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CLINICAL INVESTIGATION **Prostate**

RADICAL EXTERNAL BEAM RADIOTHERAPY FOR CLINICALLY LOCALIZED PROSTATE CANCER IN JAPAN: CHANGING TRENDS IN THE PATTERNS OF CARE PROCESS SURVEY

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Purpose: To delineate changing trends in radical external beam radiotherapy (EBRT) for prostate cancer in Japan.
Methods and Materials: Data from 841 patients with clinically localized prostate cancer treated with EBRT in the Japanese Patterns of Care Study (PCS) from 1996 to 2005 were analyzed.
Results: Significant increases in the proportions of patients with stage T1 to T2 disease and decrease in prostate-specific antigen values were observed. Also, there were significant increases in the percentages of patients treated with radiotherapy by their own choice. Median radiation doses were 65.0 Gy and 68.4 Gy from 1996 to 1998 and from 1999 to 2001, respectively, increasing to 70 Gy from 2003 to 2005. Moreover, conformal therapy was more frequently used from 2003 to 2005 (84.9%) than from 1996 to 1998 (49.1%) and from 1999 to 2001 (50.2%). On the other hand, the percentage of patients receiving hormone therapy from 2003 to 2005 (81.1%) was almost the same as that from 1996 to 1998 (86.3%) and from 1999 to 2001 (89.7%). Compared with the PCS in the United States, patient characteristics and patterns of treatments from 2003 to 2005 have become more similar to those in the United States than those from 1996 to 1998 and those from 1999 to 2001.
Conclusions: This study indicates a trend toward increasing numbers of patients with early-stage disease and increasing proportions of patients treated with higher radiation doses with advanced equipment among Japanese prostate cancer patients treated with EBRT during 1996 to 2005 survey periods. Patterns of care for prostate cancer in Japan are becoming more similar to those in the United States. © 2011 Elsevier Inc.

Patterns of care study, Prostate cancer, Radical external beam radiotherapy, Changing trend.

INTRODUCTION

The Patterns of Care Study (PCS) national survey is a retrospective study designed to establish the national practice process of therapies for selected malignancies over a specific time period (1–3). In addition to documenting the practice process, data from PCS surveys are important for developing and disseminating national guidelines for cancer treatment that help promote a more uniform care process in the country. The PCS is also designed to complement the role of clinical trials in enhancing the standard of care for cancer patients (1, 4).

To improve the quality of radiation oncology, PCS methodology has been imported to Japan from the United States. The Japanese PCS Working Group of Prostate Cancer started a nationwide process survey of patients treated with radiotherapy between 1996 and 1998 (5, 6). Subsequently, the Working Group conducted a second PCS of patients treated with radiotherapy between 1999 and 2001 and previously reported the results of this second PCS for prostate cancer patients in Japan treated with radiotherapy (7–18). At present, we have conducted a third PCS of patients treated with radiotherapy from 2003 to 2005 (19).

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Conflict of interest: none.

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Over the past 10 years, remarkable changes have occurred in prostate cancer treatment policy in Japan. The number of deaths due to prostate cancer has been on a steep increase, especially in elderly patients. The proportion of prostate cancer deaths to total cancer deaths also showed an increase from 0.9% in 1960 to 4.2% in 2000 (20). Since the introduction of prostate-specific antigen (PSA) screening, prostate cancer cases are being detected at earlier stages of disease, which allows early-stage patients a better chance of successful treatment and reduction of death from prostate cancer (21, 22). Moreover, recently, the use of radical external beam radiotherapy (EBRT) for prostate cancer has increased rapidly, as significant new radiation treatment planning technologies and methodologies have become available. Therefore, to optimally treat Japanese prostate cancer patients, it is important to accurately delineate the intrinsic changes taking place in the national practice process of radiotherapy for prostate cancer in Japan. In this report, we present the results of our analysis of the time-dependent transition of the process of care for prostate cancer patients treated with radical EBRT in the time periods from 1996 to 1998, 1999 to 2001, and 2003 to 2005.

METHODS AND MATERIALS

PCS surveys from 1996 to 1998, 1999 to 2001, and 2003 to 2005 in Japan contain detailed information about a total of 1,286 patients with prostate cancer treated with radiotherapy during the respective survey periods (307 patients were treated in 1996-1998; 387 patients in 1999-2001 PCS; and 592 patients in 2003-2005). PCS methodology has been described previously (1–4). Briefly, the PCS surveys were extramural audits that utilized a stratified two-stage cluster sampling design. The Japanese PCS used an original data format developed in collaboration with the American College of Radiology (Philadelphia, PA). The PCS surveyors consisted of 20 radiation oncologists from academic institutions. For each institution, one radiation oncologist collected data by reviewing patients' charts. To validate the quality of the collected data, the PCS used an Internet mailing list including all of the surveyors. On-site real-time checks and adjustments of the data input were available to each surveyor and to the PCS committee.

Of the 1,286 patients comprising the PCS 1996 to 1998, 1999 to 2001, and 2003 to 2005 surveys, patients with a diagnosis of adenocarcinoma of the prostate were eligible for inclusion in the present study unless they had one or more of the following conditions: (*1*) hormone-refractory cancer; (*2*) evidence of distant metastasis; (*3*) concurrent or prior diagnosis of any other malignancy; (*4*) prior radiotherapy; (*5*) or prior prostatectomy. In the current study, we considered the exclusion of patients with concurrent or prior diagnosis of nonmelanoma skin cancer would not affect the results of our PCS survey because the incidence of nonmelanoma skin cancers in Japan has been low compared to those in Western countries. A total of 841 patients with clinically localized prostate cancer treated with EBRT met these eligibility criteria and were selected for analysis (1996-1998 PCS included 161 patients from 51 institutions; 1999-2001 PCS included 283 patients from 66 institutions; and 2003-2005 PCS included 397 patients from 61 institutions). Criteria for institutional categories in the 1996 to 1998, 1999 to 2001, and 2003 to 2005 surveys have been detailed elsewhere (10, 11). Briefly, the PCS divided Japanese institutions into academic institutions (university hospital or cancer center) and nonacademic institutions (other hospitals).

In the current study, we used the risk groups utilized by D'Amico *et al.* (23), based on serum PSA level, biopsy, Gleason combined score, and 1992 American Joint Commission on Cancer (AJCC) clinical tumor category. Low-risk patients had a PSA of 10 μg/l or less, a Gleason score of 6 or less, and a 1992 tumor category of stage T1c or T2a. Intermediate-risk patients had PSA levels of 10.1 to 20 μg/l or a Gleason combined score of 7 or a 1992 AJCC tumor category of stage T2b. High-risk patients had a PSA level of more than 20 μg/l or a Gleason combined score of 8 or a 1992 AJCC tumor category of stage T2c.

Statistical analyses were performed using the Statistical Analysis System at the PCS data center at Osaka University (24). Statistical significance was tested using the chi-square test, Student's *t* test, and the Mann-Whitney U test. A probability level of 0.05 was chosen for statistical significance.

RESULTS

Patient characteristics

Patient characteristics for the PCS surveys from 1996 to 1998, 1999 to 2001, and 2003 to 2005 are shown in Table 1. There were significant increases over time in the proportion of patients with stage T1 to T2 disease (34.6% of patients in the 1996-1998 PCS; 48.2% of patients in the1999-2001 PCS; and 61.4% of patients in the 2003-2005 PCS) and decreases in median PSA values at diagnosis (: 22.0 ng/ml in the 1996-1998 PCS; 20.0 ng/ml in the 1999-2001 PCS; and 14.9 ng/ml in the 2003-2005 PCS). Data for the Gleason combined score were missing for 73.9% (119/161) of the patients in the 1996 to 1998 PCS and for 39.6% (112/283) of the patients in the 1999 to 2001 PCS, while only 5.5% (22/397) of patients were missing in the 2003 to 2005 PCS. The number of patients in the low-risk group increased gradually over time, while the number of patients in the high-risk group decreased gradually (Fig. 1). Table 1 and Fig. 2 indicate the reasons for selecting radiotherapy during these different time periods. There were significant increases over time in the number of patients treated with radiotherapy by their own choice (5.9% of patients in the 1996-1998 PCS; 26.5% of patients in the 1999-2001 PCS; and 41.4% of patients in the 2003-2005). This change in the rate of "patient choice" was significantly different ($p < 0.0001$).

Treatment characteristics

Treatment characteristics are shown in Table 2. The frequencies of radiation energies >10 MV, the use of portal or electronic portal images, and all field treatment each day increased gradually from 1996 to 1998 to 2003 to 2005. Also, the frequency of computed tomography (CT)-based treatment planning was 90.9% in 2003 to 2005, but 80.7% in 1996 to 1998, and 85.5% in 1999 to 2001. Moreover, the frequency of conformal therapy increased more rapidly from 2003 to 2005 (84.9%) than from 1996 to 1998 (49.1%) and 1999 to 2001 (50.2%).

Median radiation doses were 65.0 Gy and 68.4 Gy from 1996 to 1998 and from 1999 to 2001, respectively, increasing up to 70 Gy from 2003 to 2005. Stratifying patients by

Table 1. Patient and disease characteristics

Patient characteristic	PCS survey 1996-1998 (n = 161 patients)	PCS survey 1999-2001 (n = 283 patients)	PCS survey 2003-2005 (n = 397 patients)	Significance (p value)
Institution	51	66	61	
Median age, years (range)	70.4 (46.5–89.8)	71.8 (49.7–92.2)	72.1 (50.7–87.7)	0.4556
Mean age ± SD	70.8 ± 8.1	71.8 ± 6.6	71.5 ± 6.1	0.3446
Median KPS % (range)	90 (40–100)	90 (50–100)	90 (60–100)	<0.0001
Mean ± SD	87.0 ± 8.9	89.1 ± 7.1	90.9 ± 8.5	<0.0001
Missing data	7	8	0	
Pretreatment PSA level (%)				
Median PSA level (range)	21.95 (0.3–900.0)	19.99 (0.6–856.9)	14.94 (0.7–3,058.0)	0.0176
Mean PSA level ± SD	51.5 ± 93.5	54.1 ± 99.5	48.2 ± 179.2	0.8719
<10	41/146 (28.1%)	77/268 (28.7%)	121/391 (30.9%)	0.0066
10-19.9	25/146 (17.1%)	57/268 (21.3%)	113/391 (28.9%)	
≥20	80/146 (54.8%)	134/268 (50.0%)	157/391 (40.2%)	
Missing data	15	15	6	
Lower pretreatment PSA level (%)				
<4	17/146 (11.6%)	8/268 (3.0%)	9/391 (2.3%)	<0.0001
≥4	129/146 (88.4%)	260/268 (97.0%)	382/391 (97.7%)	
Missing data	15	15	6	
Differentiation (no. patients/total) (%)				
Well	24/159 (15.1%)	62/264 (23.5%)	67/376 (17.8%)	0.0148
Moderate	79/159 (49.7%)	93/264 (35.2%)	152/376 (40.4%)	
Poor	46/159 (28.9%)	93/264 (35.2%)	99/376 (26.3%)	
Other	0/159 (0.0%)	2/264 (0.8%)	7/376 (1.9%)	
Unknown	10/159 (6.3%)	14/264 (5.3%)	51/376 (13.6%)	
Missing data	2	19	21	
Gleason combined score (%)				
2-6	11/42 (26.2%)	77/171 (45.0%)	118/375 (31.5%)	0.0014
7	18/42 (42.9%)	35/171 (20.5%)	134/375 (35.7%)	
8-10	13/42 (31.0%)	59/171 (34.5%)	123/375 (32.8%)	
Missing data	119	112	22	
T stage (no. patients/total) (%)				
TX-T0	1/159 (0.6%)	10/272 (3.7%)	1/394 (0.3%)	<0.0001
T1	8/159 (5.0%)	22/272 (8.1%)	88/394 (22.3%)	
T2	47/159 (29.6%)	109/272 (40.1%)	154/394 (39.1%)	
T3-T4	102/159 (64.2%)	124/272 (45.6%)	134/394 (34.0%)	
Unknown	1/159 (0.6%)	7/272 (2.6%)	17/394 (4.3%)	
Missing data	2	11	3	
N stage (no. patients/total) (%)				
NX-N0	136/157 (86.6%)	249/270 (92.2%)	372/394 (94.4%)	0.0038
N1	18/157 (11.5%)	15/270 (5.6%)	12/394 (3.0%)	
Unknown	3/157 (1.9%)	6/270 (2.2%)	10/394 (2.5%)	
Missing data	4	13	3	
Risk group (no. patients/total) (%)				
Low risk	1/127 (0.8%)	16/242 (6.6%)	40/381 (10.5%)	< 0.0001
Intermediate risk	7/127 (5.5%)	26/242 (10.7%)	107/381 (28.1%)	
High risk	119/127 (93.7%)	200/242 (82.6%)	234/381 (61.4%)	
Missing patient data	34	41	16	
Reason for selection of RT (no. patients/total) (%)				
Patient choice	8/136 (5.9%)	71/268 (26.5%)	159/384 (41.4%)	
Advanced or high-risk disease	43/136 (31.6%)	83/268 (31.0%)	121/384 (31.5%)	
Intercurrent disease	0/136 (0.0%)	0/268 (0.0%)	62/384 (16.1%)	
Medical contraindication	7/136 (5.1%)	36/268 (13.4%)	0/384 (0.0%)	
Old age	37/136 (27.2%)	44/268 (16.4%)	94/384 (24.5%)	
Other	9/136 (6.6%)	8/268 (3.0%)	6/384 (1.6%)	
NA or unknown	32/136 (23.5%)	26/268 (9.7%)	27/384 (7.0%)	
Missing data	25	15	13	

Abbreviations: KPS = karnofsky performance status; PSA = prostate-specific antigen; RT = radiotherapy; NA = data not available; SD = standard deviation.

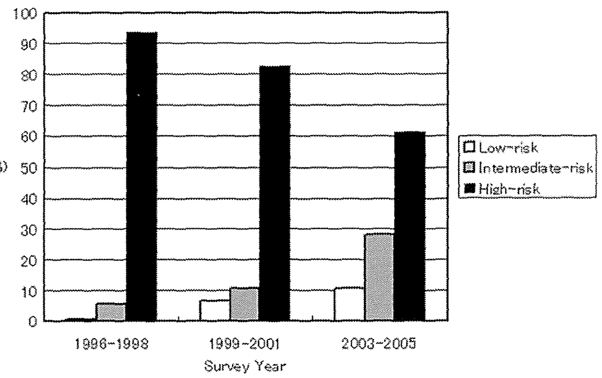

Fig. 1. Distribution of patients with prostate cancer according to risk group among 1996-1998, 1999-2001, and 2003-2005 Japanese PCS surveys.

total dosage revealed that 24.8% of patients received total radiation doses below 60 Gy in the 1996 to 1998 PCS, decreasing to only 2.0% from 2003 to 2005. Also, only 17.4% of patients received total doses of >70 Gy from 1996 to 1998, which increased dramatically to 52.0% from 2003 to 2005 (Fig. 3). Increased radiation doses were administered predominantly in academic institutions (Table 2).

The percentage of patients receiving hormone therapy from 2003 to 2005 (81.1%) was almost the same as that from 1996 to 1998 (86.3%) and that from 1999 to 2001 (89.7%). Hormonal therapy was used before, during, and after radiotherapy for a mean duration of 30.1 ± 29.8 months, 43.9 ± 36.7 months, and 40.6 ± 34.3 months, respectively (86.3% of patients in 1996-1998; 89.7% of patients in 1999-2001; and 81.1% in 2003-2005). The proportion of patients receiving hormone therapy was analyzed according to risk group. Most patients in the intermediate- and high-risk groups were treated with hormone therapy during 1996 to 1998, 1999 to 2001, and 2003 to 2005 survey periods (Fig. 4). In the low risk-group, approximately 50% to 70% of patients were treated with hormone therapy in the periods 1999 to 2001 and 2003 to 2005. We could not precisely analyze the incidence of low-risk patients treated with hormone therapy during the 1996 to 1998 period because only 1 patient, who was not treated with hormone therapy, was available for this analysis.

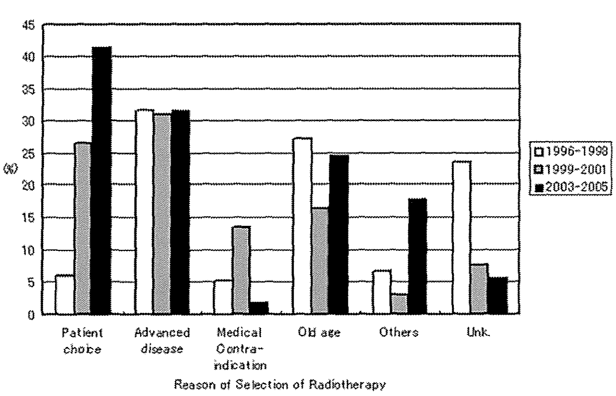

Fig. 2. Reasons of selection of EBRT for patients with prostate cancer among 1996-1998, 1999-2001, and 2003-2005 Japanese PCS surveys.

FTE radiation oncologists

For academic institutions, the mean numbers of full-time equivalent (FTE) radiation oncologists increased gradually over time (results of the surveys for 1996-1998, 1999-2001, and 2003-2005 were 2.13, 2.36, and 2.86, respectively). For nonacademic institutions, the mean numbers of FTE radiation oncologists also increased gradually over time (results for 1996-1998, 1999-2001, and 2003-2005 were 0.57, 0.62, and 0.75, respectively), but the numbers were extremely low compared with those in academic institutions.

Comparisons of changing trends in patient and treatment characteristics between Japan and the United States

Changing trends between Japan and the United States were analyzed with regard to patient and treatment characteristics by using the US PCS data reported by Zelefsky *et al.* (25). In Japan, the proportions of patients with stage T3 to T4 disease and PSA levels >20 ng/ml decreased gradually from 1996 to 1998 to 2003 to 2005, but the proportions of patients with T3 to T4 disease, a Gleason score of 8 to 10, and a PSA level of >20 ng/ml were over 30% among the three surveys (Fig. 5a). On the other hand, in the United States, the proportions of patients with T3 to T4 disease, a PSA level of >20 ng/ml, and a Gleason score of 8 to 10 were almost the same, and the proportions of patients with T3 to T4 disease, a PSA of >20 ng/ml, and a Gleason score of 8 to 10 were approximately 20% or less during the survey period (Fig.5b).

Regarding treatment characteristics, in Japan, the proportions of patients receiving conformal radiotherapy and higher radiation doses (72 Gy or more) increased, as 84.9% of patients were treated with conformal therapy, and 16.9% of patients were treated with higher radiation doses in 2003 to 2005. On the other hand, use of hormone therapy was over 80% during the survey periods (Fig.6a). In the United States, the proportions of patients receiving hormone therapy and higher radiation doses (72 Gy or more) increased continuously over the survey periods, and the proportions of patients receiving hormone therapy and higher radiation doses were approximately 45% to 50% (Fig. 6b). Concerning conformal therapy in the United States, 80% of patients were treated with conformal radiotherapy in 1999, which was almost the same frequency as patients treated from 2003 to 2005 in Japan.

DISCUSSION

Results of the current study indicate that there were significant increases in the proportions of prostate cancer patients with stage T1 to T2 disease and lower initial PSA values in the 1996 to 2005 survey periods in Japan. Numbers of patients in the low-risk group increased gradually, while

Table 2. Treatment characteristics

Treatment	PCS survey 1996-1998 (n = 161)	1999-2001 (n = 283)	2003-2005 (n = 397)	Significance (p value)
Received radiotherapy				
Energy (≥10 MV) (%)				
Yes (no. patients/total) (%)	98/161 (60.9%)	208/279 (74.6%)	312/386 (80.8%)	<0.0001
Missing data	0	4	11	
Portal films or electric portal images used (%)				
Yes (no. patients/total) (%)		210/280 (75.4%)	388/397 (97.7%)	<0.0001
Missing data		3	0	
All fields treated each day (%)				
Yes (no. patients/total) (%)	44/65 (67.7%)	215/283 (76.0%)	363/397 (91.4%)	<0.0001
Missing data	96	0	0	
CT-based treatment planning (%)				
Yes (no. patients/total) (%)	130/161 (80.7%)	241/282 (85.5%)	361/397 (90.9%)	0.0006
Missing	0	1	0	
Received conformal radiotherapy (%)				
Yes (no. patients/total) (%)	79/161 (49.1%)	142/283 (50.2%)	337/397 (84.9%)	<0.0001
Received pelvic irradiation (%)				
Yes (no. patients/total) (%)	69/161 (42.9%)	102/283 (36.0%)	95/397 (23.9%)	<0.0001
Radiation dose (cGy)				
A+B (total)				
Median (range)	6,500 (2,200–7,400)	6,840 (1,400–8,200)	7,000 (800–8,410)	<0.0001
Mean ± SD	6,090.9 ± 990.5	6,602.9 ± 731.1	6,764.0 ± 621.9	<0.0001
A median (min-max)	6,500 (2,200–7,400)	6,600 (1,400–8,200)	7,000 (800–8,410)	<0.0001
Mean ± SD	6,250.9 ± 976.8	6,610.3 ± 766.5	6,855.8 ± 708.0	<0.0001
B median (min-max)	5,940 (3,400–7,000)	6,900 (3,000–8,000)	6,600 (3,000–7,640)	<0.0001
Mean ± SD	5,622.4 ± 885.6	6,592.6 ± 681.9	6,654.9 ± 480.5	<0.0001
Prescription dose levels (Gy) (no. patients/total) (%)				
<60	40/161 (24.8%)	17/282 (6.0%)	8/396 (2.0%)	<0.0001
60-65	36/161 (22.4%)	56/282 (19.9%)	57/396 (14.4%)	
65-70	57/161 (35.4%)	102/282 (36.2%)	125/396 (31.6%)	
≥70	28/161 (17.4%)	107/282 (37.9%)	206/396 (52.0%)	
Missing data	0	1	1	
Higher prescription dose levels (no. patients/total) (%)				
<72	159/161 (98.8%)	261/282 (92.6%)	329/396 (83.1%)	<0.0001
≥72	2/161 (1.2%)	21/282 (7.4%)	67/396 (16.9%)	
Missing data	0	1	1	
Received hormone therapy (%)				
Yes (no. patients/total) (%)	138/160 (86.3%)	253/282 (89.7%)	321/396 (81.1%)	0.0284
No (no. patients/total) (%)	21/160 (13.1%)	29/282 (10.3%)	73/396 (18.4%)	
Unknown	1/160 (0.6%)	0/282 (0.0%)	2/396 (0.5%)	
Missing data	1	1	1	
Received chemotherapy				
Yes (no. patients/total) (%)	20/159 (12.6%)	17/274 (6.2%)	5/394 (1.3%)	<0.0001
No (no. patients/total) (%)	137/159 (86.2%)	255/274 (93.1%)	387/394 (98.2%)	
Unknown	2/159 (1.3%)	2/274 (0.7%)	2/394 (0.5%)	
Missing data	2	9	3	

Abbreviation: SD = standard deviation.

numbers of patients in the high-risk group decreased gradually. These results suggest that the likelihood of early-stage prostate cancer patients being treated with radiotherapy is greater than ever before in Japan. In the United States, most of the prostate cancer patients have early-stage tumors, and radiotherapy has been recognized as the first-line therapy for prostate cancer (25–28). Because of the prevailing use of PSA screening and the increasing number of patients treated with radiotherapy in Japanese institutions (29), the opportunities for treating early-stage prostate cancer patients with radical EBRT should increase even more in the future.

In the current study, the data for a Gleason combined score were missing for 73.9% of the patients in the 1996 to 1998 PCS and 39.6% of the patients in the 1999 to 2001 PCS, while data for only 5.5% of the patients in 2003 to 2005 PCS were missing. These results suggest that previously in Japan, physicians did not realize the importance of the

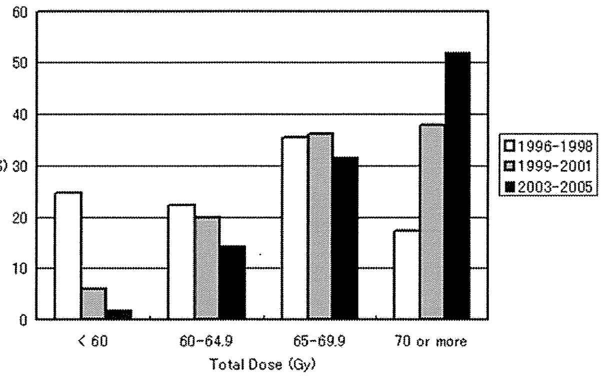

Fig. 3. Distributions of total radiation doses of external beam radiotherapy for patients with prostate cancer among 1996-1998, 1999-2001, and 2003-2005 Japanese PCS surveys.

Gleason combined score, but recently, they are becoming aware that the Gleason combined score is of critical importance in the evaluation and management of prostate cancer patients. Further studies are required to confirm whether physicians in Japan will routinely use the Gleason combined score in the management of prostate cancer patients in future.

The current study also revealed a remarkable change in the reason for choosing radiotherapy in Japan among the 1996 to 2005 survey periods. Only 5.9% of the patients were treated with radiotherapy by their own choice from 1996 to 1998, but 41.4% of patients chose radiotherapy from 2003 to 2005. EBRT did not become a popular treatment modality for prostate cancer in Japan until the end of the 1990s. A strong surgical tradition and an insufficient number of radiation oncology centers capable of delivering appropriate treatment prevented earlier dissemination of this type of therapy. However, in conjunction with significant improvements in the availability of new radiation treatment planning technologies and methodologies for treatment planning and delivery, Japanese patients are becoming increasingly aware of the effectiveness of radiotherapy for prostate cancer (30, 31). Therefore, the increasing percentage of patients choosing radiotherapy might reflect a growing acceptance of radical external EBRT as one of the main treatments for prostate cancer patients in Japan.

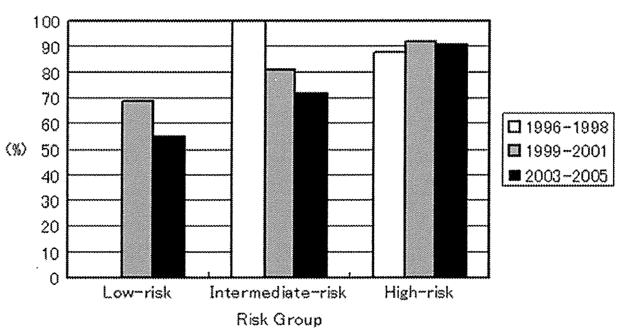

Fig. 4. Hormonal therapy distribution according to risk group for prostate cancer in Japan among 1996-1998, 1999-2001, and 2003-2005 Japanese PCS surveys.

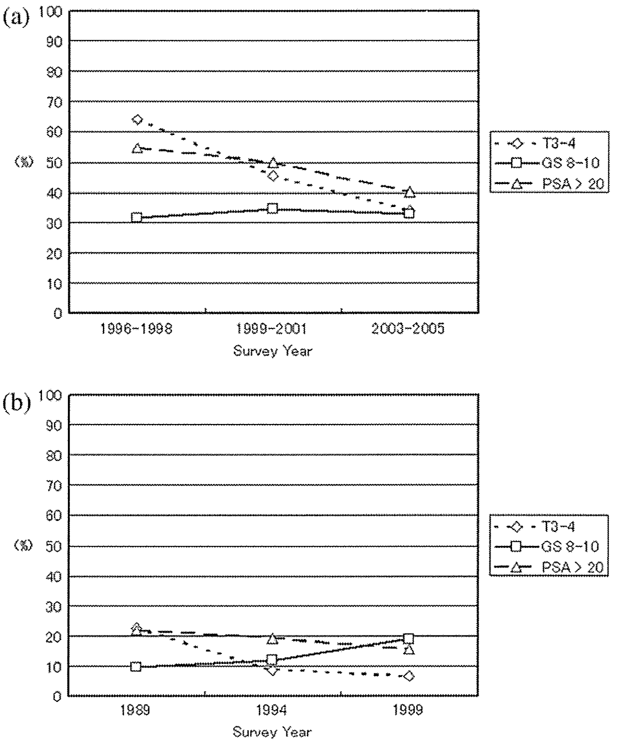

Fig. 5. (a) Changing trend in patient characteristics in Japan. (b) Changing trend in patient characteristic in the United States. (Data from ZelefskyMJ, Moughan J, Owen J, et al. Changing trends in national practice for external beam radiotherapy for clinically localized prostate cancer: 1999 patterns of care survey for prostate cancer. Int J Radiat Oncol Biol Phys 2004;59:1053-1061)

Moreover, the radiotherapy strategy appears to have changed among the 1996 to 1998, 1999 to 2001, and 2003 to 2005 survey periods. The frequency of CT-based treatment planning increased up to 90.9% in 2003 to 2005, and the usage of conformal therapy increased rapidly from 2003 to 2005 (84.9%). The median radiation doses were 65.0 Gy and 68.4 Gy from 1996 to 1998 and from 1999 to 2001, respectively, increasing up to 70 Gy from 2003 to 2005. Also, the proportions of patients receiving total radiation doses below 60 Gy decreased, while the proportions of patients receiving total doses of >70 Gy increased rapidly during the survey period (Fig. 3). These results indicate that patients receiving lower radiation doses with obsolete treatment equipment was more common between 1996 and 1998, while higher doses with high-technology radiation equipment prevailed between 2003 and 2005. US PCS results indicate that many prostate cancer patients have been routinely treated with total doses of >70 Gy in the United States (25, 28). The use of increasing radiation doses in Japan might reflect the widespread dissemination of clinical trial results (32–35) and also a growing acceptance by radiation oncologists and urologists that radical EBRT is effective for treating prostate cancer (30, 31).

Results of the current study indicate that hormone therapy was commonly used in conjunction with radiotherapy during the survey period in Japan. Moreover, it was not only

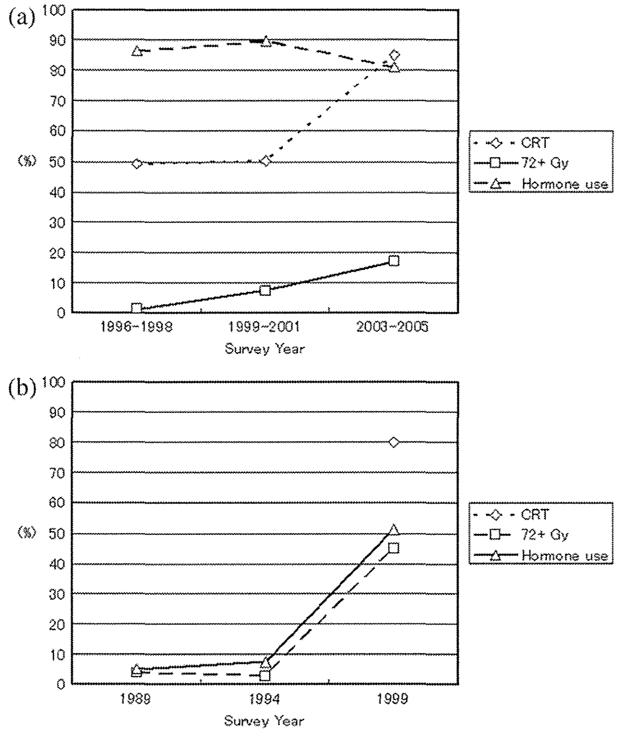

Fig. 6. (a) Changing trend in treatment characteristics in Japan. (b) Changing trend in patient characteristics in the United States. (*Data from* Schröder FH, Hugosson J, Roobol MJ, *et al.* Screening and prostate-cancer mortality in a randomized European study. *N Engl J Med* 2009;360:1320-1328.)

patients in the intermediate- and high-risk groups but also patients in the low-risk group who were frequently treated with hormone therapy during 1999 to 2001 and 2003 to 2005 (Fig. 4). However, several studies from the United States have indicated that radical radiotherapy alone could control the disease in low-risk patients. Zietman *et al.* (34) indicated that a total dose of 70 Gy was sufficient to control the disease when the pretreatment PSA level was less than 10 ng/ml. Hanks *et al.* (35) found that prostate cancer patients with a pretreatment PSA level of <10 ng/ml did not benefit from a dose escalation above 70 Gy (35). Therefore, radical EBRT without hormone therapy has been the primary treatment for patients in the United States with low-risk diseases. The high rate of health insurance coverage for Japanese people may explain the frequent administration of hormone therapy in Japan (36). Another reason may be that at present, many Japanese radiation oncologists may consider the higher dose levels (>72 Gy) unnecessary for prostate cancer patients when combined with long-term hormone therapy. Therefore, radical EBRT without hormone therapy should also be the treatment of choice for low-risk patients in Japan.

In the current study, the mean numbers of FTE radiation oncologists increased gradually over time in both academic and nonacademic institutions. However, the median number of FTE radiation oncologists remained low, especially in nonacademic institutions. Publication data documenting a progressive increase in the number of prostate cancer patients treated with radiotherapy in every institution, demonstrating a need for both academic and nonacademic Japanese institutions to upgrade their radiation equipment and to recruit more radiation oncologists (29).

Changing trends between Japan and the United States were analyzed with regard to patient and treatment characteristics. In Japan, proportions of patients with T3 to T4 disease, a Gleason score of 8 to 10, and a PSA level of >20 ng/ml were all over 30%, but proportions of patients with T3 to T4 disease and a PSA level of >20 ng/ml decreased gradually during the survey period (Fig. 5a). In the United States, the proportions of patients with T3 to T4 stage disease, a PSA level of >20 ng/ml, and a Gleason score of 8 to 10 were almost the same, and the proportions of patients with T3 to T4 stage disease, a PSA level of >20 ng/ml, and a Gleason score of 8 to 10 were approximately 20% or less during the survey period (Fig.5b). These results indicate that although patients in Japan had more advanced disease than those in the United States, patient characteristics in Japan have been changing, becoming more similar to patients in the United States. Further studies are required to confirm this finding.

Concerning treatment characteristics: in Japan, proportions of patients receiving conformal radiotherapy and higher radiation doses have been increasing, and 84.9% of patients were treated with conformal therapy, and 16.9% of patients were treated with higher radiation doses in 2003 to 2005 (Fig. 6a). In the United States, conformal therapy was administered to 85% of patients in 1999, and higher radiation doses (72 Gy or more) have increased continuously from 1989 to 1999 (Fig. 6b). These results indicate that although radiotherapy characteristics were still developing in Japan compared to the United States, the proportions of modern radiotherapy have been increasing both in Japan and the United States during the survey period.

The percentage of patients receiving hormone therapy remained high during the periods from 1996 to 1998 to 2003 to 2005 in Japan. On the other hand, there was a rapid increase in the use of hormone therapy in the United States from 1994 to 1999. The significantly increased use of hormone therapy for high-risk patients in the United States reflects the penetration and growing acceptance of clinical trial results that have demonstrated the efficacy of these treatment approaches (32, 33). The randomized Radiation Therapy Oncology Group 8610 trial demonstrated an increase in disease-free survival at 2 years (76% vs. 62% survival) for locally advanced prostate cancer patients treated with neoadjuvant total androgen blockade plus radiation compared to those treated with radiation therapy alone (33). In Japan, hormone therapy was administered to approximately 90% of patients with high-risk disease, and these high rates of hormone therapy have continued for several years. Therefore, radiotherapy in conjunction with hormone therapy appears to be an accepted approach for the unfavorable risk group in Japan and in the United States.

CONCLUSIONS

By comparing the PCS results of 1996 to 1998, 1999 to 2001, and 2003 to 2005 surveys, we can delineate changes in the process of care for prostate cancer patients treated with radiotherapy in Japan. Study data indicate a trend toward increasing early-stage disease and increasing proportions of patients treated with higher radiation doses with advanced equipments, suggesting that radical EBRT is gaining acceptance as a first-line treatment for prostate cancer in Japan. Also, our results indicate that patterns of care for prostate cancer in Japan are becoming more similar to those in the United States. In the future, to optimize the delivery of radiotherapy, more advanced equipment and more FTE radiation oncologists are warranted. Also, repeat surveys and point-by-point comparisons of results from other countries, such as the United States, will demonstrate how EBRT for prostate cancer has been developed and optimized for patients in Japan.

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Strahlentherapie
und Onkologie

Original Article

Japanese Structure Survey of Radiation Oncology in 2007 with Special Reference to Designated Cancer Care Hospitals

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Background and Purpose: The structure of radiation oncology in designated cancer care hospitals in Japan was investigated in terms of equipment, personnel, patient load, and geographic distribution. The effect of changes in the health care policy in Japan on radiotherapy structure was also examined.

Material and Methods: The Japanese Society of Therapeutic Radiology and Oncology surveyed the national structure of radiation oncology in 2007. The structures of 349 designated cancer care hospitals and 372 other radiotherapy facilities were compared.

Results: Respective findings for equipment and personnel at designated cancer care hospitals and other facilities included the following: linear accelerators/facility: 1.3 and 1.0; annual patients/linear accelerator: 296.5 and 175.0; and annual patient load/full-time equivalent radiation oncologist was 237.0 and 273.3, respectively. Geographically, the number of designated cancer care hospitals was associated with population size.

Conclusions: The structure of radiation oncology in Japan in terms of equipment, especially for designated cancer care hospitals, was as mature as that in European countries and the United States, even though the medical costs in relation to GDP in Japan are lower. There is still a shortage of manpower. The survey data proved to be important to fully understand the radiation oncology medical care system in Japan.

Key Words: Structure survey · Radiotherapy facility · Radiotherapy personnel · Radiotherapy equipment · Caseload · *Medical care system*

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Japanische Strukturerhebung zur Radioonkologie im Jahr 2007 unter besonderer Berücksichtigung von auf Krebsbehandlung spezialisierten Krankenhäusern

Hintergrund und Ziel: Es wurde die Struktur der Radioonkologie in auf Krebsbehandlung spezialisierten Krankenhäusern in Japan untersucht, und zwar im Hinblick auf Ausrüstung, Personal, Patientenaufkommen und geografische Verteilung. Ebenso

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wurden die Auswirkungen von Veränderungen in der japanischen Gesundheitsfürsorge-Politik auf die Strahlungstherapie-Struktur untersucht.

Material und Methodik: Die Japanische Gesellschaft für radiologische Therapie und Onkologie hat eine Erhebung zur nationalen Struktur der Strahlungsonkologie im Jahr 2007 durchgeführt. Dabei wurden die Strukturen von 349 auf Krebsbehandlung spezialisierten Krankenhäusern und 372 anderen Strahlentherapie-Einrichtungen verglichen.

Ergebnisse: Die jeweiligen Ergebnisse in Bezug auf die Ausrüstung und das Personal in den auf Krebsbehandlung spezialisierten Krankenhäusern und anderen Einrichtungen waren: Linearbeschleuniger pro Einrichtung: 1,3 bzw. 1,0; jährliche Patientenzahl pro Linearbeschleuniger: 296,5 bzw. 175,0. Das jährliche Patientenaufkommen pro Vollzeitäquivalent-Radioonkologe betrug 237,0 bzw. 273,3. In geografischer Hinsicht stand die Anzahl der auf Krebsbehandlung spezialisierten Krankenhäuser in Relation zur Bevölkerungszahl.

Schlussfolgerung: Die Struktur der Radioonkologie in Japan war, was die Ausrüstung und insbesondere die auf Krebsbehandlung spezialisierten Krankenhäuser betrifft, ebenso ausgereift wie oder ausgereifter als in europäischen Ländern und in den Vereinigten Staaten, obwohl die medizinischen Kosten im Verhältnis zum BIP in Japan geringer sind. Es besteht weiterhin ein Mangel an Arbeitskräften. Die Erhebungsdaten haben sich als bedeutsam für ein umfassendes Verständnis des Radioonkologie-Krankenpflegesystems in Japan erwiesen.

Schlüsselwörter: Strukturerhebung · Strahlentherapie-Einrichtung · Strahlentherapie-Personal · Strahlentherapie-Ausrüstung · Patientenaufkommen · Medizinisches Versorgungssystem

Introduction

In developed countries in Europe, such as France, Germany, Italy, and the UK, as well as in the United States, the rates of radiotherapy use for cancer treatment are as high as 50% or more because there are sufficient radiotherapy facilities and personnel, such as radiation oncologists (ROs), medical physicists (MPs), and radiotherapy technologists (RTTs) [1, 2, 5, 11]. On the other hand, the current utilization rate of radiotherapy for new cancer patients in Japan is only 26.1% [19] and surgery is still predominant. In Japan, the Cancer Control Act has been implemented since 2007 in response to patients' urgent petitions to the government [8]. This law strongly advocates the promotion of radiotherapy. At the same time, the Ministry of Health, Labor, and Welfare began the accreditation of "designated cancer care hospitals (DCCHs)" with the aim of correcting regional differences in the quality of cancer care and strengthening cooperation between regional cancer care hospitals [3, 9, 13]. The Japanese Society of Therapeutic Radiology and Oncology (JASTRO) has conducted national structure surveys of radiotherapy facilities in Japan every 2 years since 1990 [18, 19]. The structure of radiation oncology in Japan has improved in terms of equipment and its functions in response to the increasing number of cancer patients who require radiotherapy.

In this study, the recent structure of radiation oncology in Japan was analyzed with special reference to DCCHs in terms of equipment, personnel, patient load, and geographic distribution. The effect of changes in the cancer care policy by the Japanese government on radiotherapy structure was also investigated. Furthermore, the medical care situation in Japan was compared with European countries and the United States.

Materials and Methods

JASTRO carried out a national structure survey of radiation oncology in 2007 by administering a questionnaire in 2008 [19]. The questionnaire consisted of items related to the number of treatment machines and modality by type, the number of personnel by job category, the number of patients by type, and the site. A response was received from 721 of 765 (94.2%) radiotherapy facilities in Japan. There were 377 DCCHs facilities by the end of fiscal year 2009. The surveys were not returned by 16 facilities, and 13 facilities did not have departments of radiotherapy at the time of the survey. Thus, the structures of 349 DCCHs and 372 other radiotherapy facilities were analyzed. In this survey, full-time equivalent (FTE) (40 hours/week only for radiation oncology service) data were surveyed depending on clinical working hours for radiotherapy of each staff. SAS® 8.02 (SAS Institute Inc., Cary, NC, USA) [12] was used for the statistical analysis. The statistical significance was tested by means of the X^2 test, Student's t test, or analysis of variance (ANOVA).

The Japanese Blue Book Guidelines (JBBG) [6, 7] were used for comparison with the results of this study. These guidelines pertain to the structure of radiation oncology in Japan based on Patterns of Care Study (PCS) [15, 17] data.

Results

Current Situation of Radiation Oncology

Table 1 shows the current situation of radiation oncology in Japan. The numbers of new patients and total patients in all radiotherapy facilities in Japan were estimated at approximately 181,000 (170,229 × 765/721) and 218,000 (205,087 × 765/721), respectively. For DCCHs, the corresponding numbers were approximately 117,000 (112,101 × 364/349) and 141,000 (135,383 × 364/349). The number of patients in DCCHs, thus, accounted for approximately 65% of the number of patients, both new and total (117,000/181,000 and 141,000/218,000), in all radiotherapy facilities. The average numbers of new patients/facility were 321.2 for DCCHs and 156.3 for the other radiotherapy facilities, and for the average numbers of total

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%.

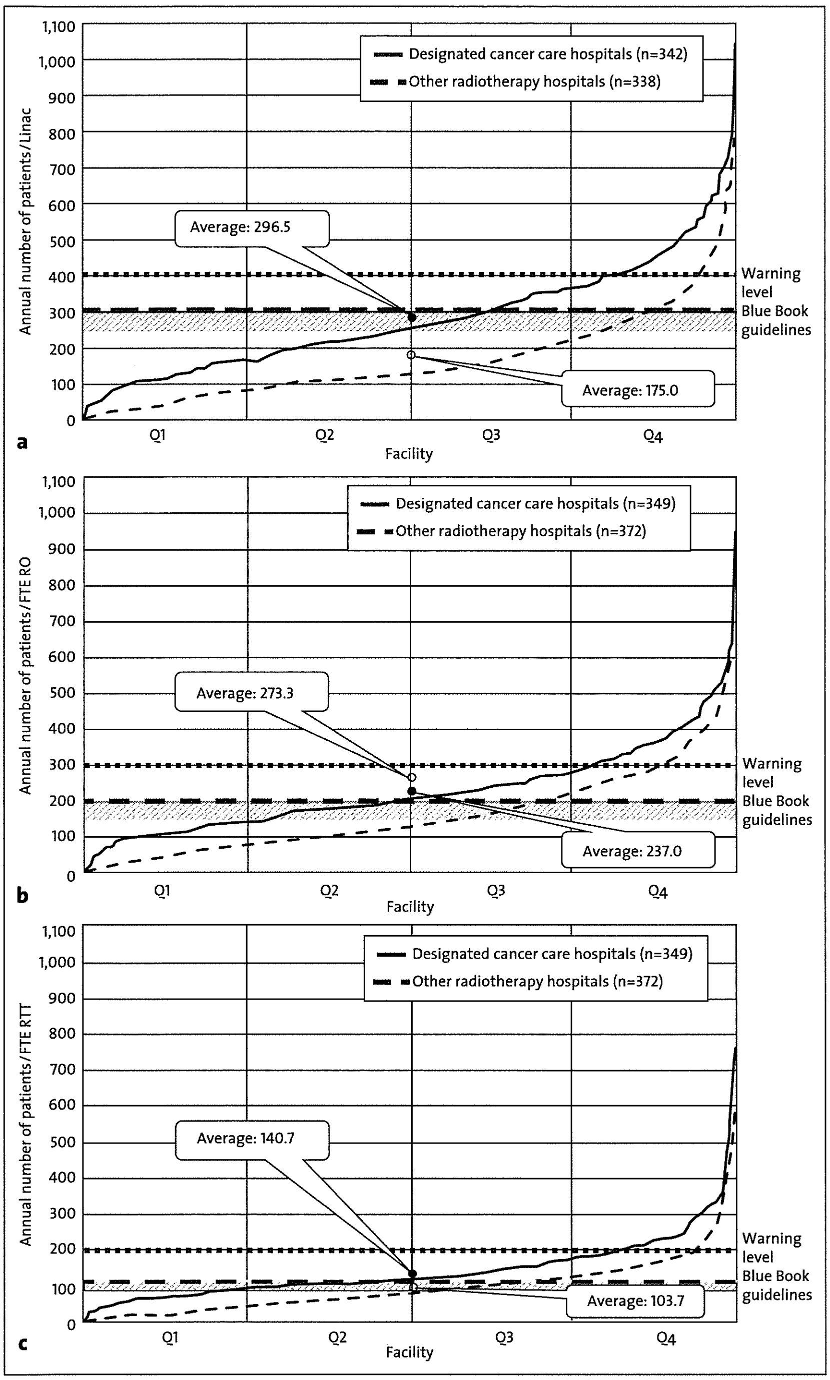
The patterns for radiotherapy planning systems (RTPs) and other equipment are shown in Table 2. X-ray simulators were installed in 69.3% of the DCCHs and in 53.0% of the other radiotherapy facilities, CT simulators in 75.7% and 56.7%, and RTPs in 96.8% and 93.8%, respectively. A noteworthy difference 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.

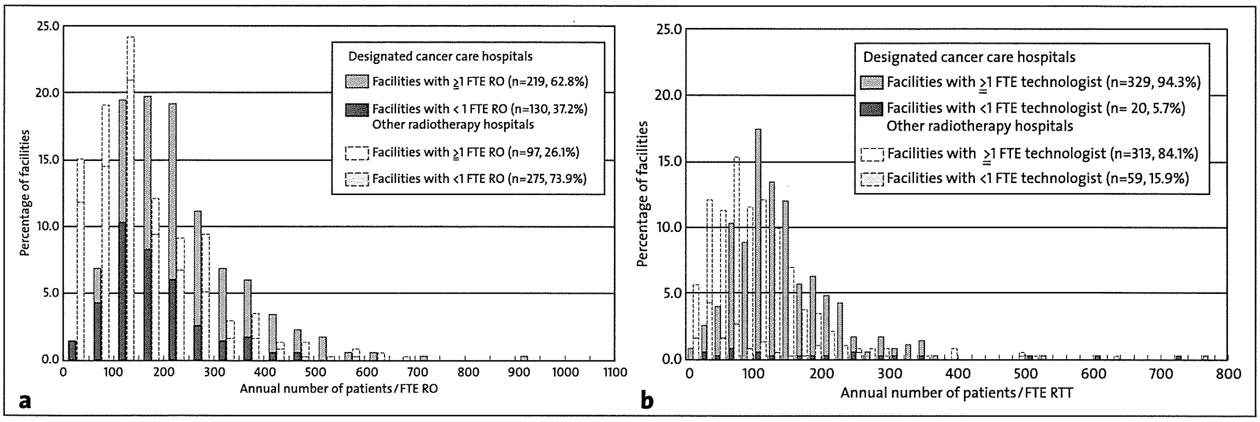
Geographic Patterns

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.

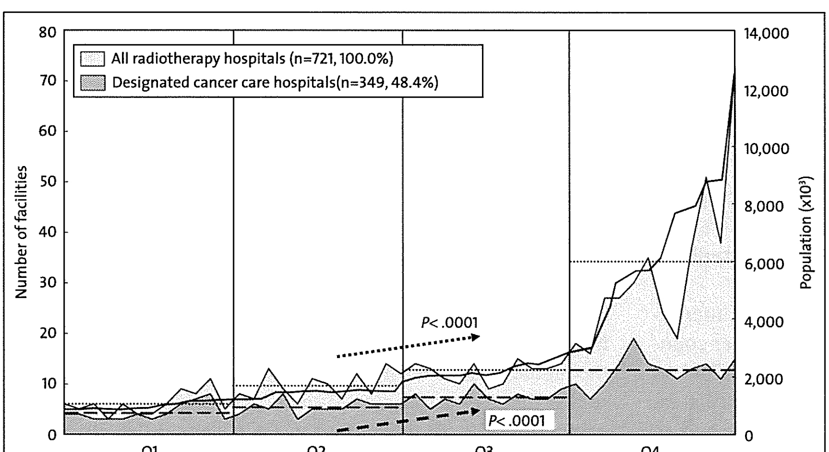


Figure 3. Geographic distribution for 47 prefectures of the number of facilities arranged in order of increase in population. The dotted line shows the average number of facilities of the prefectures per quarter for all radiotherapy hospitals and the dashed line shows the average number for designated 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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