.006	0.011
On the top of the right eye	0.006	0.010

(mGy)

When a protection plate was introduced together with the protection eyewear, the scattered dose reduced to about 1/7 on average, suggesting that the combined use of eyewear with a protection plate has a very considerable effect on lens radiation protection [3].

In the measurements for the present study, the maximum dose that a technologist is exposed to in one procedure in cardiovascular angiography would be 0.300 mGy on the lateral-external side of the left eyewear without protection eyewear and without a protection plate, with an average of 20 mGy over 5 years. Therefore, the threshold value of the eye lens will be exceeded after performing 66 procedures. The result immediately above the right eye is 0.13 mGy, and with this exposure the threshold dose will be exceeded after performing 153 procedures, and even with protection eyewear without a protection plate there is the possibility of exceeding the upper limit of the threshold dose for the eye lens.

Considering a maximum of 50 mGy per year, 166 cases can be handled.

However, physicians who handle many cases or perform treatment that last longer periods may exceed the threshold dose. With protection eyewear and protection plate, the maximum exposure per procedure dose is 0.095 mGy at the lateral-external side of the left eyewear. Assuming a threshold value of 20 mGy, 210 cases could be acceptable, and if the threshold is considered as 50 mGy, 526 cases would become acceptable. Overall, these numbers suggest that it is preferable to use a radiation protection plate together with the protection eyewear.

It is estimated that the maximum dose of scattered radiation that a radiologic technologist who assists patients in general radiography receives in one month is 0.15 mGy immediately above the left eye without protection eyewear and protection plate, averaging 20 mGy over 5 years. Based on this estimate, a radiologic technologist can perform assistance 133 times. The dose immediately above the right eye is 0.131 mGy, giving an estimated number of possible procedures of 153. However, if the annual number of working days is 200, there is a strong possibility that this upper limit will be exceeded. With a maximum dose of 50 mGy per year, this would allow 333 times of exposure. In this case, 1.6 times of assistance per day for 200 days could exceed the threshold value. With protection eyewear, the dose immediately above the left eye is 0.022 mGy, and that at the right eye 0.099. Compared to the situation without protection eyewear, the exposure doses with protection eyewear were 1/6.80 for the left eye and 1/1.30 for the right eye. These results show the necessity to use protection eyewear when assisting patients during general radiography, resulting in good agreement with the results reported by Takei [5].

Results of the measurements assuming fluoroscopy showed that the exposure doses with both protection eyewear and protection cloth decreased to 1/78 on the left eye and 1/43.5 on the right eye compared to the case without such devices. The doses with only protection cloth became 1/26 on the left, and 1/29 on the right eye. Considering the threshold value of 20 mGy, 128 tests could be performed without using protection eyewear and protection cloth, and 645 with only protection eyewear. Using both, it will be possible to handle 10,000 tests annually. This suggests the advantage of using protection eyewear at the very least.

When using the C-arm, the maximum dose without protection eyewear is 0.011 mGy immediately above the left eye, averaging 20 mGy for 5 years, and suggesting 1,818 tests are possible. Further, wearing only protection eyewear is effective because the exposure dose is reduced by half.

This present study did not measure the doses at CT tests, but it is considered that wearing protection eyewear is an effective means for protecting the eye lens of technologists who assist patients during CT examination or perform biopsies with CT.

Akahane reported that "The shielding effect of protection eyewear is affected by the positional relationship between the head, the eyewear, and the radiation source. If the position of a technologist is not directly facing the radiation source, the shielding effect of the protection eyewear is reduced. If the gap between the eyewear and the face is large, the shielding effect of the protection eyewear may easily be attenuated. When a dosimeter is attached to the inside of the protection eyewear, it is difficult to detect the attenuation of the shielding effect of the protection eyewear, and there is a risk of underestimation when using these values as a standard for the eye lens equivalent dose" [6]. As described above, because the distribution of the scattered radiation is complicated, it is possible that the results in the present study will differ from the results of other basic experiments on lenses and materials, and there may be influences of wraparound radiation (radiation from unexpected angles) and the secondary scattering as errors due to the influence of the incident direction.

The measurement results are notated as Gy as physical quantities. Further, we think it is acceptable to consider the absorbed dose in Gy of the eye lens and the equivalent dose in Sv as equal because this study targets the eye lens, and the radiation weighting factor is 1.0 for X-rays.

Limitations of the study

The measurements in the present study showed a high protective effect, but in actual clinical practice, some cases take more time for the treatment, and in that case, the fluoroscopy time, the number of radiographies, and the large angle of the load would increase, affecting the values of the protective effect.

Conclusions

We conducted a basic evaluation of the JIS-compliant protection eyewear developed in this study. As the results show highly protective effects for various clinical settings, it was established that the protection eyewear are effective as a device for eye lens protection.

Acknowledgments

We wish to express our sincere gratitude to Ikuo Kobayashi (Nagase Landauer, Ltd.) for helpful and supportive cooperation in this study.

Conflict of interest

This study was conducted with research funding under a contract for joint research and development between the Dr. Japan Co., Ltd. and Showa University.

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Global Extension of Medical Technologies: What can Radiologic Technologists do for Global Health?

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Suppose that you are asked a questions from one of your colleagues like, "What can we do for global health?" How would you answer the question? Most of our colleagues would probably say "Sorry, pal. That should not be for radiologic technologists but for medical doctors and nurses."

I would do likewise, unless I had participated in the project of global extension of medical technologies.

Most of the readers however, may not be familiar with this.

The projects are defined as follows;

The projects of global extension of medical technologies dispatch Japanese experts in the field of health policy, social security, health care and health industry to developing countries and accept health staff from various countries. Through these activities, Japan intends to share experiences of medical institutions such as the public health insurance scheme and promote excellent medical technologies, drugs and equipment. Thus, the projects aim to improve public health and medicine in developing countries while facilitating growth of Japanese health industry. Such activities are expected to increase trust in Japan in the international society and derive win-win relation between Japan and developing countries [1).

As you can image, there are many applicants and lots of projects are carried out in developing countries. Among them, one that I joined in and broadened my horizon is "Enhancing computed tomography (CT) and cardio angiography in Republic of Zambia".

For those who are not well informed of, let me introduce Zambia.

Zambia, unlike most of its neighbors, has managed to avoid the war and upheaval that has marked much of Africa's post-colonial history, earning itself a reputation for political stability. The landlocked country has experienced rapid economic growth over the last decade as Africa's second largest copper producer after the DR Congo. But its over-reliance on copper has made it vulnerable to falling commodity prices. Zambia also has one of the world's fastest growing populations with the UN projecting that its population will triple by 2050. But economic growth and massive Chinese investment have failed to improve the lives of most Zambians, with two-thirds still living in poverty [2).

Zambia used to be British territory and the official language is English (less language barrier to us comparing to French-speaking area). Victoria Falls, one of three largest waterfalls in the world, attract lots of people from all of the world. The distance between Tokyo and Lusaka, the capital of Zambia, is approximately 12,917 km, and the flight time (Emirates flights) from Narita international airport to Lusaka

Fig.1

Fig.3

Fig.2

airport is 22 hours and 25 minutes via Dubai (Fig.1, 2, 3)! No direct flight service is available. You cannot survive without movies or video games!

The summary of the "Enhancing CT imaging and cardio angiography in Rep. of Zambia" project is as follows; University Teaching Hospital (UTH) in Lusaka procured two Canon's radiology systems in 2015: CT and cardio angiography. However, owing to the lack of skills and knowledge of the staff, and sometimes infrastructure gap (blackouts happen quite often), the systems were not used effectively before the project (Fig.4).

Here is our story.

● CT (2017)

Four radiologic technologists from the UTH were invited and received education in Japan.

Contents of education include imaging protocol management, CT radiation dose control, quality assurance/quality control (QA/QC) of medical imaging devices, patient treatment, etc. Through the intense hard training, trainees in this project succeeded cardiac CT angiography (cardiac CTA). Eventually, Zambia became the second country (after Rep. of South Africa)

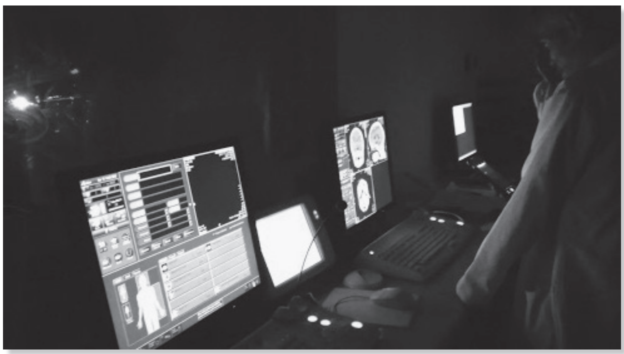

Fig.4

Fig.5

to perform cardiac CTA in Southern African countries. The fact was reported through the media (TV and newspaper) across the country and drew lots of attention.

Improved diagnostic CT imaging gathers more clinical requests and resulted in increasing the number of CT cases from 40 a day (before the project) to 60 (after the project) :a 50% jump rise! (Fig.5). The impact of the project has progressively grown and finally extended to Ministry of Health and Welfare. CT scanner's maintenance and user support contract were concluded in 2019.

Please note that it is very unusual for a developing country to conclude an equipment maintenance contract.

After the conclusion, the CT scanner has been running 24/7 and providing useful clinical imaging.

UTH even procured a new Japanese 3D work station in 2019, preparing for explosive increase in Cardiac CTA. They decided to strike out on their own.

● Cardio angiography (2018 and 2019)

Added to four radiologic technologists, one cardiologist and three nurses from UTH were invited and received education in Japan for this project.

The purpose of this project is to provide world-standard cardio angiography and percutaneous coronary intervention (PCI) in UTH. Unless otherwise, they would have to go to South Africa for the medical treatment. Education contents for radiologic technologists include imaging protocol management, radiation dose control, quality assurance/quality control (QA/QC) of medical imaging devices, patient treatment, etc. They received training in the cath lab of National Center for Global Health and Medicine (NCGM) and Terumo Medical Planex (Terumo Co. Tokyo, Japan).

After the hard training of two years, the UTH cath lab team succeeded the first PCI case in November 2019: the second country (after Republic of South Africa) in Southern African countries (Fig.6).

Like the CT project, the fact was reported in the local media (TV and newspaper) throughout the country (Fig.7). The cardiologist became famous overnight and was invited to see "Vice President of Zambia". The meeting was so quite an event to her that he keep appearing on her cell phone wall paper since then.

On the last day of our visit to UTH in November 2019, an unforgettable event happened. A South African patient of acute myocardial infarction was transferred from a modern private hospital for his treatment. Although it was an early morning emergency case, PCI was successful. The patient was then discharged in a couple of days later and returned to Rep. of South Africa safely.

The UTH director was so delighted to hear the news and it is not surprising to see that he

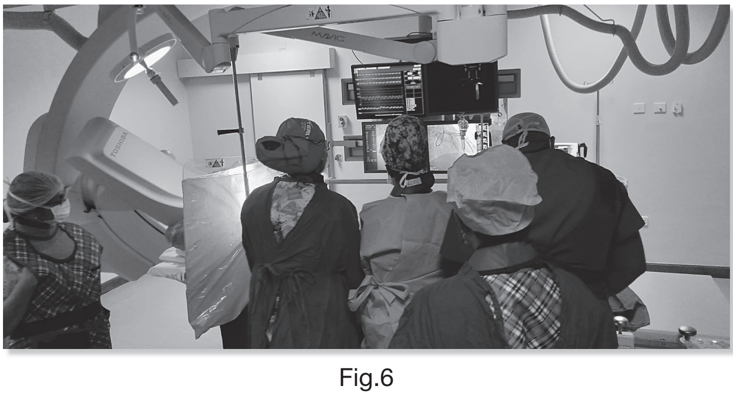

Fig.6

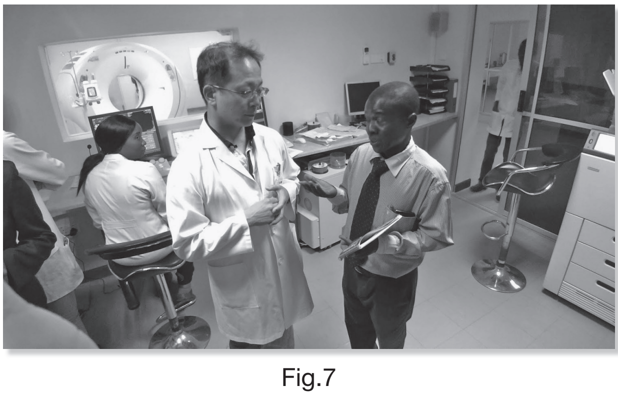

Fig.7

Fig.8

Fig.9

called the cardiologist “My daughter” since.

Please keep in mind that it is very unusual to transfer patients from a private hospital (often foreign-affiliated and modernized) to a public one (often older and not well-equipped).

The UTH staff were kind enough to invite us Japanese staff to join a weekend safari park tour. We had a big party over there (Fig.8, 9).

UTH team and NCGM still keep in contact with each other; which serves great assets to us. The project also had impact on academic performance and achievement. Several of the UTH staff were motivated to enroll in a college and a postgraduate course.

So after the event, if a friend of mine ask me “Hey, what’s in it flying over such a long distance to see your colleagues?”

I would answer the silly question “For global health promotion and it is definitely worthwhile.”

The project made me believe this.

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Regulations and Requirements for Submissions to the Journal of the Japan Association of Radiological Technologists

Submission Regulations

Revised: April 1, 2013
October 30, 2013
February 20, 2016
April 20, 2019
October 3, 2020

Objective
Article 1. These regulations are based on the operations defined in Article 4 of the articles on the incorporation of the Japan Association of Radiological Technologists (hereafter "the Association"). They stipulate the criteria for submissions to the Journal and informational magazines published by the Association (hereafter "the Journal, etc.").

Eligibility
Article 2. Only members of the Association may submit to the Journal, etc., unless the author is not a radiographer, in which case this condition does not apply.

Copyright
Article 3. The copyright of the published manuscript is based on rules regarding the management of the works of the Society.

Obligations
Article 4.
4-1. The topic of submitted manuscripts must belong to a relevant domain to technologies for prevention, diagnosis, and treatment related to radiation therapy, and manuscripts must be unpublished.
4-2. Submitted papers, whether for fundamental or applied research, must sufficiently consider bioethics, and authors must bear the ultimate responsibility for their content.
4-3. Fabrication, forgery, plagiarism, violation of the law, and other forms of wrongdoing are not allowed in submissions.
4-4. If the author has already reported similar content to that of the published manuscript or submitted it to another journal, the author is required to explain the difference from the manuscript in a separate document.
4-5. The author must disclose all information regarding conflicts of interest.
4-6. The author shall be held accountable for any misconduct regarding the content of the publication, and the Society shall not be involved at all.

Submissions
Article 5. The types of accepted submissions are categorized as follows:
(1) Original articles
Highly original research papers with clear objectives and conclusions.
(2) Review articles
Articles systematically summarizing a specific research domain from a particular perspective.
(3) Rapid communications
Reports of original research that must be published rapidly.
(4) Reports
Surveys of significance to the study of radiological technology or reports of interesting and important cases.
(5) Notes
Articles on the development or evaluation of new equipment, techniques, products, etc.
(6) Technical material
Compilations of survey data or technical aspects, or anything that can serve as a reference for research and technology.
(7) Overview articles
A compilation of technologies, principles, or basic elements with reference to the literature. However, what was explained in the development and use of equipment and software constitutes a technical explanation.
(8) Miscellaneous
Other items approved by the editorial committee for publication, such as lecture transcripts, courses published as journal articles, and newspaper/magazine articles that were not published in Issues 1–7.

How to submit
Article 6.
6-1. Use the online posting system.
6-2. The author shall save the duplicate data of the submitted manuscript until the publication decision.

Formatting

Article 7. The explanation of the manuscript shall be provided according to the submission procedure specified separately.

Reception of submissions

Article 8. The reception date shall be the date on which the editorial board has determined to comply with this regulation.

Review

Article 9.

9-1. Received manuscripts will be reviewed carefully and impartially by peer-reviewers selected by the editorial committee.

9-2. Peer reviews are limited to two times. However, in the case of Article 5, items 7 and 8, in principle, peer review is not performed.

9-3. The acceptance or rejection of the manuscript will be decided by the editorial committee in consideration of the opinions of the reviewers, and the date will be the final acceptance date.

Corrections

Article 10.

10-1. In principle, the author must proofread the manuscript up to twice and return it by the designated date. If the deadline is breached, the school will be completed with the proofreading of the editorial board.

10-2. The correction of words and plates that were not included in the manuscript is not allowed.

Printing

Article 11.

11-1. 20 copies of the papers published in the Journal, etc., will be presented to their authors as an offprint.

11-2. The authors must bear the expenses of any additional offprints. If additional offprints are required, they must be requested by the time corrections are submitted.

Revision or repeal of regulations

Article 12.

12-1. This regulation will come into effect on April 1, 2012.
12-2. This regulation will come into effect on April 1, 2016.
12-3. This regulation will come into effect on April 20, 2019.
12-4. This regulation will come into effect on October 3, 2020.

Requirements for Submissions to the Journal of the Japan Association of Radiological Technologists

Revised: February 20, 2016
April 20, 2019
October 3, 2020

The formatting requirements for manuscripts specified in Article 7 of the submission regulations of the Journal of the Japan Association of Radiological Technologists are as follows:

1. How to write original articles, reviews, breaking news, reports, notes, materials, and explanations.

1) Title and abstract

Enter the following items in the online posting system.

①Enter the author's name, facility name, affiliation, occupation, and contact information, and select the specialized field.
②Select the type of post.
③Enter the title and co-author information in Japanese and English. Co-authors are limited to members of the Society. However, this does not apply if the co-author is not a radiological technologist.
④Summarize the abstract in Japanese and English within 300 characters (words).
⑤Enter the keywords in English. Keywords should be in noun forms and should be limited to five.

2) Text and figures/tables

For the text and figures/tables, create and post both a separate file and a file containing figures and tables within the text.

①The manuscript should be written in Japanese or English.
Create the manuscript using Word with a paper size set to the A4 size. The type and size of the fonts should be 12 points for both Japanese and English fonts, Mincho font, and Times. The line spacing should be 18 points. Leave a margin of 2 cm or more on the top, bottom, left, and right.
②The specified number of pages and excess page costs of the manuscript are as shown in the following table.

Type of submission	Number of pages (as published)	Fee for additional pages
Original articles	8	¥10,000 per page
Review articles	8	
Rapid communications	3	
Reports	3	
Notes	8	
Technical material	8	
Overview articles	8	
Technical overview articles	4–6	None
Miscellaneous	2 (strictly enforced)	

③As a general rule, academic terms should conform to Cabinet Notification No. 2 and JIS.
④The unit of quantity is the International System of Units (SI).
⑤Indicate the insertion position of the figure/table in red in the text created as a separate file from the figure/table.
⑥The figures and tables created as separate files from the main text are of higher resolution and can be subjected to secondary processing in production.
⑦For academic treatises, write the title and characters in the table in English.
⑧When reprinting figures/tables, specify the source and obtain permission.
⑨Attach the explanation of the figures and tables in Japanese in a separate file.

3) References

References should be listed in the order in which they appear, with the numbers in parentheses at the end of the referenced text.
The notation format is as follows.
①For magazines
Author names: Title (article title) Magazine name (abbreviation), volume, first-last page, year of publication.
②For a book
Author names: Book title, First-last page, publisher, year of publication.
③If there are two or more authors, enter only the first author and enter “other” and “et al.”

4) Trademark name

If a trademark name is required, write the trademark name in both parentheses after the common name and add ®.

2. Submission of copyright transfer agreement

(1) The first author and co-authors must agree with the contents of the copyright transfer agreement stipulated in the copyright management regulations.
(2) The copyright transfer agreement shall be stipulated by the rules regarding copyright management, and the format specified on the Society’s website should be used.
(3) The copyright transfer agreement must be signed by the first author and co-authors, and provided when the manuscript is submitted.

3. About secondary publication

(1) Obtain approval from the editorial departments of both the first and second journals.
(2) The period until the secondary publication should be decided through discussions between the editorial departments of both parties and the author.
(3) Secondary publications of treatises are intended for different types of readerships.
(4) The secondary publication of a treatise should faithfully reflect the content of the first treatise.
(5) Specify the source of the original treatise.
(6) Specify in the title that it is a secondary publication.

4. About technical commentary requested by the editorial board.

The composition of the text is as follows (1) to (9).
(1) Abstract (100-150 words in Japanese and English)
(2) Keywords (3 words)
(3) Introduction:
(4) Purpose of explanation (overview)
(5) Main paper
(6) Comparison and consideration with previous research (development technology)
(7) Clinical usefulness
(8) Conclusion
(9) References

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