Table 1. Numbers of new patients and total patients (new plus repeat) requiring RT in designated cancer care hospitals and other hospitals.

Tabelle 1. Anzahl neuer Patienten und aller Patienten (neu plus wiedereingeliefert), die der Strahlentherapie bedürfen, in auf Krebsbehandlung spezialisierten Krankenhäusern und anderen Strahlentherapie-Einrichtungen.

	Designated cancer care hospitals	Others	Total
Facilities	349	372	721
New patients	112,101[a]	58,128	170,229[b]
Average no. new patients/facility	321.2	156.3	236.1
Total patients (new + repeat)	135,383[a]	69,704	205,087[b]
Average no. total patients/facility	387.9	187.4	284.4

[a]Since the number of designated cancer care hospitals with RT was 364, the number of new patients in designated cancer care hospitals was estimated at approximately 117,000 (112,101 × 364/349), and the corresponding number of total patients (new plus repeat) at approximately 141,000 (135,383 × 364/349).
[b]Since the number of radiotherapy facilities was 765 in 2007, the number of new patients was estimated at approximately 181,000 (170,229 × 765/721), and the corresponding number of total patients (new plus repeat) at approximately 218,000 (205,087 × 765/721).

patients/facility, the corresponding figures were 387.9 and 187.4, respectively.

Facility and Equipment Patterns and Patient Load/Linac

The radiotherapy equipment patterns and related functions in Japan are shown in Table 2. In DCCHs, 453 linacs and 103 ^{192}Ir RALSs were in current use, while the corresponding data for the other radiotherapy facilities were 354 and 20, respectively. The rate of ownership of equipment at DCCHs was significantly higher than at the other radiotherapy facilities. As for the linac system in DCCHs, the dual-energy function was used in 339 units (74.8%), the three-dimensional conformal radiotherapy (3D-CRT) function in 341 (75.3%), and the IMRT function in 165 (36.4%). For the other radiotherapy facilities, the corresponding figures were 200 (56.5%), 214 (60.5%), and 70 (19.8%). The respective patient load/linac was 296.5 at DCCHs and 175.0 at the other radiotherapy facilities. The distribution of annual patient load/linac in Japan is shown in Figure 1a. The patient load at 20% of DCCHs and 6% of the other radiotherapy hospitals exceeded the JBBG warning level of 400 patients/linac. However, the average patient load/linac at the other facilities was below the guideline level. Compared with the data for 2005 [3], the rate of linac ownership and rate of installation of the various functions (dual-energy, 3DCRT, and IMRT function) in linac increased by 1.7%, 1.7%, 7.8%, and 6.4%, respectively at DCCHs. At the other radiotherapy facilities, these rates increased as well and the corresponding percentages were 1.7%, 0.2%, 7.8%, and 5.9%.

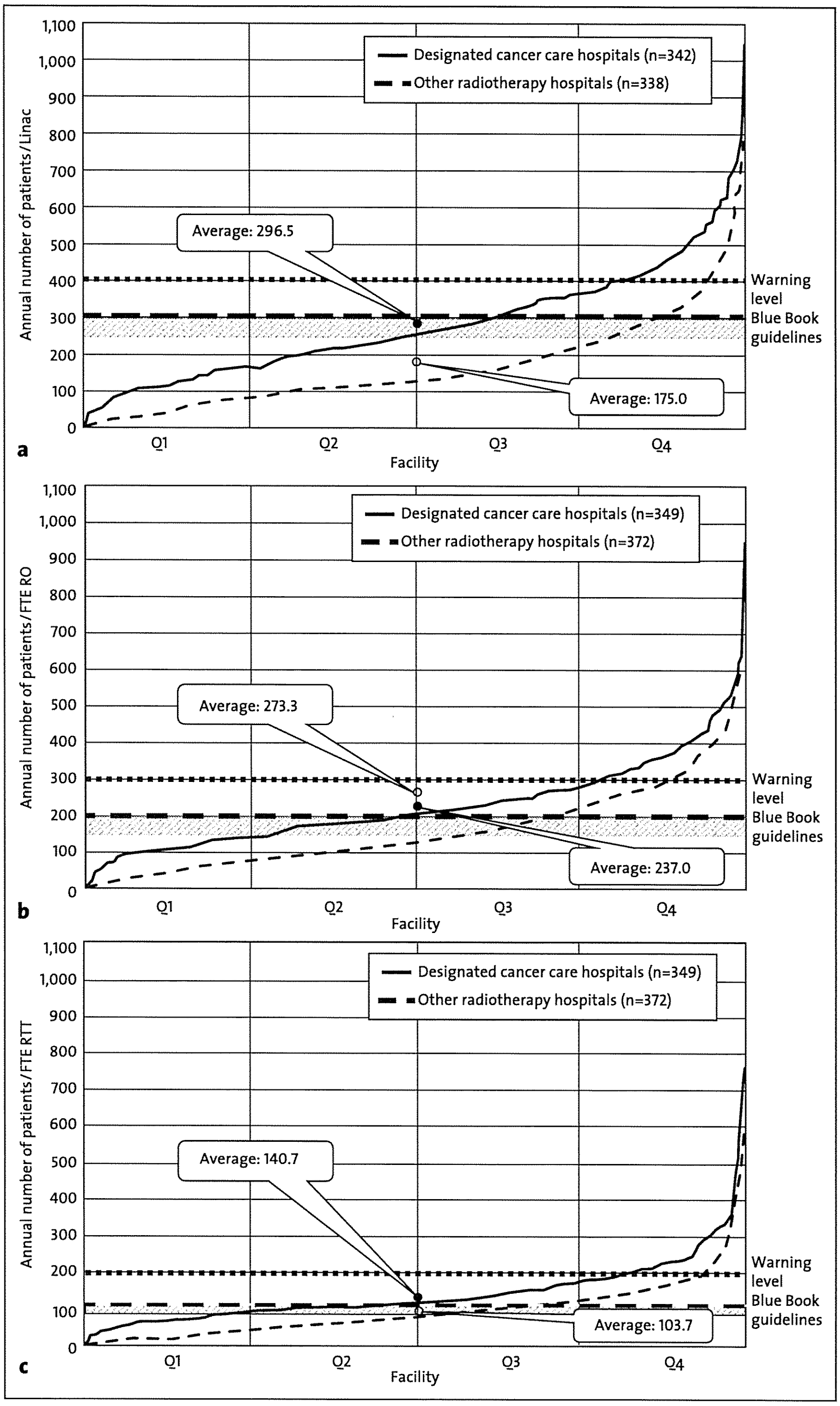
The patterns for radiotherapy planning systems (RTPs) and other equipment are shown in Table 2. X-ray simulators were installed in 69.3% of the DCCHs and in 53.0% of the other radiotherapy facilities, CT simulators in 75.7% and 56.7%, and RTPs in 96.8% and 93.8%, respectively. A noteworthy difference between the two types of facilities was found in the rates of X-ray simulator and CT simulator installation. Compared with the data for 2005 [3], X-ray simulator ownership decreased by 9.8%, while CT simulator and RTP ownership increased by 11.8% and 0.5%, respectively, at DCCHs, while

Table 2. Items of equipment, their function and patient load per unit of equipment in designated cancer care hospitals and other hospitals. Linac: Linear accelerator; IMRT: intensity-modulated radiotherapy; RALS: remote-controlled afterloading system; CT: computed tomography; 3D-CRT: three-dimensional conformal radiotherapy; RTP: radiotherapy planning.

Tabelle 2. Bestrahlungsgeräte, deren Funktion und Patientenaufkommen pro Gerät in auf Krebsbehandlung spezialisierten Krankenhäusern und anderen Strahlentherapie-Einrichtungen. Linac: Linear accelerator; IMRT: intensity-modulated radiotherapy; RALS: remote-controlled afterloading system; CT: computed tomography; 3D-CRT: three-dimensional conformal radiotherapy; RTP: radiotherapy planning.

	Designated cancer care hospitals (n = 349)		Comparison with 2005	Others (n = 372)		Comparison with 2005	Total (n = 721)	
	n	%	%	n	%	%	n	%
Linac	453	98.0[a]	1.7[c]	354	90.9[a]	1.0[c]	807	94.3[a]
with dual energy function	339	74.8[b]	1.7[c]	200	56.5[b]	0.2[c]	539	66.8[b]
with 3D-CRT function (MLC width ≤1.0 cm)	341	75.3[b]	7.8[c]	214	60.5[b]	7.8[c]	555	68.8[b]
with IMRT function	165	36.4[b]	6.4[c]	70	19.8[b]	5.9[c]	235	29.1[b]
Average no. linac/facility	1.3	–	–	1.0	–	–	1.1	–
Annual no. patients/linac	296.5[d]	–	–	175.0[d]	–	–	243.2[d]	–
^{192}Ir RALS (current use)	103	29.5[a]	–	20	5.4[a]	–	127.0	17.1[a]
X-ray simulator	246	69.3[a]	–9.8[c]	199	53.0[a]	–8.7[c]	445	60.9[a]
CT simulator	277	75.1[a]	11.8[c]	220	56.7[a]	8.3[c]	497	65.6[a]
RTP computer	630	96.8[a]	0.5[c]	440	93.8[a]	3.4[c]	1,070	95.3[a]

[a]Percentage of facilities which have this equipment.
[b]Percentage calculated from the number of systems using this function and the total number of linac systems.
[c]Comparison with the data of 2005, calculated with the formula: *data of 2007* (%) – *data of 2005* (%)
[d]Percentage calculated from the number of patients and the number of linac units. The facilities without linac were excluded from the calculation.



Figures 1a to 1c. **a** Distribution of annual patient load/linear accelerator at designated cancer care hospitals and other radiotherapy facilities. Horizontal axis represents facilities arranged in order of increase in annual number of patients/treatment equipment within facilities. **b** Distribution of annual patient load/FTE RO at designated cancer care hospitals and other radiotherapy facilities. Horizontal axis represents facilities arranged in order of increase in annual number of patients/FTE RO within facilities. The number of FTE RO for facilities with FTE <1 was calculated as FTE =1 to avoid overestimating patient load/FTE RO. **c** Distribution of annual patient load/RTT at designated cancer care hospitals and other radiotherapy hospitals. Horizontal axis represents facilities arranged in order of increase in annual number of patients/RTT within facilities. The number of FTE RTT for facilities with FTE <1 was calculated as FTE =1 to avoid overestimating patient load/FTE RTT. Q1: 0–25%; Q2: 26–50%; Q3: 51–75%; Q4: 76–100%.

Abbildungen 1a bis 1c. a) Verteilung des jährlichen Patientenaufkommens pro Linearbeschleuniger in auf Krebsbehandlung spezialisierten Krankenhäusern und anderen Strahlentherapie-Einrichtungen. Die horizontale Achse stellt die Einrichtungen dar, die nach der jährlichen Anzahl der Patienten pro Behandlungsgerät innerhalb der Einrichtungen in aufsteigender Reihenfolge angeordnet wurden. **b)** Verteilung des jährlichen Patientenaufkommens pro Vollzeitäquivalent-Radioonkologe in auf Krebsbehandlung spezialisierten Krankenhäusern und anderen Strahlentherapie-Einrichtungen. Die horizontale Achse stellt die Einrichtungen dar, die in aufsteigender Reihenfolge nach der jährlichen Anzahl der Patienten pro Vollzeitäquivalent-Radioonkologe innerhalb der Einrichtungen angeordnet wurden. Bei Einrichtungen mit Vollzeitäquivalent <1 wurde die Anzahl der Vollzeitäquivalent-Radioonkologen mit Vollzeitäquivalent =1 berechnet, um eine Überschätzung des Patientenaufkommens pro Vollzeitäquivalent-Radioonkologe zu vermeiden. **c)** Verteilung des jährlichen Patientenaufkommens pro Strahlentherapie-MTA in auf Krebsbehandlung spezialisierten Krankenhäusern und anderen Strahlentherapie-Krankenhäusern. Die horizontale Achse stellt die Einrichtungen dar, die in aufsteigender Reihenfolge nach der jährlichen Anzahl der Patienten pro Strahlentherapie-MTA innerhalb der Einrichtungen angeordnet wurden. Bei Einrichtungen mit Vollzeitäquivalent <1 wurde die Anzahl der Vollzeitäquivalent- Strahlentherapie-MTAs mit Vollzeitäquivalent =1 berechnet, um eine Überschätzung des Patientenaufkommens pro Vollzeitäquivalent- Strahlentherapie-MTA zu vermeiden. Q1: 0–25%; Q2: 26–50%; Q3: 51–75%; Q4: 76–100%.

at the other radiotherapy facilities X-ray simulator ownership decreased by 8.7% and CT simulator and RTP ownership increased by 8.3% and 3.4%, respectively.

Staffing Patterns and Patient Loads

Staffing patterns and patient loads in Japan are detailed in Table 3. The total numbers of FTE ROs were 571.3 for DCCHs

Table 3. Structure and personnel of designated cancer care hospitals and other hospitals. RT: radiotherapy; RO: radiation oncologist; FTE: full-time equivalent (40 hours/week only for RT practice); JASTRO: Japanese Society of Therapeutic Radiology and Oncology.

Tabelle 3. Struktur und Personal von auf Krebsbehandlung spezialisierten Krankenhäusern und anderen Strahlentherapie-Einrichtungen. RT: radiotherapy; RO: radiation oncologist; FTE: full-time equivalent (40 hours/week only for RT practice); JASTRO: Japanese Society of Therapeutic Radiology and Oncology.

	Designated cancer care hospitals (n = 349)	Comparison with 2005 (%)	Others (n = 372)	Comparison with 2005 (%)	Total (n = 721)
Facilities with RT bed	171	–	110	–	281 (39.0)
Average no. RT bed/facility	4.3	–	2.0	–	3.1
Total (full + part-time) RO FTE	571.3	21.2[a]	255.0	–15.9[a]	826.3
Average no. FTE ROs/facility	1.6	14.3[a]	0.7	–22.2[a]	1.1
JASTRO-certified RO (full-time)	378	29.0[a]	99	–25.6[a]	477
Average no. JASTRO-certified ROs/facility	1.1	22.2[a]	0.3	–25.0[a]	0.7
Patient load/FTE RO	237.0	–5.8[a]	273.3	14.1[*]	248.2
Total (full + part-time) RT technologist FTE	962.2	–	671.9	–	1634.1
Average no. FTE RT technologists/facility	2.8	–	1.8	–	2.3
Patient load/FTE RT technologist	140.7	–	103.7	–	125.5
Total (full + part-time) medical physicist FTE	42.0	–	26.4	–	68.4
Total (full + part-time) RT nurse FTE	304.3	–	190.1	–	494.4

[a]Rate of increase compared with the data of 2005, calculated with the formula: $\frac{\text{data of 2007 (n)} - \text{data of 2005 (n)}}{\text{data of 2005 (n)}}$ 100 (%)

and 255.0 for the other radiotherapy facilities, while the corresponding average numbers of FTE ROs/facility were 1.6 and 0.7 and the numbers for the patient load/FTE RO 237.0 and 273.3. The distribution of annual patient load/FTE RO in Japan is illustrated in Figure 1b. More than 300 patients/RO (JBBG warning level) were treated in 22% of DCCHs and in 11% of the other facilities. In Figure 2a, the percentage of distribution of facilities by patient load/FTE RO is shown. The largest number of facilities featured a patient/FTE RO level in the 150–199 range for DCCHs and in the 100–149 range for the other radiotherapy facilities. The facilities which have less than 1 FTE RO still account for about 37.2% of DCCHs and 73.9% of the other radiotherapy facilities. In DCCHs, the average numbers of FTE ROs/facility and full-time JASTRO-certified ROs/facility increased by 14.3% and 22.2%, respectively, compared with 2005 data. In other radiotherapy facilities, however, those numbers decreased by 22.2% and 25.0%. The annual patient load/FTE RO decreased by 5.8% in DCCHs and increased by 14.1% in other radiotherapy facilities.

The total numbers of FTE RTTs were 962.2 for DCCHs and 671.9 for the other radiotherapy facilities, and the average numbers per facility were 2.8 and 1.8, respectively. The patient loads/FTE RTT were 140.7 and 103.7, respectively. The distribution of annual patient load/FTE RTT in Japan is shown in Figure 1c. More than 200 patients/RTT (JBBG warning level) were treated in 18% of DCCHs and in 8% of the other radiotherapy facilities, while Figure 2b shows the percentage of distribution of facilities by patient load/FTE RTT. The largest number of facilities featured a patient/FTE RTT level in the 100–119 range for DCCHs and in the 60–89 range for the other radiotherapy facilities. The total numbers of FTE MPs and FTE radiotherapy nurses were 42.0 and 304.3 for DCCHs and 26.4 and 190.1 for the other radiotherapy facilities.

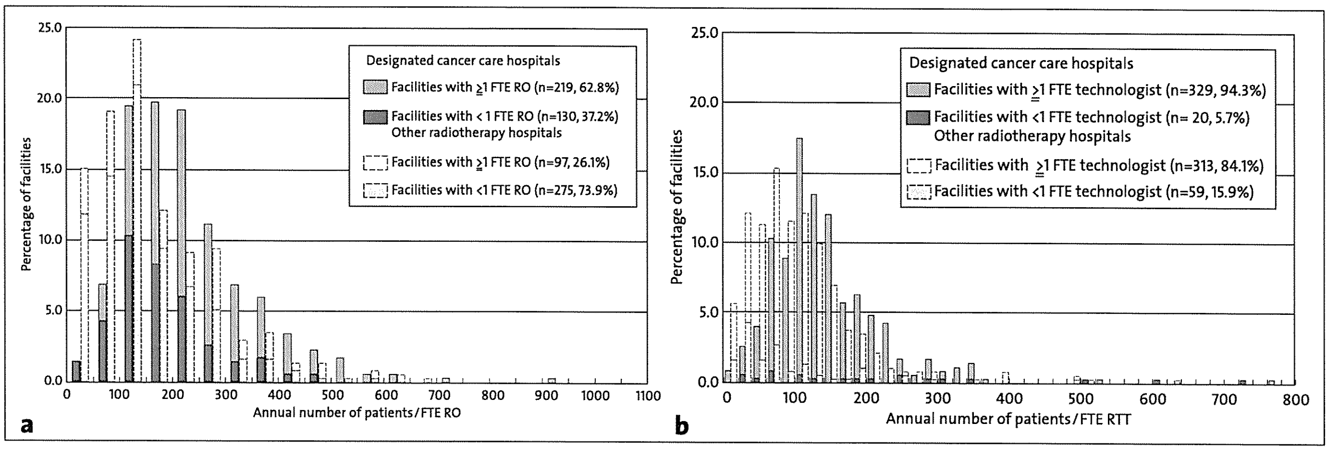
Geographic Patterns

Figure 3 shows the geographic distribution for 47 prefectures of a number of radiotherapy facilities arranged in order of increasing population for all prefectures in Japan [14]. There were significant differences in the average number of facilities per quarter for both all radiotherapy facilities and DCCHs (both: $p<0.0001$). The numbers of all radiotherapy facilities and DCCHs were strongly associated with population size (respective correlation coefficients: 0.95 and 0.82).

Discussion

The utilization rate of radiotherapy for new cancer patients in Japan is less than a half of that for developed countries in Europe, such as France, Germany, Italy, and UK, as well as for the United States. Radiotherapy is expected to play an increasingly important role in Japan because the increase in the elderly population is the highest among developed countries. In Japan, the majority of facilities still rely on part-time ROs, especially in facilities other than DCCHs. The percentage distribution of facilities by patient load/RO in DCCHs proved to be largely similar to that of the United States in 1989 [16]. However, the facilities which have less than one FTE RO still account for about 37% of DCCHs in Japan. In European countries and the United States, on the other hand, most facilities have a full-time RO.

On a regional basis, the results of this study proved that DCCHs were in appropriate locations. In the 2005 survey [9], there were not enough DCCHs in some regions with a large population because many university facilities were not



Figures 2a and 2b. **a** Percentage of facilities by patient load/FTE RO for designated cancer care hospitals and other radiotherapy hospitals. Each bar represents an interval of 50 patients per FTE RO. The number of FTE ROs for facilities with FTE <1 was calculated as FTE =1 to avoid overestimating patient load/FTE RO. **b** Percentage of facilities by patient load/FTE RTT for designated cancer care hospitals and other radiotherapy hospitals. Each bar represents an interval of 20 patients per FTE staff. The number of FTE RTTs for facilities with FTE <1 was calculated as FTE =1 to avoid overestimating patient load/FTE RTT.

Abbildungen 2a und 2b. **a** Prozentsatz der Einrichtungen nach Patientenaufkommen pro Vollzeitäquivalent-Radioonkologe bei auf Krebsbehandlung spezialisierten Krankenhäusern und anderen Strahlentherapie-Krankenhäusern. Jeder Balken stellt ein Intervall von 50 Patienten pro Vollzeitäquivalent-Radioonkologe dar. Bei Einrichtungen mit Vollzeitäquivalent <1 wurde die Anzahl der Vollzeitäquivalent-Radioonkologen mit Vollzeitäquivalent =1 berechnet, um eine Überschätzung des Patientenaufkommens pro Vollzeitäquivalent-Radioonkologe zu vermeiden. **b** Prozentsatz der Einrichtungen nach Patientenaufkommen pro Vollzeitäquivalent-Strahlentherapie-MTA bei auf Krebsbehandlung spezialisierten Krankenhäusern und anderen Strahlentherapie-Krankenhäusern. Jeder Balken stellt ein Intervall von 20 Patienten pro Vollzeitäquivalent-Mitarbeiter dar. Bei Einrichtungen mit Vollzeitäquivalent <1 wurde die Anzahl der Vollzeitäquivalent-Strahlentherapie-MTAs mit Vollzeitäquivalent =1 berechnet, um eine Überschätzung des Patientenaufkommens pro Vollzeitäquivalent-Strahlentherapie-MTA zu vermeiden.

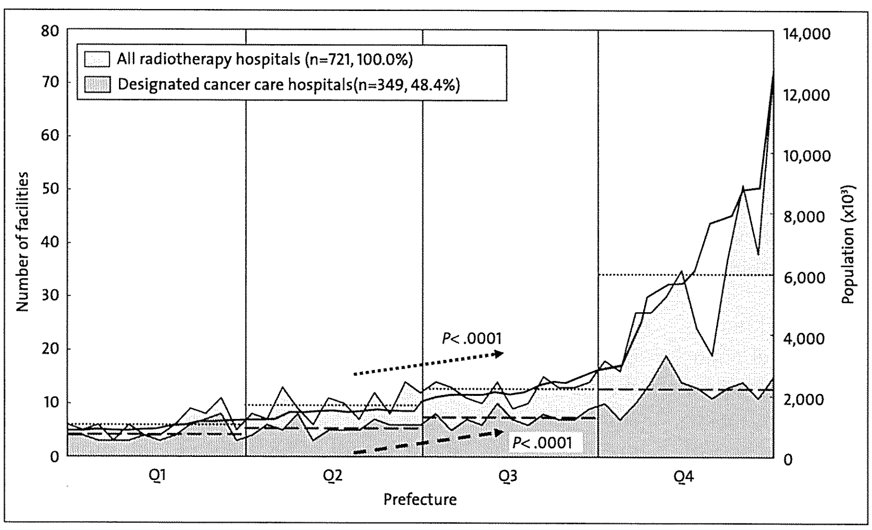


Figure 3. Geographic distribution for 47 prefectures of the number of facilities arranged in order of increase in population. The dotted line shows the average number of facilities of the prefectures per quarter for all radiotherapy hospitals and the dashed line shows the average number for designated cancer care hospitals. Q1: 0–25%; Q2: 26–50%; Q3: 51–75%; Q4: 76–100%.

Abbildung 3. Geografische Verteilung der Anzahl der Einrichtungen in 47 Präfekturen, geordnet in aufsteigender Reihenfolge nach der Bevölkerungszahl. Die gepunktete Linie zeigt die durchschnittliche Anzahl der Einrichtungen der Präfekturen pro Viertel für alle Strahlentherapie-Krankenhäuser, und die gestrichelte Line zeigt die durchschnittliche Anzahl für auf Krebsbehandlung spezialisierte Krankenhäuser. Q1: 0–25%; Q2: 26–50%; Q3: 51–75%; Q4: 76–100%.

certified as DCCHs by the Ministry of Health, Labor, and Welfare. The findings of the current survey show that some university facilities with many patients undergoing radiotherapy were certified as DCCHs. There are, thus, enough radiotherapy facilities in Japan with a nationwide distribution. The medical situation in Japan is susceptible to the effect of measures taken by local governments. Current radiotherapy potential in radiotherapy facilities other than DCCHs in Japan is underutilized because of personnel shortages.

In Japan, a new educational system is being developed to train specialists for cancer care, including ROs, MPs, medical oncologists, oncology nurses, and palliative care doctors. Although the numbers of ROs in DCCHs have increased, the numbers in the other radiotherapy hospitals have decreased. In Japan, many radiotherapy hospitals do not even have their own department of radiotherapy, while we are of the opinion that all radiotherapy hospitals, whether designated or not, need to have

Table 4. Structural features and personnel related to radiation oncology in developed countries and cost adapted from the Directory of Radiotherapy Centers of the International Atomic Energy Agency [4]. RO: radiation oncologist; GDP: Gross Domestic Product.

Tabelle 4. Strukturmerkmale und Personal im Bereich Radioonkologie in entwickelten Ländern und Kosten nach dem Strahlentherapiezentren-Verzeichnis der Internationalen Atomenergie-Organisation [4]. RO: radiation oncologist; GDP: Gross Domestic Product.

Country	RT facilities	ROs	Medical physicists	Population (million)[a]	Facilities/ Population	RO/ Population	Medical physicists/ Population	Medical costs of GDP (%)[b]
Germany	219	835	626	82.7	2.6	10.1	7.6	10.4
Italy	151	839	392	58.2	2.6	14.4	6.7	8.7
France	186	574	267	60.9	3.1	9.4	4.4	11.0
USA	2,514	2,943	1,879	303.9	8.3	9.7	6.2	16.0
Japan[c]	721	826.3[d]	68.4[d]	128.3	5.6	6.4	0.5	8.1

[a]Based on Demographic Yearbook of United Nations [20].
[b]Based on Demographic OECD Health Data 2009 [10].
[c]Based on JASTRO structure survey 2007.
[d]These data are expressed as full-time equivalent. Most ROs or other oncologists at academic facilities work part-time at affiliated hospitals. Therefore, the total numbers of ROs does not reflect the actual structure of radiation oncology personnel in Japan.

their own department of radiotherapy. It was found that MPs work mainly in metropolitan areas or academic facilities, such as university hospitals or cancer centers. At present, there is no national license for MPs in Japan, but those with a master's degree in radiation technology or science and engineering can take the accreditation test for MPs administered by the Japanese Board of Medical Physics (JBMP). The number of RTTs is more satisfactory that that of ROs and MPs, but RTTs are extremely busy because they are also partially act as MPs in Japan. The average number of radiotherapy staff members in DCCHs was greater than that in the other radiotherapy hospitals. Equipment ownership in the other radiotherapy facilities increased compared with 2005, being more firmly established in DCCHs than in the other radiotherapy hospitals. Therefore, the accreditation of DCCHs is closely correlated with the maturity of the radiation oncology structure. Further accreditation of DCCHs by the Ministry of Health, Labor, and Welfare would be a move in the right direction for the geographical consolidation of radiotherapy facilities in Japan.

The Directory of Radiotherapy Centers of the International Atomic Energy Agency has disclosed the member countries' data for the structure of radiation oncology [4]. Table 4 shows the data for the structure of radiation oncology in Japan, Germany, Italy, France, and the United States. The numbers of ROs and MPs per million population in Japan (6.4 and 0.5) are smaller than in France (9.4 and 4.4), Germany (10.1 and 7.6), and Italy (14.4 and 6.7). However, the number of radiotherapy facilities per million population in Japan (5.6) is larger than in France (3.1), Germany (2.6), and Italy (2.6). As for the United States, the numbers of ROs, MPs, and radiotherapy facilities per million population (9.7, 6.2, and 8.3) are all larger than in Japan. These findings do not necessarily mean that the medical care system in Japan is inferior. Even though the medical costs in relation to GDP [10] in Japan are the lowest among the aforementioned five countries, the outcome of cancer treatment in Japan is the same or better than in the other developed countries.

To evaluate medical care systems for cancer at regular intervals, it is very important to collect detailed information for all cancer care facilities. In Japan, JASTRO regularly surveys the structural information for all radiotherapy facilities and PCS has been conducted every 4 years to investigate the processes and outcomes of cancer care using radiotherapy. However, the collection of outcome information is insufficient. In the United States, a National Cancer Data Base was established and has been collecting the data for approximately 75% of cancer patients. This database is used as the quality indicator for improvements in the processes and outcomes of cancer care. We have recently established a Japanese National Cancer Database based on the radiotherapy data, and we are preparing to collect cancer care data with this system.

Conclusion

The structure of radiation oncology in DCCHs in Japan showed more maturity than that of other facilities in terms of equipment, functions, and staff. However, there is still a shortage of manpower. The survey data presented and discussed here are important and fundamental for clearly understanding the medical care system of radiation oncology in Japan. As the survey data make clear, a national policy is needed to solve the problem of the establishment of DCCHs and the shortage of manpower for cancer care.

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Original Article

Patterns of Practice in Intensity-modulated Radiation Therapy and Image-guided Radiation Therapy for Prostate Cancer in Japan

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Background: The purpose of this study was to compare the prevalence of treatment techniques including intensity-modulated radiation therapy and image-guided radiation therapy in external-beam radiation therapy for prostate cancer in Japan.
Methods: A national survey on the current status of external-beam radiation therapy for prostate cancer was performed in 2010. We sent questionnaires to 139 major radiotherapy facilities in Japan, of which 115 (82.7%) were returned.
Results: Intensity-modulated radiation therapy was conducted at 67 facilities (58.3%), while image-guided radiation therapy was conducted at 70 facilities (60.9%). Simulations and treatments were performed in the supine position at most facilities. In two-thirds of the facilities, a filling bladder was requested. Approximately 80% of the facilities inserted a tube or encouraged defecation when the rectum was dilated. Some kind of fixation method was used at 102 facilities (88.7%). Magnetic resonance imaging was routinely performed for treatment planning at 32 facilities (27.8%). The median total dose was 76 Gy with intensity-modulated radiation therapy and 70 Gy with three-dimensional radiation therapy. The doses were prescribed at the isocenter at the facilities that conducted three-dimensional radiation therapy. In contrast, the dose prescription varied at the facilities that conducted intensity-modulated radiation therapy. Of the 70 facilities that could perform image-guided radiation therapy, 33 (47.1%) conducted bone matching, 28 (40.0%) conducted prostate matching and 9 (12.9%) used metal markers. Prostate or metal marker matching tended to produce a smaller margin than bone matching.
Conclusions: The results of the survey identified current patterns in the treatment planning and delivery processes of external-beam radiation therapy for prostate cancer in Japan.

Key words: radiation therapy – urologic-radoncol – radiation oncology

INTRODUCTION

External beam radiation therapy (EBRT) has developed rapidly in recent years (1,2) and treatment equipment with which intensity-modulated radiation therapy (IMRT) and/or image-guided radiation therapy (IGRT) can be conducted are being introduced into Japan (3). IMRT and IGRT are particularly useful in EBRT for prostate cancer and are routinely used in the USA (4) and recommended in worldwide guidelines (5,6).

In Japan, IMRT and IGRT were listed as eligible for insurance reimbursement in 2008 and 2010, respectively. However, the present situation regarding the use of these techniques in EBRT for prostate cancer remains unclear (7,8). Therefore, we conducted a survey that would clarify the operational situation, treatment planning and treatment processes of IMRT and/or IGRT when used in EBRT for prostate cancer.

PATIENTS AND METHODS

In February 2010, we sent a questionnaire on EBRT for prostate cancer to 139 major facilities including university hospitals, cancer centers and designated prefectural cancer centers and hospitals. The questionnaire was also sent to the hospitals which had treatment machines with IGRT functions, including Novalis (BrainLAB, Heimstetten, Germany), Tomotherapy (Accuray Inc., Sunnyvale, USA) and MHI-TM2000 (Mitsubishi Heavy Industries, Ltd., Nagoya, Japan).

The survey was composed of categories regarding treatment planning, dose fractionation and methods of implementation of EBRT for prostate cancer. If methods differed according to the type of radiation techniques used such as three-dimensional radiation therapy (3DCRT) or IMRT, we required responses regarding the most precise radiation method presently used. Among the 139 facilities to which we sent the survey, 115 (82.7%) gave responses, which were then analyzed. The high response rate allowed an extensive and representative data analysis.

RESULTS

General Information

Figure 1 shows the distribution of the number of patients with prostate cancer treated with EBRT at facilities in 2009 over the course of 1 year. There were 30 facilities (26.1%) at which over 50 patients were treated in 1 year. Of the 115 total facilities, 67 (58.3%) conducted IMRT, 70 (60.9%) conducted IGRT and 58 (50.4%) conducted both.

Treatment Planning

Figure 2 shows the condition of the bladder at the treatment planning stage and during the treatment. In approximately two-thirds of the facilities, a filling bladder was requested. The time spent pooling urine was 1 h at 56 facilities (48.7%), 1–2 h at 8 facilities (7.0%) and 30 min at 7 facilities (6.1%). Seven facilities (6.1%) also asked patients to drink water prior to treatment.

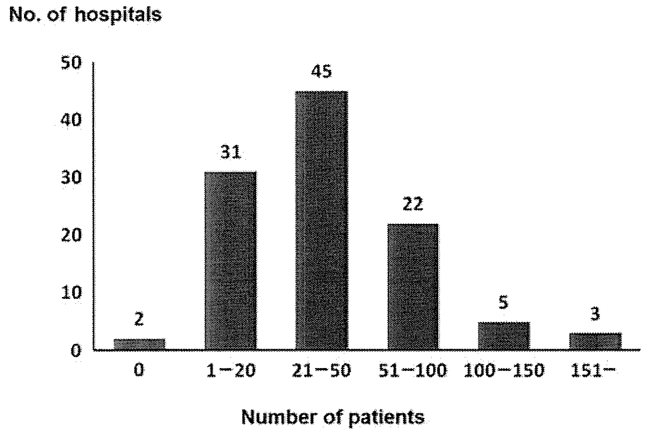

Figure 1. Total number of patients with prostate cancer treated with external-beam radiation therapy at facilities in 2009. Because some data were missing, the total numbers of patients were less than the actual number.

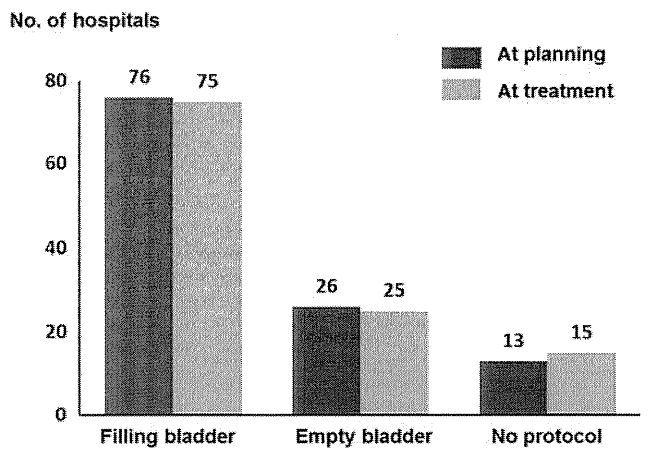

Figure 2. Condition of the bladder at the treatment planning stage and during treatment.

Figure 3 shows the condition of the rectum. Approximately 80% of the facilities inserted a tube or encouraged defecation when the rectum was dilated. Laxative medication was used at one-quarter of the facilities.

Simulations and treatments were performed in the supine position at 105 facilities (91.3%) and the prone position at 10 facilities (8.7%). Figure 4 shows methods of patient fixation. Some kind of fixation method was used at 102 facilities (88.7%). Although various methods were reported, a vacuum cushion, thermoplastic shell and foot support were used most frequently.

Magnetic resonance imaging (MRI) was routinely performed for treatment planning at 32 facilities (27.8%). Of these, 15 facilities (13.0%) performed computed tomography

(CT)-MRI image fusion with treatment planning software. MRI taken at the time of diagnosis was used as a reference at 66 facilities (57.4%), while 17 facilities (14.8%) did not use MRI for treatment planning.

Treatment

Radiation therapy was carried out with 2 Gy per fraction at 100 facilities (86.9%), 2.1–3 Gy at 14 facilities (12.2%) and 1.8 Gy at 1 facility (0.9%). Most facilities conducted treatment five times a week. Treatment was conducted three times a week at five facilities (4.3%) and four times a week at three facilities (2.6%).

Figure 5 shows the distributions of radiation doses delivered to the prostate at facilities using a fraction dose of 2 Gy. The median total dose was 76 Gy with IMRT and 70 Gy with 3DCRT. The doses were prescribed at the isocenter at the facilities that conducted 3DCRT. In contrast, the dose prescription varied greatly at the facilities that conducted IMRT. Of the 67 facilities that conducted IMRT, D95, which is the minimum absorbed dose that covers 95% of the planning target volume (PTV), was used as a dose prescription at 24 facilities (35.8%). A dose prescription requiring that 95% of the prescribed isodose line cover 95% of the PTV was used at 4 facilities (6.0%), the mean PTV dose was used at 13 facilities (19.4%) and other methods at 26 facilities (38.8%).

The most popular IGRT methods (54 facilities) involved 2D matching with X-ray fluoroscopy or 3D matching with a flat-panel cone-beam CT. Eight facilities used CT on rail and 4 facilities used ultrasonic devices. Of the 70 facilities that could perform IGRT, 33 (47.1%) conducted bone matching, 28 (40.0%) conducted prostate matching and 9 (12.9%) used metal markers. At the treatment of prostate cancer, 60 facilities (85.7%) always conducted IGRT, while 9 (12.9%) conducted IGRT at regular intervals.

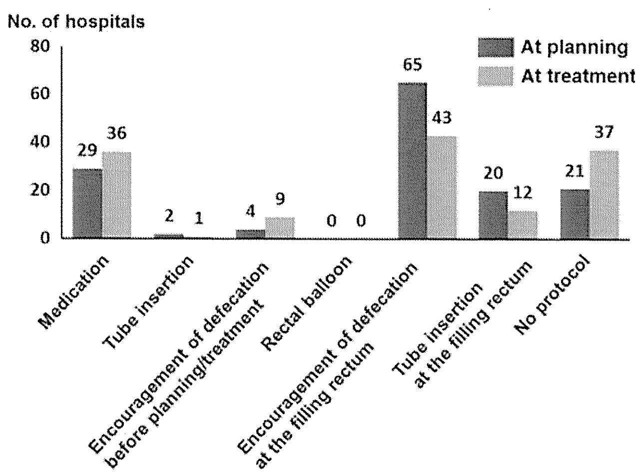

Figure 3. Condition of the rectum at the treatment planning stage and during treatment. Multiple answers allowed.

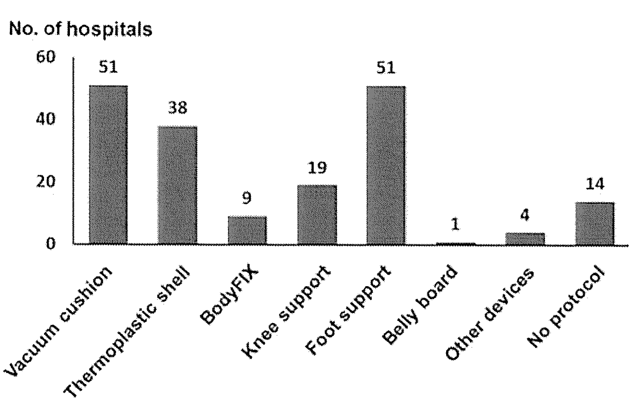

Figure 4. Fixation of the patients at the treatment planning stage and during treatment. Multiple answers allowed.

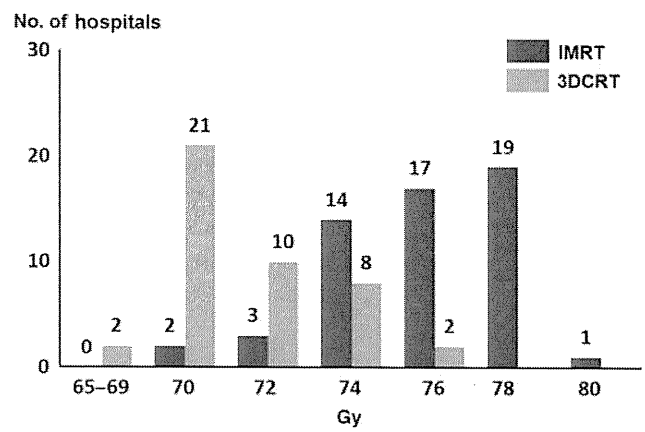

Figure 5. Total dose to the prostate.

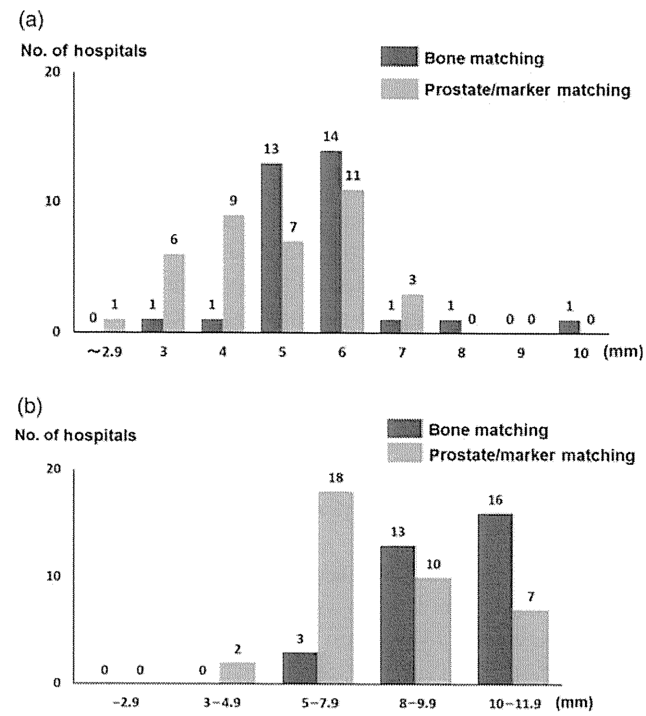

Figure 6. Margins from the prostate to planning target volume for patients with T1–2 tumors treated with IGRT: (a) rectal side and (b) other sides.

Figure 6 show the distribution of the prostate-PTV margins for patients with typical T1–2 tumors treated with IGRT. Prostate or metal marker matching tended to produce slightly smaller margins than bone matching.

DISCUSSION

This study provides a clear picture of present practices of IMRT and/or IGRT for prostate cancer in Japan.

Simulations and treatments were performed in the supine position at most facilities. However, facilities employed various fixation methods. In most facilities, some kind of fixation method was used, although immobilization devices for body malignancies are not covered by health insurance in Japan. In the patterns of care study on prostate cancer patients who were treated with EBRT from 2003 to 2005, immobilization devices were used on only 15% of patients (7). One reason for the high frequency of the usage of patient immobilization devices in this study could be the gradual popularization of fixation methods over time. An additional reason is probably the fact that some sort of fixation method tends to be used in more precise radiation treatment, because patient immobilization can be an important contributor to the reproducibility and accuracy of radiotherapy (9).

The pretreatment condition of the bladder and rectum also varied greatly among facilities. Although fixation of the prostate is frequently conducted with a rectal balloon in Western countries (10), this method has not been used at all in Japan.

In this study, we did not investigate PTV margins when IGRT was not used. Therefore, we were unable to clarify whether IGRT causes decreased margins. However, PTV margins tended to be slightly smaller with prostate or fiducial marker matching than that with bone matching. PTV margins should be determined at each facility taking into account position errors caused not only by the IGRT method, but also by the patient position, fixation method and pretreatment condition of the bladder and rectum. Enmark et al. (11) demonstrated that a margin of 4 mm in all directions was adequate to account for uncertainties including the inter- and intrafraction motions, if IGRT with fiducial markers is performed on a daily basis. Some facilities have chosen prostate-PTV margins of <4 mm. Because of uncertainties such as intrafraction motion or uncertainty of the target delineation, decreases in the PTV margin should be carefully performed even when IGRT is applied.

The radiation dose administered at most facilities was 2 Gy per fraction. The median value of the total radiation dose was 76 Gy with IMRT and 70 Gy with 3DCRT. It is well known that the radiation dose is a strong independent predictor of failure (12), and IMRT can reduce the unwanted doses to nearby organs at risk. Therefore, as IMRT becomes more widespread in Japan, more appropriate higher dosages of radiation should be utilized. However, a significant problem is the fact that the IMRT dose prescription varies. It is necessary to define and develop recommended guidelines for dose prescription and a dose reporting system for IMRT in Japan (13).

IMRT and IGRT were being conducted at approximately half of the facilities in this study. However, our survey targeted large-scale facilities. If all radiation therapy facilities in Japan were to be surveyed, this proportion would probably be smaller (3). At present, high-precision radiation therapy devices such as IMRT and IGRT are being rapidly introduced (3,14), and an increasing number of facilities will surely come to adopt IMRT and IGRT. The results of the survey in this study will provide beneficial information to those facilities as they begin treatment.

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Conflict of interest statement

None declared.

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DISEASES OF THE ESOPHAGUS

Original article

The endoscopic diagnosis of nonerosive reflux disease using flexible spectral imaging color enhancement image: a feasibility trial

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SUMMARY. **Nonerosive reflux disease (NERD) is classified into grade M (minimal change, endoscopically; erythema without sharp demarcation, whitish turbidity, and/or invisibility of vessels due to these findings) and grade N (normal) in the modified Los Angeles classification system in Japan. However, the classification of grades M and N NERD is not included in the original Los Angeles system because interobserver agreement for the conventional endoscopic diagnosis of grades M or N NERD is poor. Flexible spectral imaging color enhancement (FICE) is a virtual chromoendoscopy technique that enhances mucosal and vascular visibility. The aim of this study is to evaluate whether the endoscopic diagnosis of grades M or N NERD using FICE images is feasible. Between April 2006 and May 2008, 26 NERD patients and 31 controls were enrolled in the present study. First, an experienced endoscopist assessed the color pattern of minimal change in FICE images using conventional endoscopic images and FICE images side-by-side and comparing the proportion of minimal change between the two groups. Second, three blinded endoscopists assessed the presence or absence of minimal change in both groups using conventional endoscopic images and FICE images separately. Intraobserver variability was compared using McNemar's test, and interobserver agreement was described using the kappa value. Minimal changes, such as erythema and whitish turbidity, which were detected using conventional endoscopic images, showed up as navy blue and pink-white, respectively, in color using FICE images in the present FICE mode. The NERD group had a higher proportion of minimal change, compared with the control group (77% and 48%, respectively) ($P = 0.033$). In all three readers, the detection rates of minimal change using FICE images were greater than those using conventional endoscopic images ($P = 0.025$, <0.0001, and 0.034 for readers A, B, and C, respectively). The kappa values for all pairs of three readers using FICE images were between 0.683 and 0.812, while those using conventional endoscopic images were between 0.364 and 0.624. Thus, the endoscopic diagnosis of grades M or N NERD using FICE images is feasible and may improve interobserver agreement.**

KEY WORDS: **flexible spectral imaging color enhancement (FICE), interobserver agreement, intraobserver variability, minimal change, nonerosive reflux disease (NERD).**

INTRODUCTION

Nonerosive reflux disease (NERD) is a common disease whose incidence rate has been increasing in recent years in Japan. The prevalence of NERD is about 50–70% of the general gastroesophageal reflux disease (GERD) population,[1] and NERD patients are similar to reflux esophagitis patients with regard to the strength of symptoms and the disease's negative impact on quality of life.[2] The pathophysiology of NERD is complex with potentially multiple underlying mechanisms for NERD symptoms, and the disease has still not been wholly elucidated. Multifactorial elements may be involved in NERD symptoms in about 30% of NERD patients.[3,4] Such factors as hypersensitivity to acid reflux events within the normal range, non-acid-related intraesophageal stimuli, and gastric hypomotility are considered as causes of NERD symptoms.[5–8]

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In Japan, NERD is further classified into grade M (minimal change, endoscopically; erythema without sharp demarcation, whitish turbidity, and/or invisibility of vessels due to these findings) and grade N (normal) in the modified Los Angeles classification system.[9–11] However, the classification of grades M and N NERD is not included in the original Los Angeles system because interobserver agreement for the conventional endoscopic diagnosis of grades M or N NERD is poor.[12,13]

Flexible spectral imaging color enhancement (FICE) (Fujinon Co., Saitama, Japan) is an image-processing software for video endoscopy where three spectral images for each wavelength are selected from conventional endoscopic image and then allocated an RGB signal to enhance mucosal and vascular visibility. Recently, several studies demonstrated that FICE was useful in the endoscopic diagnosis of the gastrointestinal fields.[14–19] In examination of the esophagogastric junction, Osawa *et al.* reported that FICE images allowed recognition of the palisade vessels more clearly in Barrett's esophagus mucosa, and enhanced the color contrast between palisade vessels and Barrett's esophagus mucosa.[14] However, there are no reports of the endoscopic diagnosis of NERD using FICE image. The aim of this study is to evaluate whether the endoscopic diagnosis of grade M or N NERD using FICE images is feasible.

MATERIALS AND METHODS

Subjects

Of the patients who underwent esophagogastroduedenoscopy (EGD) between April 2006 and May 2008 in the Kyushu University Hospital at Beppu, the patients with typical reflux symptoms (heartburn and acid regurgitation) in subjects with the absence of mucosal breaks at EGD comprised the NERD group. The patients without any reflux symptoms served as the control group. Patients with no recorded endoscopic images of adequately stretched esophagogastric junction were excluded from this study. Patients with erosive esophagitis, open gastroduodenal ulcer, malignancy, angina, resected stomach or previous proton pump inhibitor (PPI) therapy in the last 4 weeks before EGD were also excluded. Finally, 26 patients as the NERD group and 31 patients as the control group were enrolled in this retrospective study. The mean age of all 57 patients was 62.3 years (range 32–85 years). This study was conducted with the approval of the Ethics Committee of Kyushu University.

Endoscopy equipment and procedures

A conventional endoscope (EG590WR, Fujinon Co., Saitama, Japan) was used. The system was equipped with the EPX 4400 processor (Fujinon Co.). An experienced endoscopist (the first author, MM) performed the conventional endoscopy in all subjects and digitally recorded conventional endoscopic images of the esophagogastric junction. The same experienced endoscopist produced the corresponding FICE images from the recorded conventional endoscopic images within a few days after the conventional endoscopy was performed. In the present study, the FICE process was performed at the following wavelengths: R, 500 nm; G, 470 nm; and B, 415 nm.

Image evaluation

First, the same experienced endoscopist assessed the color pattern of minimal change in FICE images using a total of 57 conventional endoscopic images of the esophagogastric junction in both groups and the corresponding 57 FICE images side-by-side and comparing the proportion of minimal change between the two groups.

Second, three blinded endoscopists, each with 5–15 years of endoscopic experience, assessed the presence or absence of minimal change using a total of 57 conventional endoscopic images of the esophagogastric junction in both groups and the corresponding 57 FICE images separately. First, the 57 conventional endoscopic images were displayed randomly with a 10-s interval on a personal computer screen. Subsequently, the corresponding 57 FICE images were displayed randomly with a 10-s interval on the same personal computer screen. All these images were selected and listed in random order by another experienced endoscopist. The three readers individually assessed those images with the same personal computer screen in the same room. The presence or absence of minimal change was assessed according to the definition of grades M and N NERD in the modified Los Angeles classification system. Each reader was provided with an introduction and training for the assessment of minimal change with sample images of grade N and M NERD (Figs 1 and 2). None of the three readers was given any clinical information, and the three readers were unaware of each other's assessments.

Statistical analysis

All statistical analyses were performed with JMP statistical discovery software (JMP, version 7.0.1; SAS, Cary, NC). The characteristics between the NERD group and control group were compared using Fisher's exact test for categorical variables and the *t*-test for continuous variables. The proportion of minimal change between the NERD group and control group was compared using Fisher's exact test. The intraobserver variabilities using conventional endoscopic images and FICE images were compared using

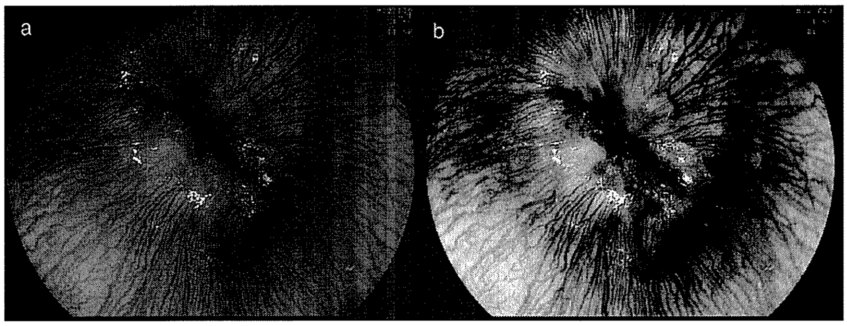

Fig. 1 A case without minimal change, with a conventional image (a) and the corresponding flexible spectral imaging color enhancement (FICE) image (b). The clear palisade vessels are visible more easily in the FICE image.

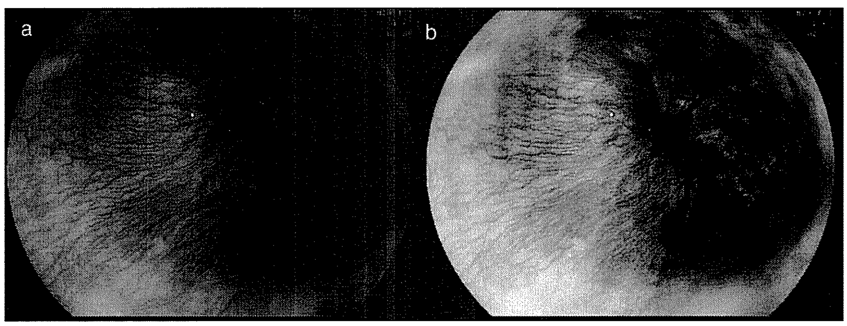

Fig. 2 A case with minimal change, with a conventional image (a) and the corresponding flexible spectral imaging color enhancement (FICE) image (b). Minimal change with the unclear palisade vessels is visible more easily in the FICE image.

McNemar's test. A *P*-value of <0.05 was considered statistically significant. Interobserver agreements for all pairs of three readers using conventional endoscopic images or FICE images were calculated using kappa statistics. The kappa value estimates the strength of agreement beyond chance. The level of agreement by kappa values was categorized according to the definitions proposed by Landis and Koch, which are as follows: 0–0.20, slight; 0.21–0.40, fair; 0.41–0.60, moderate; 0.61–0.80, substantial; 0.81–1.00, almost perfect.[20]

RESULTS

Patient characteristics

The characteristics of the NERD group and control group are shown in Table 1. There were no significant differences between the both groups with regard to distribution of age ($P = 0.166$) or presence of hiatal hernia ($P = 0.160$), but the male/female ratio of the NERD group was significantly lower than that of the control group ($P = 0.033$).

Color pattern of minimal change in FICE image

Minimal changes, such as erythema and whitish turbidity, which were detected using conventional endoscopic images, showed up as navy blue and pink-white in color, respectively, using FICE images in the present FICE mode. In addition, palisade vessels showed up as navy blue in color using FICE images in the present FICE mode.

Comparison of minimal change between the NERD group and control group

The proportion of minimal change for the NERD group (77%, 20 of 26) was higher than that for the control group (48%, 15 of 31) ($P = 0.033$).

Table 1 Patient characteristics in the NERD group and control group

	NERD ($n = 26$)	Control ($n = 31$)	*P*-value
Age (M ± SD) (years)	59.2 ± 14.8	64.4 ± 12.5	$P = 0.166$*
Sex (M/F)	3/23	12/19	$P = 0.033$**
Hiatal hernia (+/–)	24/2	24/7	$P = 0.160$**

**t*-test. **Fisher's exact test. SD, standard deviation.

Table 2 Intraobserver variability for the endoscopic diagnosis of minimal change (grade M or N) using conventional endoscopic images and FICE images

		Reader A		Reader B		Reader C	
		FICE image					
	Grade	N	M	N	M	N	M
Conventional image	N	16	5	11	16	11	7
	M	0	36	0	29	1	38

FICE, flexible spectral imaging color enhancement.

Intraobserver variability

For the presence or absence of minimal change, the intraobserver variabilities using conventional endoscopic images and FICE images are shown in Table 2. The diagnosis with regard to minimal change was changed from grade N to grade M in 5–16 cases of 57 subjects using FICE images, whereas the diagnosis was changed from grade M to grade N in only 0–1 case of 57 subjects using FICE images. In all three readers, there were significant differences between conventional endoscopic images and FICE images in the detection rate of minimal change, with the detection rates of minimal change using FICE images being greater those using conventional endoscopic images ($P = 0.025$, <0.0001 and 0.034 for reader A, B, and C, respectively).

Interobserver agreement

For the presence or absence of minimal change, the kappa values for all pairs of three readers using FICE images were between 0.683 and 0.812, with standard errors between 0.089 and 0.120, indicating substantial or almost perfect interobserver agreement, while those using conventional endoscopic images were between 0.364 and 0.624, with standard errors between 0.113 and 0.116, indicating fair to substantial interobserver agreement (Table 3).

Table 3 Interobserver agreement for the endoscopic diagnosis of minimal change (grade M or N) using conventional endoscopic images and FICE images

Readers	Image	Kappa	SE
A and B	Conventional	0.436	0.115
	FICE	0.718	0.103
B and C	Conventional	0.364	0.116
	FICE	0.683	0.120
A and C	Conventional	0.624	0.113
	FICE	0.624	0.089

NERD, nonerosive reflux disease; FICE, flexible spectral imaging color enhancement; SE, standard error.

DISCUSSION

NERD is a common disease in the clinic, but a gold standard for the diagnosis of NERD does not exist.[21–24] NERD is defined as 'the presence of troublesome reflux-associated symptoms and the absence of mucosal breaks at endoscopy' in the Montreal definition.[25] Although 24-h esophageal pH monitoring has been used for confirmation of NERD, false negative or false positive results are not uncommon.[26,27] Of the histological findings evaluated as features of GERD (e.g. intrapapillary vessel dilatation, elongation of papillary vessels, hyperplasia of the basal layer, acanthosis, inflammatory cells infiltration), Takubo *et al.*[28] reported that minimal changes such as erythema and whitish turbidity in esophageal mucosa correspond to areas of dilatation of multiple intrapapillary vessels and acanthotic squamous epithelium, respectively. However, the usefulness of histological examination for NERD is controversial; current guidelines do not recommend this.[26,29] Combined esophageal pH-impedance monitoring allows the differentiation of acid, nonacid liquid and gas reflux events and has been introduced to assess the reflux pattern of GERD in recent studies.[3,30,31] However, in many previous studies, the definition of 'NERD' has included all patients with typical reflux symptoms (heartburn and acid regurgitation) and the absence of mucosal breaks at EGD because the diagnosis on the basis of the typical GERD symptoms and the absence of mucosal breaks at EGD is the simplest method and is not unduly burdensome to patients. Similarly, in the present study, the definition of 'NERD' has included all patients with typical reflux symptoms and the absence of mucosal breaks at EGD.

The classification of grades M and N NERD has not been commonly accepted worldwide. However, it has been reported that grade M NERD patients experienced more frequent esophageal acid reflux than grade N NERD patients in 24-h esophageal pH monitoring, suggesting that the presence of esophageal acid reflux can be ascertained to some degree on the basis of minimal change esophagitis.[32] Moreover, it was reported that NERD patients significantly more often showed endoscopic signs of minimal change, such as punctuate erythema, than the control group using magnifying endoscopy.[21] The present study also demonstrates that the NERD group has a higher proportion of minimal change, compared with the control group.

To our knowledge, only two studies have examined the interobserver agreement for the endoscopic diagnosis of grade M or N NERD using conventional endoscopic images. However, these studies demonstrated that the interobserver agreement for the endoscopic diagnosis of grade M or N NERD was poor.[12,13] It has been pointed out that the vague definition of grade M in the modified Los Angeles classification system was the most common cause of the poor agreement in these studies.[12]

The present study is the first report of the use of FICE images for the endoscopic diagnosis of NERD. The FICE process was performed at the following wavelengths: R, 500 nm; G, 470 nm; B, 415 nm. In the present FICE mode, the detection rates of minimal change using FICE images in all three blinded readers were greater than those using conventional endoscopic images. Moreover, the interobserver agreement for the endoscopic diagnosis of grade M or N NERD using FICE images was higher than that using conventional endoscopic images. These results suggest that FICE images allow for more clear identification of minimal change, compared with conventional endoscopic images.

The present study has several limitations. The diagnostic criteria of NERD based on GERD symptoms may have led to heterogeneous groups with other gastrointestinal functional diseases. It is possible that a more homogeneous NERD group would have been selected if combined esophageal pH-impedance monitoring had been used for confirmation of NERD. We also did not evaluate the histological findings for minimal change. In addition, this is retrospective study on a small number of readers and subjects.

In conclusion, the endoscopic diagnosis of grade M or N NERD using FICE images is feasible and may improve interobserver agreement. Further prospective studies using FICE images for larger populations of NERD patients will be needed to examine these possibilities.

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Quantification of Cold Spots Caused by Geometrical Uncertainty in Field-in-field Techniques for Whole Breast Radiotherapy

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Objective: To quantify the cold spot under geometrical uncertainties in field-in-field techniques for whole breast radiotherapy.
Methods: Ten consecutive patients from both the left- and right-sided treatment site groups who received whole breast radiotherapy with the field-in-field technique were included. Virtual plans were made with moving isocenters to the posterior direction having two amplitudes (5 and 10 mm) and prescribing the same monitor unit as the original plan (FIF_5 and FIF_10). The planning target volume for evaluation was defined by subtracting the areas within 5 mm from the skin and within 5 mm from the lung from the whole breast. The differences in V90, V95 and D98 of planning target volume for evaluation were measured between the original and virtual plans. As a reference, the same measurements were taken for the wedge techniques (Wedge_5 and Wedge_10).
Results: The differences in V95 were −0.2% on FIF_5, −1.7% on FIF_10, −0.5% on Wedge_5 and −1.5% on Wedge_10. The differences in V90 were −0.02% on FIF_5, −0.3% on FIF_10, −0.05% on Wedge_5 and −0.1% on Wedge_10. The differences in D98 were 0 Gy on FIF_5, −0.1 Gy on FIF_10, −0.2 Gy on Wedge_5 and −0.4 Gy on Wedge_10. The differences in D98 between the original plans and virtual scenarios for field-in-field techniques were significantly smaller than those for wedge techniques, but there were no statically significant differences in V90 and V95.
Conclusions: The quantity of the cold spots caused by the geometrical uncertainties in field-in-field techniques was similar to that for the wedge techniques and was acceptable.

Key words: breast cancer – radiotherapy – whole breast radiotherapy – field-in-field technique – geometrical uncertainty

INTRODUCTION

Whole breast radiotherapy has been widely used after breast-conserving surgery to prevent local recurrence in patients with early breast cancer. A tangential parallel-opposed technique is used for whole breast radiotherapy. Achieving acceptable dose homogeneity across the whole breast volume is difficult because of the continuous change in breast shape across multiple planes and the effect of the lung tissues that are included in the irradiated volume (1, 2).

Several groups have reported that the field-in-field (FIF) technique can reduce dose inhomogeneity in whole breast radiotherapy (3–7). FIF is a forward planning intensity modulating technique. Fields are created using multileaf collimator (MLC) leaves such that the leaves are strategically placed in areas where the dose to the breast is considerably higher than the prescription dose, otherwise known as hot spots (7). However, geometrical uncertainties arising from set-up errors and respiratory motion are not considered in this

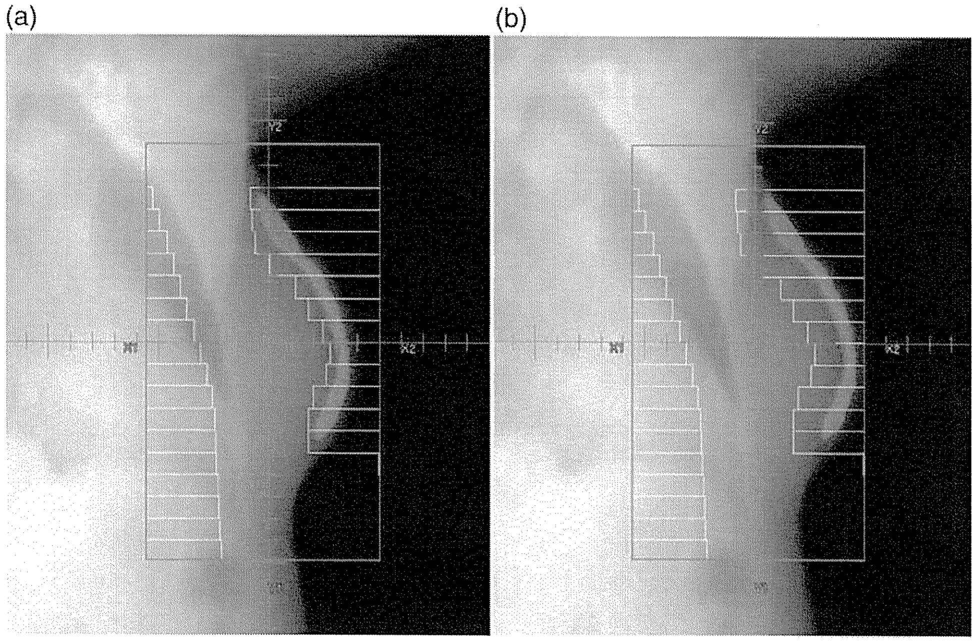

Figure 1. (a) An example of a reduction field to eliminate the hot spots. (b) A virtual field tilted to the posterior direction by 1 cm. In each figure, 107% isodose cloud is shown in blue.

strategy. If the MLC leaves are tilted to the posterior direction because of the geometrical uncertainties, cold spots where the dose to the breast is considerably lower than the prescription dose may arise.

We evaluated the quantities of cold spots caused by geometrical uncertainties in FIF techniques for whole breast radiotherapy compared with wedge plans.

PATIENTS AND METHODS

Ten consecutive patients from both the left- and right-sided treatment site groups who received whole breast radiotherapy with the FIF technique at St Luke's International Hospital were included in this study. Computed tomographic scans were performed with a LightSpeed RT16 (GE Healthcare) helical scanner and 5 mm slice thickness without breath holding. All patients were treated with 4 MV X-ray. All patients were treated with four fields, two of which were reduction fields to eliminate hot spots where the doses are higher than 107–110% of the prescription dose (Fig. 1). The treatment machine was CLINAC21EX (Varian) which has 1 cm thick MLCs. The treatment planning system (TPS) was Pinnacle ver. 8.0 m (Phillips).

We have in-house regulations to ensure the accuracy of the TPS when we use FIF techniques: do not put MLC leaves within 1 cm from the reference point, the minimum monitor unit (MU) in each field is 5, do not make any part of the field narrower than 2 cm, and the proportion of field blocked by MLC leaves must be <50%.

Virtual plans were made on the TPS by moving isocenters to the posterior direction with two amplitudes (5 and 10 mm) and prescribing the same MU as in the original plan

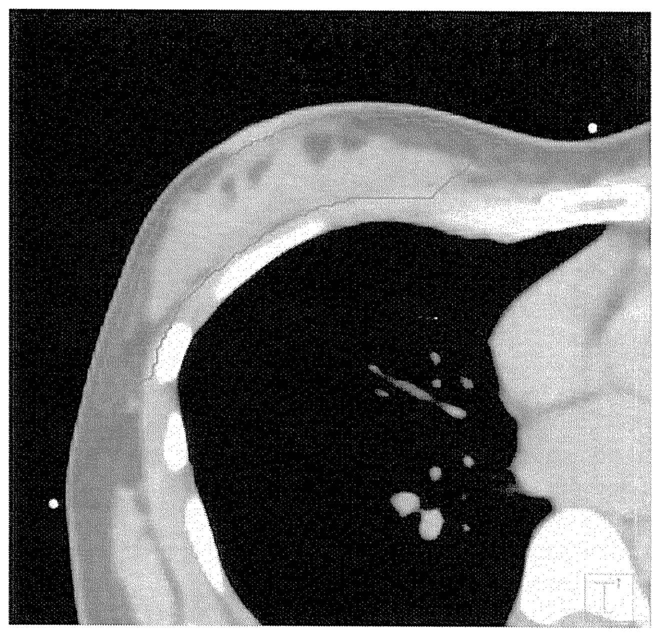

Figure 2. An example of delineation of the planning target volume for evaluation (PTV_EV), defined by subtracting the areas within 5 mm from the skin and within 5 mm from the lung from the whole breast.

(FIF_5 and FIF_10) (Fig. 1). The planning target volume for evaluation (PTV_EV) was defined by subtracting the areas within 5 mm from the skin and within 5 mm from the lung from the whole breast (Fig. 2). The differences in the percentages of the volume of the PTV_EV which receive more than 90 and 95% of the prescribed dose (V90 and V95) and the doses received by 98% of the PTV_EV (D98) were compared between the original and virtual plans. As a reference,